



HAL
open science

**Travail coopératif entre une professeure de physique et
une professeure d'anglais dans le secteur LANSAD
(LANGues pour les Spécialistes d'Autres Disciplines) :
une étude menée dans le cadre d'une ingénierie
didactique CLIL (Content and Language Integrated
Learning)**

Tracy Bloor

► **To cite this version:**

Tracy Bloor. Travail coopératif entre une professeure de physique et une professeure d'anglais dans le secteur LANSAD (LANGues pour les Spécialistes d'Autres Disciplines) : une étude menée dans le cadre d'une ingénierie didactique CLIL (Content and Language Integrated Learning). Education. Université de Bretagne occidentale - Brest, 2020. Français. NNT : 2020BRES0055 . tel-03366555

HAL Id: tel-03366555

<https://theses.hal.science/tel-03366555>

Submitted on 5 Oct 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

DOCTORAT / EDUCATION

BRETAGNE / LANGAGES, INTERACTIONS

LOIRE / COGNITION, CLINIQUE



Université de Bretagne Occidentale

THESE DE DOCTORAT DE

L'UNIVERSITE
DE BRETAGNE OCCIDENTALE

ÉCOLE DOCTORALE N° 603

Education, Langages, Interaction, Cognition, Clinique

Spécialité : « *Sciences de l'éducation* »

Par

Tracy BLOOR

Travail coopératif entre une enseignante-chercheuse de physique et une professeure d'anglais dans le secteur LANSAD (LANGues pour les Spécialistes d'Autres Disciplines) : une étude clinique en TACD menée dans le cadre d'un projet CLIL (Content and Language Integrated Learning)

Thèse présentée et soutenue à Rennes, le 29 octobre 2020

Unité de recherche : EA 3875

Rapporteurs avant soutenance :

Jérôme SANTINI MCF (HDR), Université de Côte d'Azur

Anke WEGNER, Professeure, Dr., Université de Trier, Allemagne

Composition du Jury :

Président du jury : Jérôme SANTINI, Maître de conférences, HDR, Université de Côte d'Azur

Anke WEGNER, Professeur, Université de Trier

Nicole DÉCURÉ, HDR, Professeure émérite, IUT A, Université Paul Sabatier, Toulouse III

Alan JAMEAU, Doctorat, Maître de conférences, INSPE de Bretagne, UBO

Directeur de thèse : Gérard SENSEVY, HDR, Professeur émérite, INSPE de Bretagne, UBO

Co-directrice : Brigitte GRUSON, HDR, Maître de conférences émérite, INSPE de Bretagne, UBO

'To the being of fully alive, the future is not ominous
but a promise; it surrounds the present like a halo.
Give the pupils something to do, not
something to learn; and the doing is of
such a nature as to demand thinking;
learning naturally results.'

John Dewey

Acknowledgements

This thesis has been possible thanks to many fortuitous encounters, sharing of knowledge, and generosity of spirit. My first thanks go to my thesis supervisors Gérard Sensevy and Brigitte Gruson who have guided me on a challenging path with remarkable patience. I have learnt a great deal under their careful, expert and generous tutelage.

I sincerely thank Jérôme Santini for agreeing to be a jury reporter for this thesis. I also thank him for past discussions on scientific practice and didactics, as well as for his sound counsel on how to approach a PhD. Likewise, I sincerely thank Anke Wegner for agreeing to be a jury reporter, as well as for her insightful feedback on the occasions that I have exchanged with her. I would like to thank Nicole Décuré and Alain Jameau for agreeing to be members of my jury and I thank them in advance for their expertise.

I would especially like to thank Gabrielle Regula for her immense generosity in sharing her knowledge of physics. It has been a privilege and a pleasure to discover something of her field. She is the author of the wonderful representations of protocols to measure tennis balls in this work.

I sincerely thank Aude Caussarieu for our many rich exchanges and for her generous sharing of references emanating from her own research on the subject of uncertainty in measurement: this made a substantial contribution to chapter 7 of this work. I should also like to thank Giovanni Vriens for his time and expertise in sharing his IT skills for the data production in chapter 3.

Thank you, too, to Carole Le Hénaff and other members of the Séminaire-action research group, especially Mireille Morellato for her support and helpful advice. My thanks to Donna Hurford for proof-reading some of the chapters in this work.

I would also like to thank my friend and colleague, Thelma Coyle, for the vital feedback she provided having taught the course investigated. I am also grateful to Aix Marseille University for the reduction in my teaching responsibilities so that completing this PhD became possible. I extend my heartfelt thanks to the many AMU students who have participated in the course in question, and from whom I have learnt a great deal.

Finally, an enormous thank you for the support and troubleshooting skills of my kind and loving family, without whom this thesis would not have been possible: Joy Vriens, Boris Vriens and Maya Vriens.

Contents

Acknowledgements.....	5
Introduction.....	12
PART I: The Context of the Study.....	16
Chapter 1: Second and Foreign Language Learning Literature Review.....	17
1.1 The Epistemological Underpinnings of this Study.....	17
1.2 Language and the Joint Action Theory in Didactics	18
1.3 The Origins of the Common European Framework for Languages.....	19
1.4 Second/Foreign Language Acquisition Research Developments.....	21
1.5 Implications for Classroom Practice.....	22
1.6 Cognition, Creativity, Thought and Language	23
1.7 Second and Foreign Language Review Conclusions.....	25
Chapter 2: Content and Language Integrated Learning.....	26
2.1 The Origins of CLIL as a Contemporary Practice	26
2.2 The Origins of the Acronym CLIL/EMILE	27
2.3 The Growth of CLIL Practices.....	27
2.4 What is CLIL Practice?	28
2.5 The Balance between Content and Language.....	30
2.6 CLIL and Frameworks of Analysis	31
2.7 Issues Arising in CLIL.....	34
2.8 CLIL Review: Conclusion	39

Chapter 3: The Institutional Context	41
3.1 The LANSOD Sector	41
3.2 LANSOD Student Profiles.....	42
3.3 LANSOD Student Profiles: Aix Marseille University	43
3.4 Statistical Data Conclusions	44
3.5 The AMU Students in this Study.....	47
3.6 The CLIL Sequence.....	47
 PART II: The Joint Action Theory in Didactics (JATD).....	 50
 Chapter 4: JATD as a Theoretical Framework.....	 51
4.1 Origins and Objectives.....	51
4.2 The Dialectics of Contract-Milieu and Reticence-Expression	53
4.3 The Genesis Triplet and Student-Originators.....	56
4.4 Didactic Games.....	57
4.5 Seeing-As, Jargon and Thought Style	59
4.6 The JATD: Conclusion	60
 Chapter 5: The Methodology	 61
5.1 Cooperative Engineering.....	61
5.2 JATD: A Clinical Approach.....	62
5.3 JATD: Situating the Knowledge at Stake	63
5.4 From Description to Analysis	63
5.5 Other Sources of Data	64
5.6 The Teacher-Researcher.....	65
5.7 The Choice of Extracts	66
5.8 Methodology: Conclusion	67

PART III: The Epistemic Analyses	69
Chapter 6: The Origins of Scientific English and its Associated Thought Style	70
6.1 The Written Language of Scientists: The Emergence of the Experimental Report	70
6.2 The Seeds of Modern Empiricism	72
6.3 Early Newton: the “New Theory” Publication.....	73
6.4 Logos, Ethos, Pathos and the Rhetoric of Science	75
6.5 From “New Theory” to Opticks: A Rhetorical Analysis	76
6.6 Newton’s Language Games	78
6.7 Arthur Compton and The Compton Effect	80
6.8 The Compton Effect and Jargon as a Dialogic Process.....	81
6.9 Scientific English and its Thought Style: Conclusions.....	83
Chapter 7: The Nature of Science (NOS) Debate and Uncertainty.....	85
in Measurement	85
7.1 Nature of Science (NOS).....	85
7.2 Scientific Inquiry	86
7.3 NOS and Scientific Practice: Scientific Measurement	87
7.4 A French Study	89
7.5 The NOS Debate: Conclusions	91
PART IV: The Empirical Analyses.....	92
Chapter 8: The Analysis of the Sequence	93
8.1 Research Questions and Hypotheses.....	93
8.2 The Exploratory Lesson	96
8.2.1 Preliminary Conclusions with regard to the Study Research Questions.....	117
8.3 The Genesis of a Thought Style	120

8.3.1 Preliminary Conclusions with regard to the Study Research Questions.....	146
8.4 The Enhancing-Fluency Exchange	149
8.4.1 Preliminary Conclusions with regard to the Study Research Questions.....	160
8.5 The Laboratory Report	162
8.5.1 Preliminary Conclusions with regard to the Study Research Questions.....	192
8.6 The Extended Roleplay	195
8.6.1 Preliminary Conclusions with regard to the Study Research Questions.....	229
Chapter 9: Findings and Discussion.....	233
9.1 General Conclusions	235
9.2 The Exploratory Lesson in Comparison to the CLIL Sequence	238
9.3 The Conditions of the CLIL Programme.....	247
9.4 Cooperative Action and the Interweaving of Content and Language	254
9.5 Obstacles to Integrating Content	255
9.6 Discussion and Future Research	257
Résumé Long.....	259
List of Tables	272
List of Acronyms	273
References	274
List of Appendices.....	287
Résumé/Abstract	337

Introduction

This study explores the educational approach of Content and Language Integrated Learning (CLIL) in the LANguages for Specialists of Other Disciplines (LANSOD) sector. Using the Joint Action Theory in Didactics (JATD) framework, it contributes to a growing body of research in this field by investigating the specific conditions of a CLIL programme designed for science undergraduates in a French university.

A short, 4-session, Content and Language Integrated Learning (CLIL) programme was designed by two teachers working cooperatively: an associate professor of physics and an English language teacher. The programme produced is composed of 4 sessions and is based on problem-solving situations (Dewey, 1938; Sensevy, 2011) in keeping with certain JATD epistemological underpinnings with regard to language.

Wittgenstein's conception of the nature of language is the view of language adopted in the Joint Action Theory of Didactics (JATD). Language is seen as being composed of language games within forms of life which produce certain *thought styles* (Fleck, 1935/2008) and ways of perceiving or seeing-as (Wittgenstein, 1953/2004). Such seeings-as both produce and are produced by *jargon* (Sensevy, Gruson & Le Hénaff, 2019) which is considered to be the linguistic component of a social game. The concept of jargon, therefore, denotes more than vocabulary: it includes the notion of jargon as an understanding of the background to the practice from which it emerges.

As this English language course was for undergraduate science students, a science subject was chosen as the content aspect of the CLIL project. A notion in experimental science that is often over-simplified or misunderstood by students is that of uncertainty in measurement. The teaching sequence was thus designed around the ostensibly simple task of devising a basic protocol or procedure to measure the diameter of a tennis ball. Exploring this question necessitated developing an appropriate thought style/jargon associated with uncertainty in measurement.

The CLIL programme resulting from this cooperative project is the subject of analysis of this study. The didactic action produced in class by the CLIL uncertainty in measurement sequence is fully investigated in order to explore its potential for learning. It also identifies the conditions of the practice itself.

The thesis is divided into four parts. In part one, the general context of the study is described. It begins with a review of current research in second and foreign language learning and situates the study within current developments. It then presents a review of CLIL research and practice and outlines the questions arising in relation to this approach. Part one is completed with a presentation of the institutional context of the study and a general description of the uncertainty in measurement CLIL sequence.

Part two presents the JATD theoretical and methodological framework used to analyse this project. The main JATD notions are described, in particular the notions of jargon and thought style. The JATD methodological approach, as applied in this study, is presented. This includes detailed descriptions of classroom practice based on filmed didactic activity, analyses of the epistemic stakes of the CLIL sequence, and finally, classroom practice modelled and analysed in relation to the epistemic stakes identified. To contextualise these elements further, other data are presented and described: student productions, communication between the two teachers and the teaching resources resulting from their cooperative work.

Part three presents two epistemic analyses of the sequence. The first is an overview of the historical origin of experimental science and its particular thought style, as expressed in scientific written English. The second is an outline of the current Nature of Science (NOS) debate in science education in relation to the specific question of scientific measurement.

The final section, part four, is the empirical analysis of this study, including its research questions and findings. Five different classroom practice situations are described and analysed using the JATD. A range of CLIL didactic activities are thus investigated and questioned in detail, and the components of the CLIL practice as experimented in this study are identified.

This thesis contributes to questions arising in CLIL research as well as second and foreign language learning generally. It proposes the JATD framework as a tool for investigating these fields and as a means for developing cooperative projects linking theory and practice. It also gives some insight into how a cooperative action of the kind described in this thesis can be a fruitful basis for developing future CLIL projects.

PART I: The Context of the Study

Chapter 1: Second and Foreign Language Learning Literature Review

There is some debate as to the similarities and differences between Second Language Teaching and Learning (SLTL) and Foreign Language Teaching and Learning (FLTL) (see Gruson, 2006; Whyte, 2016). This review seeks to identify the various influences contributing to changing teaching and learning practices in both fields. Therefore, research developments in both the domain of SLTL, also known as Second Language Acquisition (SLA), and FLTL will be referred to in this chapter. However, the context of the practice at the heart of this study can be clearly situated in the domain of foreign language teaching and learning.

Both foreign and second language teaching/learning practice have changed considerably over the last century, undergoing a range of theoretical and methodological innovations. The dominating model of traditional grammar at the beginning of the twentieth century has long been supplanted, though its influence and uses undoubtedly remain. Christian Puren (2006) recounts the 1960s flourishing of audio-visual drilling and repetition methods, in keeping with the Taylorist and behaviourist trends of the time. He describes how they were replaced in the 1980s by a more communication-based approach. A founding text in this development (Theoretical Basis of Communicative Approaches to Second Language Teaching and Testing) was that of Canale and Swain who gave a number of guiding principles for a communicative approach to second language teaching (Canale & Swain, 1980). This evolution then itself later developed into the current action-oriented approach (AoA) recommended by the Common European Framework for Languages (CEFR) in 2001 (Council of Europe, 2001; Piccardo, 2014; Piccardo & North, 2019).

1.1 The Epistemological Underpinnings of this Study

The question as to the nature of language is extremely complex; varying positions can be found on the subject emanating from different fields of research, both within linguistics and beyond. It is, however, an important question, as foreign language learning and teaching practice will vary, according to the underlying conception of the nature of language. For example, the grammar methods of the beginning of the last century can be readily associated with the notion of language as linguistic phenomena that can be studied as an abstract system (Bloomfield, 1933; Chomsky 1957, 1965). In contrast, the current action-oriented approach of

the CEFR is more readily associated with views of language as a semiotic system (Peirce, 1977; Sensevy, Gruson & Forest, 2015) and as context-sensitive (e.g. Foucault, 1969/2005; Halliday, 1985/2004; Sensevy, Gruson & Le Henaff, 2019). Such positions entail language use being studied, or rather experienced, as an event and not a code or a system; an event entailing acts, activities and interactions. It also includes a temporal element and places greater emphasis on the subject: their intentions, interpretations, actions and felt experience (Bazerman, 1988; Phelps, 1988; Van Lier, 2004; Wegner, Hudson & Loquet, in press).

The conviction that language should be understood in its context is the conclusion reached by Wittgenstein on the nature of language:

For a large class of cases — though not for all — in which we employ the word “meaning” it can be defined thus: the meaning of a word is its use in the language (Sect. 43 of Wittgenstein’s *Philosophical Investigations* 1953/2009).

From Wittgenstein’s perspective on language, words, gestures, expressions and so on, come alive within a language game, a culture or ‘a form of life’.

1.2 Language and the Joint Action Theory in Didactics

Wittgenstein’s conception of the nature of language is the view of language adopted in the Joint Action Theory of Didactics (JATD) and in this thesis. Language is seen as being composed of language games within forms of life, which produce certain thought styles (Fleck, 1935/2008; Sensevy et al., 2019) and ways of perceiving or seeing-as (Wittgenstein, 1953/2009). Such seeings-as both produce and are produced by jargon (Sensevy et al., 2019), which is considered to be the linguistic component of a social game. The concept of jargon, therefore, denotes more than vocabulary: it includes the notion of jargon as an understanding of the background to the practice in which it is embedded and which gives it shape. It is also both a vital clue in deciphering a given thought style as well as being a means of initiation into that same thought style. This notion is described in more detail in 2.5 as it will serve as an important tool for analysing the classroom practice in this study.

1.3 The Origins of the Common European Framework for Languages

The origins of the Common European Framework for Languages (CEFR) can be traced to changing perspectives on language, as illustrated by a debate stemming from the influential distinction made by Noam Chomsky between competence and performance (Piccardo & North, 2019). Chomsky considered competence to be knowledge of grammatical rules, ‘the underlying system of rules that has been mastered by the speaker-hearer’ (1965, p. 4), and performance to be the actual language used in context viewed as ‘fairly degenerate in quality’ (1965, p. 31).

We thus make a fundamental distinction between competence (the speaker-hearer’s knowledge of his language) and performance (the actual use of language in concrete situations) ... In actual fact, it [performance] obviously could not directly reflect competence. A record of natural speech will show numerous false starts, deviations from rules, changes of plan in mid-course, and so on (Chomsky, 1965, p. 4).

The ethno-linguist Dell Hymes disagreed with this distinction as he viewed performance as being at the centre of linguistic inquiry as opposed to the periphery. In reaction, he coined the term communicative competence (Hymes, 1966; Campbell & Wales, 1970) to denote the knowledge necessary to use language in social context. This notion includes not only grammatical competence (or implicit and explicit knowledge of the rules of grammar), but also contextual or sociolinguistic competence (knowledge of the rules of language use). As Hymes wrote later, ‘Every speech community is to some degree caught up in a changing relationship with a larger context ... The term competence should be employed within just such a perspective’ (1996, p. 59).

Canale and Swain (1980), resume in some detail the notion of *communicative competence* as viewed by Hyme, which lends some insight into the origin of the CEFR:

Communicative competence is thus viewed by Hymes as the interaction of grammatical (what is formally possible), psycholinguistic (what is feasible in terms of human information processing), sociocultural (what is the social meaning or value of a

given utterance), and probabilistic (what actually occurs) systems of competence (p. 16).

Hymes proposed the term 'ethnography of speaking' (Hymes, 1966, 1996) for the study of all the constitutive components of language in use, such as setting, form, forms of interpretation and so on (Canale & Swain, 1980, p. 17). He was thus instrumental in instigating a more social and contextual view of language which permeated second and foreign language acquisition research (Firth & Wagner, 1997) and ultimately led to the CEFR where this notion of competence¹, as defined by Hymes, is fundamental.

The JATD framework prefers the term 'L2 skill' in preference to 'competence'. An overview of the etymological origins of the terms skill and competence helps clarify how the former term is more in keeping with the JATD vision of education as a quest toward the mastery of cultural bodies of knowledge. For example, 'skill' in the late 12c referred to the 'power of discernment', which came from Old Norse 'skil' meaning 'distinction, ability to make out, discernment, adjustment'² This can be compared with the origins of 'competence'. In the 1590s it denoted 'rivalry' (based on compete), and also 'adequate supply'. Both senses are now obsolete. A more recent meaning is 'adequate range of capacity or ability, sufficiency to deal with what is at hand' from 1790. There is also a legal sense 'capability or fitness to be heard in court' from 1708.³

For the JATD, a 'skill' requires discernment, judgement and an ability to fully comprehend a given domain. In contrast, the term competence is more recent and limited in scope and ambition.

¹ It is worth noting a number of points related to the term competence: (i) "Compétence" in French translates both the term skills (the four skills/les quatre compétences, though skills is no longer used in the CEFR framework) and the sociolinguistic, grammatical or pragmatic competences. It may also be used for the term proficiency in English (Piccardo, 2014). (ii) In British English the plural is competences, whereas in US English the plural is competencies. (iii) The term also appeared in the workplace in the late 1960s as a means of identifying what workers were able to do and how they adapted to change. (Piccardo, 2014, p. 21). It is commonly used in professional environments today.

² Online Etymology Dictionary, (20 October, 2020) <https://www.etymonline.com/search?q=skill> Etymonline.com

³ Online Etymology Dictionary, (20 October, 2020) https://www.etymonline.com/word/competence#etymonline_v_28463

1.4 Second/Foreign Language Acquisition Research Developments

With a more encompassing notion of language came a broadening area of research. In the late 1980s, the field of Second Language Acquisition (SLA) underwent a process of epistemological expansion: subfields of linguistics and/or psychology entered the SLA scene, including anthropological linguistics, cognitive linguistics, corpus linguistics, cultural psychology, developmental psychology, neurolinguistics, bi/multilingualism, socio linguistics, and systemic-functional linguistics (The Douglas Fir Group, 2016).

This list belies the inherent tension in both second and foreign language research between conceptions of language acquisition based on individual cognition in contrast to those based on social anthropological factors.

This tension remains, however the influence of a conception of language viewed in context has gained influence, and consequently the focus of second and foreign language (S/FL) research has evolved. In 1997, Alan Firth and Johannes Wagner called for a reconceptualization of S/FL research so that it would include an enhanced awareness of the contextual and interactional dimensions of language use, as well as greater participant-relevant sensitivity. This was in order for it to become 'a theoretically and methodologically richer, more robust enterprise, better able to explicate the processes of second or foreign language (S/FL) acquisition ...' (Firth & Wagner, 1997).

Claire Kramsch (2002) talked of the changing metaphors in the field of language acquisition. In the 1960s the dominating metaphor was that of 'LEARNER-AS-COMPUTER' where the language learner is seen as an information processor receiving input and ultimately producing output of a measurable kind (p. 1). She contrasts this with the more recent metaphor of 'LEARNER-AS-APPRENTICE' in a community of practice (p. 2) where language is not seen as input, but as a tool for getting things done. In this approach, the focus is less on how systems are acquired and more on the way language practices are organised within a community of practice. She calls for an 'ecology' metaphor that would include language acquisition and language socialisation and that would '... seek new ways of conceptualizing the relationship of the dancer and the dance' (p. 5).

1.5 Implications for Classroom Practice

An example from Firth and Wagner's study (1997) will illustrate the implications of a reconceptualization of S/FL research. It concerns an exchange between a Danish English language learner, and a native English speaker. During the exchange, the learner does not know the term 'story' and so uses the word 'historie'. The native speaker nevertheless grasps her meaning and eventually contributes the word 'story' to the exchange.

Firth and Wagner claim that from a cognitive conception of language learning, the focus would probably be on the learner's language deficiency, considering it to be a problem, whereas from a language-in-context conception of language, the focus is more on the learner's ability to avoid a problem by code-switching. This allows the communication to continue and the participants to

... conjointly accomplish meaningful communication with the resources ... at their disposal. ... the point is that the meaning or sense is that which is conjointly negotiated and implicitly agreed upon in the talk. ... Meaning, from this perspective, is not an individual phenomenon consisting of private thoughts executed and transferred from brain to brain, but a social and negotiable product of interaction, transcending individual intentions and behaviours (Firth & Wagner, 1997).

This kind of conjoint meaning-making is termed mediation in the current CEFR framework (see CEFR 2018 companion volume). The introduction of this notion reflects the framework's reinforced consideration of the social aspect of language: As North and Piccardo state:

Mediation takes this aspect, i.e. the awareness of the dynamic nature of meaning making, to another level. In fact, it integrates and goes further than the co-construction of meaning by underlining the constant link between the social and individual dimensions in language use and language learning. (North & Piccardo, 2016, p. 4)

This notion of code-switching is one of a number of notions emerging in S/FL research which will be seen to be pertinent to the empirical analysis of this study. Also of interest are the notions of 'Repair' (Schegloff, 1977/2007; Hall, 2016) and 'Plurilingualism'.

Plurilingualists ‘... have a *single*, inter-related, repertoire that they combine with their general competences and various strategies in order to accomplish tasks’ (CEFR Section 6.1.3.2, Companion Volume with New Descriptors). Swain and Lapkin (2013) suggest that students should be given an opportunity to use their first language during collaborative dialogues or private speech, so that they could

...mediate their understanding and generation of complex ideas (languaging) before they produce an end product (oral or written) in the target language ... they should be allowed to mediate their thinking via their first language (Swain & Lapkin, 2013, pp. 122-123, as quoted in North & Piccardo, 2016, p. 15).

The empirical analyses (8.2-8.6) in this study include a number of examples of plurilingualism, code-switching and repair which will be analysed within the context of the ongoing didactic activity. As we shall see, the JATD descriptive notions seek to render visible how such strategies can serve to contribute to foreign language learning.

1.6 Cognition, Creativity, Thought and Language

The debate between the importance of individual cognition as compared to social, anthropological factors in language acquisition also extends to first languages.

Ludwik Fleck claimed that cognition is a collective activity emerging from exchanges within thought collectives and that as such transformation does not so much occur in people’s heads as in their interpersonal space (1935a, 11.4, as quoted in the Stanford Encyclopedia of Philosophy). This raises some interesting issues regarding the role of Interactional Competence (Hall, 2018), cognition, creativity and the transition from thought to language.

We might consider, for example, the concept of discovery in this light. Timothy Koschmann⁴ considers the ‘light-bulb in the head’ image of discovery to be misleading and argues it is more accurate to consider ‘discovery’ as a recalibration of available referential

⁴ (Koschmann, 28 March, 2012, *What is discovery?* Education et sciences de l’apprendre, IFé Lyon)

resources. He refers to the discourse surrounding the 'discovery' of pulsar light to illustrate this point, a transcript of which is quoted below:

'Disney: (We've got a little bit of shape now). (0.4)

McCallister: We::ll, (1.0)

McCallister: (It's) about like I saw in that sky: over there, t' tell you the truth. (0.5)

McCallister: Ther's a nice di(hh)p on the (hh) si(hh)de of that sky. (0.5)

McCallister: I'm gonna turn this thing down. (2.5)

Disney: We've got a bleeding pulse here. (2.0)

Cocke: He::y! (4.5)

Cocke: Wo::w.! 11.21 (0.5) ((machine sound - probably gain switch))

Cocke: You don't suppose that's really it, do you? (2.0)

Cocke: Ca::n't be

Disney: It's right bang in the middle of the period. (Look), I mean right bang in the middle of the (sca::le). (0.8)

Disney: It really looks something (from here) at the moment. (0.8)

Cocke: Hmm:!

Disney: (An') it's growing too. (Hey) (1 .0)

Disney: It's growing up the side a bit too.'

(Garfinkel, Lynch & Livingston, 1981)

What is striking in this extract is that until 'the thing that didn't exist' became something that could be talked about, the terms used in the initial stages of the description of this event were vague, as the frequent use of the pronoun 'it' reveals.

This dialogue would thus appear to correspond to Fleck's premise of human cognition being a collective activity. If this be indeed the case, there are implications as regards human thought and language acquisition. It would suggest that an important aspect of language is the necessity of limited expression in human interactions as new ideas emerge in interpersonal spaces. If this is valid for a first language it would follow that this also holds true for a second or foreign language.

1.7 Second and Foreign Language Review Conclusions

These issues raise some interesting questions regarding second and foreign language teaching and learning research.

The empirical didactic analyses in this thesis, in particular 8.6, reveal that the gaps in certain exchanges are an essential stage in the interaction concerned (Bloor, 2019; Hall, 2018). It can be concluded that such pauses, as well as phenomena such as code-switching and repair, can be considered to be important aspects of second and foreign language acquisition.

In order to explore these questions, amongst others, the Joint Action Theory in Didactics (JATD) framework will be employed to describe and analyse a Content and Language Integrated Learning (CLIL) sequence, which is the basis of this study. Evidence will be sought of participation in semiotic systems (Gruson, 2019; Sensevy, Gruson & Forest, 2015), where words, gestures and expressions come alive in the co-construction of meaning. These will be considered as epistemic games (Santini et al., 2018) in foreign language acquisition.

Chapter 2: Content and Language Integrated Learning

Content and Language Integrated Learning (CLIL) is in some respects an ancient educational practice as the principle of learning a language in context is not a new one. The Hungarian, Lutheran pastor and headmaster Matthias Bel (1684–1749) stated ‘Teach the words by getting to know the reality — the world around us’ (Pokrivčáková et al., 2015). Bel taught in German-Hungarian-Slovak-Czech regions where he strove to develop the language skills of his students by increasing their interest in the cultural context of the neighbouring languages. Content-based language teaching practices have thus naturally tended to emerge in bilingual or multilingual regions as a consequence of the needs of the various language groups living in those areas.

2.1 The Origins of CLIL as a Contemporary Practice

In contemporary Europe, Hugo Baetens-Beardsmore’s ‘European Models of Bilingual Education’ (1993), was a landmark publication in engendering more recent interest in bilingual education. This work describes a range of successful, content-based, bilingual or multilingual teaching models in Europe, such as the promotion of bilingualism through the teaching of Information Technology in Welsh, or the education of trilingual citizens via language-enrichment programmes in Luxembourg (Baetens-Beardsmore, 1993). The models described in the work developed within a range of circumstances: some sought to expand threatened linguistic patrimonies (as in Wales, Catalonia and the Basque country), others were designed to accommodate cross-border linguistic minorities (as in Nordschleswig), and yet others to provide multilingual proficiency (as in Luxembourg or Brussels). However, all of the models naturally favoured a cultural, contextual emphasis as regards language learning and the success of such models awakened interest in the methods that were used.

It is also likely that the prevailing climate of the action-oriented approach in the 1990s (Piccardo, 2014; Puren, 2006g), contributed to an increased interest in such models. Language teaching taught through subject-matter offered opportunities to create the task-based learning situations necessary to the action-oriented approach.

2.2 The Origins of the Acronym CLIL/EMILE

The term 'CLIL' used to refer to such practices was first coined by David Marsh in 1994. The acronym was adopted with a view to describing and further designing successful models of European teaching which entailed the use of an additional language (Coyle, Hood & Marsh, 2010 p. 13).

CLIL refers to situations where subjects, or parts of subjects, are taught through a foreign language with dual-focussed aims, namely the learning of content, and the simultaneous learning of a foreign language (Marsh, 1994).

In France, CLIL was then translated into « Enseignement d'une Matière par l'Intégration d'une Langue Étrangère » (EMILE). This happened to have a positive connotation as it is a reminder of Jean-Jacques Rousseau's ideal vision of education in 'Emile' (or 'On Education', 1762). As with elsewhere in Europe, much has been written and discussed on EMILE/CLIL in France.⁵

2.3 The Growth of CLIL Practices

Since 1994, interest in CLIL practices has continued to increase: a 2006 Eurydice statistical study revealed an exponential uptake of CLIL practices across Europe (Coyle, Hood & Marsh, 2010 p. 17).

The widespread uptake of CLIL practices, especially in Finland and the Netherlands in the 90s (Marsh et al., 2001; Šulistová, 2013) and later in Spain in the 2000s (Dalton-Puffer, 2011), as well as its continuing growth (Eurydice, 2006), can be attributed to its perceived benefits. Its promise is such that it has been featured in a number of European Commission declarations (1995, 2003, 2008); a European Commission 2005 document states:

⁵ for a comprehensive list see: <https://www.emilanguages.education.fr/international/emile-clil-europe>, Visite d'étude EMILE Bibliographie et sitographie).

Content and language integrated learning (CLIL) ... has a major contribution to make to the Union's language learning goals ('Promoting language learning and linguistic diversity. An action plan 2004-06', European Commission, 2005).

The current definition of CLIL, as defined by Coyle, Hood, and Marsh in a work summarising CLIL practices in Europe, is in keeping with that of 1994 in slightly more extended terms:

Content and Language Integrated Learning (CLIL) is a dual-focused educational approach in which an additional language is used for the learning and teaching of both content and language. That is, in the teaching and learning process, there is a focus not only on content, and not only on language. Each is interwoven, even if the emphasis is greater on one or the other at a given time (Coyle, Hood & Marsh, 2010).

In this more recent CLIL definition, the addition of 'interwoven' describing the relationship between content and language, reveals one of a number of underlying questions inherent in CLIL practice which include the following list. Firstly, what factors should be taken into account in determining the balance between content and language in CLIL practice? Secondly, how might CLIL practice interweave these two elements? Finally, in what ways are content and language then influenced by their convergence in CLIL practice? These are some of the questions which this study seeks to address in the didactic analyses from 8.2-8.6.

2.4 What is CLIL Practice?

As CLIL is a generic term to describe a wide range of practices, the answer to this question is in part related to the context of the learning in which the practice occurs; there is no single blueprint of content and language integration. (Baetens Beardsmore, 1993; Coyle, Hood & Marsh, 2010).

In chapter 2 of 'CLIL', Coyle, Hood and Marsh outline eleven CLIL models which will be briefly summarised here:

Models A1 – A3: Primary, 5-12 years

Secondary education:

Model B1: Dual-school education. Schools in different countries share the teaching of a

specific course or module.

Model B2: Bilingual education. Learners study a significant part of the curriculum through the CLIL language.

Model B3: Interdisciplinary module approach. A specific module, for example environmental science, is taught through CLIL involving teachers of different disciplines.

Model B4: Language-based projects. The type differs from examples B1-B3 in that it is the language teacher who takes primary responsibility for the CLIL module. It therefore includes more language-teacher output.

Model B5: Specific domain vocational CLIL. Learners develop competence in the CLIL language so that they are able to carry out specific task-based functions e.g. customer service.

Tertiary (higher education):

Model C1: Plurilingual education. More than one language is used through CLIL during different years in related content programmes. Closely linked to prestigious forms of higher education where internationalisation is viewed as an integral part of the programme.

Model C2: Adjunct CLIL. Language teaching runs parallel to content teaching with a specific focus on developing the knowledge and skills to use the language so as to achieve higher-order thinking.

Model C3: Language embedded content courses. Content programmes are designed from the outset with language development objectives.

According to the criteria presented by Coyle Hood and Marsh to define CLIL types, the sequence which is the focus of this study can be loosely categorised as a C2 model. That is to say, the English language teaching ran parallel to the students' mainstream science courses, and the focus was 'on developing the knowledge and skills to use the language so as to achieve higher-order thinking'. The sequence took place during English language lessons where the primary concern was to develop the students' L2 skills. Nevertheless, as language is considered integral to a social game of some form (see chapter 1), progress in language is necessarily combined with progress in other capacities.

2.5 The Balance between Content and Language

A key issue arising in CLIL practice is the question as to what form the interplay between content and language should take. CLIL practice can neither be equated to second/foreign language teaching, nor to subject-teaching. As the authors Marsh, Enner and Sygmund state:

Teachers have found that content and language integrated learning is about far more than simply teaching non-language subject matter in an additional language in the same way as the mother tongue [It] is not a matter of simply changing the language of instruction (Marsh, Enner & Sygmund, 1999 p. 17, as quoted in 'CLIL', 2010).

Dalton-Puffer argues that CLIL practice, by definition, includes second and foreign language learning objectives:

At present, at least in Austria, a CLIL curriculum is defined entirely through the curricula of the content subjects, with the tacit assumption that there will be incidental language gains. But why should we be doing CLIL at all if there are no language goals present? (Dalton-Puffer, 2007, p. 295)

However, as Cammarata and Tedick state 'what it takes to systematically and meaningfully integrate language in the context of content teaching has yet to be fully understood' (2012, p. 254).

This issue is of particular interest as the specificity of CLIL, it might be argued, is its *convergence* of content learning and teaching with that of second and foreign language learning as a result of its dual-focussed approach. It is in the *interweaving* of these two domains that CLIL-specific forms of didactic practice might emerge.

There is a growing body of research which seeks to identify and define more precisely what form such CLIL-specific didactic practices might take. Below is a brief outline of some of the research exploring this question.

Mohan and van Naerssen (1997) proposed four precepts as a basis for didactic organisation in CLIL practice:

- (i) Language is a matter of meaning as well as of form.
 - (ii) Discourse does not just express meaning. Discourse creates meaning.
 - (iii). Language development continues throughout our lives, particularly our educational lives.
 - (iv). As we acquire new areas of knowledge, we acquire new areas of language and meaning.
- (Mohan and van Naerssen, 1997 p. 2)

Gajo (2007) also underlines the central role of discourse in any analysis of the integration of language and content in CLIL practice:

Discourse is in the central position, both as an essential ‘trace’ of knowledge and as an ‘entrance door’ for teacher and learner as well as for the researcher. Discourse is structured by both the subject and the linguistic paradigms, which are at the same time structured by it. Knowledge is shaped in this complex interrelation (Gajo, 2007b, p.568).

The central role attributed to discourse in the analysis of the integration of language and content in CLIL practice, is also the position of the JATD. In the didactic analysis of this study, the notions of *jargon* and *thought-style* (chapter 4) will be used to trace the interwoven progress of both language and content in the joint construction of knowledge in classroom practice.

2.6 CLIL and Frameworks of Analysis

The question arises as to a suitable framework for analysing CLIL practice.

The Language Triptych

Coyle (2000, 2002) proposes the language Triptych as a means of analysing language needs in various CLIL contexts by distinguishing between different types of linguistic demand: language of learning, language for learning and language through learning (as quoted in ‘CLIL’, 2010, chapter 3).

The 'language of learning' refers to the language needed to understand and use content. That is to say, the language related to a particular theme or subject, for example the language related to protocols to describe a protocol to measure a tennis ball. Genre analysis stemming from systemic functional linguistics (Halliday, 2004) focusses on this aspect of language: that is to say 'a social activity in a particular culture, the linguistic realisations of which make up a register' (Llinares & Whittaker, 2006, p. 28, quoted in 'CLIL', 2010). In terms of language teaching, this approach would entail being more concerned with functional and notional levels of difficulty rather than grammatical levels of difficulty. For example, a learner needing to use the past tense in a science lesson would learn certain phrases as past 'markers', as opposed to learning paradigms of verbs conjugated in the past tense (Coyle et al. 2010, pp. 28-29)

The 'language for learning' refers to the kind of language needed by learners to participate in learning activities. For example, pair work, cooperative group work, questioning, and debating. This entails developing a repertoire of speech acts appropriate to the learning activity: for example, phrases to ask and give an opinion for a debate, or evaluating phrases for discussing a protocol such as 'How can you be sure ...', and so on.

The 'language through learning' refers to language required to express new areas of knowledge and new meanings emerging from the didactic activity. It is based on the principle that effective learning involves both language and thinking:

This emerging language needs to be captured, recycled and developed strategically by teachers and learners.... Language through learning is to do with capturing language as it is needed by individual learners during the learning process – and this by definition cannot always be predicted in advance. It encourages the teacher to find ways of grasping emerging language in situ. It also addresses the need to define how linguistic development (language learning) will be systematically achieved through continuous recycling for further development of language, based on an upward spiral for progression rather than step-by-step grammatical chronology. (Coyle et al., 2010, p. 30).

This question of emerging language *in situ*, and how best to grasp such language in classroom activity, is an interesting question for CLIL practice. This point is related to ‘Cognition, Creativity, Thought and Language’ as discussed in chapter 1. Here, we saw an example of a dialogue during the discovery of pulsar light (Garfinkel, Lynch & Livingston, 1981) which involved very little vocabulary and much use of the pronoun ‘it’. A possible conclusion from this extract is that minimal language use might be a necessary aspect of certain cognitive activities involving language and thinking, especially emerging or new thinking. If this is so, it could be argued that language learning activities involving new ideas and language should allow for this phenomenon (Bloor, 2019).

In the JATD, the notions of *contract* and *milieu* are used in this study to describe this kind of emerging language. An example will be presented in the description of the extended roleplay (8.6) where students can be seen to introduce and discuss a new idea using symbolic signs.

The 4Cs Framework

In their exploration of the dual-focussed aspect of CLIL practice, Coyle et al. (2010) suggest the term synergy to describe the integrative aspect of CLIL: ‘The word synergy comes from the Greek *synergos* which implies working together “in a dynamic state” where the whole is greater than its parts’ (p. 22). They suggest the 4Cs as a framework for both designing and analysing CLIL practice: content, communication, cognition and culture. The framework seeks to allow for the integration of content learning and language learning by placing them within specific contexts. It acknowledges the symbiotic relationship that exists between these elements and argues that effective CLIL practice occurs thanks to this symbiosis. That is to say, that in progressing in knowledge and skills related to content, learners are engaged in communication and cognitive processing which lead to the appropriation of language knowledge and skills. The authors outline a detailed tool kit for teachers to plan CLIL programmes in order to ensure that ‘... learners will be cognitively challenged yet linguistically supported to enable new dialogic learning to take place’ (Coyle et al., 2010, p. 34).

The Joint Action Theory in Didactics

Rita Carol presents a case for the use of the Joint Action Theory of Didactics framework (2015) for CLIL practice. She argues there is a necessary interdependence between thought, language and any given field of knowledge. Given this interdependence, she proposes the JATD notions of mesogenesis, chronogenesis and topogenesis (see chapter 4) as appropriate tools for detailing the didactic transposition of a specific discipline and its associated language. In preparing a CLIL sequence, discipline teachers should thus consider a number of questions. First, what is required of the students to participate in an activity as regards its field of knowledge, language and genre? Second, are the students armed with these means? Third, do they require cognitive or linguistic support to facilitate comprehension or to produce language output? In other words, implementing a CLIL programme requires careful planning and communication (2015) if it is to be effective.

During a CNESCO conference (Centre National d' Étude de Systèmes Scolaires) in 2019, Carol defended the success of CLIL initiatives on the condition that they be implemented following a full analysis of the language needs of the discipline involved in the CLIL programme. This would require the integration of the various necessary components of a CLIL programme in a complex process of several stages.

In a recent study, Jameau and Le Hénaff (2018) undertook a study of a CLIL physics-chemistry/English project in a high school. They used the JATD notion of jargon to identify the articulation between scientific knowledge and language knowledge. They found that knowledge of both the linguistic and scientific aspects of the CLIL practice they studied advanced, but not simultaneously.

2.7 Issues Arising in CLIL

(i) Overchallenging Learners

Doubts as to the validity of the CLIL approach include, for example, the argument that it can represent an excessive cognitive challenge for learners. According to the Cognitive Load Theory (Sweller, 2011), students must first integrate new knowledge in their working memory before they can store it in their long-term memory. However, working memory is limited in

capacity and duration and therefore this must be taken into account in the design of teaching sequences. Sweller states 'Simultaneously processing content and language might have put an overload on (...) working memory capacity leading to smaller learning gains' (Cognitive Load Theory, Sweller et al., 2011).

Similarly, in 'Learning subject content through a foreign language should not ignore human cognitive architecture: A cognitive load theory approach' (2017), Roussel, Joulia, Tricot, and Sweller concluded from a study on 294 students in higher education that the presentation of information in a foreign language decreased both language and content learning.

In a study comparing teacher and student impressions of CLIL lessons, Anke Wegner (2012) stressed the central importance of students being able to fully grasp specialist terms and concepts in CLIL lessons: she found evidence of students not having acquired an in-depth understanding of important concepts.

Coyle et al (2010) stress the need to correctly implement CLIL practice if the approach is to deliver its potential merits. Referring to Vygotsky's 'zone of proximal development' (ZPD) theory, they advocate:

.... a type of learning which is challenging yet within reach of a learner, and where the teacher facilitates cognitive challenges according to an individual's ZPD...This involves the teacher in maintaining a balance between cognitive challenge for learners and appropriate and decreasing support as learners progress (2010, p. 23).

In JATD, Vygotsky's ZPD is modelled as a dialectic between contract (what is already known to the learner), and milieu (what is to be learnt, including the activity designed to enable this). The balance maintained by the teacher between these two poles so as to facilitate cognitive change for learners is termed the didactic equilibration. These terms are described in chapter 4. They are employed in the didactic analysis, especially 8.3 and 8.4.

(ii) Form Versus Meaning

Second or foreign language learning research, including the domain of CLIL, necessarily explores the issue of the relative importance of form versus meaning in language acquisition. This is related to the question of what is considered to be the nature of language discussed in chapter 1. In simple terms, should priority be given to grammatical accuracy or to fluency in the language classroom? CLIL practice is generally associated with a social-constructivist view of learning and the action-oriented approach to language learning. As such, dialogue is naturally privileged in the joint construction of both content and language knowledge.

In *Seeing the Bigger Picture* (2012), Wegner's conclusions confirm this tendency. She states:

CLIL lessons (...) are primarily focussed on the acquisition of English through speaking in a psychologically safe environment where students can experiment with language without fear of being graded. (...) In order to support language learning, teachers also need to listen, perceive learning difficulties and problematic linguistic areas and address them in focussed language instruction (p. 32).

This question of form versus meaning is frequently discussed. Coyle Hood and Marsh (2010) refer to French immersion programmes in Canada: the emergence of such programmes in the 1960s, together with the research they generated, are a reference in bilingual education. It is thus interesting to consider the issue of form versus meaning as it is discussed in this research community. Lyster's (1987, p. 14) work showed that whilst students could communicate effectively, they were not able to demonstrate consistent grammatical accuracy. However, Swain's work (2000), also in Canada, showed how students who were engaged in collaborative, knowledge-building work, also reflected on language form. The students in the study can be seen to be engaged in 'repair' work (Schegloff, Jefferson, & Sacks, 1977): that is, following reflection and research students corrected their own language output.

Moving to second and foreign language learning research communities in the United States, Hall (2019) is critical of the continued use of the term *grammar* to refer to the system and structure of language, arguing that it limits understanding of the variability of second

learner language. The notion of 'repair', that is the ability to rectify a grammatical error, is also coherent to this position. Hall argues in favour of the notion of *semiotic resource* for a usage-based understanding of language (The Douglas Fir Group, 2016). This refers to context-networked options for making meaning in social contexts. Semiotic resources include prosodic conventions (intonation, stress, tempo, pausing etc) and nonverbal means of meaning-making (facial expressions, eye gaze, gesture, body positionings, and movement). This position is of particular interest to the didactic analysis in 8.6.

To conclude on this point: if it is assumed that both form and meaning are essential to language acquisition, the challenge is determining the kind of didactic action that might facilitate this objective. This would include exploring when and where one aspect might be justifiably be given preference to another. Hall (2019) argues, that it would be more useful to abandon the notion of grammar/form in context and usage-based approaches to second and foreign language learning. Whilst it remains to be proven that it is preferable to abandon entirely the notion of grammar as a system in all second and foreign language learning, it can be asserted that it is preferable to abandon this as a concern during certain kinds of learning activities. For example, in the didactic activity analysed in 8.3 (The Genesis of a Thought Style), 8.4 (The Enhancing Fluency Extract) and to a certain extent 8.6 (The Extended Roleplay), though students can be seen to employ useful 'repair' strategies in 8.6 using their grammatical knowledge of English. As Swain (2000) states, more research is required 'to unravel this layered complexity' (p. 112).

(iii) Immersion Interlanguage, plurilingualism, Translanguaging and Code-Switching

There is a growing recognition of the validity of second and foreign language learning approaches which allow for the expression of languages other than the target language during didactic activity. Research into CLIL and second/foreign language classrooms has revealed various language forms emerging in the didactic activity of a language classroom. For example, Lyter's research (1987) found that the care teachers took to avoid discouraging student language use by overcorrection had led to a type of 'immersion interlanguage' in classroom practice between the target language and the learner's first language.

The inclusion of the pluralistic approach in the CEFR framework of competences is evidence of an increasing recognition of diversity in language forms:

(...) the plurilingual approach emphasizes the fact that as an individual person's experience of language in its cultural contexts expands, from the language of the home to that of society at large and then to the languages of other peoples (...), he or she does not keep these languages and cultures in strictly separated mental compartments, but rather builds up a communicative competence to which all knowledge and experience of language contributes and in which languages interrelate and interact. (CEFR, 2001, p. 4).

Swain and Lapkin (2013) argue in favour of a plurilingual approach where students should be allowed to mediate their thinking via their first language (as quoted in North & Piccardo, 2016, p. 15).

The term code-switching, which refers to the practice of alternating between languages within the context of a specific communication, is another pertinent term to describe some of the language emerging in CLIL and SLA classrooms. Gajo (2007) gives an example of teachers tolerating code-switching in a CLIL-type classroom in Switzerland; he explains that this was due to their considering it as a means of developing and extending a concept. This relates to the point discussed earlier in Wegner's (2012) study on the central role of specialist terms and concepts.

Similarly, translanguaging, a term originating in bilingual education in Wales, denotes a process of meaning and sense-making where the user draws upon a range of linguistic, cognitive and semiotic resources to make meaning and make sense. (Van Kampen, retrieved online 8 Feb, 2016). Examples of this kind of plurilingual activity are encountered in the didactic analyses (especially 8.4, 8.6) where the students can be seen to rely on such practices in their learning strategies.

As stated in chapter 1, this study is founded on a conception of language as having meaning in context: it therefore adopts a context-based approach to language learning.

Though the issue of code-switching and translanguaging is not investigated directly, it is a point of interest in this CLIL research and an interesting area for future research.

2.8 CLIL Review: Conclusion

The claimed merits of CLIL practice are numerous and far-reaching. Coyle, Hood and Marsh (2010) cite a number of examples: authenticity of purpose (p. 8), greater learner autonomy (p.4), gains in cognitive flexibility (p.7), student motivation (p. 7), and collaborative working styles (p. 23).

These claims are not directly investigated in this research, though its conclusions can undoubtedly be considered as pertinent to discussion on the merits outlined above. This study first seeks to identify how the CLIL practice investigated might be described in detail (8.2 – 8.6) so as to unravel its layered complexity (Swaine, 2000). From this, it then hopes to contribute to the issues arising in CLIL practice and theory that have been identified in this chapter. To conclude, they are summarized below:

First, what factors should be taken into account in determining the balance between content and language in CLIL practice? As we shall see, any answer to these questions will depend very much on the specific nature and conditions of the didactic activity in question.

Second, how might content and language be influenced by their convergence in CLIL practice. How might they be interwoven? What evidence is there of 'CLIL specific' didactic activities and what is their purpose? Is there any evidence of CLIL practice being conducive to producing 'emerging language' (Coyle, 2010) and if so, how might this language be 'grasped and recycled' (Coyle, 2010, pp. 28 – 29).

Third, are concerns that CLIL has a propensity to overchallenge learners with a cognitive overload justified?

Fourthly, might CLIL practice compromise form excessively in its focus on meaning?

Finally, what role might more recent plurilingual approaches such as immersion languages, code-switching and translanguaging play with regard to the above questions?

These are some of the discussions in CLIL research communities which this study hopes to contribute to. Whilst these issues are not addressed directly, the findings hope to show how issues of such kind are related to the specific conditions of the didactic activity in question; conditions which must therefore be clearly identified and described.

Chapter 3: The Institutional Context

The CLIL sequence at the heart of this study was designed for LANSOD students (LANguages for Students of Other Disciplines), or LANSAD in French (LANgues pour Spécialistes d'Autres Disciplines). That is to say, foreign language teaching in higher education for students whose main subject of study is a discipline other than English.

An initial version was first implemented in December 2014 (The Exploratory Lesson, see 8.2), then redesigned in a research-action iterative process between September 2015 and June 2017 (see 8.3-8.6).

3.1 The LANSOD Sector

The LANSOD sector in France is not easy to characterise as practices and conditions differ. The number of course hours, course content, and the material and facilities available for teaching, as well as the profile of the students for whom the courses are destined, vary greatly (Van der Yeught, 2016). A national survey of LANSOD teaching conditions and practices by Brudermann, Mattioli, Roussel and Sarré (2016) characterised some aspects of this diversity. As regards teaching practices, most respondents in the survey identified with the action-oriented approach recommended by the Common European Framework of Reference for Languages (CEFR). Various course objectives were specified by participants, such as developing intercultural skills, oral interaction, translation skills and grammatical proficiency. As regards CLIL (EMILE in the survey) and English for Specific Purposes (ASP in the survey), 16% of respondents stated they were engaged in these approaches when asked what practices they pursued emanating from research.

The survey also revealed varying tendencies amongst respondents as regards the number of lesson-hours in the sector, ranging from 12 to 50 hours per term, and averaging approximately 25 hours per term.

At the time of this study, 24 lesson-hours per term were attributed to the first-year Aix-Marseille University science undergraduates who were the main participants in this research. All first-year students followed a common programme based on contemporary cultural issues so as to reinforce general language skills in preparation for an end of term

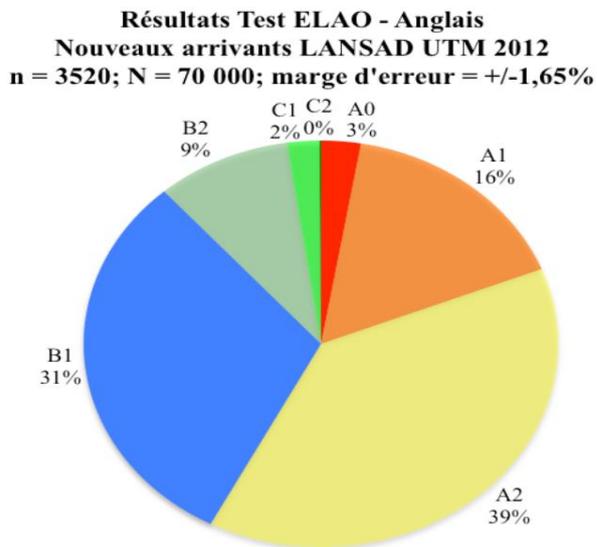
evaluation: the ECLAM (Épreuve Commune de Langues des Universités d'Aix-Marseille). This consisted of 60 multiple choice questions which tested written comprehension, oral comprehension, knowledge of generalised and specialised vocabulary and grammar and phonetics. The students' final mark was based on the ECLAM result (50%) together with a coursework mark (50%), or at certain periods, uniquely the ECLAM result (100%) if absent from classes (class attendance later became obligatory for a final mark). The coursework mark generally included a mark for spoken expression/interaction and attendance, though the details of this mark varied from teacher to teacher. For the groups involved in this research-action CLIL project between September 2016 and June 2017, 8 lesson-hours were allocated to the programme and the students were attributed a mark representing 50% of the coursework mark (i.e. 25% of their final term mark).

3.2 LANSOD Student Profiles

The general diversity of the LANSOD sector is further reflected in the heterogeneity of LANSOD students' language levels (Crosnier & Décuré, 2018). Terrier and Maury's study of the results of an English language assessment for 3,700 first or second-year university LANSOD students in Toulouse confirm this point. As can be seen in Figure 1, the students' English levels, according to an ELAO Test (Efficient Language Assessment Online), ranged from A0/A1 to C1 using the CEFR categories, with the majority of students having an A2 or B1 level. The ELAO test evaluated written comprehension, oral comprehension, and lexical and grammatical knowledge (Terrier & Maury, 2015).

Figure 1

ELAO Test Results for English (Efficient Language Assessment Online)
New LANSOD Arrivals 2012 (Terrier and Maury, 2015)



3.3 LANSOD Student Profiles: Aix Marseille University

ECLAM and coursework results at Aix Marseille University (AMU) further confirm the heterogenous profile of LANSOD students. The data presented in Figures 2 and 3 below are based on the first term results of 500 (± 50) first year science students for each year between 2013 and 2018. These were the results for one of the three science campuses of the university.

The French university grading system requires a mark out of 20 which has been converted into a CEFR category using a conversion table. The CEFR common reference levels are practical tools for identifying student language levels. However, as with any grading system, they are not infallible representations of students' language levels (see for example Clare Tardieu, 'Votre B1 est-il mon B1?' [Is your B1 my B1?], 2010). To illustrate this point further, the conversion table used for this data is detailed below in Table 1, Campus 1. This table was not unanimously agreed upon by language teachers at Campus 1. Furthermore, it differs from that used by a colleague at another AMU science campus (see Table 1, Campus 2). The main difference between the two tables concerns the A2/weak B1 category. The

conversion Campus 1 table (see Table 1) used in this study was more ‘forgiving’: given the difficulty of the texts used in the ECLAM final test (often from The Economist), it was reasoned a mark over 7/20 could be considered to be a weak B1 level as an A2 level is mainly concerned with basic, every day matters. Also, the ECLAM test was not considered to be sufficiently sensitive to measure the difference between a C1 and a C2 level (high academic level) in the Campus 1 version and so did not distinguish between C1 and C2.

Table 1

CEFR Conversion Table

Campus 1		Campus 2	
Grade	CEFR Profile	Grade	CEFR Profile
0-7	A1/A2	1-5	A1
7.1-9	Weak B1	6-9	A2
9. -11	B1	10-13	B1
11.1-13	Excellent B1	14-17	B2
13.1-15	B2	18-19	C1
15.1-18	Excellent B2	20	C2
18.1-20	C1/C2		

There are arguments for the validity of each of the conversion charts of course, which are in any case essentially similar. The main point to note is the necessity of the use of some judgement in the compilation of statistical results. Statistics are not cold, hard facts. As Nate Silver states in ‘The Signal and the Noise’: ‘The numbers have no way of speaking for themselves. We speak for them. We imbue them with meaning’ (2012, p. 9).

3.4 Statistical Data Conclusions

The data presented in Figures 2 and 3 are based on the Campus 1 conversion table. It shows the results for each CEFR profile for the five-year period between 2013 and 2018.

Figure 2

Student Results 2013-2018

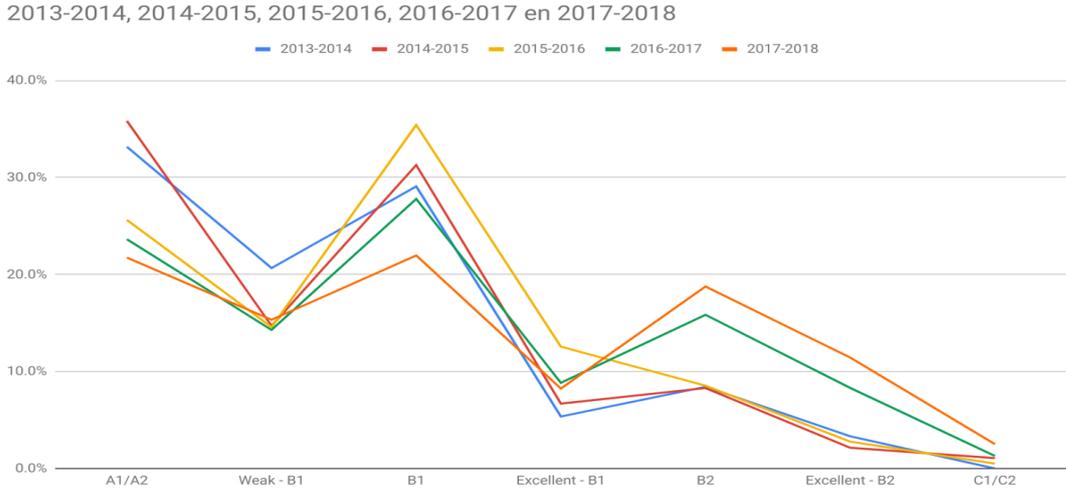
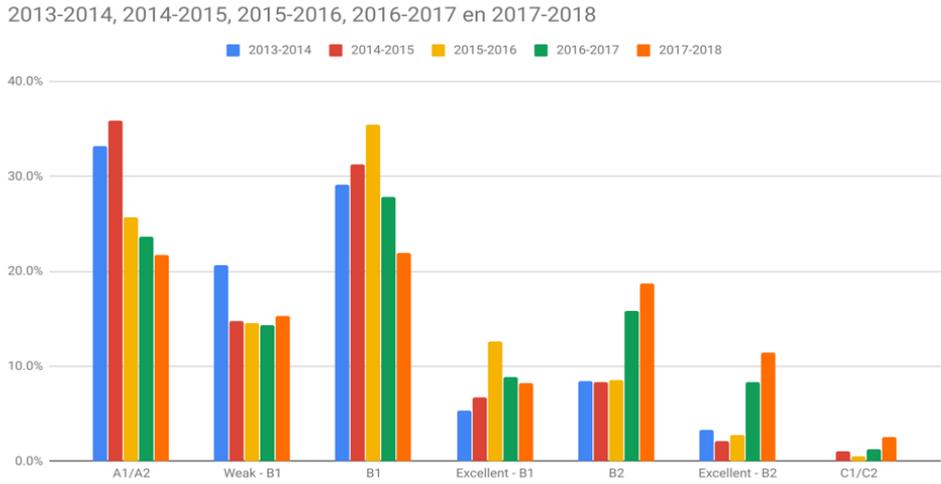


Figure 3

Student Results 2013-2018



It is interesting to note some striking tendencies over the last five years. There is a notable decrease in the percentage of A1/A2, weak B1 and B1 profiles and a less striking, yet still marked increase in the percentage of B2, excellent B2 and C1/C2 profiles between 2013 and 2018. This is especially so after 2015-2016. The influence of social media and smart

phones might be a plausible hypothesis to explain this phenomenon as students rarely have absolutely no contact with the English language compared to five years ago.

The tendency described above is more visible in the chart below, which specifies the actual percentages for each profile from year to year.

Table 2

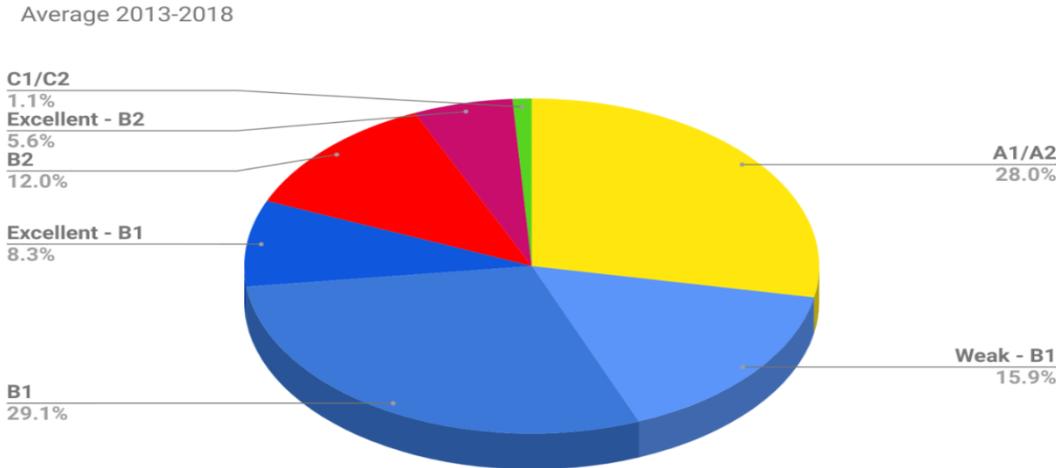
AMU Student Results 2013-2018

Level	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	Average
A1/A2	33.2%	35.8%	25.6%	23.6%	21.7%	28.0%
Weak - B1	20.7%	14.7%	14.6%	14.3%	15.3%	15.9%
B1	29.1%	31.3%	35.4%	27.8%	22.0%	29.1%
Excellent - B1	5.4%	6.7%	12.6%	8.8%	8.2%	8.3%
B2	8.4%	8.3%	8.5%	15.8%	18.8%	12.0%
Excellent - B2	3.3%	2.1%	2.8%	8.3%	11.4%	5.6%
C1/C2	0.0%	1.1%	0.5%	1.3%	2.5%	1.1%

The pie chart in Figure 4 represents the average percentage of each CEFR reference level for the 2013-2018 period as a whole. This confirms the heterogeneity of LANSOD student profiles with just over half of students in the B1 range.

Figure 4

CEFR Profiles Based on the Average of the 2013-2018 Results



3.5 The AMU Students in this Study

The students who participated in this study were mainly first-year science undergraduates in maths or physics. Most of the extracts chosen for the empirical analyses (8.2, 8.3, 8.4, 8.5) were taken from filmed lesson activity with such groups. As the sequence was generally useful for developing students' oral and written scientific English, it was also used with other groups such as the third-year maths undergraduate group analysed in a chosen extract in 8.6 (The Extended Roleplay). The empirical analyses give a detailed description of the various didactic issues arising during the development of the sequence. It is perhaps interesting to note that the phenomenon of heterogeneity did not arise as an issue or point of particular interest in this CLIL research-action project.

3.6 The CLIL Sequence

A general outline of the CLIL sequence developed and experimented in this study is presented in Table 3. Table 4 is how the sequence is presented to language teachers as an introduction to its general organisation. A more detailed account of the knowledge objectives and possible classroom scenarios is also presented to language teachers (see Appendix A). This information is essentially an *a priori* analysis (see chapter 5) of the teaching/learning content.

Table 3*Estimating Uncertainty: Problem-Solving and Learning-by-Doing in English and Physics*

	General Language Objectives: Action-oriented approach. Using English in context in an inquiry-based, problem-solving project. Describing, developing hypotheses, explaining, debating and summarizing.	General Objectives in Physics: Develop an understanding of all the factors to take into account in estimating the degree of uncertainty in a measurement. Develop an understanding of the importance of a rigorous protocol to reduce the uncertainty in any measurement
Week 1	Describe a protocol. Research and use all available language resources.	Execute a protocol successfully. Encounter and understand the subjective aspect of estimating an uncertainty in measurement.
Week 2	Describe in detail a new protocol. Justify an uncertainty estimate. Speculate on how a protocol might be improved. Listening comprehension: identify the main ideas in the execution of a protocol.	Design a protocol to measure an object and include an uncertainty estimate. Identify the potential for uncertainty in the measurement. Write a measurement result correctly. Understand Walter Lewin's reasoning in his experimental set up (MIT Video).
Week 3	Write a clear, detailed scientific laboratory report of a protocol executed in a mini-group. Summarise information researched and compiled from different sources.	Write a laboratory report which corresponds to the standards of scientific practice.
Week 4	Evaluation of the different language competences targeted in the sequence Oral Expression in interaction: roleplay Written Expression: write a report	

Table 4

Synoptic Table of the Uncertainty Sequence: Lesson Organisation

<p>Séance 1</p> <p>Time: 30 mins</p> <p>Activity: Create protocol in pairs/research vocab</p> <p>Teaching resources: protocol instruction sheet</p> <p>Material: tennis balls (ruler, protractor); Space for students to work in small groups. Computer or smartphone for vocab research</p>	<p>Time: 30 mins</p> <p>Activity: describe and exchange protocol to partner using the same instruments</p> <p>Teaching resources: none</p> <p>Material: space for students to exchange in twos or threes</p> <p>Rulers, protractors, string etc. Board for results</p>	<p>Time: 20-30 mins</p> <p>Activity: Class discussion of results on board</p> <p>Distribute new protocol instruction sheet for next week</p> <p>Teaching resources: None</p> <p>Protocol instruction sheet for HW</p> <p>Material: Board, chalk</p>	<p>Time: 20 mins</p> <p>Activity: Class discussion around a worksheet</p> <p>Contribute to list of words on Moodle</p> <p>Teaching resources: choice of worksheets</p> <p>Material: Board, chalk</p> <p>Wifi, computers</p>
<p>Séance 2</p> <p>Time: 45 mins</p> <p>Activity: Enhancing fluency exchange</p> <p>Teaching resources: Enhancing-fluency/listening sheet (optional).</p> <p>Material: Space to exchange. Microphones for dictating (optional)</p>	<p>Time: 10 mins</p> <p>Activity: Brainstorm the components of a lab report.</p> <p>Ask the students to write up their improved protocol in a lab report for HW</p> <p>Teaching resources: none</p> <p>Material: Board, chalk</p>	<p>Time: 60 mins</p> <p>Activity: Walker Lewin extract or Worksheets</p> <p>Work on the extract (comprehension, vocabulary, uncertainty)</p> <p>Teaching resources: Listening worksheets</p> <p>Material: Video projector, computer, video extract</p> <p>Also available on Moodle and YouTube</p>	<p>Time: -</p> <p>Activity: Worksheets</p> <p>Last significant figures. Scientific notation.</p> <p>Teaching resources: choice of worksheets</p> <p>Material: Board, chalk. Computer access to put vocabulary on Moodle</p>
<p>Séance 3</p> <p>Time: 40 mins</p> <p>Activity: Mix and Match reading comprehension activity (Lab report)</p> <p>Put in the right order. Answers on board</p> <p>Teaching resources: Description of the components of a lab report</p> <p>Example of a mixed-up lab report using shadow method</p> <p>Example of a lab report in correct order</p> <p>Material: Board, chalk,</p>	<p>Time: 80 mins</p> <p>Activity: Using the model, write-up of protocol on Drive document in groups of 4/5</p> <p>Teaching resources: Example of a lab report</p>	<p>Time: -</p> <p>Activity: HW Re-read the lab report and contribute to the vocabulary list on Moodle</p> <p>Teaching resources:</p>	<p>Material: Wifi and computer</p>
<p>Séance 4</p> <p>Time: 15 mins</p> <p>Activity: Explain the role-play.</p> <p>Distribute role-play sheets.</p> <p>Compose the groups made up of students with different protocols</p> <p>Teaching resources: roleplay sheets</p> <p>Material: space for group exchanges</p>	<p>Time: 45 mins</p> <p>Activity: Evaluated interaction activity to category protocols</p> <p>Teaching resources: evaluation sheets</p> <p>Material: space for group exchanges</p>	<p>Time: 60 mins</p> <p>Activity: Write report on the meeting and its conclusions. Work in small groups</p> <p>Teaching resources: evaluation sheets</p> <p>Material: access to Drive document</p>	

PART II: The Joint Action Theory in Didactics (JATD)

Chapter 4: JATD as a Theoretical Framework

This chapter is a presentation of the notions and descriptors which are particularly useful in this study. That is to say, those used to describe and analyse the didactic activity of the extracts presented in 8.2 to 8.6. The full glossary of current JATD notions can be consulted on the JATD website.⁶

4.1 Origins and Objectives

A precursor to the Joint Action Theory in Didactics can be found in the work of Guy Brousseau (2004), who in the 1970s developed a theory of didactic situations to explain how learning might occur in classroom practice. He considered knowledge to be encapsulated in situations and that learning was possible as a result of experiencing such situations. Brousseau focussed on the study of fruitful teaching-learning situations to transmit mathematics, of which the most emblematic example is that of the tangram-like, jigsaw puzzle situation. Here, students were asked to enlarge a jigsaw puzzle but in doing so they were confronted by the need to use the targeted knowledge, that is to say, the principle of proportionality. On first tackling the problem presented, students invariably increased each piece of the puzzle by the same amount. The feedback or *retroaction* of the situation confronted them with the error of this approach as this meant the pieces of the puzzle no longer fitted together. Students were thus constrained to recognise the need for the principle of proportionality and to work toward the integration of this principle.

Another precursor to the JATD is the work of Yves Chevallard. He introduced the notion of *didactic transposition* (1985) which highlights how knowledge is transformed in order to be taught in an institutional context. He developed the Anthropological Theory of the Didactic (ATD or TAD in French) to explain how knowledge is linked to teaching-learning practices which he called *praxeologies*: an interlinking of practices and discourses. This concept has been reconceptualised in the notions of social game, jargon and thought style in the JATD which will be explained in more detail later. Other notions introduced by Chevallard and

⁶ (<http://tacd.espe-bretagne.fr/glossaire/>).

subsequently developed in the JATD are those of *mesogenesis*, *topogenesis* and *chronogenesis*. These will also be presented in more detail in this chapter.

The origins of the TACD can be found in an article published in a maths education journal by Sensevy, G., Mercier, A. and Schubauer-Leoni, M.L. (2000). This article was the beginning of an increased focus on the role of the teacher in didactic action.

G rard Sensevy and Alain Mercier (2007) then integrated this anthropological approach into the Joint Action Theory in Didactics (TACD in French). At this point, concepts were developed to describe in detail the various elements involved in the teaching-learning process. In particular, the concept of a game was used (learning game or *jeu d'apprentissage* in French) as well as the necessity of the *joint action* of the teacher and the pupils in order for learning to occur.

The notions developed within the Joint Theory Action Theory in Didactics as used in this study, are founded on the principles expounded by Sensevy (*Le Sens du savoir*, 2011), and the collective of authors contributing to 'Didactique pour enseigner' (*Collectif Didactique pour Enseigner*, 2019). The notions developed are not static, but on-going notions with the potential to evolve or become densified with use.

The purpose of the JATD framework is multiple. First, it aims to theorise a specific process of design-based research called Cooperative Engineering (Sensevy et al., 2013, Joffredo-Le Brun et al., 2018, Gruson, 2019, Sensevy & Bloor, 2019). This refers to the collective development of teaching sequences by teachers and researchers. It is founded on an iterative process between practice and theory in a bottom-up, Deweyan-like approach: 'Principles are methods of inquiry and forecast which require verification by events' (Dewey, 1922, p. 239). It is as a part of this evolving process that notions might be subject to further nuancing and/or be further consolidated.

Second, it seeks to undertake a scientific investigation of didactic practices by determining what is actually happening in classrooms in relation to the knowledge taught. To this end, the constantly developing JATD descriptive notions offer the means to finely describe classroom practice vis- -vis a given body of knowledge. This leads to a third objective: an

engagement in discussions of central importance with regard to classroom activity and education in general. This is seen to begin with a careful description of the reality of classroom practice; there are many issues in classroom practice which science has not yet even begun to investigate. Detailed descriptions of practice are thus the first step in identifying the nature of the issues to be addressed (Sensevy & Bloor, 2019).

4.2 The Dialectics of Contract-Milieu and Reticence-Expression

The two JATD dialectics of *contract-milieu* and *reticence-expression* (Sensevy, Gruson & Forest, 2015) render visible aspects of evolving classroom practice. Both these notions are integral to the didactic analyses undertaken in this study.

The Dialectic of Contract-Milieu

The notion of didactic contract should be understood in relation to that of didactic milieu. The contract represents what is already known by a student, whether that be their existing knowledge or learning habits. When encountering a problem, students will first rely on their existing knowledge and habits in their attempts to solve a problem. This represents their *already-there* in the didactic contract.

The milieu represents what is as yet unknown to the student; that is to say, the knowledge targeted in relation to the problem being explored. Initially, the diverse elements of this unknown targeted knowledge will appear as disparate, scattered signs making little sense. Here, the milieu can be said to be *resistant*, as it cannot be interpreted by the student. This is why the milieu can be said to symbolise the problem that the student is attempting to solve.

In using the contract, that is to say, the *already-there*, and in engaging in *transactions* with the teacher, the student will come to link together the various signs in the milieu into a coherent system of meanings which correspond to the targeted knowledge. This notion of milieu is similar to the notion of situation as expounded by John Dewey, and which Dewey linked to the notion of inquiry: 'inquiry is the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and

relations as to convert the elements of the original situation into a unified whole.’ (Dewey, 1938, pp. 104 -105).

For learning to occur, students must be constrained to go beyond their *already-there*, the contract, and to explore the potential knowledge in the milieu. This means that students must be confronted with some kind of imbalance between the contract and the milieu so that in their effort to counter this imbalance they develop strategies which enable them to access new knowledge. If this were not the case, they would not go beyond what they already knew in the contract and consequently they would not learn anything new. However, if the distance between the contract and the milieu is too great, or if the students are not successfully guided to navigate this imbalance between the contract and the milieu, learning will not occur either, as students will not be sufficiently armed to explore the milieu successfully.

The reader might appreciate specific examples of these notions used in context in order to better grasp their particularities. This can be found in the didactic analyses of this thesis from 8.2 – 8.6. An example of a milieu which the students are not able to decipher can be found in 8.2. This is a description of an exploratory lesson where the gap between the contract and the milieu will be seen to be too great for the students to be able to develop successful strategies and access the knowledge in the milieu. In 8.3, ‘The Genesis of a Thought Style’, another example of a challenging, resistant milieu is described. However, in this example the milieu is successfully deciphered by the students. As we will see, the students identify successful strategies to explore the milieu thanks to the transactions with the teacher who engages them in an inquiry-based process of learning, despite the distance between the contract and the milieu.

In JATD terms, the teacher can be said to facilitate some kind of *didactic equilibration* (Sensevy, Gruson & Forest, 2015) between the two poles which is sufficient to enable the students to devise successful learning strategies.

The notion of didactic equilibration might be better understood by referring to the descriptions of the action of the teacher in her efforts to guide students to navigate between the contract and the milieu in order for learning to occur. This will also be a key notion in the analysis of ‘The Genesis of a Thought Style’ and ‘The Enhancing Fluency Exchange’. In the

former extract, as mentioned above, the action of the teacher will be seen to signal to students the aspects of the contract, the *already-there*, that will be useful to them so as to help them identify effective strategies to explore the milieu. In the latter extract, the teacher will be seen to situate her action between the two poles differently in relation to the two students Walid and Pedro. This will be shown to be due to her identifying a different successful strategy for each student depending on their different existing knowledge, that is to say, their different contracts.

The Dialectic of Reticence-Expression

The notions of reticence and expression (Sensevy, Gruson & Forest, 2015) render visible the opposite and complementary facets of a teacher's didactic practice. Choosing to be reticent or expressive is the main means available to a teacher to guide students in the milieu. When a teacher is reticent, that is to say when they do not reveal what they know, they constrain students to discover for themselves what is not revealed. When a teacher is expressive, that is to say, when they do reveal what they know, they provide clear signals as to what is expected in order to access knowledge. In navigating between reticence and expression, teachers can indicate to students how best to develop effective strategies to appropriate new knowledge in the milieu.

The dialectic of reticence and expression is most effective in well-designed situations where students are able to appropriate knowledge thanks to a manageable didactic equilibration between the contract and milieu. Once again, specific examples of this dialectic can be found in the didactic analysis of this thesis. In 8.2, 'The Exploratory Lesson' provides an example of how the dialectic of reticence and expression might not compensate for a poorly-designed situation and a major imbalance between a contract and milieu. In 8.3, 'The Genesis of a Thought Style' provides an example of how the dialectic of reticence and expression can be a powerful tool for teachers to enable students to devise successful learning strategies despite a challenging milieu.

As with the dialectic of contract and milieu, the dialectic of reticence-expression is most useful for representing didactic practice when considered as two sides of the same coin. Hence, a given context is not so much considered wholly contract or milieu, but can be best

understood as tending more toward one or the other in a flexible, reactive manner. Similarly, a teacher can be expressively reticent: the fact of choosing not to speak, for example, can be a strong sign to be interpreted in the milieu.

As didactic practice is a moving, living practice, the dialectic aspect of these descriptors allows for a description of the reactive, constantly-moving nature of classroom activity.

4.3 The Genesis Triplet and Student-Originators

Other notions used in this study to render visible the various aspects of didactic activity include the genesis triplet of *mesogenesis*, *chronogenesis* and *topogenesis* (Sensevy, 2011; Collectif Didactique pour Enseigner, 2019). The mesogenesis might at times be used independently, but these notions are particularly effective when used together, as a system, in conjunction with the double dialectic of contract-milieu/reticence-expression.

Mesogenesis, Chronogenesis and Topogenesis

This triplet is used to indicate the influence of various changing variables in relation to the knowledge targeted. It can be seen to be particularly useful in rendering visible the didactic activity at play in 'The Genesis of a Thought Style'.

The mesogenesis refers to a student recognising what might at first appear to be disparate signs as actually being the various linked elements of a particular symbolic representation of the knowledge at stake. It is in interpreting correctly these various signs that students eventually come to piece together the different elements essential to a relevant strategy. That is to say, a strategy for appropriating knowledge available in the milieu. Identifying and describing the mesogenesis process is a means of showing how the process of inquiry is evolving in the joint action of the teacher and the students.

The notion of topogenesis renders visible the role of various actors in piecing together initially disparate signs. When a teacher plays a leading role in linking together various elements, he or she is said to have a topogenetically high position and the students a low position. When a student's, or students' contribution can be seen to link together the disparate elements, they are said to have a high position.

The notion of chronogenese completes the triplet by rendering visible at what moment in the didactic activity a sign might be integrated into the bigger picture. This descriptor tends to lead to a questioning as to why and how a particular element emerged at a particular moment during the didactic activity. When a particular contribution can be seen to help the inquiry along, it is said to be chronogenetic.

Student-Originators

The role of student-originators is of particular importance in this study as the sequence was designed to ensure students contributed a maximum of L2 language output. To that end, certain habits of action were integrated early into the sequence. This entailed students contributing much of the material that was explored in class. That is to say, the teacher organised a large part of the didactic activity around material produced by the students themselves; they were thus at the origin of the work and the joint action in the classroom.

4.4 Didactic Games

The notion of game is central to the Joint Action Theory in Didactics' modelling of didactic practice (Sensevy, 2011; Sensevy, 2012; Gruson, Forest & Loquet, 2012; le Collectif Didactique pour Enseigner, 2019). Whilst it is not considered to be a perfect representation of classroom practice, it is recognised as what Pierre Bourdieu termed 'the least worst' means to model the social world (Bourdieu, 1987, pp. 80 - 81).⁷

The notion of didactic game allows for an exploration of various aspects of teaching-learning phenomena. For example, the fact that a didactic game is a cooperative game where teachers and students work together to achieve the same objective, that is to say, student learning. In fact, the teacher can only be seen to 'win' the game if and only if students learn during the didactic game.

⁷ « L'image du jeu est sans doute la moins mauvaise pour évoquer les choses sociales. »

This modelling also has the advantage of engendering the useful question ‘What is the purpose of the game?’ In this way it provides an efficient means of discerning the implicit or explicit intentions integral to classroom activity. This is aided further by the fact that the semantic field associated with games can be integrated into the modelling. For example, with terms such as rule, stake or strategy.

Learning Games, Epistemic Games, Epistemic Capacities

The notion of didactic game to model classroom activity is specified further in the JATD with the notions of learning game and epistemic game. A learning game, as its name suggests, represents the organisation of classroom activity which is intended to produce student learning. It enables a description of an activity undertaken which includes a definition of its objectives and expected outcome. As classroom practice is a dynamic and evolving phenomenon, a single activity might entail a series of learning games to represent the changing stakes and objectives of evolving classroom practice.

Epistemic can be defined as relating to knowledge or knowing. To appreciate the notion of epistemic game, as used in the JATD, it is first necessary to understand the concept of knowledge as defined within the framework. In chapter 1, the epistemological premises of this study as regards language are outlined: in keeping with the second Wittgenstein⁸, language is seen to have meaning in the context of a certain cultural practice. Similarly, knowledge in general is considered to be a cultural phenomenon: the product of human invention to deal with the problems people encounter. Knowledge, seen from this perspective, must be considered within the context of its cultural practice for it to have meaning. Cultural practices, including their associated elements such as jargon and thought style, are thus modelled as epistemic games (Santini, Bloor & Sensevy, 2018).

Based on these foundational premises, education in the JATD is considered to be the manner in which epistemic capacities (Gruson, 2019) are developed through participation in

⁸ Wittgenstein is one of the rare philosophers to completely question his own thinking to the point of rejecting his own work (*Tractatus Logico-Philosophicus*). He then worked on a new understanding of language in a later period of reflection leading to *Philosophical Investigations* (1953/2009), published posthumously.

learning games. Epistemic capacities are defined as such because they can be seen to present similar characteristics to those of an epistemic game. They are thus said to present some form of epistemic kinship (Sensevy, 2011; Santini et al., 2018) with an expert in the field, that is to say a connoisseur of the practice (DpE, 2019).

4.5 Seeing-As, Jargon and Thought Style

The second Wittgenstein is an important reference as regards the epistemological underpinnings of the JATD. For Wittgenstein, social life is composed of various ‘forms of life’ (i.e. cultural practices or social games), each of which has its own associated seeing-as, jargon and thought style. A seeing-as refers to the intertwined perception and conception developed within a particular form of life. What one sees is not an action which is independent from the conception of the ‘object’ of one’s gaze: there is an organic relationship between perception and conceptualisation. This moulded disposition is what can be considered to be the seeing-as of a given community.

A form of life and its associated seeing-as will include a particular thought style (Fleck, 1935/2008) and jargon (Sensevy, Gruson, & Le Hénaff, 2019) which will be common to the different members of the community engaged in that form of life. The thought style, as it has been developed in the JATD, is very similar to the notion of seeing-as. It too refers to a community’s common disposition to perceive/conceive in a particular way.

The notion of jargon represents the linguistic component of a social game; it is both a product and a building block of that same social game. The concept of jargon denotes more than vocabulary as it includes an understanding of the background to the practice in which it is embedded and which gives it shape. The jargon of a cultural practice is thus its linguistic system: a network of terms, expressions and various discourses that might occur within the forms of life specific to that cultural practice. The example to illustrate this point, taken from this study, is the issue of uncertainty in measurement and the way it might be discussed (in the widest sense of the term) within a community of physicists sharing that form of life. Such discussions would entail specific language games (Wittgenstein, 1953/2009) associated with the practice of measurement. These would then be both the source and the result of the jargon related to the practice. It is in acquiring and mastering the jargon of a particular form

of life that individuals ultimately come to be integrated into the thought style of the community of practice engaged in that particular form of life.

4.6 The JATD: Conclusion

The notions and descriptors outlined above are best understood within the context of the overall JATD framework. This framework might be considered to have an advantage in that it has been tested by teachers and researchers emanating from a range of backgrounds over the last twenty years (see Collectif Didactique pour Enseigner, 2019). It is in this respect a mature theoretical and methodological approach.

One of the questions arising in CLIL practice is how the field might be effectively described. For example, in 'CLIL', Coyle, Hood and Marsh devote a chapter of their comprehensive overview of CLIL practice and theory to this issue: 'This chapter explores the types of evidence that should be produced during an evaluation of the impact of a CLIL programme.' (Coyle et al., 2010, p. 134).

This thesis intends to make a contribution to this discussion. Using the JATD notions and descriptors outlined in this chapter, it seeks to present examples of didactic activity that are rendered visible using the JATD framework. It hopes that these examples will be of interest to future CLIL practice and research.

Chapter 5: The Methodology

This chapter presents some essential components of the Joint Action Theory in Didactics research paradigm (Sensevy, 2011; Sensevy & Bloor, 2019) and describes how the JATD methodological tools were used for the investigation of the teaching sequence at the heart of this study.

5.1 Cooperative Engineering

The Joint Action Theory in Didactics framework models a specific kind of research which is termed cooperative engineering (Sensevy, 2011; Sensevy & Bloor, 2019):

Cooperative engineering (CE) refers to a methodological process in which a collective of teachers and researchers engage in a joint action to codesign, implement and re-implement a teaching sequence on a particular topic. Each stage of the process is based on an analysis and evaluation of the previous stage, and thus a crucial aspect in the building of a cooperative engineering is its iterative structure (...). Another fundamental aspect of this methodological process, similar to a characteristic of educational action research (...) is the participation of teachers in the conception of the cooperative engineering process. CE also shares some of the traits of collaborative research (...), in particular its focus on the way teachers and researchers can work together (Sensevy & Bloor, 2019).

The sequence developed and investigated in this thesis can be generally characterised as a cooperative engineering. The cooperative action of the two actors in this research-action project can be considered as a burgeoning collective: the English teacher described in the didactic analysis (8.2 – 8.6) is also the author of this thesis and as such assumed a teacher-researcher role. She worked in a cooperative action with an associate physics professor. The latter played a key role in the development of the teaching sequence analysed, especially in its instigation and the co-design of its initial form. She was also a constant advisor during later stages of the sequence's development.

The sequence was first implemented in December 2014. It was subsequently analysed and evaluated in a joint action by the teacher-researcher and the associate physics professor.

Following this evaluation, the sequence was redesigned and re-implemented. This approach continued in an iterative process between September 2015 and September 2017.

Following the development of the sequence, from September 2018, various other English teachers 'tested' the resulting programme by teaching the course in their own lessons. This generated interesting feedback which, though not directly presented and analysed in this thesis, could be the source of a future collective working in a cooperative engineering to continue to reflect on the sequence's on-going development.

The work presented thus shares three characteristics of a cooperative engineering: the beginnings of a collective of researchers and teachers, the iterative aspect of a CE as the teaching sequence was implemented and re-implemented following analysis and evaluation, and finally, the collaborative nature of its elaboration.

5.2 JATD: A Clinical Approach

The didactic analysis of the sequence was undertaken using the clinical approach developed within the JATD. Filmed lessons played an essential role in documenting the main features of classroom activity (Sensevy, 2011; Tiberghien & Sensevy, 2014). This was to provide an analogic representation of the actual didactic activity in class. That is to say, a representation which included a maximum of detail without any additional commentary or interpretation. Whilst filmed activity is not to be confused with reality itself, it nonetheless is an excellent source of empirical data for representing the social world.

The information a picture carries in digital form can be rendered only by some enormously complex sentence. (...) Most pictures have a wealth of detail, and a degree of specificity, that makes it all but impossible to provide even an approximate linguistic rendition of the information the picture carries. (Dretske 1981, p. 138, as quoted in Sensevy, 2011, p. 224).

The films of classroom practice were then transcribed and carefully *described* (Ryle, 1968/2009; Sensevy, 2011) before any attempt was made to analyse them. This was to provide an initial source of data which was as close as possible to the actual practice.

5.3 JATD: Situating the Knowledge at Stake

Identifying the knowledge at stake in the classroom in relation to its epistemological origins was also a major component of the initial stages of the didactic analysis. This entailed both pinpointing the exact knowledge at stake in each given context as well as identifying how that knowledge related to the overall culturally-constructed body of knowledge from which it emanated. To that end, an *a priori* analysis of the targeted knowledge was undertaken (see Appendix A, lesson description for teachers), as well as an epistemic/epistemological analysis of the targeted knowledge (see chapter 6 and 7) in the sequence studied.

These were the various components of the preliminary stage of the didactic analysis: the filmed empirical data which was transcribed and described in detail, together with the *a priori* and epistemic/epistemological analyses of the knowledge at stake in the teaching sequence. Once these elements of the didactic analysis were assured, an *analysis* of the classroom activity was possible.

5.4 From Description to Analysis

The first step in analysing the classroom activity was identifying the system of intentions of the various actors in each context studied in relation to the knowledge at stake. One of the major particularities of the JATD paradigm is that knowledge objectives are closely examined *in situ* within the context of interactions: this is integral to the JATD approach. This focus on classroom activity *in situ*, especially the various moves of the actors in relation to knowledge objectives, is why the JATD is defined as an anthropological approach.

Identifying the systems of intentions manifested during class interactions required a *micro* analysis using filmed classroom activity as the main source of empirical data. Multiple viewing of filmed didactic activity provided clues (Ginzburg, 1979) to identify signs of actors' mutual adjustments in semiotic systems (Sensevy, Gruson & Forest, 2015). Of particular interest was the joint action of the teacher and the students with regard to the knowledge at stake; this was viewed as the object of transactions (Dewey, 1935/2008; Sensevy, 2011) between the different actors.

As with all JATD studies, this micro analysis was rendered possible by the use of the JATD notions outlined previously in chapter 4. These were the tools for describing and modelling the complexity of classroom activity. It is the modelling of didactic activity which makes it possible to apprehend the role of the various phenomena identified at a micro level in relation to both the didactic activity as a whole, as well as the epistemic stakes inherent in the classroom practice. In this way the didactic phenomena were identified from a meso and macro level of analysis (Sensevy, 2011; Sensevy, 2012).

5.5 Other Sources of Data

The micro, meso and macro analyses of the didactic activity in this study relied on additional sources of data to contextualise the modelled practice. Various sources of data contributed to the final analysis including students' productions, classroom material and communication between the two teachers.

For example, student written productions were analysed in detail at a micro level (see 8.5) to identify signs of epistemic capacities that were targeted in the sequence.

Also essential to the analysis was the examination of the teaching resources developed by the two teachers. This was for two reasons. First, in order to fully comprehend the learning games and interactions between the different actors in relation to those resources. Descriptions of filmed classroom activity are therefore preceded by detailed presentations of the teaching material distributed during class. Second, in order to offer insight into important aspects of the cooperative action of the two teachers and how their cooperation led to their co-design of not only classroom material but also the sequence as a whole.

The co-design of classroom material was possible thanks to the frequent and productive communication between the two teachers. An example of their communication included in 8.5 renders visible how this aspect of their collaborative action fed into both the teaching resources and the practice of the English teacher in class.

5.6 The Teacher-Researcher

This research project is the result of a teacher-researcher study. As both the author of this thesis and the English teacher in the didactic activity analysed, I assumed the dual role of teacher-researcher. This statute is a subject of some debate. There is some concern that efforts by the same person to pursue both teaching and research goals lead to the compromise of the work of the teacher, or the researcher, or even both. However, there are also arguments to suggest that the two roles are complimentary (Sensevy, 1994), especially in the context of cooperative engineering where a shift of interest towards teachers' representations and practices is welcomed (Artigue, 2020; Sensevy & Bloor, 2019).

This is a complex issue which, though pertinent to the context of this study, is beyond the scope of the didactic analysis of this thesis. However, having undertaken this dual-role, I shall hazard the following observations as a general appraisal of the teacher-researcher statute as I experienced it: certain aspects of the dual role of teacher-researcher were challenging, though not impossible to manage, whereas others proved to be more complimentary.

Some examples of the challenges encountered whilst juggling the two roles included the following. Firstly, competing demands on time to complete tasks related to teaching practice as well as those related to research practice. For example, the physical and logistical efforts to organise the use of a camera in addition to that required to transport and set up material related to teaching a lesson. Secondly, dealing with both the logistics of classroom practice as well as those of data collection. It was in general better to separate these two concerns. For example, when in a teacher role I filmed students closely whilst they were at work, the result of this interaction was problematic. It produced disappointing data that was not typical of actual classroom practice. Furthermore, the effort to fulfil both roles (by filming and talking to students at the same time) led to unfocused teaching practice; I felt I was not fully available as a teacher to best respond to various student needs (e.g. answering questions, guiding practice, evaluating and assessing students' output). The communication between the students and myself was undoubtedly hindered by the intrusive presence of a camera

between us (this is in contrast to the camera simply being strategically placed in the room then quickly forgotten).

An example of a complimentary aspect of the teacher-researcher statute includes the fact that there was, of course, a high degree of cooperation between the teacher and the researcher. This is a significant advantage in terms of the time required for communication between the two, and the potential of one role feeding into the other. The fact that, as a teacher, I was constantly shadowed by myself as a researcher meant that I had an insight into the entire iterative process of this (burgeoning) cooperative engineering (Sensevy & Bloor, 2019). A researcher seeking to gain such insight would have needed to invest considerable time in lengthy and detailed exchanges with a teacher. This was of particular interest when choosing the extracts to be analysed, as we shall see below.

These are a few examples of issues arising in teacher-researcher practice. A further implication will be briefly discussed below, with an example of how my teacher role informed my researcher role for certain choices. As mentioned earlier, teacher-researcher practice is not analysed in detail in this thesis, but it is likely to be explored in research elsewhere as this is an increasingly common practice.

5.7 The Choice of Extracts

The JATD framework is a means of representing the reality of classroom practice through the lens of a specific thought style (Fleck, 1935/2009; Sensevy, 2011). As described above, this includes analysing in detail the interactions of the various actors during classroom practice in relation to the targeted knowledge. This knowledge must be fully explored in order to include in the analysis a full understanding of the epistemic stakes implicit in the classroom practice analysed.

The choice of extracts for the study was often based on practical concerns such as the quality of sound, the visibility of the actors, or even what came most easily to hand. As it is the framework itself, its thought style, which renders visible the various phenomena at play, this practical motivation is not particularly an issue.

Having said this, some care was taken to provide extracts which described the various stages of the four-week sequence so as to offer insight into the changing priorities as the knowledge developed throughout the programme. As a teacher and witness to each lesson, my awareness of the evolving stakes within the sequence informed the choices of extract made as a researcher. For example, the analysis of the laboratory report was included as it rendered visible the interplay between work on oral and written expression. It transpired that the detail of the analyses was such that it also rendered visible the joint action of the English teacher with the associate physics professor. Similarly, as a teacher and witness of the improvements and changes made to the sequence itself, my knowledge of this process informed my concern as a researcher to give some insight into the reasons for these modifications. This was the reason for the decision to contrast 'The Exploratory Lesson' with later versions of the sequence. It was then in my role as a researcher that I sought to render visible these reasons in using the JATD framework.

An analysis based on alternative extracts would of course have modified the thesis in some form. Nevertheless, I would argue that the essence of the didactic analysis in this thesis would be essentially the same even if based on alternative data: it is not so much the extracts as such which are revealing but the extracts viewed through the lens of the JATD thought style.

This raises some interesting questions as to the nature of proof in the learning sciences and the differences between statistical and cultural evidence (Sensevy, Santini, Cariou, & Quilio, 2018). The evidence presented in this thesis can be considered to be practice-based evidence of a cultural nature. That is to say, it is founded on a connoisseur's detailed understanding of the classroom practice presented within the context of its epistemic and even epistemological stakes.

5.8 Methodology: Conclusion

The three interlinked levels of micro, meso and macro descriptions were essential to the didactic analysis in this study.

The micro analysis of classroom activity rendered visible the subtle aspects of classroom practice essential to understanding the progression of knowledge objectives *in situ*.

However, the subtle aspects of classroom practice only became revealing when they were considered in relation to the meso/macro levels of analysis. The relevance and epistemic value of an actor's move when considered on a micro level, can only be adequately analysed when considered in relation to the epistemic potential of a given context.

Following the JATD approach, the methodology used in this thesis thus relied on a multi-layered process of scientific inquiry in order to piece together the traces of the classroom activity analysed. The description of film-making by the Russian film director and theorist Pudovkin provides a useful metaphor to appreciate the multi-layered process of a didactic analysis:

In order to receive a clear and definite impression of a demonstration, the observer must perform certain actions. First, he must climb upon a roof of a house to get a view from above of a procession as a whole and measure its dimension; next he must come down and look out through the first-floor window at the inscriptions carried by the demonstrators; finally, he must mingle with the crowd to gain an idea of the outward appearance of the participants. (Pudovkin, 1926, quote in Kracauer, 1969/1995, p. 122. Quoted in French in Sensevy, chapter 6, 2011).

PART III: The Epistemic Analyses

Chapter 6: The Origins of Scientific English and its Associated Thought Style

In order to gain a clearer picture of the epistemic stakes inherent in the sequence at the heart of this study, the form and style of scientific discourse in the English language will be analysed in some detail. As stated in chapter 1, language and practice are considered to be intrinsically linked in the JATD (Sensevy et al., 2019; Wittgenstein, 1953/2009). It is thus necessary to study scientific English within the context of scientific practice itself.

To do this, it will be useful to begin by focusing in some detail on the origins of empirical science. This is in order to identify the language games and forms of life (Sensevy, Gruson, & Le Henaff, 2019; Wittgenstein, 1953/2009) inherent to this domain and which enable a scientist to participate in scientific practice and be recognised as an authority in their field. As we shall see, this will depend on a scientist's ability to master the language games, or *jargon* (Sensevy, et al., 2019) embedded in the concrete practice or forms of life from which they emanate.

6.1 The Written Language of Scientists: The Emergence of the Experimental Report

The experimental report is today the standard form of written communication used in experimental science to communicate research, but this is a consequence of the evolving thought style and practices of scientific communities; it was not commonly used, and certainly not in its current form, in the early days of empirical science. The Royal Society, founded in 1660 in London, came to play a primary role in gaining recognition for the natural sciences, and the appearance of the prestigious scientific journal 'The Philosophical Transactions of the Royal Society of London (PTRS)'⁹ in 1665 has left us a rich trace of changing scientific discourse and its written forms.

Dwight Atkinson's detailed linguistic and rhetorical study covering 300 years of the 'Transactions' (PTRS), shows how the experimental report only gradually acquired the

⁹ Bazerman, 1988, P. 129. He also notes that The French *Journal des Scavans* first appeared three months prior to the *Transactions*

scientific status with which we accredit it today (1998, p. 81). As the identity of the early empirical scientists was intimately bound up with the social position of that of the gentleman (p.149), the letter was the naturally preferred medium of reporting scientific research in the Transactions (*PTRS*), as it was the form of life commonly shared by members of the early Royal Society. In fact, the letter remained an important medium of communication in the Royal Society right up until the nineteenth century (p. 152):

The single most common generic form in which articles appeared between 1675 and 1875 was the letter... In the 1675 volume, 51% of all *PTRS* articles appeared in letter form, while in 1725 only 33% were letters. In 1775, 48% of articles appeared as letters, and in 1825 29% appeared in this form. It was only a little more than 100 years ago then in 1875 that the letter is seen to have dropped completely out of the repertoire of reporting genres in the *PTRS* (Atkinson, 1998, p.81).

In his study of the genre and activity of the experimental report in science (*Shaping Written Knowledge*, 1988), Charles Bazerman traces the social and rhetorical forces at play which came to bear on its form. Bazerman includes in his study, an historical account of the changing form of scientific discourse which he too (prior to Atkinson) identifies from an analysis, amongst other documents, of 'The Philosophical Transactions of the Royal Society' from 1665-1800. He states that in the mid-seventeenth century, books and correspondence were the main mediums for disseminating information in natural philosophy and the nature of scientific discourse was essentially that of observations and reports of natural events. Experiments were not the focus of debate, and those that were discussed were of an early form; they concerned any manipulation of nature and were not especially concerned with a demonstration or discovery (Bazerman, 1988, P. 65).

Between the mid-seventeenth century and the end of the eighteenth century, scientific discourse had radically changed and its preferred mediums of communication had evolved. The scientific article had become the uncontested means of publishing scientific findings and the experimental report had become the standardised, recognisable model of how to present empirical experience as a statement of knowledge. For our study, an understanding of the influences that led to this transformation will help identify the nature of

the language games, jargon and forms of life of the scientific community throughout this period, and to this end it is useful to begin with an overview of the origins of the thinking within this thought collective (Fleck, 1935/2008), the practices of which are at the origin of modern empiricism.

6.2 The Seeds of Modern Empiricism

The origins of the thought collective of modern empiricism can be traced back to the period of transition from the Renaissance to the early modern era, at a time when Francis Bacon (1561 – 1626) was a key figure. His thinking was indicative of one of the earliest signs of a break with the Aristotelian ideal of deduction from ‘true and necessary’ axioms that was prevalent during the Renaissance. Bacon’s procedure and thinking was a major contribution to the special thought style within the thought collective (Fleck, 1935/2008; Sensevy et al, 2008) of scientific discourse founded on accountability to empirical facts.

In Bacon’s works, ‘Novum Organum’ (The New Method, 1620) and ‘The New Atlantis’ (1627), he described his scientific method of induction whereby he strived to develop a procedure ‘which by slow and faithful toil gathers information from things and brings it into understanding’ (Farrington, 1964, p. 89). Bacon urged his contemporaries to free their minds from ‘idols’ when engaged in knowledge acquisition, the term he used to describe what he saw as the false conceptions and prejudices arising from the mind’s pre-disposition to distort reality. Bacon writes in The New Method:

There are and can be only two ways of searching into and discovering truth. The one flies from the senses and particulars to the most general axioms, and from these principles, the truth of which it takes for settled and immoveable, proceeds to judgment and to the discovery of middle axioms. And this way is now in fashion. The other derives axioms from the senses and particulars, rising by gradual and unbroken

ascent, so that it arrives at the most general axioms last of all. This is the true way, but as yet untried¹⁰ (Bacon IV [1901], 50).¹¹

The influence of Bacon's approach can be discerned in the work of Isaac Newton,¹² a major figure in the manner in which the collective thought style of the scientific community evolved, as Charles Bazerman's analysis of Newton's written work reveals. Bazerman highlights the decisive influence of Newton in shaping the ultimate form of the experimental report and he details the forces at play which had come to bear on Newton and which had led him to present his findings in a particular way. It is therefore useful for this study to consider in some detail the nature of these forces and Newton's change in style.

6.3 Early Newton: the 'New Theory' Publication

In *Shaping Written Knowledge*, Bazerman undertakes a minutely detailed analysis of a range of Newton's written documents which include: Newton's notes on other scientists' publications in the *Transactions* between 1668-9, an early publication, 'A New Theory of Light and Colors' in 1672, all of the correspondence between Newton and his contemporaries in reaction to the 'New Theory' (often published in the *Transactions*, and finally *Opticks* in 1704).

Newton first presented his optical findings publicly with 'A New Theory of Light and Colors' in 1672 which was published in the 'Transactions' (PTRS). In his examination of the 'New Theory' paper, Bazerman describes how Newton had adopted what might be called a Baconian style, where he presents his own findings as concrete facts, as real as any natural event, even though the events that rendered these facts visible were brought about by his own experimental activity. Bazerman writes 'Newton attempts to make his findings appear as

¹⁰ Bacon is concerned here with the ascent from the abstract to the concrete in scientific practice; an epistemological underpinning of JATD

¹¹ As cited in the Stanford Encyclopedia of Philosophy

¹² 'In a justly famous Baconian pronouncement on method, Newton affirms experimentation as the driving force behind theory and as the prime source of certainty' (Gross, 2006, P. 71). 'Bacon's Idea and Newton's Practice of Induction', (Ducheyne, 2005, pp. 115–128)

concrete facts by establishing in a discovery narrative his own authority as a proper observer of concrete facts.' He quotes Newton's 'New Theory' 1672 publication to illustrate this point:

... in the beginning of the Year 1666 (at which time I applied myself to the grinding of the Optick glasses of other figures than Spherical,) I procured me a Triangular glass-Prisme, to try therewith the celebrated Phaenomena of Colours. And in order thereto having darkened my chamber, and made a small hole in my window-shuts, to let in a convenient quantity of the Suns light, I placed my Prisme at his entrance, that it might be thereby refracted to the opposite wall. It was at first a very pleasing divertissement, to view the vivid and intense colours produced thereby; but after a while applying myself to consider them more circumspectly, I became surprised to see them in an oblong form; which according to the received laws of refraction, I expected should have been circular... (1988, pp. 90–91).

Bazerman maintains that Newton's attitude of naïve wonder at the spectacle of nature, stumbling across the surprise of an oblong projection, is a narrative style which enables him to present himself as being led only by the observed facts. However, in reality, this narrative is undoubtedly a simplified account of the numerous controlled experiments that Newton would have undertaken to obtain the results he describes in the above account. Bazerman is able to substantiate this claim with evidence of various discrepancies in Newton's different accounts of this particular experiment (1988, pp. 90–95).

Returning to the issue of Newton's influence on the scientific community of his time: the 1672 paper was received by Newton's contemporaries with considerable criticism and Newton felt so badly bruised by the experience that apart from one brief, hurried paper in response to the criticism, he refused to publish another paper in the journal (Bazerman, 1988, p.82). In response to criticism of the 'New Theory', he did, however, communicate regularly with his contemporary scientists over the next thirty years via published letters in the

'Transactions' (PTRS). This ended with the publication in book form of his major work, 'Opticks', in 1704 (1988, p. 82).¹³

Bazerman argues that Newton's ongoing correspondence with his contemporary scientists in the intervening period between 'New Theory' and 'Opticks' in fact enabled him to develop the rhetorical style necessary to convince other scientists of the validity of his findings. He states:

The controversy over the *New Theory* article, initiated by Hooke, lasted four years, into 1676, and seems to fall into three periods. In response to each set of criticisms, Newton develops a related set of rhetorical strategies, such that by the close of the period, the main features of the presentation of the *Opticks*, Book 1, are set (p. 100).

He concludes that as a result of these acquired rhetorical skills, Newton's publication 'Opticks' was favourably received and his powerful model of argument had a lasting influence on all subsequent scientific publications (1988, p. 131).

6.4 Logos, Ethos, Pathos and the Rhetoric of Science

The term rhetorical to describe the communication skills of a scientist might be questioned by some (2006).¹⁴ Bazerman (1988) and Gross (2006) consider scientific publications to be as much a product of a particular rhetorical style as any other literary genre. However, they insist this is not to deny the validity and grandeur of the scientific venture. Bazerman writes: 'persuasion is at the heart of science, not at the unrespectable fringe. An intelligent rhetoric practiced within a serious, knowledgeable, committed research community is a serious method of truth seeking' (1988, p. 321). Gross writes: 'Scientists are not persuaded by logos alone; science is not exception to the rule that the persuasive effect of authority and the values it embodies weighs heavily' (2006, p. 26).

¹³ By which time he had himself become president of the Royal Society, a position he retained up until his death in 1727

¹⁴ In response to criticism of his use of this rhetorical framework, this question is discussed at length by Alan Gross in *The Place of Rhetoric in Science Studies*, pages 3–31

The use of a rhetorical framework, therefore, to analyse scientific discourse can be seen as a means to focus on the social practices and language games/jargon of the scientific community as a thought collective. And given Newton's lasting influence on scientific discourse, understanding the transformation which took place in his rhetorical style between the 'New Theory' publication and 'Opticks' will also enable us to discern some of the language games, or jargon, of current day scientific discourse.

6.5 From 'New Theory' to Opticks: A Rhetorical Analysis

Let us compare how Newton described the above quoted extract of an experiment in 'New Theory' with part of the same extract in his later version of the same experiment in 'Opticks':

In a very dark Chamber, at a round Hole, about one third Part of an Inch broad, made in the Shut of a Window, I placed a Glass Prism (as quoted by Bazerman, 1988, p. 121).

As we can notice even from this brief quote given by Bazerman, this version is detached from a discovery account of events. Bazerman goes on to detail other significant changes in style that he has identified from his detailed analysis of all the aforementioned Newton texts. Experiments are described in far greater detail as for example, the solar image in an experiment described at the beginning of 'New Theory': formerly one sentence long, it takes a page in 'Opticks' (p. 121). Also, Newton not only describes what occurred but also describes the care he took to avoid mistakes, as if anticipating the problems he had encountered following the publication of 'New Theory' when one or two fellow scientists (e.g. Moray or Pardies) criticised his work by suggesting different results might be obtained when undertaking his experiments. Newton clarified this issue by giving more detailed descriptions of the experiment so as to avoid this outcome (1988, p. 121).

In 'Opticks', every step in reasoning is backed up with a careful description of an experiment, which is then placed within a framework so that it will be understood, performed and interpreted as Newton intended (1988, p. 121). Bazerman thus demonstrates how Newton had mastered a persuasive, rhetorical style that he had acquired by dealing with the various criticisms of his earlier publication in the 'New Theory'. His style in 'Opticks' was one

of authority and certainty of argument that overcame the prevalent belief that empirical experience could only produce uncertainty and probabilities (1988, p. 123).

Alan Gross (2006) presents a similar reading of Newton's change in tactics. Gross states that in 1672, at the time of Newton's 'New Theory' publication, Descartes's optics were firmly established and this included the conviction that white light was basic and colour derivative. Newton challenged this belief in 'New Theory' by asserting white light to be a compound of all the lights of the visible spectrum, and, furthermore, he broke with tradition by giving precedence to experiment over rational intuition in the quest for knowledge. As stated above, Newton's conclusions in this earlier publication were widely criticised: as he had not gone to great lengths to fully describe his experimental procedures, other scientists attempting to execute the same experiments did not obtain the same results which detracted from his publication's credibility.¹⁵ When a more mature Newton published 'Opticks' in 1704, Gross argues, like Bazerman, that Newton had mastered a rhetorical style which successfully persuaded his contemporaries of the validity of his findings. Gross writes

In his final masterpiece, Newton transformed optics, and experimental science, by allowing his readers to believe that an adherence to the new did not entail a fundamental rejection of the old. This strategy was successful: throughout the eighteenth century in England and on the continent, the physics of light was Newton's physics (2006, p. 64).¹⁶

¹⁵ Newton's description 'is accompanied by neither diagram nor clear directions' (Gross, 2006, p. 71).

¹⁶ Bazerman writes 'Although the Newtonian system gained authority in England, it did not do so in continental Europe, where a different conceptual/empirical/rhetorical/social climate reigned. There the objections excluded in England through Newton's narrowing of issues and experience remained alive, as described in Henry Guerlac, *Newton on the Continent*. The rhetorical interchange between Newtonian England and the continent is explored in part in Schaffer, but interesting questions remain to be studied concerning the interaction of the two distinctive rhetorical systems' (p.118). Chapter V of 'Newton on the Continent', 'Newton in France, The Delayed Acceptance of His Theory of Color' suggests Newton's influence ultimately prevailed. This concurs with what David Banks writes in *The Birth of the Academic Article* (2019) 'French scientists were to adopt the Newtonian point of view (...) in the course of the eighteenth century' (p.44). Nevertheless, I suspect interesting questions remain to be explored as regards the rhetorical style of the experimental report in English compared to that in French.

Gross identifies three significant changes in style in Newton's 'Opticks' compared to 'A New Theory of Light and Colors', the overall conclusions of which concur with Bazerman's analysis. First, in contrast to the scanty experimental details of his first publication, Newton was careful to provide dozens of meticulously described experiments in the 'Opticks', thereby ensuring his experiments could be successfully reproduced. This also ensured his experimental method dominated the paper by its very presence (p. 74). Second, using a Euclidean arrangement to set out his material, and being careful to acknowledge traditional views on optics, Newton implemented a rhetorical strategy that implied historical continuity, as the following quotation from 'Opticks' illustrates:

What Descartes did (the discovery of the sine law) was a good step... If I have seen further it is by standing on (th)e sholders of Giants.¹⁷

Third, he employed a rhetorical questioning that produced disguised positive assertions: 'Are not the Rays of Light very small Bodies?' (Gross, p. 75). In other words, rays of light are very small bodies. In this way, Newton undermined previous criticisms in the scientific community of his assertion that light was substance: his experiments consistently showed that light was indeed substance and his 'queries' presented a credible argument to support this position.

6.6 Newton's Language Games

As Newton's 'Opticks' was very influential in establishing the characteristics of the language games of scientific discourse, it is possible to discern in its style the traits of modern-day scientific writing: First, the fundamental commitment to empirical experience leading to an absence of emotionally-charged language. Second, minutely detailed descriptions of experimental designs and observed phenomena so that they may be repeated exactly. Third, the embedding of experiments within a conceptual framework, or paradigm as we would call it today. Finally, the discussion of findings within scientific thought collectives which are opened up for public appraisal in professional forums of publication.

¹⁷ As quoted by Gross (2006, p.73). Thus said, Gross underlines a tension between the deductive form Newton purports to adopt and the actual inductive form Newton employs.

These are the practices or forms of life of the scientific community which have given rise to certain language games or jargon emanating from the social and cultural games of this community. The written scientific discourse of this community has developed a distinctive literary style that can be identified. Gross states:

In scientific, as distinct from literary prose, the resources of language from which presence is created are decidedly limited. Because scientific prose is designed to create the impression that its language refers unproblematically to a real world existing independently of any perceiving subject, it generally excludes the subjective dimension of description, the use of emotion-charged words or irony (2006, p. 57).

In a contemporary work on mastering science in the classroom, Jay Lemke identifies the resulting grammatical forms of this literary style:

The language of science has evolved certain grammatical preferences, especially in writing, but also in formal speech (...). There is a lot of use of the passive voice, of abstract nouns in place of verbs, of verbs of abstract relation (e.g., be, have, represent) in place of verbs of material action (Lemke, 1990 p. 21).

The overall impression such choice of language gives is just as Newton would have wished: 'science as a simple description of the way the world is, rather than as a human, social activity, an effort to make sense of the world' (Lemke, 1990, p. 131).

A further, more contemporary example of this dialectical process in scientific writing, again from Bazerman's *Shaping Written Knowledge*, is illustrated below with the example of Arthur Compton during the preparation of his paper on *The Compton Effect*¹⁸.

¹⁸ The Compton effect is the term used for an unusual result observed when X-rays are scattered on some materials. By classical theory, when an electromagnetic wave is scattered off atoms, the wavelength of the scattered radiation is expected to be the same as the wavelength of the incident radiation. Contrary to this prediction of classical physics, observations show that when X-rays are scattered off some materials, such as graphite, the scattered X-rays have different wavelengths from the wavelength of the incident X-rays. This classically unexplainable phenomenon was studied experimentally by Arthur H. Compton and his collaborators, and Compton gave its explanation in 1923. To explain the shift in wavelengths measured in the experiment, Compton used Einstein's idea of light as a particle. The Compton effect has a very important place in the history of physics because it shows that electromagnetic radiation cannot be explained as a purely wave phenomenon. The explanation of the Compton effect gave a convincing argument to the physics community that

6.7 Arthur Compton and The Compton Effect

As we saw, the nature of scientific discourse is empirically based. Bazerman writes:

... the individual is placed within a communicative context that constantly encourages and demands that the individual at many junctures considers how empirical results either can advance the claim-making procedure or call for reconsideration of the claims and representations of phenomena. Through individual behavior and practice, the discourse is brought into increasingly close and precise exchange with the phenomena being examined. Through living people, the symbols of language come into contact with the world (1988, p. 188).

In this way, the language of the scientist working in the laboratory is strongly connected to both their empirical work, and the scientific discourses concerning the interpretation of that empirical work. The writing up of results necessarily entails mobilising representations of experiences in the laboratory, and such representations are themselves based on the words and thoughts (jargon), and forms of life (social/cultural games) of ongoing scientific discourses.

This can be illustrated with Bazerman's detailed analysis of the circumstances leading up to Compton's paper on the nature of x-rays. At the time of his research, there were two competing theories to account for the properties of x-rays: one based on classical electrodynamics and one based on quantum theory. Compton in fact preferred the classical explanation until he could no longer account for his data without the quantum explanation. (Bazerman, p. 194). Thus, despite Compton initially conceiving of the nature of the problem through the lens of a classical electrodynamic paradigm¹⁹, he was compelled by empirical evidence to shift to a new quantum theory paradigm, of which he was aware due to the ongoing discussion in his field.

electromagnetic waves can indeed behave like a stream of photons, which placed the concept of a photon on firm ground. <https://phys.libretexts.org/Special:Search?gid=&fpid=230&fpth=&path=&q=the+compton+effect>

(consulted on the 5th January 2019)

¹⁹ The notion of paradigm as defined by Kuhn (1996 3rd edition)

Roger Stuewer describes the reaction of the scientific community to Compton's findings. (1975, pp. 237–73). The article was attacked on both theoretical and empirical grounds, whilst at the same time it inspired other scientists, including Compton himself, to seek to improve on the findings. Gradually, Compton's work was accepted by specialists in the field and cited as the Compton Effect. His conclusions then became recognised and presented in less argumentative ways to a broader public.

6.8 The Compton Effect and Jargon as a Dialogic Process

Compton's changing, scientific written production described above is an example of the dialectical and dialogic process between jargon and social/cultural games. The case of Compton is also of relevance to another aspect of this thesis: the question of measurement uncertainty. It was in the context of the changing paradigm described above, that Compton wrote a follow-up paper 'Measurements of β -Rays Associated with Scattered X-Rays' so as to bolster his findings in the field. The precise details of his paper are beyond the scope of this thesis, however the extract concerning the question of uncertainty in measurement is of interest on two counts. First, it is an example of the pivotal role of this notion between the empirical experience of scientists and their relation to the scientific discourse surrounding their laboratory work. Second, it exemplifies once more, the nature of the dialogic/dialectical process between language and scientific practice, or jargon and social games.

During the work on this follow-up article, Compton became aware of an error in the experimental design which he included in his description of the experiment:

The potential measurements required corrections due to a slight 50 warping of the frame holding the spheres, and to the lowering of the line voltage when the condenser was charged for the illuminating spark. The latter error was eliminated in the later photographs, at 34, 21, and 74 kv, and the former error was corrected by a subsequent measurement of the sphere gap distances, checked by a measurement of the lengths of 55 the P tracks obtained at the lowest potential. The probable errors of potential measurements are thus unfortunately large, amounting to perhaps 10 percent in every case except that of 74 kv, which is probably accurate to within 5 per cent. (Compton, 1925, pp. 50–59).

Bazerman analyses the inclusion of this 'admission' thus:

To retain the integrity of the data, to make clear that he is constrained by the data and not fiddling with it, he must expose the error of calculation and measurement which leaves the reality of machinery and photographic plates untouched. Thus, the representation of a certain class of error is necessary in the article to keep the relation between laboratory happenings and the report of those happenings as clean as possible (Bazerman, 1988, p. 209).

It becomes clear from this extract that Compton's words are as much a result of his concern for communication with other specialists in the field as with the description of his empirical findings.

An observation made by Bazerman when comparing Compton's final article with a draft version annotated by Compton is another example of interest on this point. It reveals Compton's fine-tuning process when estimating his uncertainty or error, and his struggle with language to achieve a better fit between symbolisation and the experienced world. Bazerman writes:

In the original data tables in the notebook, the observed maximum ranges are all measured to the first decimal, but in the transfer of the table to the draft and the consequent revision three observed ranges are rounded off to the nearest integer, in accordance with a prior admission that the observed track lengths 'could be estimated probably within 10 or 20 percent (...)'. That is, the decimals give an appearance of greater accuracy than was probable. Two calculated values, as well, are rounded off to the nearest integer. On these calculated values no error range restrictions apply, but since the degree of statistical correspondence being demonstrated is quite broad (as large as k3mm or 33 percent of the measured value), the decimals are unnecessary for the demonstration. Compton gives no greater statistical precision than he legitimately can or needs to (1988, p. 213).

This is an example of both how a scientist manages her or his empirical data, taking care not to misrepresent their data, but also of the complexity implied in estimating a

reasonable, probable measurement uncertainty and the necessary personal judgement of the scientist in their final estimation.

6.9 Scientific English and its Thought Style: Conclusions

It can be concluded from this review of the origins of written scientific discourse that the ethos²⁰ of scientific practice is established in the use of a fact-based, detailed and unadorned manner of writing, and by carefully following all standard procedures leading to publication. These procedures require gaining peer recognition which is an integral part of scientific practice.

Scientific facts are thus constructed within thought collectives (Fleck, 1935/2008) in the peer-review process. Throughout the nineteenth century and up until the present, scientific disciplines have both proliferated and become increasingly specialised, as well as becoming more distant from each other. This means that the communal aspect of scientific practice has had an even stronger impact on scientific writing: the peer-review process is now at the very heart of specialised thought collectives in any given field.

Specialised scientific communities both engender and manage scientific discourse in codified, conflict-based interactions which are the language games and forms of life which set the norms of scientific practice. In deference to a communal project, the judgement of the collective is accepted as a social fact. The language choices of the language users in science have both shaped and been shaped by this social fact thus integrating language and practice (Sensevy et al., 2008; Sensevy et al., 2019; Wittgenstein 1953/2009). Scientific practice has become in this way:

(...) a socially legitimated, critical, socially interactive, and cumulative communal process centered on publication in socially recognized forums, screened by gatekeepers, facing public criticism, being cited by others, and being accepted into a codified literature (Bazerman, p. 139).

²⁰ See a recent science magazine article entitled 'Mind Your Ethos' as an example of scientists' awareness of this aspect of publication <https://www.asianscientist.com/2014/10/columns/scientists-mind-ethos/>

This is the nature of the dialectical process between language and scientific practice, or jargon and social games. The didactic objectives of this study thus seek to engage students in epistemic practices (Santini et al., 2018) which bear some kinship to these social games by having them undertake activities which include this dialectical process between language and scientific practice.

Chapter 7: The Nature of Science (NOS) Debate and Uncertainty in Measurement

In chapter 6 we considered in some detail the origins of empirical science and the jargon and thought style (Fleck, 1935/2009; Sensevy et al., 2019), or practice language (Collins, 2011), emanating from this cultural body of knowledge. An epistemic analysis of the epistemological underpinnings of this form of knowledge includes exploring ideas about Nature of Science (NOS). In particular, NOS in relation to uncertainty in measurement, which is the scientific practice integrated into the CLIL sequence at the heart of this study. The following section reviews work in this area and the epistemic stakes inherent in the practice of scientific measurement.

7.1 Nature of Science (NOS)

The question as to what constitutes NOS is of considerable scope and continues to generate debate both in terms of its definition and the educational practices which would better enable students to grasp its essence (Lederman, 2007; Santini, Bloor & Sensevy, 2018; Sensevy, Tiberghien, Santini, Laubé & Griggs, 2008). It is related to the time-old question as to what constitutes science itself, an on-going, perennial debate (Cartwright, 1999; Chalmers, 2013; Hacking, 1983; Kind, 2017). The epistemological underpinnings of science as a way of knowing and producing knowledge are integral to NOS as a construct (Cartwright, 1999; Lederman, 1992; Sensevy et al., 2008).

Nancy Cartwright (1999), in her seminal work: 'The Dappled World: A Study of the Boundaries of Science', rejects what might be termed a classical view of science where the 'laws of nature' are seen to universally apply. Cartwright states 'There is no universal cover of law' (1999, p. 6) and that 'To grant that a law is true (...) is far from admitting that it is universal ...' (1999, p. 24). Rather, she states 'Theories are successful where they are successful, and that's that' (1999, p. 31). She illustrates this point with examples from physics: Newton's $F=ma$ and its applications (p. 25), a thousand-dollar bill swept away by the wind (p. 27) and the laws of mechanics (p. 28). She insists:

we must not confuse a wide-ranging nature with the universal applicability of the related law. To admit that forces tend to cause the prescribed acceleration (...) is a long way from admitting that $F=ma$, read as a claim of regular association, is universally true (1999, p. 29).

Sensevy et al., (2008) include Cartwright (1983, 1999), Fleck (1935/2008) and Hacking (1983) in an epistemological positioning that they term 'new empiricism'. Briefly explained, this is a position whereby emphasis is placed on experimentation, and where perception is no longer considered to be the interface between concept and reality; rather it is seen to be inextricably linked to concept. In other words, concept is necessarily involved in the perception of reality and as such 'the abstract makes the concrete possible' (Sensevy et al., 2008, p. 435).

The work in this thesis is situated within the perspective of this renewed empiricism where knowledge produced by a scientific community is seen to be constructed within a context. This is in contrast to what can be considered to be an erroneous conception of science: a knowledge form based on absolutes, devoid of human intervention.

7.2 Scientific Inquiry

The term scientific inquiry is widely used and may refer to many different aspects of science education. R. D. Anderson delineates three main uses, all of which are of interest to this study: (i) the diverse ways used by scientists to study the world, (ii) an active process of learning, (iii) inquiry teaching which takes various forms and is not as yet clearly understood. (Abell & Lederman, 2007, pp. 808–810).

N.G. Lederman (Abell & Lederman, 2007, p. 835) is at pains to distinguish NOS, fundamentally tentative, from scientific inquiry, the latter being founded on the scientific processes used to collect and analyse data and draw conclusions. Furthermore, based on the literature on the subject, he does not conclude that the one may have an influence upon the other: 'More concretely, if an individual believes that scientific knowledge is tentative (subject to change) and another individual believes the knowledge to be absolute/static, how would

this be evident in their behavior during a laboratory activity?’ (2007, p. 868). This is an interesting question to explore.

Anderson, like Lederman, questions to what extent, if any, there is a link between the NOS and science course content: ‘To what extent can words in a book capture an understanding of the nature of science inquiry? To what extent must it be experienced?’ (Abell & Lederman, 2007, p. 819)

In contrast, a study in Taiwan by Tsai (1999) suggested an interplay between students’ scientific epistemological views and their experimental work. Tsai contrasted students with what he termed a ‘constructivist’ view of science where meaning is negotiated, with students having an ‘empirical’ view of science. He found the latter tended to prefer doing laboratory work following codified procedures without question, whereas the constructivist learners had a deeper understanding of scientific practice. He concluded that an appropriate understanding of the epistemology of science should be included in science education.

7.3 NOS and Scientific Practice: Scientific Measurement

A study in South Africa²¹ addressing the relationship between students’ views on NOS and their view on the nature of scientific measurement (Buffler et al., 2009) is of particular interest to this thesis. The researchers noted that the majority of students arrive at university with the view that, in principle, a scientific measurement will yield an exact result. For such students, a scientific measurement is to be obtained by executing an experiment with the utmost care so as to identify the exact value. It then follows there is little need to repeat the experiment if care is taken. In contrast,

students who believe that scientific experiments are inventions of scientists, constructed from observations that are then validated through further experimentation, are more likely to have a view of the nature of scientific

²¹ Views About Scientific Measurement (VASM, 2005). The questionnaire was composed of 8 questions on scientific measurement (e.g. the meaning of the term ‘exact’; the reasoning behind measurement decisions) and 6 questions on NOS (e.g. the nature and origin of scientific knowledge, the relationship between experiment and theory, the role of scientific experiments in the production of knowledge; and scientists’ use of the scientific method and their own creativity).

measurement that is underpinned by the uncertain nature of scientific evidence. (Buffler et al., 2009, p. 1138).

The Buffler, Lubben and Ibrahim (2009) paper reports on the results of the VASM 2005 questionnaire in which first-year university physics students were attributed one of four NOS ‘profiles’. Their views on measurement were classified according to either the ‘point’ or ‘set paradigms’. The profiles were labelled ‘modellers’, ‘experimenters’, ‘examiners’, and ‘discoverers’, with modellers considered to hold the most appropriate view of NOS as this profile recognised the uncertain nature of scientific evidence. The point paradigm was used to describe students who drew conclusions about the measurand directly from individual data points, whilst those using the set paradigm drew conclusions about the measurand from the whole ensemble of available data (Buffler et al., 2009, p. 1145). Table 5 summarises the criteria used in the 2009 paper to define the ‘point’ and ‘set’ paradigms²² (taken from Buffler et al., 2003 as quoted in VASM, 2005).

Table 5

The ‘Point’ and ‘Set’ Paradigms (Buffler et al., 2003, p. 2)

Point Paradigm	Set paradigm
The measurement process allows you to determine the true value of the measurand.	The measurement process provides incomplete information about the measurand.
“Errors” associated with the measurement process may be reduced to zero.	All measurements are subject to uncertainties that cannot be reduced to zero.
A single reading has the potential of being the Value.	All available data are used to construct distributions from which the best approximation of the measurand and an interval of uncertainty are derived

As can be seen from table 5, the set paradigm indicates a better understanding of all the factors involved in scientific measurement. The study found that:

²² The term ‘paradigm’ was used as a ‘constellation of beliefs, values, techniques, ... shared by members of a given community’ (Kuhn, 1970).

students with a NOS profile dominated by a belief that the laws of nature are to be discovered by scientists are more likely to have a view of the nature of scientific measurement characterised by a belief in “true” values (Buffler et al., 2009, p. 1137).

In other words, these students were inclined to have views of scientific measurement corresponding to the point paradigm. In contrast, students with a ‘modellers’ profile were more likely to have a view of scientific measurement described by the set paradigm. The vast majority of students’ answers (73%) were in keeping with the point paradigm, and only one in five students (20%) had views in keeping with the set paradigm.

The study concluded by recommending that science education should include the interplay between theory and experimental data which entails indicating the quality of the knowledge communicated. In the case of scientific measurement, this means indicating the uncertainty of a measurement in a consistent way: this research team designed a course to that effect based on the probabilistic framework of metrology.²³

7.4 A French Study

Researchers in a study of a first-year physics course at a French university (Caussarieu & Tiberghien, 2017) stress the importance of measurement uncertainties with regard to NOS: ‘Measurement uncertainties are central in the validation process of knowledge production and the tentativeness of the knowledge claims in science; therefore, students need to understand these uncertainties to construct adequate views of NOS’ (Caussarieu & Tiberghien, 2017, p. 998).

A number of standard practices in physics are outlined in this study which it is useful to review here. The following result is given as an example of how uncertainty estimates should be noted in physics: ‘ $\tau=(0.25\pm 0.5) \text{ s}$.’²⁴. The first number refers to the value of the

²³ Introduction to Measurement in the Physics Laboratory, A probabilistic approach. Buffler et al., 2009

²⁴ It is interesting to note that the brackets are specific to France. Also, in an exchange on this point, Aude Caussarieu confirmed that in general the uncertainty on a measurement is of the same order of magnitude as the last significant digit, except in very rare cases. In accordance with the wishes of the physics lecturer working on the sequence in this study, students were taught to respect this norm in both English and Physics lectures/classes.

measurand and the second to the uncertainty of the value of the measurand. The authors stipulate that the value of the measurement should be written with a reasonable number of significant figures. The term 'reasonable' is not explained, but as we shall see later, this is a problematic area for many students.

The authors describe three forms of notation: (i) interval notation as in the example above, (ii) a point notation which does not include the uncertainty estimate and (iii) approximate notations where the symbol ' \approx ' is used to acknowledge uncertainty on the last significant figure. The interval notation is what is expected of students, though (ii) and (iii) might be used by physicists when the order of magnitude is known and the uncertainty can be assumed to be on the last significant figure.

Caussarieu and Tiberghien note the two different frameworks identified by Buffler, Lubben and Ibrahim (2009) with regard to uncertainty estimates: the historical classical approach (or error approach) and the contemporary uncertainty approach. They highlight a difference between these two frameworks: whereas the classical approach estimates the upper limit of the absolute value of the total error with a cumulative value, the contemporary GUM²⁵ approach takes into account that one uncertainty source offsets another by using probability. In the Buffler study, the two approaches are presented as having two different epistemological underpinnings, the classical approach being more easily associated with a positivist view of science and the contemporary approach with that of a post-positivist view.

The findings of this French study based on an analysis of university course documents, showed that the classical approach to uncertainty in measurement was more common than the contemporary probabilistic approach and recommended a design-based research programme to better align instructors' goals with course content. However, they are critical of any normative approach which does not align instruction on measurement uncertainties with the context in which the measurement is used. Whilst they agree that the GUM probability approach is a coherent approach, with solid epistemological underpinnings within the SET paradigm, they do not agree that it is the only valid approach. They argue that if the

²⁵ Guide to the Expression of Uncertainty in Measurement

context of the measurement did not justify the complex reasoning and calculations of the probability approach it might even lead to confusion within the scientific community for whom the measurement uncertainty was destined²⁶.

7.5 The NOS Debate: Conclusions

The conclusions of this chapter are in keeping with a point highlighted by Bazerman's rhetorical analysis of scientific writing (1988). As we saw with Bazerman's example of Compton, an important aspect of estimating uncertainties is the message it communicates to those working within the same thought collective (Fleck, 1935/2008).

This is a strong argument for including a consideration of this communicative aspect of measurement uncertainty in course teaching on the subject: the practice of adapting an uncertainty measurement according to the context of the measurement implicitly recognises the tentative aspect of scientific practice. It might even affect the manner in which that practice is undertaken so that it bears a greater kinship to scientific measurements undertaken by connoisseurs of the practice.

This brings us back to the question of the link between views on NOS and science course content. Returning to the question raised earlier by Lederman, 'if an individual believes that scientific knowledge is tentative (subject to change) and another individual believes the knowledge to be absolute/static, how would this be evident in their behaviour during a laboratory activity?' (Abell & Lederman, 2007, p. 868).

The question of considering the context of a measurement in order to better estimate its uncertainty suggests that students recognising the tentative aspect of scientific practice would more readily integrate this aspect of measurement uncertainty in their scientific practice. This reasoning also recognises a link between views on NOS and scientific practice and hence opens up an interesting research question which is partially explored in this thesis.

²⁶ This clarification of the authors' position follows an email exchange with Aude Caussarieu, 9 January, 2019)

PART IV: The Empirical Analyses

Chapter 8: The Analysis of the Sequence

This research questions the conditions necessary for the joint construction of a conceptual understanding of measurement as a scientific practice as a means to developing English language skills in a Content and Language Integrated Learning (CLIL) programme. Based on the analysis of a case study, an understanding of measurement as a scientific practice, as well as effective work on language skills, is sought in students' engagement in the co-construction of meaning between themselves and in the didactic joint action with the teacher. The following research questions are pursued:

8.1 Research Questions and Hypotheses

Question 1: How can the combined objectives of a conceptual understanding of scientific practice, together with work on language skills, be effectively described?

As detailed in chapter 4, the Joint Action Theory in Didactics has developed a range of notions to describe in detail didactic activity in class. The following are key notions employed in the description of the didactic activity in this study: the double dialectics of contract-milieu and reticence-expression, the notions of jargon and thought-style (Sensevy et al., 2019), as well as learning game, epistemic game (Santini et al., 2018), and systems of epistemic capacities (Gruson, 2019).

As a central role is attributed to discourse in the integration of language and content in this CLIL practice, the notions of jargon and thought-style (Sensevy et al., 2019) serve to analyse the interweaving of content (i.e. acquiring a fitting conception of measurement as a scientific practice, in particular uncertainty in measurement) and language (i.e. acquiring skills in English as a second or foreign language) in the joint construction of knowledge in classroom practice.

Question 2: What capacities can be identified in the didactic activity of the students participating in the case study, and what evidence is there of effective work on those capacities in the didactic activity between themselves and with the teacher?

As we saw in chapter 7, a major premise of this study is that ‘modelling’ in scientific practice should be seen as designing a relationship between the conceptual and the empirical (Sensevy 2008, 2011; Hacking, 1983; Cartwright, 1999; Buffler, 2009), and that this is a fitting conception of scientific practice. Therefore, didactic activity which seeks to co-construct a thought style where scientific practice is seen in this light is considered to be an epistemic game (Santini et al., 2018) in science education. Likewise, as we saw in chapter 1, participation in a semiotic system (Sensevy, Gruson & Forest, 2015; Gruson, 2019), where words, gestures and expressions come alive in the co-construction of meaning, is also to be considered an epistemic game in second/foreign language acquisition. Evidence of effective work on the capacities required to participate in these epistemic games will be sought in the analysis of the didactic activity in chapter 8.

Question 3: What are the concrete conditions of a CLIL programme which enable students to develop a conceptual understanding of scientific practice whilst improving their English language skills?

As stated in chapter 1, this project is founded on a contextualized notion of language. As such, a major premise of the study is that for an expression to be understood, it must be encountered in the practice within which it plays its role (Sensevy et al, 2019). A CLIL teaching sequence was thus devised which was comprised of scientific epistemic games in English. It was designed with the objective of developing in students a desired thought-style approaching that of an experimental scientist.

A notion in experimental science that is often over-simplified or misunderstood by students, is that of uncertainty in measurement. The teaching sequence was thus designed around the ostensibly simple task of devising a basic protocol or procedure to measure the

diameter of a tennis ball. This was to explore the issue of uncertainty in measurement whilst developing an appropriate seeing-as and jargon associated with the practice. In this way, a specific epistemic game in experimental science, that of estimating the degree of uncertainty in a measurement, served to develop a CLIL sequence where the link between a practice and its jargon could be explored in a semiotic (Sensevy et al., 2015; Gruson, 2019), dialogic system.

Sub-questions: There are a number of sub-questions related to question 3: How ought CLIL practice interweave content and language, and in what ways are these two elements then influenced by their convergence? What are the frontiers in a given speciality that necessitate language teachers cooperating with specialists of a body of knowledge?

Hypotheses Explored in the Didactic Analysis

This study seeks to explore how and where language is acquired actively in class using the notions of jargon to identify the construction of a particular thought style inherent in the practice of uncertainty in measurement.

The notions are posited as useful theoretical tools in both the analysis and design of language learning didactic environments, and in particular for the elaboration of CLIL projects balancing content and language input.

The first hypothesis explored in this study is as follows: language is acquired by practicing jargons (Sensevy et al., 2019) in social practices, termed social games in the JATD, and within recognisable and constructed thought styles (Sensevy et al., 2019; Fleck, 1935) inherent to those social practices. A particular thought style can be both recognised and constructed via its corresponding jargon.

In this CLIL study, combining foreign language acquisition with the question of uncertainty in measurement in physics, our hypothesis is, therefore, that in activating the social practice related to this question students will develop its corresponding jargon and thought style, and in doing so develop their English language skills. As language and practice are considered to be organically interlaced, the scientific practice of measurement became the basis of a CLIL sequence focussing on the epistemic potential inherent in the linguistic socialisation of scientists related to this practice (Collins, 2011).

A second hypothesis explored is that in seeking to develop students' language skills through the social game of a scientific practice, epistemic capacities bearing some kinship to those of scientists engaged in that social game —the connoisseurs of the practice (DpE, 2019)— will be developed (Sensevy, 2011; Santini, Bloor & Sensevy, 2018).

8.2 The Exploratory Lesson

This empirical analysis will begin with a didactic analysis of the lesson at the origin of the CLIL sequence which was developed in the study. It is based on an analysis of three extracts taken from the lesson. For practical purposes this lesson shall be termed 'The Exploratory Lesson'.

Context

Following an email exchange between the language department and a science department suggesting an MIT video for use in English classes, an English teacher invited a physics associate professor into her lesson so as to explore the possibility further. The physics associate professor was motivated by an interest in exploring how to help students better understand uncertainty in measurement, and was a keen advocate of improving the English of the science students. The English teacher was interested in developing programmes where students would learn language heuristically, using English actively in context; she considered a science subject as a promising opportunity to design suitable teaching material with that end in mind.

The two teachers conferred on an English lesson plan in two parts: the first part would be based on an MIT Walter Lewin video extract dealing with the subject of uncertainty in measurement. This was to prepare students for the second part of the lesson: a mini-group activity using English, where the students would be required to measure a range of small objects and estimate the degree of uncertainty in the measurement.

Walter Lewin is now a retired professor of physics from the Massachusetts Institute of Technology. His past lectures are published via MIT's OpenCourseWare. An extract transcription from the Lewin lecture used in the first part of the lesson can be found below,

together with a description of a class discussion of the extract. The second part of the lesson, the mini-group activity, is presented in the form of two extracts taken from this activity.

Presentation of Part One of the Lesson: the MIT Extract

The lesson in question was for LANSOD students (Languages for Students of Other Disciplines; LANSAD in French), that is to say students whose main subject of study is a discipline other than English. The group of twenty students in this exploratory lesson were studying a mathematics and physics course in preparation for entry into engineering schools. The main content of the MIT video extract concerned an experimental set-up, devised by Walter Lewin, in order to test his grandmother's assertion that a person lying down was taller than a person standing up. To do this, he asked for a student to volunteer to be measured standing up then lying down. Prior to this, he assessed the precision of his two experimental set-ups, as well as his reading of the measurements by measuring an aluminium bar. He did this first with the vertical set-up, then the horizontal set-up, and he concluded he could measure with an accuracy of up to 1mm. This was based on the 'reasonable assumption' (Walter Lewin) that an aluminium bar does not vary in length. Below is a full transcription of the MIT extract viewed, followed by a transcription of the class activity during this part of the lesson and a section of the worksheet accompanying the MIT video.

Transcription of the MIT Video Extract

1 **Walter Lewin:** Now all important in making measurements, which is always ignored in every college book, is the uncertainty in your
2 measurement. Any measurement you make without any knowledge of the uncertainty is meaningless, I will repeat this, I want you to hear
3 it tonight at 3 o'clock when you wake up, any measurement that you make without a knowledge of its uncertainty is completely
4 meaningless. My grandmother used to tell me that, that, at least she believed it, that someone who is lying in bed is longer than someone
5 who stands up, and in honor of my grandmother, I'm going to bring this today to a test. I have here a set-up where I can measure a person
6 standing up and a person lying down, it's not the greatest bed, but lying down. I have to convince you about the uncertainty in my
7 measurement because a measurement without knowledge of the uncertainty is meaningless and therefore what I will do is the following.
8 I have here an aluminum bar and I make the reasonable, plausible assumption that when this aluminum bar is sleeping, when it is horizontal,
9 that it is not longer than when it is standing up. If you accept that we can compare the length of this aluminum bar with this set-up and
10 with this set-up. At least we have some kind of calibration to start with. I will measure it, you have to trust me, during these three months
11 we have to trust each other, so I measure here 149.9 cm. **However, I would think that the – so this is the aluminum bar, this is in vertical**
12 **position, 149.9 - but I would think that the uncertainty of my position is probably 1 mm. I can't really guarantee you that I did it accurately**
13 **any better - so that's the vertical one. Now we're going to measure the bar horizontally for which we have a set-up here. The scale is on**
14 **the other side, so now I measure the length of this bar - 150.0 horizontally - 150.0 again plus or minus 0.1 centimeter, so you will agree**
15 **with me that I am capable of measuring plus or minus one millimeter, that's the uncertainty of my measurement.**
16 Now if the difference in lengths between lying down and standing up, if that were one foot, we would all know it, wouldn't we? You get
17 out of bed in the morning, you lie down and get up and you go clunk and you're one foot shorter, and we know that that's not the case. If
18 the difference were only one millimeter we would never know. Therefore, I suspect that if my grandmother was right, that it's probably
19 only a few centimeters, maybe an inch, and so I would argue that if I can measure the length of a student to one-millimeter accuracy that
20 should settle the issue. So, I need a volunteer. You're the volunteer? Ok, what is your name? Zak. Ok Zak- nice day today Zak, yeah? You
21 feel all right? Your first lecture at MIT. I don't. Ok man. Stand there, yeah ... - ok 183. (...)2. Stay there! Stay there! Don't move! ... Zak ...
22 (writes 183. on the board) this is vertical... what did I say 180? ... (several students answer his implicit question) ... Only one person ...
23 three? (turning towards the students in the amphitheater) ... Come on! (Impatiently picks up the sliding headpiece of his measuring set up
24 to measure Zak again, so as to be sure) ... point two ... ok (said whilst re-measuring Zak) ... 183.2 Yep! (returning to the blackboard) and an
25 uncertainty ... of about ... 1 – oh this is centimeters - 0.1 centimeters. And now we are going to measure him horizontally. Zak, I don't want
26 you to break your bones so we have a little step for you here. Put your feet there - oh let me remove the aluminum bar - watch out for the
27 scale that you don't break that because then it's all over.... Ok I'll come on your side I have to do that- ... yeah, yeah relax - think of this as a
28 small sacrifice for the sake of science all right? Ok you good? ... You're comfortable? You're really comfortable right?
29 **Zak:** Wonderful
30 **Lewin:** You're ready? ... Ok ... OK ... 185.7 - Stay where you are! 185.7 (walking to the blackboard) - I'm sure - we first want to make the
31 subtraction, right? 185.7 (writes this on the blackboard)- plus or minus 0.1 centimeters -oh (does the calculation on the blackboard) ... that
32 is 5 ... that is 2.5 plus or minus 0.2 centimeters. You are about one inch taller when you sleep than when you stand up. My grandmother
33 was right. She's always right. Can you get off here?

It is worth analysing in some detail the language in Walter Lewin's lecture. For example, in speech turns 1–20, which is mainly the content of the physics lecture, the language is rich in the jargon of the field, that is to say a dialogical style of language related to the practice of physics and its accompanying thought style (e.g. the uncertainty in your measurement, making measurements, make the reasonable, plausible assumption, calibrating a set-up with an aluminium bar, measure him horizontally, to one millimetre accuracy etc.). Though this is a lecture and there is not a dialogue as such, there is an implicit dialogical aspect to Lewin's discourse as he socialises the students into his practice. In approximately speech turns 20–32, when Walter Lewin is implementing his experiment for public view, the language is less domain-specific. At times it is the jargon of social English as he exchanges a few social niceties with the volunteer student so as to put him at ease (nice day, all right, ok man, comfortable,

ready), at other times a self-descriptive jargon, as when Walter Lewin describes his own behaviour, as if in a poorly dubbed film (we are going to measure him, let me remove the aluminium bar, I'll come on your side I have to do that). This jargon is to render explicit the meaning of his actions with regard to the experiment. However, there are moments of silence as he conducts his calculations (speech turns 30–32), as well as moments of frustration, probably due to his being distracted by the need to communicate with the audience: for example, when he forgets the measurement he took and asks the students, in an impatient tone, to remind him ('Come on!' speech turn 23).

A number of points were concluded from the above examination of language use, as well as from elsewhere (e.g. the 'Measuring a Small Object Episode'), which had a significant bearing on the subsequent design of the sequence. Firstly, executing a protocol requires concentration, dexterity and observation: having to communicate at length whilst doing an experiment hinders the practitioner. Likewise, communicating the details of an experiment requires concentration and focus of attention: executing a protocol simultaneously hinders the communicator. This study therefore premised that elaborating a protocol can be effective in activities seeking to develop students' better understanding of the link between a practice, its associated thought style and its jargon. However, in activities seeking to develop students' spoken language output, a primary objective in the sequence, it appeared to be more effective to separate the task of implementing an experiment and communicating about it, so that students could better focus on the language aspect of the practice.

As an underlying premise of this research is that language and practice are organically linked, both activities were included in the sequence. However, based on the position that substantial student output is a necessary condition for progress in language (Swain & Lapkin, 1995), the onus, ultimately, was on orchestrating situations where the concentrated use of the jargon or practice language of physics was explored so as to develop students' language skills. The objective was not to have students doing laboratory work in English, but to integrate their experiences of laboratory work in French into the English language classroom. The reflection encouraged on the nature of that laboratory work was hoped to be a useful additional source of reflection to that undertaken during students' scientific practice.

These priorities were in keeping with a C2 CLIL model (Coyle et al., 2010) where: 'Language teaching runs parallel to content teaching with specific focus on developing the knowledge and skills to use the language so as to achieve higher-order thinking'.

The MIT video extract transcribed above, led to discussion in class with the use of a worksheet. Below is an extract taken from this activity in class, followed by its accompanying worksheet.

Transcription of Class Activity

1. **T:** It's true (*This is said with regard to statement c. on the worksheet*). It is a reasonable assumption that an aluminium bar has exactly the same length horizontally as vertically. Can you maybe express now why he chooses to do that - why he's doing that? +++ Why is he doing this, measuring the aluminium bar vertically and horizontally? (student Gabriel raises his hand)
2. **T:** That's great Gabriel - thank God you're here. Anybody else want to try?
3. **T:** Pascal? (Adrien moves his hand and appears frustrated).
4. **Pascal:** To know, er to know the difference between ... er... an aluminium bar and a human body (Adrien shuffles in his chair and is visibly agitated)
5. **T:** Not exactly er Adrien?
6. **Adrien:** There is no flexibility with the aluminium bar...
7. **T:** Good and so therefore? He says he wants to convince us of something - what does he want to convince us of?
8. **Adrien:** When it is a solid object... it is not possible ... er... to change



Frame 1: Walter Lewin



Frame 2: finding the words

erthe size of this object er
because ... it is horizontal or
vertical

9. T : Well done. Yes



Frame 3: discussing the MIT extract

The English teacher and the students discuss the video with the use of the worksheet (see above). Gabriel has been participating frequently so the teacher encourages other students to contribute too (speech turn 2). Adrien is at first hesitant (speech turn 3, frame 2, student in bottom right-hand corner) but eventually contributes and gives an answer which shows understanding of how Walter Lewin calibrated the instruments in his experimental set-up using the aluminium bar (speech turns 6, 8, frame 3, student in bottom right-hand corner).

Extract from the Worksheet Accompanying the Class Activity (Answers are provided in italics)

Worksheet: Walter Lewin MIT Extract

(i) As you listen, identify the terms for the following:

Hypothèse faible	<i>Assumption</i>
Expérience	<i>Experiment</i>
Précision	<i>Accuracy</i>
Vérifier	<i>Check</i>
Dispositif expérimental	<i>Experimental set-up</i>
Appareil de mesure	<i>Measuring instrument</i>

(ii) Listen to the video and decide if the following statements are true or false:

- a. Any measurement you make without knowledge of the uncertainty is meaningless **True**
- b. According to Walter Lewin's grandmother, someone lying in bed is shorter than someone standing up **False**
- c. It is a reasonable assumption that an aluminium bar has exactly the same length horizontally as vertically **True**
- d. The difference in length between lying down and standing up is one foot (30.48cm) **False**
- e. Horizontally, Zak measures (183.2 ± 0.1) cm **False**
- f. Zak is (2.5 ± 0.2) cm longer lying down than standing up **Is claimed to be True**

(1 inch = 2.54cm, one foot = 30.48cm):

Discussion in Class following the MIT Video Extract

This episode occurred just after the students had listened to an extract from the MIT lecture, and had worked as a class, with the English teacher, on the worksheet which accompanied the extract (see above). The professor in the extract, Walter Lewin, is insisting on the importance of uncertainty in measurement. The physics associate professor (PP) in the

class (the woman with the yellow wall behind her), is talking to the students, and to the English teacher (T, the woman with her hand under her chin), about Walter Lewin's estimation of only 1mm uncertainty for the measurement of the aluminium bar (the relevant passage is in bold in the Walter Lewin transcript above, lines 11–15).

10. **PP:** ... measurement. It's two times 1mm in that case. So, he should have taken 0.2 ... Centimetre. So, two millimetres. And he didn't take that so ... for him his eye precision in the ruler when he looks at the length he's measuring the starting point and the end of the measurement is not 1mm. What is it?
11. **T** and students: ... (#4 silence)
12. **T:** So, it should be 2mm?
13. **PP:** It should be 2mm
14. **T:** (inaudible)... only 1mm?
15. **PP** and **T** at the same time: inaudible
16. **PP:** The ruler is 1mm. So, you have to put the beginning of the measurement like a starting point (frame 4) plus or minus 1mm and at the end it's plus or minus 1mm. So, the whole thing is ...
17. **Antoine:** 3mm
18. **PP:** ... 2mm. And he takes one millimetre, why? It's obvious but he doesn't tell it. It's obvious for the students, they're not raising their finger ... their finger and saying oh you're wrong. It's his estimation.
19. **T:** He made a mistake? He made a mistake or ... it's a choice?
20. **PP:** No, no. It's a choice. He doesn't tell it.



Frame 4: 1mm at the start and the end of his measurement



*Frame 5: Discussing the uncertainty
T is in the middle of the room and PL has the yellow wall behind her*

The PP (speech turn 10) discusses Walter Lewin's estimation of 1mm uncertainty for the measurement of the aluminium bar used to calibrate the vertical and horizontal measuring set-ups, suggesting 2mm would also be possible. The English teacher and the students struggle to understand why and respond either with silence (speech turn 11, T and students are silent), a question (speech turn 12, Teacher) or a suggestion of 3mm uncertainty (speech turn 17, Adrien). The PP says the reason for Walter Lewin's choice is obvious

(speech turn 18) but T does not find this choice obvious (speech turn 19 “He made a mistake ... or a choice?”).

There were a number of challenges in the elaboration of this cooperative work. Both teachers had to invest time to ensure that the English teacher could follow the thought style of the physics professor. In this Exploratory Lesson, the English teacher does not fully understand, at this stage, the point the physics associate professor wishes to make regarding the choices involved in estimating uncertainty in measurement (speech turns 11, 12, 19). Subsequent exchanges with the physics associate professor led her to better understand the discernment entailed in estimating uncertainties: Walter Lewin could have chosen 1mm uncertainty (0.5mm for each end of his measurement), or 2mm (1mm for each end of his measurement), depending on his general assessment of the protocol’s accuracy.

The above scene illustrates the advantage of cooperative work between specialists in a field and language teachers. The English teacher had the opportunity to explore the rich epistemic potential of the subject of uncertainty in measurement thanks to the associate professor’s suggestion of the theme. It was also the associate professor who had suggested the student-originator measuring activity, typical of classroom practice in science subjects, as the basis of the CLIL sequence that was developed. Thanks to their cooperative work together, the English teacher thus gradually acquired some understanding of the associate professor’s thought style as a physicist, as well as the opportunity to explore aspects of scientific practice sufficiently dense in epistemic potential to develop a CLIL sequence. The physics lecturer did not leave the cooperative work empty-handed either. She had opportunities to gain in fluency and language accuracy, and found the focus on language production, typical of L2 practice, a point of interest. She also found discussing the content with the English teacher gave her some insight into students’ difficulties: the English teacher’s questions were a reminder of aspects of the knowledge which were obvious for an expert in the field but which remained elusive for those who had not as yet acquired the appropriate thought style. An example of this can be seen in speech turns 10-20 when the English teacher asks beginner questions that the students might not have been comfortable expressing.

A final point, when teachers are not used to sharing a classroom, some lack of coordination is to be expected: the two teachers are at times so busy communicating with

each other they don't notice a student raising his hand to contribute to the discussion (frame 5).

General Didactic Analysis of Part One of the Exploratory Lesson

The table below is a general analysis of the system of epistemic capacities (Gruson, 2019) that the students would ideally develop as a result of progress in the situation presented (the extract + discussion). In the case of this CLIL sequence, these were also the epistemic capacities that the English teacher needed to develop in physics in order to be able to orientate the students in the milieu.

Table 6

Part One: System of Epistemic Capacities

System of epistemic capacities (English)	System of epistemic capacities (physics)
<p>Translanguaging: identifying the <i>jargon</i>: the English terms which correspond to experimental procedures studied and practiced in the students' physics courses.</p> <p>Joint construction, as a class, of the meaning of the video (limited opportunity for expression): interpreting and discussing the content of the video using the <i>jargon</i> encountered, and in the <i>thought style</i> appropriate to the practice.</p>	<p>Understand the <i>thought style</i> inherent in Walter Lewin's protocol: the hypothesis he sought to test, how the protocol sought to test this, how he calibrated the instruments in his experimental set up.</p> <p>Understand, in developing the appropriate <i>thought style</i>, the importance of a high-quality protocol to reduce any random error in a measurement. (or measurement error, using the GUM 2012 definitions).</p> <p>Through development of the appropriate <i>thought style</i>, be aware of all the factors that may have an impact on the uncertainty in a measurement.</p>

	Understand the <i>thought style</i> of a practicing physicist (a connoisseur of the practice) so as to evaluate Walter Lewin's uncertainty estimation in the MIT video extract.
--	---

In this initial, general analysis, the learning games (Sensevy, 2011; Gruson, 2019) might be identified as: (i) 'gaining an understanding of the jargon and thought style inherent in the MIT extract through repeated viewing and interaction with an English teacher + worksheet.' This game was then immediately followed by: (ii) 'discussing the content and its implications with a physics lecturer to better understand uncertainty in measurement and its associated jargon and thought style.' In seeking to develop the resources necessary to participate adequately in these games, it was hoped the students would acquire the capacities outlined above.

Analysis of the classroom interactions show that the MIT video extract introduced some of the jargon essential to the field, and there is some slight evidence of students appropriating a few terms, in English, related to physics (speech turn 4 'To know, er to know the difference between...er... an aluminium bar and a human body', speech turn 6 'There is no flexibility with the aluminium bar...', speech turn 8, as quoted below). The extract also serves to focus the class's joint attention on several important points. First, the thought style necessary to devise a suitable protocol, in speech turns 1-9, when T and the class discuss how Walter Lewin calibrated the instruments of his experimental set-up. Second, the complex question of uncertainty in measurement and the thought style related to estimating uncertainty, in speech turns 10-20, when PP discusses the different estimates possible for Walter Lewin's protocol. The genesis of the expression, in English, of an appropriate thought style, pertinent to the design of a suitable protocol, can be discerned in Adrien's response (speech turn 8 'When it is a solid object... it is not possible ... er... to change er ...the size of this object er because ... it is horizontal or vertical'), as he expresses some insight into how Walter Lewin sought to calibrate his instruments.

However, in the discussion following the extract, there is no evidence of the students having gained a better insight into the factors involved in estimating uncertainty, that is to

say, of the appropriate thought style to tackle this complex question. The students either respond with silence (speech turn 11 'silence'), or with an answer which reveals they have not followed PP's reasoning (speech turn 17 '3mm'). The student Adrien's suggestion of 3mm uncertainty (speech turn 17) implies confusion. This is also the case for the English teacher who does not understand why the uncertainty can be justifiably 1mm or 2mm (speech turn 19). It can therefore be concluded that the learning games (i) and (ii) were not sufficiently effective in enabling students to fully acquire the capacities outlined in Table 1. We can also observe that the English teacher did not have the thought style of the practice and would not be able to orientate the students in the milieu of a CLIL classroom without the physics associate professor. In the analyses of 'Genesis of a Thought Style' and 'The Enhancing Fluency Exchange', taken from later versions of the uncertainty sequence, the English teacher can be seen to have progressed on this point and to have a better understanding of the thought style of the physics professor as regards the issue of uncertainty. This was achieved thanks to multiple exchanges and the cooperative production of teaching resources, as stated elsewhere. It is useful to note here how the process began.

Whilst the main purpose of the MIT extract, in this initial exploration, was to introduce students to the theme of uncertainty in measurement, it was also hoped it would prepare students for the exchanges in the mini-group measuring exercise that followed (see below, speech turns 21–35). Hence a third overarching learning game, englobing part one of the lesson, can be defined thus: (iii) 'appropriating the jargon and thought style explored in part one of the lesson so as to actively use it in a measuring exercise'. As the didactic analysis of part two of the Exploratory Lesson will reveal, this did not prove to be an effective preparation for the learning game explored in part two.

Before analysing part two of the lesson, more will be said on the MIT extract and its evolving role in the sequence as a result of the iterative, Deweyan approach of this JATD research. As the study progressed, the use made of the MIT video extract, as well as its perceived utility, changed. It initially proved to be a useful introduction, in English, to the theme of uncertainty, for both the students and the English teacher. It also introduced some very useful jargon into the milieu, for example, 'calibrate the instruments' 'measure with an accuracy of up to 1mm', 'the vertical set-up, the horizontal set-up' and much more. However,

it proved to be less effective with regard to two major objectives: a finer understanding of the factors involved in estimating the uncertainty in a measurement (an objective posited by the physics professor at the outset of the cooperative work), and the development of situations where student-originators produced maximum language output in a process of inquiry (an objective posited by the English teacher at the outset of the cooperative work): a necessary condition for students to develop their L2 language skills.

Each of these points shall be explained further. In lines 20–33 of the transcription of the MIT extract, Walter Lewin can be seen measuring the student Zak, first vertically with Zak standing up, then horizontally with Zak lying down. As explained earlier, this was to test his grandmother's assertion that people lying down are taller than when they are standing up. After having ascertained that he could measure with an accuracy of up to 1mm, Lewin concluded from his experiment that his grandmother was right. With his experiment he calculated that Zak was (2.5 ± 1) cm longer when he was lying down than when he was standing up. In the film, it can be noticed that Zak does not take off his sports shoes during the experiment. As sports shoes are springy so as to absorb shocks, it is possible, even likely, that the impact of the error in protocol (not having Zak take off his shoes), would result in completely falsifying the results of the experiment: Zak's weight on his sports shoes when he was standing up could very well have flattened the shoes by up to 2.5cm.

This point was noticed at the outset of the study by the physics professor, and incorporated into the worksheet by the English teacher. For example, the students are asked to decide whether the statement 'f. Zak is (2.5 ± 0.2) cm longer lying down than standing up' is true or not. In exchanges in class, similar to those described in speech turns 1–9, the teacher can draw out the fact that Lewin says there is a (2.5 ± 1) cm difference but that this may in fact not be so because of the shoe factor. Similarly, another question on the worksheet 'How could you improve Lewin's protocol?' is another opportunity to highlight factors that could influence Lewin's result, including the sports shoes. In a process of joint action, the teacher would guide the students to understand that factors such as the sports shoes, that could increase random error in a measurement, must be rigorously dealt with.

The question arises as to why Walter Lewin, an authority figure in physics, does not go into these nuances himself. Of course, he is well aware of these issues, therefore it can be concluded that the main point of his lecture is to ensure that students never forget to include their uncertainty estimate: *'I will repeat this, I want you to hear it tonight at 3 O' Clock when you wake up. Any measurement you make without a knowledge of its uncertainty is completely meaningless'*. This would explain why he chooses not to clarify here, the many factors that can have an impact on the uncertainty in a measurement, nor to stress how rigorously random error must be identified and reduced to a minimum. However, these points were a major concern of the physics associate professor, who wanted to heighten students' awareness of the complexity of uncertainty in measurement. This included a better appreciation of the importance of rigour in devising protocols: as there is necessarily a degree of uncertainty in any measurement, good scientific practice must ensure any random error is reduced to an absolute minimum. The sequence was therefore developed to include targeting this knowledge, whilst devising pair-work and groupwork activities requiring student language output in English.

Presenting the MIT early on in the sequence had the advantage of introducing the jargon of the practice of measurement, but the disadvantage of being possibly confusing for students. Depending on their level of English, as well as their understanding of the issue of uncertainty in measurement, working on the extract and then assessing it critically could be an excessively complicated activity in relation to the target knowledge stated in table 6. Furthermore, if worked on at length, it did not allow for multiple situations requiring sustained student output.

For these reasons, as work progressed in the study, the extract was no longer used as the introductory activity to the sequence. The extract was replaced by a learning game that confronted students directly with a range of factors that can have an impact on uncertainty in measurement, and that also obliged them to produce language output. This learning game sought to lead students to reflect on a milieu that was constructed with their own productions: what is termed an inquiry-based study with student originators in JATD terms. A description of this learning game, and the milieu constructed in the activity which followed it, will be presented in 'The Genesis of a Thought Style'.

Though work on the MIT extract was not retained as a central activity in the evolving form of the sequence presented in this study, it continued to be used as a teaching resource in the sequence. It was a useful means of exploring important factors related to uncertainty in measurement at various points in the sequence, including the latter part of the Genesis of a Thought Style lesson, as we shall see. For English teachers new to teaching the sequence, it is a helpful introduction to the jargon and the thought style of the practice of physics, in a simplified form. It also remains useful as a listening activity, combining the language and practice of physics. Thus, depending on students' overall understanding of uncertainty in measurement, the profile of English teachers teaching the sequence, and the time available to work on the sequence, the extract can and is used at various points because of its merits. It is also possible to imagine an alternative sequence where the extract would be exploited more fully, particularly in larger classes where group work might not be possible.

Presentation of Part Two of the Exploratory Lesson: Mini-Group Activity Measuring an Object

Following the class work on the MIT video extract, the students form small groups to measure one of a choice of objects: a tennis ball, a wooden pyramid, a two-dimensional geometrical shape and a wooden rhombohedron, which is a three-dimensional figure with six faces. They used tools made available by the teachers: rulers, a calliper, a set square, a tape measure etc. This part of the lesson was prepared by the physics associate professor and the English teacher was mainly an observer.

The Decimal Point Episode

Below is an extract from the mini-group activity

<p>21. PP: you have to tell me two figures after the comma</p> <p>22. Pascal: (...) comma?</p> <p>23. T: do you mean the decimal point? After the decimal point.</p> <p>24. PP: a dec ...?</p> <p>25. T: a decimal point</p>	 <p><i>Frame 4: a decimal point</i></p>
---	---

26. **PP:** after the decimal point.

There is some confusion between the students and the PP (speech turn 22) when PP uses 'comma' to refer to the decimal point, the comma being the equivalent of the decimal point in French. The English teacher offers the correct term (speech turn 23), a decimal point.

During the group-work, the physics associate professor communicates with one of the groups. The English teacher observes from behind the camera. At times she contributes some vocabulary as with this example of the decimal point. The exchange is another illustration of the advantage of cooperative work between specialists in a field and language teachers. The latter maintain language accuracy in teaching sequences which can also be helpful for specialists who frequently communicate in English within international scientific communities. As regards the English teacher, she gained a major insight into the thought style of physicists thanks to being present during this discussion, as shall be detailed.

Measuring a Small Object Episode

Pascal, a student working in a small group with the physics associate professor, begins measuring the side of a wooden rhombohedron whilst at the same time attempting to describe his action in English to the physics associate professor and the other students in the group. The English teacher is an observer of the action behind the camera, occasionally intervening.

27. **PP:** What are you measuring?
28. **Pascal:** I mesure the first bord of the first face
29. **T:** Side
30. **Pascal:** - oh beuf
31. **T:** - no no, English is important in this lesson. English and science!
32. **Pascal:** The first side I mesure (heavy accent)
33. **PP:** Measure
34. **Pascal:** I measure 6.5 cm



Frame 5: measuring an object

<p>35. PP: 6.50 is much more accurate than 6.5 as a physicist you should know that.</p>	
---	--

The PP generates an exchange around the activity by asking Pascal what he is measuring (speech turn 27). Pascal manages to describe his action but lacks some vocabulary (speech turn 28). T translates 'face' with 'side' though in fact edge would have been the correct term. Pascal's 'Oh beuf' suggests he does not consider the English vocabulary to be very important. T insists from behind the camera that the English is important (speech turn 31). Pascal continues his description but pronounces 'measure' incorrectly as if it were the French word 'mésure' (speech turn 32). PP corrects his pronunciation (speech turn 33). Pascal corrects his pronunciation of 'measure' and specifies 6.5 cm as his measurement (speech turn 35). PP tells Pascal and the group that they should be aware of the fact that 6.50 (stated by PP as 'six point fifty') is far more accurate than 6.5 (speech turn 35).

The student Pascal does his best to measure the object as well as respond to the various instructions of both the physics associate professor (speech turns 27, 33, 35) and the English teacher (speech turns 29, 31). He is handicapped by a limited knowledge, in English, of the jargon in the field (speech turn 28) and is ill-prepared for the multiple requirements of the activity: he must use the (English) jargon that he has not yet acquired (speech turn 31), he must pronounce new words correctly (speech turn 33), and his protocol must be directed by the thought style of a physicist (speech turn 35).

General Didactic Analysis of Part Two of the Exploratory Lesson

Table 7 below is a general analysis of the system of epistemic capacities (Gruson, 2019) that the students would ideally develop in part two of the lesson. The appearance of the notions of jargon and thought style in both columns reveal the interweaving of language and content epistemic capacities.

Table 7*Part Two: System of Epistemic Capacities*

System of epistemic capacities (English)	System of epistemic capacities (physics)
<p>Co-constructing meaning in small groups (oral, signed or written form):</p> <p>Describing a protocol step by step, including the materials used, using the jargon and thought style appropriate to the practice (e.g. estimating uncertainty, accurate measurement).</p> <p>Translanguaging: Identifying the jargon: the English terms which correspond to experimental procedures studied and practiced in the students' physics courses.</p> <p>Presenting a result using the appropriate jargon and thought style (e.g. 6.50cm - pronounced six point five oh – as opposed to 6.5 pronounced six point five)</p>	<p>Develop the thought style of a practicing physicist (a connoisseur of the practice) so as to be able to devise a suitable protocol to measure an object and estimate its uncertainty.</p> <p>Through assimilation of the appropriate thought style, be aware of all the factors that may have an impact on the uncertainty in the measurement.</p> <p>Understand, in assimilating the appropriate thought style, the importance of a high-quality protocol to reduce the random error in the measurement (or 'measurement error' using the GUM 2012 terms).</p>

As we saw above, the learning game of part two of the exploratory lesson can be defined thus: (iii) 'appropriating the jargon and thought style explored in part one of the lesson to actively use it in a measuring exercise.' In seeking to develop resources to participate in this game, it was hoped the students would acquire the capacities outlined in table 7.

In keeping with the models developed by Gruson (2019) for foreign language teaching (DLC in French), and the existing body of work in the JATD (e.g. Sensevy et al., 2015), the two

episodes described above shall be analysed so as to answer the following questions. Q1. How does the contract (the already-there) enable the students to successfully tackle the problem presented in the situation? Q2. How does the structure of the milieu (the symbolic structure of the problem posited) enable students to construct new knowledge? (Gruson, 2019, p. 130). (Author's translation)

As we saw in the description of the episodes above, the student Pascal does not have the existing knowledge (speech turns 28, 32, 34) to tackle the problem presented. That is to say, successfully measure a small object, estimate the uncertainty in his measurement in the right *thought style*, (for example, stating 6.50 as opposed to 6.5) and be able to express clearly in English how he is doing this using the *jargon* of the domain. As he is ill-equipped to deal with the problem he is presented, the only potential strategic system available to him (Sensevy, 2011; Sensevy et al, 2015), is to repeat the information given to him by the two teachers (speech turns 32, 34); the contract does not enable him to tackle the problem, independently, in a strategy leading to the construction of new knowledge. This was because what was deemed to be already known by the student had not as yet been learnt.

As a contract is the result of past transactions, it might be supposed that the student had no previous knowledge of practicing and speaking English. This was not the case: the students in this class had previously participated successfully in mini-group activities, entailing multiple exchanges. However, previous classroom exchanges, at university and at school, involved cultural topics (e.g. giving and asking for opinions or summarising cultural issues). It is likely that this was the first time the students had been confronted with a situation based on a scientific practice and therefore its accompanying *jargon* and 'practice language' (Collins, 2011). Consequently, they did not have a basic scientific vocabulary on which to build.

The double dialectics of contract/milieu and reticence/expression (Sensevy et al., 2015; Gruson, 2019), are useful in analysing how the teachers attempted to regulate this situation in this episode with a process of didactic equilibration. As we saw, both the teachers are expressive (e.g. speech turns 27, 'what are you measuring?', 29 'side', 35 '6.50 is much more accurate...'). This was no doubt in an effort to compensate for the huge gap between the contract and the milieu, so as to establish some form of contract-milieu equilibrium. However,

they were unsuccessful as there is no evidence that the student became independently capable of producing useful strategies inherent in the game to construct new knowledge. Therefore, based on this example of the classroom interactions, the answer to Q1 'How does the contract (the students' existing knowledge) enable the students to successfully tackle the problem presented in the situation?' is that it does not. The gap between the contract and the milieu was too large where the students were unable to participate in this resistant, non-transactional milieu.

As regards Q2: 'How does the structure of the milieu (the symbolic structure of the problem posited) enable students to construct new knowledge?' An important point to emphasise in the analysis of this episode, is that the situation in which the problem was presented, i.e. 'measuring an object whilst describing one's actions', was not conducive to student output. As we saw earlier with the Walter Lewin MIT lecture, efforts to produce language whilst implementing a protocol might hinder the practitioner's efforts to carry out the protocol successfully. The concentration required to execute a protocol does not marry well with the activity of describing and explaining that action.

In the extract above, language is generated by the questions of the physics associate professor (e.g. speech turn 27 'what are you measuring?'). Pascal produces (speech turn 28) 'I méasure the first bord of the first face' (I'm measuring the edge of one face), however, if the teacher were not present, which was the case for the other groups in the class, the students would not be constrained to produce output. Furthermore, as it transpired the jargon inherent in the situation was that of geometry and not of uncertainty in measurement, a targeted objective. It also appeared difficult for Pascal to concentrate on his protocol whilst being questioned by the two teachers, a point made earlier with regard to Walter Lewin.

In this respect, the situation presented was not a well-orchestrated situation for the development of successful strategies to participate in the game; that is, to acquire the epistemic capacities inherent in the scientific practice of measurement with its associated jargon or 'practice language'. Therefore, the answer to Q2. 'How does the structure of the milieu (the symbolic structure of the problem posited) enable students to construct new

knowledge?’ is also that it does not. The whole structure of this resistant, non-transactional milieu needed to be re-designed in order for it to afford effective learning.

This is a point that had a bearing on the later design of activities in the sequence, which sought to create situations necessitating the concentrated use of the jargon (practice language) of scientific practice so as to develop students’ use and understanding of that particular jargon in its context. An example of such a situation, as we shall see in the description of the context of ‘The Genesis of a Thought-Style’, was asking students to describe a protocol to another student who would follow their instructions to execute the protocol during its description. The students would then change roles and repeat the activity.

This might be contrasted with the laboratory work done by students in their main subjects where less time is spent focussing on the practice language of the discipline, though of course this is an integral part of that work. A frequent practice in laboratory classes is to have students work in small groups, and to give each member of the group a different role: spokesperson, secretary, observer, executor etc. This ensures that no student is passive during laboratory work but it does not create situations where each and every student is constrained to produce language output related to their practical work. As stated earlier, the sequence was designed to ensure student language output which is considered to be a necessary condition for progress in this study.

The Exploratory Lesson: From Words to Worlds

Despite the ineffective learning games described above, the question of uncertainty in measurement was retained for this CLIL project. Interestingly the students (see questionnaire, Appendix C) nevertheless found the lesson useful, as did the teachers who considered it sufficiently dense in epistemic potential to explore it further (with other, future students). The theme was re-worked in an iterative process (Sensevy et al., 2013) over the next two years, and developed into a sequence (current form of the sequence, 3.6) targeting systems of epistemic capacities (Gruson, 2019) of experimental science.

As stated earlier, language and practice are considered to be organically interlaced in this study (Sensevy et al., 2019; Collins, 2011). The linguistic socialisation of scientists, an essential part of their scientific practice, was the area of specific interest for this CLIL programme which targeted systems of epistemic capacities surrounding scientific discourse. This involves more than learning vocabulary as the nuts and bolts of the process; linguistic socialisation is a process more complex than simply acquiring vocabulary. For example, it is not the word 'uncertainty' as such that is vital for an experimental scientist, but the word 'uncertainty' with its attached world of everything that is implied in scientific measurement. Estimating the uncertainty of a measurement requires skill, experience and personal judgement: skill so as to be able to elaborate a rigorous protocol that avoids random error, experience in being able to foresee the many factors that might lead to random error, and judgement with regard to how well all those factors can feasibly be controlled. All of these aspects of uncertainty estimation are further complexified by the fact that the context in which the estimate is stated may be yet another determining influence. The example of Compton in chapter 4 illustrates this point, and reveals the pivotal role of an uncertainty estimation in scientists' relation to the scientific discourse surrounding their laboratory work. 'Uncertainty' viewed in this way corresponds to the notion of jargon: it was this dialogical process within scientific practice that was a real focus of interest in this study.

A striking example of jargon from the Exploratory Lesson which gave the English teacher an insight into the thought style of a practicing physicist, was the phrase '6.50 is much more accurate than 6.5' (speech turn 35). The epistemic potential in this phrase will be discussed further, following the presentation of 'The Genesis of a Thought Style' extract. This will be to show how the didactic activity of the students in this latter extract, bore more of a resemblance to a connoisseur's practice than that of the students' didactic activity in 'The Exploratory Lesson'. That is to say their practice had more of an epistemic kinship to expert practice in the field than that of the students in 'The Exploratory Lesson'.

8.2.1 Preliminary Conclusions with regard to the Study Research Questions

The research questions which are addressed in this study will be considered in relation to the above analysis.

Question 1: How can the combined objectives of a conceptual understanding of scientific practice, together with work on language skills, be effectively described? What is the role of jargon in the construction/development of a capacity?

The Joint Action Theory in Didactics' notions of contract –the already-there– and milieu were effective tools for identifying the structural inefficiencies in the learning games devised in relation to the targeted objectives. The double dialectics of contract/milieu and reticence/expression (Sensevy et al., 2015; Gruson 2019), were useful in analysing how the teachers then attempted to regulate the didactic equilibration as a consequence of this structural inefficiency. Both teachers were expressive (e.g. speech turns 27, 'what are you measuring?', 29 'side', 35 '6.50 is much more accurate...') in an effort to compensate for the huge gap between the contract and the milieu, so as to establish some form of didactic equilibration.

The notions of jargon and thought style served to identify the language (jargon) and associated body of knowledge (thought style) inherent in the milieu that could potentially lead to the development of the targeted system of epistemic capacities. In particular, the notions served as useful tools for identifying the scientific discourse (both language and practice) concerning the complex issue of uncertainty in measurement.

Question 2: What capacities can be identified in the didactic activity of the students participating in the case study, and what evidence is there of effective work on those capacities in the didactic activity between themselves and with the teacher?

In the exploratory lesson, student productions were limited and as a result there was little evidence of capacities being actively developed during the didactic activity. There were occasional smatterings of jargon associated with the practice of scientific measurement. For example, in the exchanges between the English teacher and the class during work on the co-construction of meaning with regard to the Walter Lewin video extract: 'when it is a solid

object... it is not possible...er... to change er...the size of this object er because ... it is horizontal or vertical' speech turn 8). However, there was no evidence of jargon encountered in the video being reinvested in the subsequent group-work with the associate physics professor.

As was determined in the didactic analysis, the fact that student capacities were not actively developed during the lesson can be attributed to the design of the learning game. Firstly, it was not based on an accurately assessed contract and secondly, the group-work activity was not a well-designed situation to produce a dialogical use of jargon. A well-orchestrated situation is one where students would need to produce jargon as a successful strategy for participating successfully in a learning game. This was not the case in the learning game presented in the group work: in fact, being expected to produce jargon in the context presented tended to hinder the student from concentrating on his measurement.

Question 3: What are the concrete conditions of a CLIL programme which enable students to develop a conceptual understanding of scientific practice whilst improving their English language skills?

How ought CLIL practice interweave content and language, and in what ways are these two elements then influenced by their convergence? What are the frontiers in a given speciality that necessitate language teachers cooperating with specialists of a body of knowledge?

The conditions of this CLIL programme evolved directly from the teaching priorities of the two teachers engaged in the project. That is to say, it was the focus of efforts to target the systems of epistemic capacities that each of the teachers had identified as a goal in their teaching practice. The physics teacher sought to engage students in a finer understanding of the complex issue of uncertainty in measurement and the English teacher sought to develop specialised programmes where students actively engaged in using the target L2 language in inquiry-based programmes.

The Walter Lewin video extract proved to be an efficient resource in terms of introducing some of the jargon and thought style related to the practice of measurement in physics. However, it was not fully adapted to creating a milieu corresponding to the objectives decided upon by the two teachers: namely a finer understanding of the factors contributing

to uncertainty in measurement for the physics professor, and a sequence founded on student production for the English teacher. This latter point was considered a condition for developing L2 language skills.

A primary condition of a CLIL programme, based on this study, is that it must be sufficiently rich in epistemic potential to offer an inquiry-based milieu where students can develop the targeted epistemic capacities. The subject of uncertainty was retained as an issue which corresponded to this condition.

A second condition, based on this study, is that language teachers and specialists of a field should develop projects cooperatively: this is to enable language teachers to develop the interactional expertise (Collins, 2011) necessary for such CLIL projects, and to ensure that the linguistic socialisation inherent in scientific practice remains a priority. The English teacher would not have been able to develop the project alone without the measuring activity suggested by the physics lecturer, as well as her guidance as regards the thought style of a physicist. The physics teacher would not have been able to develop the (CLIL) project alone without the language teacher's focus on the linguistic socialisation of scientists (Collins, 2011). In an attitude typical of language teachers, the English teacher ensured that the notion of uncertainty was explored in orchestrated situations where students would need to produce jargon as a successful strategy for participating in a learning game. She was also a reference for the accuracy of certain structures, terms and pronunciation with regard to the jargon introduced into the classroom by the physics teacher (e.g. 'T: do you mean the decimal point?').

In this project, the teachers engaged in multiple exchanges mainly in the cooperative production of teaching resources, as we shall see. In this way the sequence combined the objectives of both fields, with each teacher functioning as the guarantor of the knowledge in their field.

8.3 The Genesis of a Thought Style

A full detailed description (in French) of the instructions of the lesson from which this extract is taken, as given to teachers using the sequence, can be found in Appendix A. This includes a description of the activities, measuring methods, vocabulary and expected learning outcomes. It also includes possible classroom scenarios. Extracts from this description are presented as part of the context of 'The Genesis of a Thought Style'.

At this stage in the development of the sequence, the physics associate professor was no longer present in class but continued to contribute to the subsequent elaboration of the sequence. She continued to communicate and advise the English teacher on physics as a practice, and the two teachers continued to cooperate on the development of material: for example, the joint production of a laboratory report (Appendix B). This report itself originated with the English teacher's description of the physics associate professor's execution of a protocol to measure the diameter of a tennis ball using the shadow method. It was developed into a teaching resource that was then integrated into the sequence.

Context

The sequence, as it had become at this point in time, begins directly with a practical measuring activity that replaced the MIT extract used in 'The Exploratory Lesson'. It was designed in such a way so as to constrain the students to encounter the jargon inherent in the activity. They are given a tennis ball and asked to design a protocol, in pairs, to measure its diameter, using whatever resources available to hand. They can work in French and English at this stage, but they should research vocabulary so as to be able to describe their protocol to another student in English. They have access to computers and can ask for help from each other as well as the teacher. They are encouraged to use precise vocabulary, and must produce a detailed protocol, seeking out possible causes of error and reducing their impact to a minimum.

Activity One Documents

Students are given a tennis ball, the worksheet in the table below, and the following instruction: 'Working in pairs you're going to elaborate a protocol to measure the diameter of a tennis ball using instruments available in class - be careful to note down your results.'

Instruction worksheet
Imagine an experiment to determine the diameter of a tennis ball using material available in the classroom.
Research all the vocabulary necessary in order to be able to explain your protocol step by step to another student.
The student who listens to your protocol should be able to carry out the same experiment and obtain the same results.
Materials
Procedure/protocol (number each step)
Results

At this stage of the sequence, students invariably choose one of two methods to measure the diameter of their tennis ball: 'the circumference method', and 'the rigid-book method'. The details of these methods, as well as a number of other methods that students might explore outside class time, were provided by the physics associate professor and can be found in Appendix A. The details of 'the circumference method', and 'the rigid-book method', which are generally the methods used by the students in this learning game, are described below. The terms associated with each method and detailed instructions on how to execute the methods as rigorously as possible are also explained.

The Circumference Method

A) Method to measure circumference C:

This can be done with a piece of thread or string, winding it around the ball once, twice or three times. Care must be taken as the uncertainty of the measurement will depend on the position of the thread or string on the ball (whether or not it is on its equator, see Figure 5 (c,d)), and the width of the thread or string (Figure 5 (g,h)).

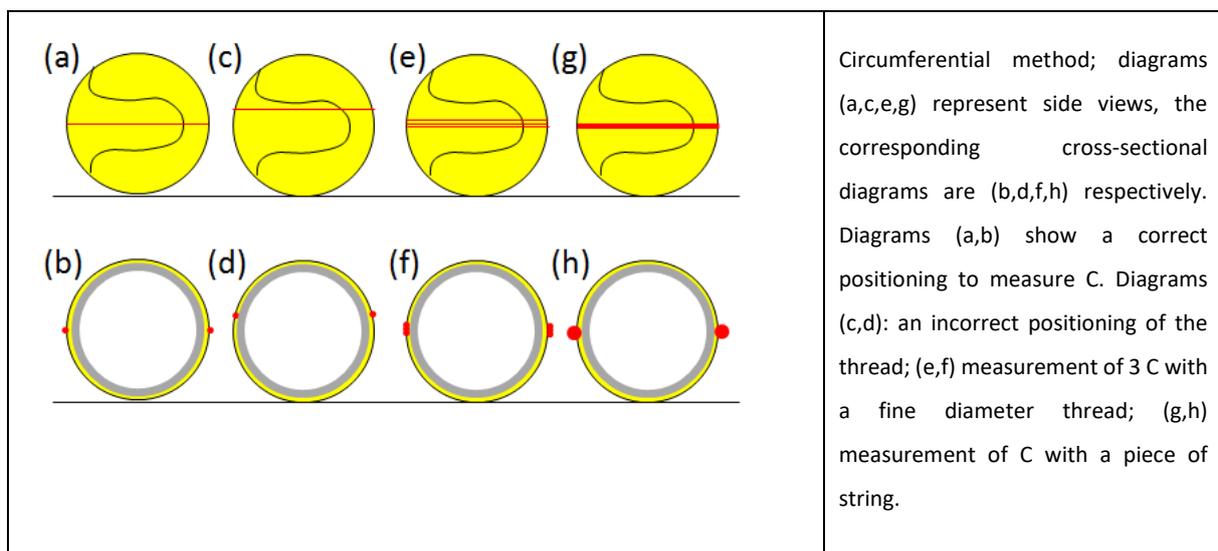
$C = \pi D$ and therefore $\Delta C = \pi \Delta D$ and finally $\Delta D = \Delta C / \pi$

It is also possible to decrease the uncertainty on D by winding the thread or string around the ball several times (n wraps around the ball divide the uncertainty on D by n but this can add error to the value sought). Use of a thick string should be avoided and it is necessary to position the thread or string close to the equator of the ball (Figure 5 (e,f)). If a thick string is wound around the ball in the same position it increases the value of the diameter of the ball being measured.

It is assumed that the wire or string is inextensible, and that it will not compress the ball locally.

Figure 5

The Circumference Method



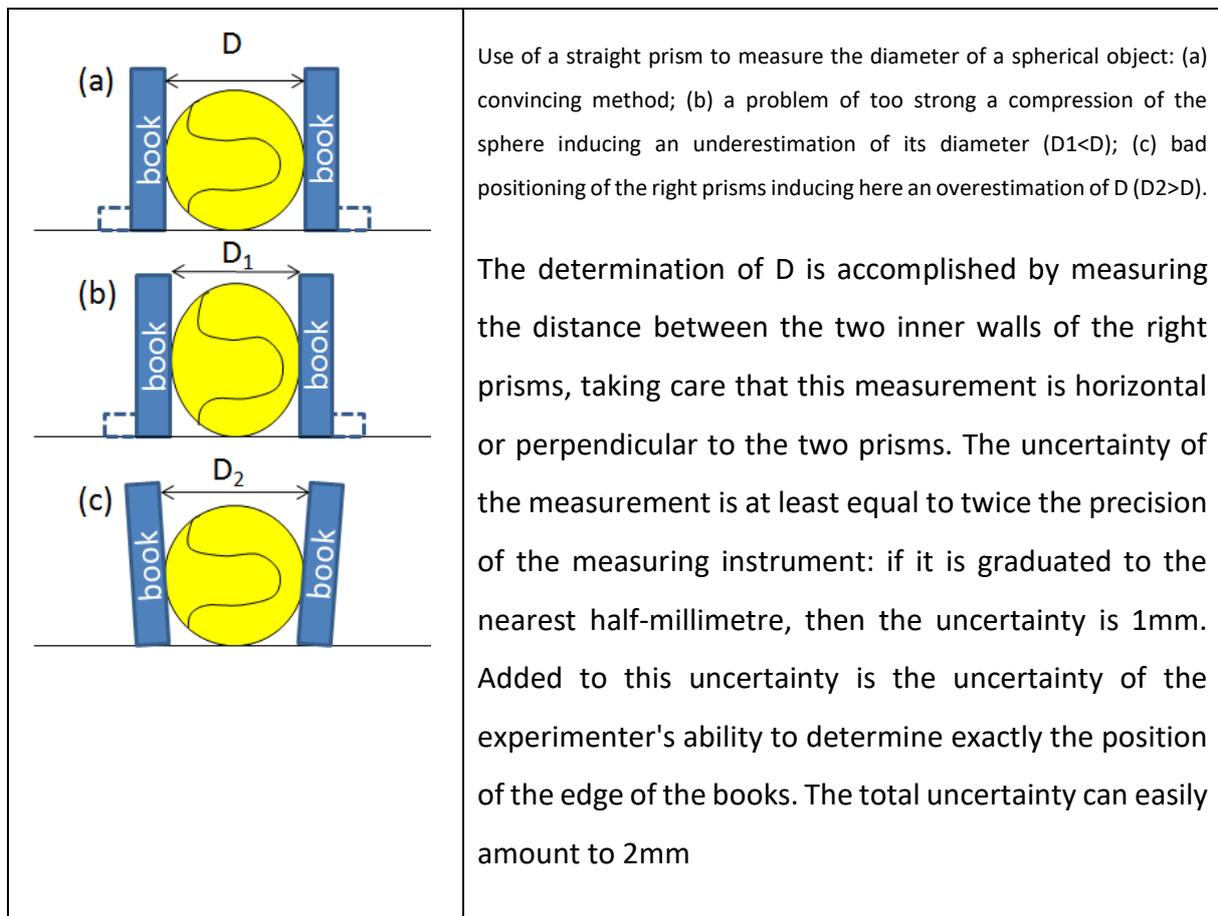
For the circumference method, teachers are advised to ask the following questions so as to guide the students to approach the activity in the right thought style whilst integrating the appropriate jargon:

How can you be sure you are exactly in the centre of the ball? How tight did you pull the wire/string/thread? How many times did you measure the ball? Which measurement did you take? Did you take the average of the measurements or the widest measurement? Which is best? Ok so you divided the circumference by pi – what about the uncertainty?

The Rigid-Book Method

Figure 6

The Rigid-Book Method



For the rigid-book method, teachers are advised to ask the following questions so as to guide the students to approach the activity in the right thought style whilst integrating the appropriate jargon:

How did you ensure the book/set square/ruler/box was exactly perpendicular to the table? Where did you check your right angles? Were you careful about parallax? Have you included that in your written protocol? How can you be sure of fixing the ball without squeezing it? Doesn't that increase your uncertainty? How many times did you take the measurement? Was it always the same person?

Below are examples of the language that should emerge from the activity

Vocabulary which should emerge from the activity (non-exhaustive list)

Verbs: align, attach, fix, insert, lodge, remove, squeeze, turn, twist, slide, wind around.

Tools: hard-backed books, protractor, rigid object, ruler, set square, string, thread, wire.

Mathematical Terms: circumference, graduations, height, length, parallel, perpendicular, squared, radius, width.

Other: front-view, back-view, side-view, aerial view, eyesight, naked eye.

Jargon (examples): lodge/block/fix the ball between 2 books; wind the thread carefully around the middle of the ball ...)

Examples of pronunciation errors and stress patterns: forewarn and correct frequently

Cir'cumference, 'Measure, 'parallel, 'ruler, 'surface, suffix -ed, wind (verb)

Grammar

At this point, exchanges between the students are essentially in the present simple; this is very appropriate for a scientific protocol.

Errors to correct at every opportunity: the incorrect 'for + base form of verb' (e.g. 'for measure') instead of the infinitive ('to measure'). Students tend to poorly translate 'pour faire ...'. Ensure students know the difference between 'measure' the verb and 'measurement' the noun.

Once the design and description of the protocol is complete, the students change partners and describe their protocol to a new partner, who must then follow their instructions to execute the protocol using exactly the same instruments. In this way, each student will experience both describing a protocol in detail and carrying out another student's protocol. They are asked to note down their results but not to share them. Invariably the students obtain different results, not only for protocols using different materials and different methods, but also, at times, for the same protocol and the same material. This is to be absolutely expected: in this way the activity heuristically raises the issue of uncertainty in measurement and heuristically confronts the students with the need to communicate in English to

participate in the game. The term heuristic, derived from the Greek word ‘to discover’, is used here in the sense that the students discover for themselves the reality of uncertainty in measurement and the jargon they require to explore it. The JATD notion of student originator corresponds to this didactic form where students engage in a process of inquiry based on the results of their own productions.

It also heuristically introduces the students to the thought style of the domain, as we shall see.

At the end of this activity, the students are asked to dictate their results to the teacher who writes them on the board. This is the point at which the extract below begins.

For the sake of clarity, it will be presented in two parts: part one where students share their results following the measuring activity described above, and part two when the results are discussed together as a class.

Presentation of Part One: Sharing Results

Following the measuring activity, the teacher (T) asks the students to direct their attention towards the blackboard and to read out the result they found for the diameter of the tennis ball.

<ol style="list-style-type: none"> 1. T: Ok, can everybody please look this way. So, for Zaïd and Ali you found 6.8 2. Zaïd: 8 - 4 (eight, four) 3. T: What? Carrots? Peas? 4. Zaïd: centimetres 	 <p style="text-align: center;"><i>Frame 6: The teacher writes the students' results on the board.</i></p>
<p>The teacher (T) asks the students to share their results (speech turn 1). She starts with Zaïd and Ali and writes the beginning of their answer (6.8) on the board. She then she turns towards them to listen to the remainder of their answer. Zaïd adds eight – four (speech turn 2). T writes 6.84 on the board. She asks ‘carrots, peas?’ (speech turn 3) to highlight they should not forget the measurement unit. Zaïd adds ‘centimetres’ for the measurement unit (speech turn 4).</p>	
<ol style="list-style-type: none"> 5. T: For Saad and - don't tell me - Fabien you found ... 	

6. **Fabien:** We found the same
7. **T:** Exactly the same?
8. **Fabien:** 6.8 (six point eight)
9. **T:** 6.8 what?
10. **Fabien:** er 4366 (four, three, six, six)

T continues to write down the students' results with Saad and Fabien (speech turn 5). Fabien says they found the same result (speech turn 6). She asks them if they are sure of this (speech turn 7). She encourages Fabien to give a more detailed answer (speech turn 9). Fabien gives a result with 5 decimal places– 6.84366 (speech turn 10) which T writes on the board.

11. **T:** For Nina and Youssef, what did you find?
12. **Youssef:** 6.54 (six point fifty-four)
13. **T:** yes, you say each digit separately after the decimal point. So, for Théo and Rémy?



Frame 7: decimals are read a single digit at a time

T asks Nina and Youssef for their results (speech turn 11): she writes Youssef's answer (6.54) on the board (speech turn 12). Youssef does not read the decimal point correctly. T reminds the students again that decimals are read a single digit at a time (speech turn 13). She uses the side of her hand to make a slashing movement, three times, to insist on this point (frame 7).

14. **Rémy:** 6.68 (six point sixty-eight)
15. **T:** 68 (six, eight)
16. **Rémy:** 5 - 6.685 (six point six, eight, five)
17. **T:** 6.685 (six point six, eight, five)

Rémy gives his result (speech turn 14). He also forgets to read the decimals a single digit at a time. T writes his result (6.68) on the board then repeats the decimals six, eight to correct this. She does so, using a rising intonation, as if a question, to show Rémy she wants him to confirm his answer. Rémy gives the remainder of his result – 5- (speech turn 16) then reads out the decimals again, one digit at a time (speech turn 17).

As this extract shows, reading aloud the results presents an opportunity to practice numbers and decimals in English (speech turns 2, 8, 10, 12, 14, 16) and to realise that, unlike in French, they are preceded by a point not a comma (speech turns 8, 12, 14, 16). The teacher

reminds the students that they should specify the unit of measurement (speech turn 3 'What? Carrots? Peas?'). The physics associate professor had informed her that students frequently forget to do this. She insists on the fact that in English, decimals are read a single digit at a time (speech turn 13, 'yes, you say each digit separately after the decimal point' speech turn 15 '68 (six, eight)'). She repeats a student's answer to give a phonological model (speech turn 17 '6.685 (six point six, eight, five)').

Presentation of Part Two: Discussion of Results

Having written the results of the individual members of the class on the board, the teacher then asks the class, as a whole, why their results were different (speech turn 18 below).

18. T: If we look at these different results ... erm ... they are different. Ok, they're similar, but they are different. How do you explain the differences in your results?
19. Zaïd: suggests an inaudible answer on the film but the teacher hears it.
20. T: ah ok, Well, that's another question but if we wanted to get a more reliable result that would be an idea. We could add them together and find the average.
21. Rémy: inaudible
22. T: Can you say that again please?
23. Rémy: The sorts of material
24. T: It's the materials
25. Rémy: Yes, it's the fault of the materials
26. T: Yes, ok so fault of - c'est un peu (*that's a little...*) judgemental we can say it's 'due to' the materials. Good. The different materials. Do you mean like the accuracy of the materials? Ca veut dire quoi accuracy? ('What does "accuracy" mean?')
27. **Student:** précision (*accuracy*)
28. T: la précision (- tout à fait - (exactly) so it's due to the accuracy. Yes, what else?

T asks the students to explain their different results (speech turn 18). Zaïd suggests an idea that could be useful for reducing the uncertainty in a given result of certain protocols (speech turn 19). However, this idea does not clarify the factors contributing to a degree of uncertainty in any measurement. T recognises the idea but states that it is the answer to a different question (speech turn 20). Rémy suggests the difference in results is related to the materials used (speech turn 23). T writes this idea on the board and encourages Rémy to continue (speech turn 24). Rémy says it's "the fault" of the materials (speech turn 25). The word "fault" used by Rémy is an example of a common tendency students have to use this inappropriate term, either due to the use of the wrong register (in both French and English) or perhaps due to an inaccurate translation of "à cause de" in French. T reformulates the suggestions replacing "fault" with "due to" and explains that this term is more neutral (speech turn 26). She introduces the word accuracy (speech turn 26) and checks the students' understanding of the word (speech turns 26, 28). In fact, the teacher uses the word incorrectly in this instance (one talks of the precision of an instrument (fidélité de mesure) and the accuracy of a measurement (l'exactitude de mesure). It would have been more appropriate to talk about the materials not being well-adapted to the task given them. She was able to clarify this later elsewhere.

29. Nina: Calculate

30. T: The calculation. What do you mean the calculation?



Frame 8: Using fingers to count the propositions

After Rémy's suggestion, T raises her thumb to represent this idea as the first of several suggestions (the precision of the instruments). In doing so she signals that she expects more propositions from the students. Nina suggests "calculate" (speech turn 29). T reformulates Nina's idea with the correct noun form in English (calculation). She raises a finger as if to count a second point, signaling she expects more ideas (Frame 8). She asks 'what do you mean the calculation?'. She again signals she expects more answers by waving her hand from the students towards herself.

31. Rémy: when + er you do er a round er inaudible er +++ er +++

32. T: your calculation

33. Rémy: yes and er +++ around er +++ er

34. T: tu veux le dire en français ? (Do you want to say that in French?)

35. Rémy: La taille (size) (inaudible except for a few words) on a arrondi (we rounded up) - circonférence - (circumference)

36. P: Ok (moving towards the board) So it can be related to erm rounding up or down. Any other ideas? On va regarder un extrait de MIT à propos de ce sujet et ensuite on va voir si vous avez d'autres idées. (We're going to watch an MIT extract on this subject and then we'll see if you have any more ideas) Has anybody got any other ideas to suggest?

37. Student: (inaudible on the film but the teacher hears it - there is some mention of error)

38. T: there could be some errors erm yes, what kind of errors?

39. Student: +++

40. T: Ok - on va enrichir ça ok ? (Ok, we're going to add to this, ok?) So, We're going to watch a video extract - you have a worksheet to accompany that.

Rémy tries to suggest another idea to explain the different results but he finds it difficult to find the right words in English (speech turns 31, 33). T suggests he says it in French (speech turn 34) then she translates his words (speech turn 36). The idea is that rounding figures up and down can explain the different results. T writes Rémy's idea on the board. She informs the group that they are going to watch a MIT extract and encourages them to make new suggestions (speech turn 36). A student suggests the differences might be due to errors made (speech turn 37) but does not expand on this when T asks them to say more (speech turns 38, 39). T then focuses the attention of the group on the worksheet and the video extract that they are about to watch (speech turn 40).

During the above exchanges, the teacher encourages the students to make suggestions to explain the different results previously identified (speech turns 18 '...How do you explain the differences in your results?', speech turn 22 'Can you say that again please?', speech turn 26, speech turn 28 'Yes, what else?', speech turn 30 '... What do you mean the calculation?', speech turn 34 'tu veux le dire en français?', speech turn 36 'So it can be related to erm rounding up or down. Any other ideas?', speech turn 38 '... what kind of errors?'). She helps them to formulate their answers in English (speech turn 24, speech turn 26 'we can say its 'due to' the materials', speech turn 30 'The calculation', speech turn 32, speech turn 36 'So it can be related to erm rounding up or down'). She writes some of the ideas on the board without commenting. The main objective at this point is to encourage students to be thinking about everything possible involved in measurement uncertainty. The different results can be explained by various factors and the students contribute pertinent propositions by suggesting the material, the calculations, rounding up or down of results as part of the explanation.

The Genesis of a Thought Style Extract: Didactic Analysis of Parts One and Two

Table 8 is a general analysis of the system of epistemic capacities (Gruson, 2019) inherent in the situation that the students could potentially develop in the situation presented: i.e. the class discussion following the measuring activity. As can be noticed in the latter part of the table, language and practice become increasingly fused in this CLIL sequence.

Table 8

Systems of Epistemic Capacities (8.3): English and physics

System of epistemic capacities (English)	System of epistemic capacities (physics)
<p>Co-construction of meaning: Interaction in oral (preferably), signed or written form: identifying the structures and vocabulary to begin to construct the <i>jargon</i> and <i>thought style</i> appropriate to the practice:</p> <ul style="list-style-type: none"> • E.g. align, wind, to measure, measurement. Words developed into jargon • Jargon examples: Align the ruler, wind the thread, to measure the ball, accuracy of a measurement, calculation of a value, rounding up/down a result, circumference of the ball • Reading decimals correctly (e.g. 6.50cm, pronounced “six point five oh cm”, as opposed to 6.5). 	<p>Understand the <i>thought style</i> of a practicing physicist (a connoisseur of the practice) so as to evaluate all the factors that may have an impact on the uncertainty in a measurement and ensure random error is avoided with a rigorous protocol:</p> <ul style="list-style-type: none"> • E.g. lodge/block/fix the ball between 2 books; wind the thread carefully around the middle of the ball etc. <p>Know that</p> <ul style="list-style-type: none"> • 6.50 is not the same as 6.5 in physics – know why • There is a subjective aspect to the estimation of a degree of uncertainty
<p>System of epistemic capacities (English and physics combined)</p>	
<p>Discussing how to reduce random error so as to restrict the factors contributing to uncertainty in measurement using the <i>jargon</i> and <i>thought style</i> appropriate to the practice. For example:</p> <ul style="list-style-type: none"> • Are the books perpendicular to the table? Let’s measure again with more light. Were you careful about parallax? We have to be sure of fixing the ball without squeezing it. • Carefully wind the thread around the middle of the ball. How can you be sure you are exactly in the centre of the ball? How tight did you pull the wire/string/thread? Ok so you divided the circumference by pi – what about the uncertainty? • How many times did you measure the ball? How many times did you take the measurement? Was it always the same person? • Which measurement did you take? Did you take the average of the measurements or the widest measurement? Which is best? • Doesn’t that increase your uncertainty? 	

The Learning Game of Parts One and Two of the Genesis of a Thought Style Extract

The learning game of parts one and two of the genesis of a thought style extract can be defined thus: 'encountering the complexity of the issue of uncertainty in measurement so as to be able to pursue it further in a process of inquiry; being initiated into the jargon and thought style of a connoisseur of the practice'. In seeking to develop strategies to participate in this game, it was hoped the students would develop the capacities outlined above.

The Semiosis Process within the Didactic Joint Action

We shall now focus on how the teacher shaped the learning game using descriptors developed within the JATD: the twofold semiotic system in relation to the double dialectics of contract/milieu and reticence/expression, as well as didactic equilibration (Bloor & Gruson, 2019; Sensevy, Gruson & Forest, 2015; Gruson, 2019). Below is a description of the teacher's moves in parts one and two of the extract.

Part One of the Genesis of a Thought Style Extract

- She begins by directing the students' joint attention to the blackboard and by asking for their results so as to construct the problem embedded in the milieu (speech turn 1
'Ok, can everybody please look this way?')
- In response to Zaïd not specifying the unit of measurement ('6.84' – speech turn 2), she suggests 'What carrots/peas?' (speech turn 3): a sign for him to realise he should specify the unit of measurement: he does so and answers 'centimetres' (speech turn 4). She is expressive in asking if the answer is 6.84 carrots or peas. A rather absurd suggestion which is in fact a means of being expressive in seeking more information, yet reticent about its exact content: the units of measurement.
- In response to Fabien saying he found the same result (speech turn 6) she uses a milieu-driven semiosis (MDS) question ('Exactly the same?' – speech turn 7) as a sign he should be more precise. Fabien picks up on the sign and gives a very precise answer: ('6.4366' – speech turn 10). She is expressive in signalling she expects more information but again reticent about exactly what that should be: more decimal places. In fact, two decimal places, or possibly three using a calliper, would be the maximum

precision possible in this exercise, but the teacher is reticent on this point so that the students can discover this for themselves in later activities, whilst in discussion in English.

- In response to Youssef not reading the decimal correctly, she explains again that decimals should be read separately (speech turn 13 'yes, you say each digit separately after the decimal point') and uses the side of her hand in a slashing gesture (frame 7) to represent each digit separately. She is expressive to be expressive. She states that decimals must be read separately and insists on this point using body language.
- The next student, Rémy, does not pick up on this sign and reads the decimals incorrectly. The teacher corrects his decimal reading ('six, eight' – speech turn 15). She is expressive to be expressive and corrects the student.
- Rémy picks up on the correction as a sign and reads his result with three decimal places, reading each decimal separately (speech turn 16 '5 - 6.685 (six point six, eight, five')
- The teacher repeats Remy's correct reading of his result whilst writing it on the board (speech turn 17 '6.685 (six point six, eight, five)'). She is expressive to be expressive by repeating the same information and writing it on the board.

Let us now look at the semiotic joint action in relation to the dialectic of reticence/expression and the teaching moves. The teacher is expressive to be reticent in speech turn 3 ('What carrots/peas?') and speech turn 7 'Exactly the same?') where she expects the students to find the answers themselves. That is to say, as science undergraduates she expects them to remember to specify a unit of measurement (speech turn 3), and she knows they realise that 6.84366 is not exactly the same as 6.84 (speech turn 7). She considers this to be the contract in their science studies and the contract in their English. That is to say "contract" as in the JAD notion of contract: the knowledge and learning habits already acquired and understood by the students, the already-there.

She is doubly expressive in the move in speech turn 13 'yes, you say each digit separately after the decimal point'), stating decimals must be read separately and insisting on this point with a slashing movement of her hand (frame 7). She is expressive in speech turn

15 '68 (six, eight)') reminding Rémy of this same point by reformulating his answer and reading the decimals separately. She is again expressive in speech turn 17 'T: 6.685 (six point six, eight, five)') on the same point when she repeats Rémy's correct reading. As regards reading decimals separately in English, she does not expect the students to know this from previous English lessons, nor from their science studies in French. By being expressive she introduces this new knowledge into the milieu. This is an example of the JATD contract/milieu dialectic, where the didactic activity can be seen to hover between existing knowledge and the new knowledge emerging during the activity.

The learning game is thus shaped to spend time on decimals: the teacher's moves heighten awareness of each decimal position, which will be useful in dealing with the questions arising around uncertainty in measurement. She introduces the jargon of decimals, in English, in the context of its related practice.

Part Two of the Genesis of a Thought Style Extract

- She begins by compelling the students to jointly construct and address the problem embedded in the milieu with a milieu-driven semiosis (MDS) question: 'How do you explain the differences in your results?' (speech turn 18). She is reticent on the physics in the milieu-problem. This question is the result of a period of trial and error in the development of the sequence and the testing of a number of counterfactuals. As was discussed earlier, the MIT extract, whilst initially useful for introducing the subject of uncertainty in English to both the students and the English teacher, was inefficient elsewhere. The joint action between the teacher and the students, exploring the milieu constructed with the results of the students' language and protocol productions, is the activity that replaced the MIT extract.
- She gives an overt sign (speech turn 20 'ah ok, Well, that's another question ...') that Zaïd's answer is not directing the student's attention in the direction she wants to go. She re-orientates the students' attention to the milieu-problem she has in mind; that is to say, the reasons why there is always a degree of uncertainty in measurement and not how to reduce it by calculating the average of several measurements. She knows from discussions with the physics professor that the average of several

measurements is of no interest if those measurements are calculated on the basis of protocols which are not executed taking the utmost care to avoid random error. She wants the students to fully understand this point in language and practice. She is expressive in the re-orientation but reticent on the milieu-problem.

- She reformulates Rémy's answer to correct the English (speech turn 24 'It's the materials'). She is expressive about the English.
- She introduces the word 'accuracy' (speech turn 26). Expressive about the English in the milieu-problem
- She asks 'What else?' (speech turn 27) to be reticent about the physics in the milieu-problem and seeks to constrain the students to construct this aspect of the milieu themselves. She starts to count the contributions on her hand to show she expects more ideas (frame 8)
- She accepts Nina's contribution but corrects the English (speech turn 30) and asks her to expand with a milieu-driven semiosis (MDS) question ('What do you mean the calculation?'). She is expressive on the English in the milieu-problem but reticent on the physics in the milieu-problem.
- She helps Rémy with his English expression (speech turn 32 'your calculation'). She is expressive on the English in the milieu-problem.
- Rémy cannot find the words in English for his idea. She suggests he say it in French (speech turn 34 'tu veux le dire en français?') then translates his contribution and writes it on the board (speech turn 36 'So it can be related to er rounding up or down.'). She is expressive on the English and thus enables the student to contribute their knowledge of physics to construct the milieu-problem.
- She asks the students for more ideas (speech turn 36 'Any other ideas?'). She is expressive to be reticent on the physics milieu-problem that she wants them to construct: this requires a precise intervention that strikes a delicate balance in the reticence/expression dialectic.
- She reformulates a student's contribution (speech turn 38) and asks them to elaborate: 'there could be some errors erm yes, what kind of errors?' She is expressive on the English in the milieu-problem and reticent on the physics in the milieu-problem.

As can be seen, it is possible to discern a pattern in the teacher's moves in the dialectic of reticence/expression. **She is expressive with regard to the English** in the milieu-problem (speech turn 24 'It's the materials'), speech turn 26 'accuracy', speech turn 30 'The calculation', speech turn 32 'your calculation' , speech turn 34 'tu veux le dire en français?'), speech turn 36 'So it can be related to erm rounding up or down. '), speech turn 38 'there could be some errors erm yes, ...')

In contrast, **she is reticent with regard to** the points concerning uncertainty in measurement, that is to say **the physics in the milieu-problem** that she wants the students to construct (speech turn 18 'How do you explain the differences in your results?', speech turn 27 'What else?', speech turn 30 'What do you mean the calculation?', speech turn 36 'Any other ideas?', speech turn 38 'what kind of errors?').

In this way, she guides the students to construct a milieu-problem where they can explore the jargon and thought style related to the problem presented, in English where possible, but otherwise in French. This is done to maintain a didactic equilibration. If the students had been compelled to only speak English, they would have been unable to contribute: there would have been no joint action. The distance between the contract and the milieu would have been too great, as was the case in the 'Measuring a Small Object Episode' in 'The Exploratory Lesson'. In this way, despite the limited jargon in the field in English, the students can begin to construct the thought style related to the practice of measurement in exploring the milieu-problem.

The analysis above highlights the moves of the teacher to maintain a didactic equilibration between the contract and the milieu-problem in a kind of criss-crossing between the content and language aspect of the CLIL programme. The activity served as a preliminary stage in the joint construction of the milieu-problem of the inquiry-based sequence. The question of uncertainty in measurement was sufficiently dense in epistemic potential for students to gradually construct both the jargon and thought style of the practice of measurement whilst co-constructing meaning in English.

In order to illustrate further the dynamics of this extract, a hypothetical model answer to the teacher's opening question 'How do you explain the differences in your results?' (speech

turn 18) is presented below. It can be understood as representing the potential knowledge in the milieu at this point in the didactic action. As the model answer indicates, a complete answer to this question includes knowledge about the scientific practice of measuring with its associated jargon and thought-style. The print in red represents the same ideas that arose in the didactic activity during 'The Genesis of a Thought Style', though of course in a hesitant form, and with difficulty of expression in English. The words in red indicate what is known (the already-there) or being encountered by the students, in relation to the knowledge inherent in the milieu indicated in black. That is to say the genesis of the knowledge at stake.

Hypothetical Model Answer

'Assuming the difference in the size of the tennis balls is negligible, **the different results** of the **measurement of the tennis ball's diameter, ranging from 6.54cm to 6.84366cm** can be explained by a number of factors which will entail a degree of uncertainty in its measurement. Firstly, the different methods of measurement used, as well as **how well-adapted the material used** was to execute it, will have an impact on a measurement uncertainty. For example, the **circumference** method entails a lower degree of uncertainty than the rigid book method (see notes appendix x), as the uncertainty of the measurement will be divided by **pi**. With regard to how well-adapted the material of this method might be, using a **fine thread** to measure the **circumference** of the ball, as opposed to a **shoe lace** for example, will reduce the uncertainty of the measurement. Secondly, a **carelessly executed** method, for example not winding a thread **exactly in the middle of a ball**, will lead to **error**; therefore, care must be taken to be as methodical and exact as possible, whilst still recognising that it is not possible to be 100% sure of having executed a protocol perfectly, nor of having read the measurement perfectly. It is therefore important to be aware of how close or not you are to a perfectly executed, accurately read measurement. Finally, having taken into consideration, as honestly as possible, all these factors, a decision must be made as to **the last significant figure** on your measurement and whether that digit should be **rounded up or down**, depending on your assessment of all the previous factors.'

Table 9 below gives some indication of how the exchanges in the extract relate to points indicated in red in the hypothetical model answer. As stated previously, they are thus indicators of the genesis of knowledge inherent in the milieu.

Links Between the Model Answer and the Didactic Activity in the Extract

Using the JATD descriptive categories of mesogenesis, topogenesis and chronogenesis (Sensevy, 2011; Sensevey & Mercier, 2007), Table 9 indicates how the milieu-problem was jointly constructed so as to guide the students in the milieu toward the knowledge at stake. The links in red represent the mesogenesis of knowledge in the milieu-problem.

Table 9

Links between the Model Answer and Class Activity

Points arising in the didactic activity Chronogenesis (+)	Link to the milieu-problem represented by the hypothetical answer	Category
T: How do you explain the differences in your results? (18) +++ At the beginning of the activity to direct joint attention	Different results +++	Teacher (T) introduces a point into the milieu-problem. Topogenesis High position (T)
Previous activity before the teacher's question (students working in small groups to devise and describe protocols)	Measurement of the tennis ball's diameter +++	The students' (Ss) measurements – a resource in the milieu emanating from the students being confronted with the different results. Topogenesis at a distance (T)
Students' results (1 – 17) ++ Immediately after opening T question	6.54cm to 6.84366cm	Students introduce the measurements they found into the milieu. Topogenesis Collective: T with Class (Cl)
Rémy: speech turns (23, 25) + It's the material	How well-adapted the material is Fine thread – shoe lace	The material is a factor influencing the uncertainty in the measurement. (The thread and lace are examples of this, though not given by student)

<p>T: speech turns 24, 26 materials, due to</p> <p>After stating results, collective construction of the milieu; joint action of T and S</p>		<p>Topogenesis (S) From a student.</p> <p>Topogenesis (T) How to say it in English</p>
<p>Rémy: (35) + circonférence</p> <p>After stating results, collective construction of the milieu; joint action of T and S</p>	<p>Circumference (one of the possible methods to measure the diameter of a tennis ball)</p>	<p>From a student. The method used is a major factor influencing the uncertainty in the measurement, though not stated explicitly by the student</p> <p>Topogenesis (S) From a student.</p> <p>Topogenesis (T) How to say it in English</p>
<p>Nina: (29) + Calculate</p> <p>T: 30 The calculation</p> <p>Rémy: (31-35) + Round up/down</p> <p>After stating results, collective construction of the milieu; joint action of T and S</p>	<p>Pi</p> <p>Significant figure</p> <p>Round up/down</p>	<p>Using pi necessarily involves rounding up or down (this is known by the students). Depending on the uncertainty estimate, figures are rounded up or down.</p> <p>Topogenesis (S) From a student.</p> <p>Topogenesis (T) How to say it in English</p>
<p>Student: speech turn (37) + Error</p> <p>T: speech turn 38 What kind of errors?</p> <p>After stating results, collective construction of the milieu; joint action of T and S</p>	<p>Error</p> <p>Exactly in the middle of the ball</p>	<p>An important part of the previous activity was to design a high-quality protocol to reduce the uncertainty in the measurement. Error can have a major impact on results.</p> <p>Topogenesis (S) From a student.</p> <p>Topogenesis (T) How to say it in English</p>

(+): symbol representing the chronogenesis. The more crosses there are, the more a given point can be seen to advance the exploration of the milieu.

Table 9, with the notions of mesogenesis, topogenesis and chronogenesis, indicates how the students explored the milieu in the joint action with the teacher, so as to build on what they already knew and progress toward the knowledge in the hypothetical model answer. The teacher's opening question 'How do you explain the differences in your results?' (speech turn 18), focusses the students' attention on the issue of the many factors influencing uncertainty in measurement; indeed, the reasons for the different results are

linked directly to these factors, as detailed in the hypothetical answer. This question, together with the different results obtained by the students, advances the didactic time. The chosen method used to measure the tennis ball will have an impact on the uncertainty of the measurement, as well as how well-adapted the material used to implement that method is. Remy's answer in speech turn 24 'It's the material' suggests the genesis of this point, though he is unable to express it clearly in English at this stage. Similarly, Remy's 'circonférence' (speech turn 35) for circumference, suggests an understanding of the impact of the circumference method, entailing the use of pi, and the need, therefore, to round up or down a result. The decision to round up or down will be directly linked to the student's estimation of uncertainty, and how confident they were about reducing error to a minimum with the material available to them. The point made by Nina in speech turn 29 ('Calculate') Remy in speech turn 31-35 ('Round up/down') and the student in speech turn 37 ('Error') suggest the genesis of this understanding, though again, they are unable to express these ideas in English. The teacher, as we saw, is reticent on these points as she wants the students to be motivated to develop their expression in English so as to be able to communicate and discuss these ideas during a roleplay, in English, later in the sequence.

As with 'The Exploratory Lesson', 'The Genesis of a Thought Style' shall be analysed using the models developed by Gruson (2019), and the existing body of work in the JATD (e.g. Sensevy et al, 2015). This is in order to answer the following questions: Q1. How does the contract (the students' existing knowledge, the already-there) enable the students to successfully tackle the problem presented in the situation? Q2. How does the structure of the milieu (the symbolic structure of the problem posited) enable students to construct new knowledge? (Gruson p. 130). (Author's translation)

To answer Q1: The notions of jargon and thought style will be useful in analysing how the students' existing knowledge (the contract) enabled them to tackle the problem presented in the situation. As the above table seeks to illustrate, the students can be seen to demonstrate knowledge of the factors contributing to different measurement results, and therefore something of the jargon (in French) and the thought style in the field. Following the activity where they are confronted with different results, they contribute relevant explanations to explain this fact: the material or method used, the way a result is calculated and the impact

of error. Whilst they struggle to express these ideas in the jargon in English, they nevertheless are able to tackle the problem presented in the situation thanks to their knowledge in physics, using what English they have, helped by the teacher.

To answer Q2: The first point is that it constrains the students to begin to acquire, and understand, the jargon in English of what they can already say in French. Secondly, they are also constrained to think in detail about all the factors which might have an impact on a result and how this should be dealt with. The term 'uncertainty' is not as yet evoked but the structure of the milieu is such that its necessity becomes compelling: the milieu is designed to foster a thought style where the necessity of indicating a degree of uncertainty, and the reasons why this is so, are encountered by the students.

In the measuring activity in pairs, students tend to mechanically suggest '1mm uncertainty' for the reading of the measuring instrument. This is a reasonable estimation of the uncertainty in this situation. However, the point of the activity is not to give the 'right' estimation: rather it is to decide on an estimation in full awareness of everything that is involved in making that estimation. The student must decide on the uncertainty in their measurement, as honestly as possible, based on all the factors mentioned in the model answer. An understanding of this aspect of experimental science is integral to the thought style of experimental science. Exploring in detail the different factors contributing to the uncertainty in a measurement is new knowledge for many of the students, as is knowing how to express and think about the practice in English.

From Words to Worlds: '6.50 is much more accurate than 6.5'

To go further in response to Q1 (How does the contract (the students' existing knowledge, the already-there) enable the students to successfully tackle the problem presented in the situation?) and Q2 (How does the structure of the milieu (the symbolic structure of the problem posited) enable students to construct new knowledge?), it is useful at this point to compare the epistemic capacities of the students in 'The Genesis of a Thought Style' with that of the students in 'The Exploratory Lesson'. The students from both situations have a similar profile: first-term, first-year science undergraduates with a B1/B2 level of English (CEFR). In fact, the students in 'The Exploratory Lesson' were in general more

comfortable in English (a B2 level), than 'The Genesis of a Thought Style' students (more B1 level), though they fared less well in the activity presented. This is precisely because the situation was not well-orchestrated, as we saw: the contract did not enable them to tackle the problem in the milieu so as to construct new knowledge.

This can be rendered more visible by considering how well-equipped each of the two groups of students was to grasp the full implications of the physics lecturer's statement '6.50 is much more accurate than 6.5'. This statement, or jargon, was a major entry into the thought style of the physics lecturer for the English teacher. In mathematics the two figures represent the same number; however, looking at the statement in this thought style renders its implications perplexing. In contrast, looking at the statement in the thought style of a physicist, the difference in the two figures becomes glaring. The extra nought provides vital extra information as it informs other scientists of where the experimenter positions her or his area of doubt, that is to say the uncertainty of their measurement, and whether it is in the tenths or the hundredths place. Executing a measurement in the thought style of a physicist therefore, entails knowing and integrating this perspective into one's practice: this is often not as yet fully integrated by first year students.

Returning to our comparison: in 'The Exploratory Lesson', the students did not have the English jargon to explore this aspect of measurement. As we saw, the situation was not orchestrated in a way that enabled them to construct knowledge around this point. In contrast, in 'The Genesis of a Thought Style' extract, the students are better placed to construct knowledge related to this point in several ways. Heuristically, in the measuring activity, they have been confronted by results accurate to the tenth, hundredth, thousandth (or more) place. They have also been oriented to consider the relevance of each extra decimal place in the activity where they dictated their different results to the teacher; she insisted the students specify each decimal place (speech turns 1 – 17). They have also constructed, as a class, knowledge on the factors that would compel a physicist to estimate their uncertainty. This fosters a thought style where they must ask themselves whether they can claim to be accurate to the tenth or hundredth place. All these points are integral aspects of the thought style of a physicist, inherent in the jargon of decimals. A translated, summarised telephone conversation with the physics lecturer is presented below. It discusses these points and

provides some evidence of the epistemic kinship between her thought style and practice and that encountered by the students in the situation.

The Telephone Conversation Summary (28.04.2018)

Below is a translation of the written summary of the English teacher's (T) telephone conversation with the physics lecturer (PP).

1. **PP:** Hi, I think you've understood but I've tried to explain even more because as I said, an estimation of uncertainty is not at all simple. A mathematical calculation can be simple (or long and fastidious) but it often gives an uncertainty which is too high because it adds together everything whereas in reality some errors are compensated for by others ...).
2. **T:** The extract concerns an episode which is a transition between a pairwork exercise and the viewing of the video extract. The students suggest ideas to explain their different results: I want to guide them towards a finer understanding of the notion of uncertainty in measurement. (...). When they suggest "materials" I think the suggestion is pertinent as it's true that depending on the instrument you can be more or less precise: it's easier to wind a computer mouse wire around a ball than a flexible ruler
3. **PP:** It's not really the material. The vocabulary isn't precise enough and the idea put forward is too general. It's rather about the different parts of the experimental set-up. The precision of the measuring instruments will be about the ruler to measure the length. Often when they say instruments they're only thinking about the ruler so they must be more specific. There are three parts to the experimental set-up to measure D using its circumference: 1) a wire, 2) an instrument to measure the beginning and the end of the circumference – a fine-tipped pen or a marker - the width of the line drawn won't be the same and this will have an impact on the measurement obtained with the ruler), 3) a ruler or some other graduated (or calibrated) instrument to measure.
It's too vague to say the instrument is imprecise. You have to say what is imprecise about the material available and why.
4. **T:** Ok, I understand better, but I've also understood that I can validate the idea that the material is a pertinent point and that it's a beginning in order to lead them towards a more precise answer with the three elements you described. It isn't incorrect to say that at this stage we can see emerging the beginning of a better understanding of both uncertainty and the language to talk about it. Significant digits are important because if I write a result which is beyond my degree of accuracy it doesn't make sense.
5. **PP** E.g.: the result on my calculator after dividing my circumference by Pi is 6.584915 (cm). How many figures should I copy down in my result? Should I write 6.6 cm? 6.58cm? 6.585cm? etc.? To decide this I have no choice, I must estimate all the errors I could have made in my measurement, though in the long run I might decide some are negligible compared to other higher ones and round up all that (uncertainty). These errors are not ONLY linked to the graduations on my ruler but also to geometry (thick, thin, flat, oval, round ...) and the nature (cotton, linen, wool) of my wire/thread (extendible or non-extendible), the position of the wire/thread (on the equator or above or below the equator) and the width of the mark; this is a lot but even if each of these 4 possible errors were 1mm (being pessimistic) the final uncertainty would be 4/3.14mm, hardly more than 1mm.
In reality, if I assume that my protocol is good (I measure several times close to the equator and I use the biggest measurement), my wire/thread is adapted and I use a fine-tipped pen or a dressmaker's measuring tape, then the maximum uncertainty would be 2/3.14mm, that is less than 1mm (around 0.7mm)!!! Given the material they have, it's the best way to determine D for them.
6. **T:** so significant figures are important not because I know how many significant figures there are in such and such a number but because it reveals to what extent the student has fully understood tenths, hundredths, thousandths: if he or she makes

the mistake of putting three figures after the decimal point when his or her measurement has only two figures after the decimal point - that shows a poor understanding of this area?

7. **PP:** That's right – it's the crux (or the cornerstone) of experimental science. I would also ask the student to explain to me why he or she stops at two figures after the decimal point. Yes, with neither calculation nor explanation he or she cannot decide or choose to do that. The experimenter with experience will not add together all the errors as that would give an uncertainty which would be too high; for myself, I estimate my uncertainty according to what I find most reasonable: if I estimate that the computer mouse wire adds a maximum of 1 mm uncertainty I include it – but a good scientist will try to prove that that is indeed the case (or that it could not be more than a millimetre).

In a later conversation (26/07/2108) another question of vocabulary arose:

English Teacher: 'when do you prefer to talk about error rather than uncertainty? When you talk about rounding up the error, I have the impression you're still talking about uncertainties?'

Physics professor: 'That's true. You're right. Some people say that we should not talk about errors, because "errors can be corrected"... I do not think so. Only systematic errors can be (and you have to figure out that there are some). Errors can have different origins and in real life, there are some compensations.'

This exchange touches on a complex aspect of this cooperative work: the divergent practices within the community of physicists. For example, the associate professor at the origin of this study, chose to use a 'modern' approach based on probability for the laboratory report used in the sequence. In other respects, like many in her field, she used the error term generally associated with the 'classical approach', as in the exchange above. Other physicists at the university preferred not to use the probability approach for simple protocols such as the tennis ball activity, considering it too elaborate. Such choices can be seen to be based on the preferences of the practitioner with regard to a range of factors: pedagogical context, the habits of a specific field, and as we saw with the Compton example, the profile of the person with whom the practitioner might be communicating.

As the sequence was used with different groups with different physics lecturers, the general aim of the English teaching, therefore, was not to take a position on these complex questions which are for specialists in the field. However, to be capable of exploring the full epistemic potential of the sequence, the more the English teacher understands about these

issues, the better: such questions are integral to the practice of physics and its associated jargon and thought style.

The sequence was developed to guide students to understand and communicate on these questions and to clarify and express their own thinking. With regard to the different approaches outlined above, the students were told to confer and check with their physics lecturers on these issues.

Thus said, the sequence has the potential to combine foreign language learning and the development of a particular approach to uncertainty in measurement along the lines of the Cape Town study (Buffler et al., 2009) presented in chapter 7. This would not necessarily be with exactly the same objectives of that particular study: defining the exact objectives would require close internal and external cooperative work between language and physics departments.

On L2 Acquisition

As the didactic analysis of 'The Genesis of a Thought Style' reveals, the students mainly tackle the problem presented in the situation thanks to their knowledge in physics, using what English they have, helped by the teacher.

The didactic equilibration and shaping of the learning game maintained by the teacher, were in keeping with a number of didactic approaches integral to the epistemological underpinnings on language learning adhered to in this study, as discussed in chapter 1.

First, the a priori that 'for an expression to be understood, the practice within which it plays its role must be appreciated.' (Sensevy et al., 2019, author's translation). In this example, the jargon of the practice can be seen to be introduced into the milieu-problem in the context of its practice. This is to facilitate an understanding of its thought-style and the practice in which it is embedded and which gives it shape.

Second, the adherence to a plurilingual approach in language learning where students: 'should be allowed to mediate their thinking via their first language' (Swain and Lapkin, 2013). This approach recognises practices such as code-switching to facilitate expanding on a concept

(Gajo, 2007), and translanguaging: a process of meaning and sense-making where the user draws upon a range of linguistic, cognitive and semiotic resources to make meaning and sense.

An adherence to a plurilingual approach should not be interpreted as dispensing with the need to create situations which challenge learners to refine L2 language skills. Rather, it should be interpreted as an approach which recognises the utility of an individual's, and a class's, entire range of linguistic resources in the overall process of L2 acquisition. This does not detract from the goal of challenging learners to become increasingly skilful in their mastery of the targeted L2.

Achieving the delicate balance between respecting a learner's range of linguistic resources, yet challenging them to refine L2 skills, can be achieved (or not) in the didactic equilibration managed by the teacher. In navigating this balance in the joint action with the teacher, a student can learn to manage this equilibration autonomously: he or she would know how to maintain an equilibrium between relying on a range of linguistic resources where necessary (contract), yet still be in a process of constantly striving to develop stronger L2 skills (milieu). For this to happen, students must find themselves in didactic situations which are orchestrated in such a way as for them to be confronted with this necessity.

A sub-hypothesis explored in this research, therefore, is that in the on-going acquisition of a jargon and a thought style related to a practice, a student will fine-tune their L2 skills if they use the range of language resources available to them in the manner best-suited at any given point in time. That is to say, in a manner that enables them to be both constantly active using their existing knowledge, and at the same time constantly challenged to progress further. More is said on this in 'The Enhancing Fluency Exchange' and 'The Extended Roleplay'.

8.3.1 Preliminary Conclusions with regard to the Study Research Questions

The research questions which are addressed in this study will be considered in relation to the genesis of a thought style analysis.

Question 1: How can the combined objectives of a conceptual understanding of scientific practice, together with work on language skills, be effectively described?
What is the role of jargon in the construction/development of a capacity?

The milieu-problem presented in the genesis of a thought style extract can be seen to be particularly complex in nature, involving both scientific and L2 learning objectives in a plurilingual, didactic environment. The Joint Action Theory in Didactics' notions of mesogenesis, topogenesis and chronogenesis, served to clarify how knowledge emerged in the milieu in the joint action with the teacher. The dialectic of reticence/expression revealed a pattern in the teacher's moves which showed how the students were led to actively construct the milieu-problem with the teacher. In being expressive with regard to the English, (e.g. speech turn 26 'accuracy', speech turn 30 'The calculation'), and reticent with regard to the practice of physics (e.g. speech turn 27 'What else?', speech turn 36 'Any other ideas?'), a didactic equilibrium was maintained between the contract and milieu.

The notions of jargon and thought style contributed to the analysis by showing how the diverse aspects of the didactic activity linked together. The close association of the practice of measurement with its practice language, emanating from the cooperative work of the language teacher and the physics lecturer, was interwoven in the design of the sequence. The notions of jargon and thought style clarified where, how and by whom (combined with mesogenesis, topogenesis and chronogenesis) these two inseparable aspects of a given practice were giving direction to class interactions. The appearance of the notions of jargon and thought style as fused objectives in Table 8, reveal the *interweaving* of language and content epistemic capacities.

At this stage in the sequence, there is no real demonstration of students use of the systems of epistemic capacities outlined in Table 8. The conclusion that students are

constructing an appropriate thought style can only be inferred, not proven, by the didactic analysis, as the students lack the means, that is to say the jargon, to express their ideas clearly.

Question 2: What capacities can be identified in the didactic activity of the students participating in the case study, and what evidence is there of effective work on those capacities in the didactic activity between themselves and with the teacher?

In the genesis of a thought style lesson, students can be seen to be encountering the jargon and thought style related to measurement in scientific practice in a plurilingual environment. There is some evidence of L2 skills being mobilised using the jargon of the field, for example practicing numbers and decimals in English (speech turns 2, 8, 10, 12, 14, 16), or identifying the factors which contribute to different measurement results for the diameter of the tennis ball (speech turn 24 'It's the materials', speech turn 35 'circonférence'). As can be seen from these examples, student productions in the L2 target language are limited and often need to be completed or translated by the teacher to be fully comprehensible (e.g. speech turn 36 'So it can be related to erm rounding up or down').

The pertinent contributions of the students concerning the factors contributing to the differences in their measurement results (e.g. speech turn 24 'It's the materials', speech turn 35 'circonférence') suggests that the students are exploring an appropriate thought style as regards measurement in scientific practice. That is to say, they are not adhering to the notion of a 'true value', but rather the notion that a measurement result cannot be separated from its context. This didactic activity, which involves reflecting on issues related to the Nature of Science debate (see chapter 7), can be considered to be evidence of the genesis of effective work on the epistemic and epistemological aspect of uncertainty in measurement.

Question 3: What are the concrete conditions of a CLIL programme which enable students to develop a conceptual understanding of scientific practice whilst improving their English language skills?

How ought CLIL practice interweave content and language, and in what ways are these two elements then influenced by their convergence?

What are the frontiers in a given speciality that necessitate language teachers cooperating

with specialists of a body of knowledge?/ that limit the scope of language teachers in a CLIL sequence?

A condition of a CLIL programme, as it was implemented in this study, is that the jargon of the practice be introduced into the milieu-problem within the context of its practice. That is to say, students should discover the jargon in its associated field. The students in the lesson from which this extract is taken, encountered the jargon either whilst researching the terms they needed to describe their own protocol, or during interactions with the teacher (e.g. How can you be sure you are exactly in the centre of the ball? How tight did you pull the wire/string/thread? How many times did you measure the ball?), or whilst describing/listening to the protocol of a classmate. This was to facilitate an understanding of the thought-style and the practice in which the jargon was embedded and which gave it shape.

A frontier that was encountered by the language teacher in this extract, was the question of the divergent practices within the community of physicists. The jargon of the field can vary from one community to another, and one from one individual to another, as was discussed with the example of the terms 'uncertainty' and 'error'. This is a complex issue and one that could be questioned further in future research.

8.4 The Enhancing-Fluency Exchange

The students in this study were presented a range of situations that were orchestrated in such a way as to ensure that they would be constrained to explore, collaboratively, various milieu-problems in the *jargon* and *thought style* of a scientific practice. This was founded on the hypothesis that in the effort to master a social game based on scientific practice, students would develop the necessary language resources to succeed in that social game. To that end, multiple activities were designed which provided opportunities for students to co-construct meaning in English whilst acquiring the jargon and thought style of the practice of measurement.

The ultimate objective in this CLIL classroom, was to guide the students to develop their L2 skills. To achieve this, students were challenged to jointly construct and play the social game of scientific measurement, in English, with the jargon and thought style of a connoisseur of the practice. Being able to practice this complex social game entailed the development of a range of epistemic capacities, some of which have been defined in the previous analyses.

In 'The Exploratory Lesson', as we saw, students were confronted with a milieu that was too challenging and which left them unable to successfully participate in the learning game. In subsequent versions of the sequence, efforts were made to break down the various targeted epistemic capacities involved in the complex social game of measurement, and to place the onus on restricted sets of epistemic capacities at any one time. Hence, the epistemic capacities targeted varied, depending on the focus of attention of a given learning game, so as to gradually develop the range of epistemic capacities necessary to participate fully in the social game of measurement in scientific practice. In 'The Genesis of a Thought Style' extract, onus was placed on opening up the question of uncertainty in measurement so as to encourage students to explore the full potential of the milieu, and to develop the necessary jargon and thought style as a strategy for doing so. The activity analysed in 'The Enhancing-Fluency Exchange', as its name suggests, focussed more specifically on developing confidence and fluency in English.

Presentation of the Enhancing-Fluency Exchange

Context

As a home assignment, students were asked to devise another more elaborate protocol to measure the diameter of a tennis ball, and to estimate the degree of uncertainty of their measurement. They were given one of the six worksheets presented below, each with a different hint at a suggested method to use, though they also had the freedom to devise their own method if they wished to.

Class Documents

<p style="text-align: center;">The impact of protocols on uncertainties</p> <p>Describe an experiment that you have decided to carry out to measure the diameter of a tennis ball. You must include in your description your protocol, the material you used and the problems you encountered and what you did to avoid them.</p> <p>Specify the degree of uncertainty you expect to encounter measuring the diameter and give the result of your work with the correct written form: $D = (x \pm \Delta x)$ unit length (i.e. cm, mm etc.).</p> <p><u>(NB: The number of significant figures written for x must correspond to the degree of uncertainty estimated.)</u></p> <p>Explain in a detailed manner the basis of your estimation and what you did to reduce it to a minimum.</p> <p>One-dimensional methods</p> <p>Worksheet 1) One-dimensional method - Hint: hard-backed books or square sets</p> <p>Worksheet 2) One-dimensional method - Hint: dough</p> <p>Worksheet 3) One-dimensional method – Hint: A photograph, a spirit level and ruler</p> <p>Worksheet 4) One-dimensional method - Hint: String or thread</p> <p>Worksheet 5) Two-dimensional method - Hint: ImageJ (free software)</p> <p>Worksheet 6) Three-dimensional method - Hint: transparent overflow vessel</p>

In class, students were asked to work in pairs to describe to each other the protocol they had executed as a home assignment. Based on similar past activities, the contract was

clear: the students were aware that the main priority in the activity was to become more fluent and confident in expression. In the episode described below, Walid and Pedro listen to each other’s protocol. Walid had been given the hint ‘dough’ as a clue to how he should devise his protocol, and Pedro had used his own method, using a protractor and a ruler.

Transcription of the Enhancing-Fluency Exchange

Below is the transcription of the two students describing the protocol they were asked to prepare at home. As we shall see, the exchange is somewhat disappointing with regard to the physics in the milieu-problem. It is highly likely that Walid had not actually executed his protocol at home and had therefore not heuristically been confronted with this aspect of the milieu-problem.

<p>41. Walid: I begin with my process. My set-up is we make er ... we make a dow with a floor and water, in this er in this dow</p> <p>42. T: dough</p> <p>43. Walid: dough, we will put the ball in.</p> <p>44. Pedro: yes</p> <p>45. Walid: so when we er, when we, when the ball is in the dow</p> <p>46. T: dough</p> <p>47. Walid: in the dough, it make a mark, and this mark, when we take off the ball, we have the mark of the ball.</p> <p>48. Pedro: yes</p> <p>49. Walid: so we just, we just have to measure the diameter of the mark’s ball... the ball’s mark in the dough. What do you think about it?</p>	 <p><i>Frame 6: describing the dough method</i></p>  <p><i>Frame 7: demonstrating a step in the protocol</i></p>
<p>Walid begins describing his protocol to Pedro. He has assimilated some pertinent vocabulary such as “set-up” “flour” and “dough” but pronounces “flour” as “floor” and “dough” as “dow” (speech turns 41, 43). T corrects the pronunciation of dough twice (speech turns 42,46). Walid pronounces it correctly on his third use (speech turn 47). Walid speaks clearly without hesitation but with some grammatical inaccuracy such as “make” instead of “makes” (speech turn 47), “will put” instead of “put” (speech turn 43). T does not correct all the errors. Walid corrects an error himself concerning the use of the possessive (speech turn 49).</p>	

50. **Pedro:** It's er a good idea. Er, well for me, I have measured the ray of the ball with a rule.

51. **T:** ruler

52. **Pedro:** a ruler. We put er put a protractor in the end of the ball, we make it (...#3)

53. **T:** Steady?

54. **Pedro:** steady. We find er, three point two centimetres for the ray, then we multiplied by two and we get finally six point four centimetres, plus or mine two millimetres for the uncertainty.

55. **T:** What did you do with the protractor exactly? Did you put it to stabilize the ball?

56. **Pedro:** yes, to stabilize the ball. Then we measured the ray of the ball

57. **T:** the ray of the ball? What's the ray of the ball?

58. **Pedro and Walid:** le rayon.

59. **T:** Ah the radius

60. **Pedro:** the radius yes, the radius of the ball and er we multiply it by two. Then we get finally the diameter of 6.4 cm plus or mine two millimetres.

61. **T:** Ok. You can ask him about how he determined his level of uncertainty.

62. **Walid:** How did you ...(inaudible)



Frame 8: Pedro describes his protocol



Frame 9: Listening to Pedro Frame 7

After listening to Walid's description Pedro makes a polite comment about Walid's protocol (speech turn 50) then begins to describe his own protocol. He makes a common error: "rule" for "ruler" probably because in French it is the same word for both (*règle*). He is hesitant in expression so T suggests "steady" to keep the flow of dialogue going. T tries to understand Pedro's protocol by asking about the protractor (speech turn 55). She does not understand the use of "ray" (speech turn 57). The two students give the French word "rayon" (speech turn 58) which T translates with "radius" (speech turn 59). Pedro has partially assimilated the "plus or minus" when talking of uncertainty in measurement, saying "mine" instead of "minus" (speech turns 60). T tells Walid to ask Pedro about his estimation of uncertainty (speech turn 61) and leaves to film another group.

The two students can be seen to describe their respective protocols with a range of appropriate jargon. As such, they are able to evoke a representation of what was entailed in

their method as regards material (dough, ruler, protractor), mathematical formulas (multiplied by two), typical actions in scientific practice (measure, determine), including uncertainty (plus or minus, uncertainty). There are a number of pronunciation errors (floor for flour, dow for dough, rule for ruler, ray for radius), which at times impede comprehension. However, the students are able to describe the general details of their protocol using only English.

General Didactic Analysis of the Enhancing-Fluency Exchange

The table below is a general analysis of the system of epistemic capacities (Gruson, 2019) inherent in the exchange that the students could potentially develop in the situation presented.

Enhancing-Fluency: Systems of Epistemic Capacities

System of epistemic capacities (English)	System of epistemic capacities (physics)
<p>Oral expression in English only: fluency, prosody, vocabulary.</p> <p>Describing a protocol step by step, including the materials used, using the <i>jargon</i> and <i>thought style</i> appropriate to the practice.</p> <ul style="list-style-type: none"> • Be able to mobilise the jargon to describe a simple protocol. Correct pronunciation, stress patterns, grammatical structures • Be able to mobilise the appropriate jargon, (plus or minus, uncertainty) to discuss uncertainty in measurement • Be able to co-construct meaning in dialogue: facilitate communication with appropriate body language, discourse patterns, confirming or not confirming comprehension 	<p>Develop the <i>jargon</i> and <i>thought style</i> of a practicing physicist (a connoisseur of the practice) so as to be able to describe a protocol to measure an object and estimate its uncertainty.</p> <ul style="list-style-type: none"> • Be able to identify sources of experimental uncertainty • Be able to evaluate specifically how identified experimental uncertainties may affect the results • Be able to describe how to minimize experimental uncertainty and actually do it

The Learning Game of the Enhancing-Fluency Exchange

The learning game of the Enhancing-Fluency Exchange can be defined thus: 'gaining confidence and fluency in English expression by practicing the jargon of protocols uniquely in English; by practicing a jargon in its context, constructing the thought style related to the practice of scientific measurement.' In seeking to develop strategies to participate adequately in this game, it was hoped the students would develop the capacities outlined above.

The Semiosis Process within the Didactic Joint Action

We shall now focus on how the teacher shaped the learning game using descriptors developed within the JATD: the twofold semiotic system in relation to the double dialectics of contract/milieu and reticence/expression, as well as didactic equilibration (Sensevy, Gruson, Forest, 2015; Gruson, 2019). Below is a description of the teacher's moves.

- The teacher remains silent as the student Walid describes his protocol. She is reticent so as to leave the space for students to speak (speech turn 1 'I begin with my process...'). The student makes two serious pronunciation errors (dow for dough, and floor for flour). She corrects one of them, dough. (speech turn 2 'dough')
- The teacher is reticent and leaves Walid to describe his protocol (speech turn 3 '... we will put the ball in.'). His use of tenses (will) is incorrect but she does not interrupt him
- The teacher is expressive to correct, again, the incorrect pronunciation of dough (6)
- The teacher is reticent. Walid finishes his description. His expression is not perfect but he pronounces dough correctly (speech turn 7 '...in the dough, it make a mark, and, this mark, when we take off the ball, we have the mark of the ball speech turn 9 so we just, we just have to measure the diameter of the mark's ball ... the ball's mark in the dough. What do you think about it?').
- The teacher is reticent and lets the next student, Pedro, describe his protocol (speech turn 10 'It's er a good idea. Er, well for me I have measured the ray of a ball with a ruler'). She corrects the pronunciation of ruler (speech turn 11), a common, major pronunciation error.

- The teacher is reticent as Pedro continues (speech turn 12), but expressive when he is blocked for vocabulary (speech turn 13 'Steady?')
- She is expressive to be reticent with a milieu-driven semiosis (MDS) question 'What did you do with the protractor exactly?', but immediately expressive offering the answer 'Did you put it to stabilise the ball?' (speech turn 15) This is perhaps to re-introduce the word 'stabilise' that Pedro has just heard, and to reinforce Pedro's acquisition of the term.
- She lets Pedro continue but asks a milieu-driven semiosis vocabulary question 'What's the ray?' (speech turn 17). The students give the term in French (speech turn 18 'le rayon') and she translates it into English 'Ah the radius' (speech turn 19)
- She asks Walid to ask Pedro a milieu-driven semiosis question (speech turn 21) about how he estimated his uncertainty as she leaves to listen to another pair of students.

A pattern can be discerned in the teacher's moves which is different for each student. As regards Walid, who speaks with some ease, she is mainly reticent and does not correct all the errors in his expression. She targets only one error (speech turn 2 'dough', speech turn 6 'dough') and is very expressive until the student assimilates that one correction. Grammatical errors such as 'will put' instead of 'put' can be compensated for by the context of a communication and so an interlocutor may still follow the speaker. The teacher is reticent on grammatical errors and leaves Walid to explore his expression.

The case of Pedro is slightly different. His opening phrase (speech turn 10) makes the phrase difficult to follow: 'It's er a good idea. Er, well for me, I have measured the ray of the ball with a rule.' The incorrect word forms 'ray' (radius) and 'rule' (ruler) make the sentence difficult to understand. The teacher continues to let Pedro express his ideas but is more expressive: she reformulates (speech turn 11 'ruler'), questions (speech turn 13 'Steady?', speech turn 15 'What did you do with the protractor exactly? ...' speech turn 17 'the ray of the ball? What's the ray of the ball?') and translates (speech turn 19 'Ah the radius') so that the phrase is finally clearer (speech turn 20 'the radius yes, the radius of the ball...').

In this way the teacher maintains a didactic equilibration between allowing the students to practice and reinforce their fluency, yet progress according to their level of expression. Walid is sufficiently comprehensible to continue unaided; the teacher's reticence and virtual non-intervention is an implicit recognition of this fact. It is an example of a teacher move, an overt sign, of doing or saying nothing to maintain a didactic equilibration. She is expressively silent.

Pedro requires more work on the accuracy of his expression to be comprehensible: the didactic equilibration is positioned so as focus on this aspect of his expression. It is a sign to Pedro that greater accuracy of word form is his immediate goal in order to successfully improve his L2 skills.

As with 'The Exploratory Lesson' and 'The Genesis of a Thought Style' we shall consider the following questions. Q1. How does the contract (the students' existing knowledge, the already-there) enable the students to successfully tackle the problem presented in the situation? Q2. How does the structure of the milieu (the symbolic structure of the problem posited) enable students to construct new knowledge? (Gruson p. 130). (Author's translation)

To answer Q1: The students know how to play the game of enhancing their fluency to practice their oral expression, as they have practiced this game previously. They use a range of pertinent jargon: set-up, measure the diameter etc. that they have successfully researched and integrated. They are able to describe, in some detail, and without too much hesitation, how to execute a protocol to measure the diameter of a tennis ball with the material proscribed or chosen, though there remains some doubt as to the viability of Pedro's method.

The rigor of the students' protocols is nevertheless questionable. Walid does not address the weakness in the dough method: the fact that the ball must be pushed down below the middle of the ball, and yet must then be extracted without disturbing the mark made. He does not link this to the issue of the uncertainty in his measurement and so is not as yet demonstrating this aspect of the thought style of the practice. Pedro gives a credible result with a unit of measurement and an uncertainty estimate. However, it is not clear in a convincing way, how he measured the radius of the ball, nor on what basis he estimated 2mm uncertainty.

To answer Q2: This activity constrains the students to use and understand the jargon in English, that is necessary to describe a protocol in some detail. However, the most important point as regards the structure of the learning game, is that it constrains students to talk at length so as to develop their fluency and confidence in speaking English. In a class situation, certain students can feel shy of speaking, and even if this is not the case, they necessarily only have a limited opportunity to speak as class discussion time is shared amongst a group. Students' contributions in class discussions are vital for constructing the milieu-problem, as we saw in both part one of 'The Exploratory Lesson', and 'The Genesis of a Thought Style', but they are not ideal for developing fluency and ease of expression. Furthermore, in class discussions, student contributions are often reformulated by the teacher, so as to maintain a clear model for learners. In contrast, group work, or even better pairwork, provides students with the opportunity to communicate and to develop their linguistic spoken fluency. They are also free to exploit translanguaging learning strategies, as they struggle to strengthen the links between thought and language arguably an essential stage in improving fluency. The use of such strategies is an important signal to be interpreted. It can of course, simply signal a lack of vocabulary in the target language and a need to compensate for this with another language, usually the native language. However, it might also be a sign of more subtle learning processes and the integration of the overall logic of the learning game above and beyond immediate vocabulary issues. This hypothesis will be explored further in the analysis of 'The Extended Roleplay'.

The Didactic Analysis of the Enhancing-Fluency Exchange: Conclusions

There is unexplored knowledge potential in the milieu-problem described in this extract on two points: (i) exploring the factors which might have an impact on the results of the protocols in greater detail, and how this should be dealt with. (ii) incorporating work focussing on the pronunciation of the students to improve their oral expression.

In another version of this activity, an accompanying worksheet was given to the students asking them to identify and note down potential uncertainties (see Appendix D) in order to constrain the students to tackle point (i). However, this detracted from the expressive

aspect of this activity as students tended to focus on the questions on the worksheet rather than listening and speaking to each other in order to explore their increasing fluency.

In yet another version, students were asked to spend time checking the pronunciation of difficult words in order to focus on point (ii). Headphones with microphones were distributed so that students could dictate their protocols onto a Word document using the microphone function setting for English.

These are useful activities, but the enhancing-fluency activity in its simplest form is very effective in improving confidence and fluency: this kind of exchange, where the main focus is gaining fluency and confidence in English, was a frequent activity in the sequence so as to guide the students to develop their level of fluency. Further analysis of 'The Enhancing-Fluency Exchange' below seeks to give some insight into the role of the activity.

The Role of Didactic Equilibration in the Development of L2 Skills

The role of didactic equilibration in accompanying students to achieve a greater level of fluency in a language is paramount. Depending on where a student is in her or his developing level of expression, the action of a teacher to maintain a didactic equilibration will vary.

It is worth considering the contrast in the teacher's moves in three different cases to highlight this fact. In 'The Genesis of a Thought Style', as we saw, there would have been little point in suspending the class construction of the milieu-problem whilst Rémy found his words, if indeed he ever did (e.g. speech turn 31, [8.3] 'when + er you do er a round er inaudible er +++ er +++', speech turn 33, [8.3] 'yes and er +++ around er +++ er', speech turn 35, [8.3] 'La taille' (size) etc. The momentum of the construction of the milieu-problem was maintained by the teacher suggesting vocabulary or translating the student's contributions (e.g. speech turn 34 [8.3] 'tu veux le dire en français ?'). This also allowed the introduction of some pertinent *jargon*.

In contrast, if in 'The Enhancing-Fluency Exchange' the teacher had intervened during Walid's presentation of his protocol (speech turn 1 'I begin with my process. My set-up ...') to correct all his pronunciation and grammatical errors, his expression would have been hindered. Perhaps even his confidence and interest in communicating would have dwindled.

However, in the same extract, the case of Pedro was slightly different. He required more work on the accuracy of the word forms he used to be comprehensible: the didactic equilibration was positioned so as focus on this aspect of his expression, whilst still allowing him space to speak. It is a sign to Pedro that greater accuracy is his immediate goal in order to successfully develop his L2 skills.

When used effectively, the dialectic of reticence and expression is used by a teacher to move between the contract and milieu in order to guide students, individually and collectively, to develop L2 skills. Didactic activity founded on maximum student output provides multiple opportunities for students to gain in fluency and confidence. Language teachers can then use a range of 'corrective feedback' (Lyster & Ranta, 1997) to this end: explicit corrections, recasts/reformulations, elicitation, metalinguistic clues, clarification requests, and repetition.

8.4.1 Preliminary Conclusions with regard to the Study Research Questions

The research questions which are addressed in this study, will be considered in relation to the enhancing fluency analysis.

Question 1: How can the combined objectives of a conceptual understanding of scientific practice, together with work on language skills, be effectively described?

What is the role of jargon in the construction/development of a capacity?

A pattern can be discerned in the teacher's moves which is different for each student. With regard to Walid, who speaks with some ease, she is mainly reticent and does not correct all the errors in his expression. With regard to Pedro, who is more difficult to follow, she is more expressive and uses a range of 'corrective feedback' (Lyster & Ranta, 1997). The notion of didactic equilibration serves to identify a guiding principle with regard to these moves: it enables the teacher to maintain a didactic equilibration between allowing the students to practice and reinforce their fluency, yet progress according to their level of expression.

Question 2: What capacities can be identified in the didactic activity of the students participating in the case study, and what evidence is there of effective work on those capacities in the didactic activity between themselves and with the teacher?

In 'The Enhancing Fluency Exchange', students can be seen to be actively developing fluency and confidence in their expression. Though the rigor of the students' protocols is questionable, they are able to describe, in some detail, and without too much hesitation, how to execute a protocol to measure the diameter of a tennis ball with the material proscribed or chosen.

A range of appropriate jargon is used by the students to evoke a representation of what was entailed in their method. This included the material (dough, ruler, protractor), mathematical formulas (multiplied by two), typical actions/objectives in scientific practice (measure, determine), and references to uncertainty (plus or minus, uncertainty). There are a number of pronunciation errors (floor for flour, dow for dough, rul for ruler, ray for radius), which at times impede comprehension. However, the students are able to describe the general details of their protocol using only English.

Question 3: What are the concrete conditions of a CLIL programme which enable students to develop a conceptual understanding of scientific practice whilst improving their English language skills?

How ought CLIL practice interweave content and language, and in what ways are these two elements then influenced by their convergence?

What are the frontiers in a given speciality that necessitate language teachers cooperating with specialists of a body of knowledge?/ that limit the scope of language teachers in a CLIL sequence?

A number of conditions necessary for a CLIL programme, as based on this study, have previously been identified: (i) sufficient epistemic potential for an inquiry-based milieu, (ii) cooperative project development between language teachers and specialists of a given field, and (iii) the introduction of jargon within the context of its practice.

As jargon is fundamentally dialogical in nature, it is thus best acquired in dialogical form, as part of the linguistic socialization related to a practice. Another condition of CLIL practice that can therefore be added to the above list, is the interest of encountering jargon within a dialogical form.

This marries well with the concern to encourage student expression throughout the sequence. The study was designed to enable maximum student output so as to provide multiple opportunities for students to gain in fluency and confidence. Language teachers can then use a range of 'corrective feedback' to guide students.

The JATD notion of didactic equilibration served to highlight how these different forms of 'corrective feedback' could be used appropriately by teachers to guide students to gain in confidence and fluency.

8.5 The Laboratory Report

The descriptions and analyses concerning the laboratory report will not be based on an analysis of didactic activity in the classroom. They seek to clarify a number of areas beyond the classroom which had a bearing on the sequence's development. Firstly, the position of the reading and writing activities in relation to the overall sequence. Secondly, the state of students' progress vis-à-vis the system of epistemic capacities in the milieu as revealed by their written output: extracts of a student pair-work written output will be investigated in some detail to explore this question. Finally, aspects of the joint action of the English teacher and the associate physics professor; their joint correction of student documents and joint development of classroom resources, including an example of how this joint action fed into the iterative process of improving the documents. Their joint action was the basis of the development of the CLIL sequence and might serve as an example of one means of developing CLIL projects.

Written Production

As we saw with Bazerman's 'Shaping Written Knowledge', both an author's objective in writing a text, as well as the profile of their intended reader, are factors which will have a determining influence on the text's final form. This is in keeping with research in linguistics which perceives language as a resource for meaning making in particular contexts (Halliday, 1994), rather than as a comprehensive theory of language based on an innate internal structure (Chomsky, 1965). Research in second and foreign language learning which draws on this position can be found in the genre-based approach. Writing programmes taught from within this approach would tend to be based on socially-situated activities ('tasks' in the CEFR and SLA research), closely linked to a written form in a particular setting (e.g. Yasuda, 2011).

The genre-based approach to teaching writing is very much in keeping with the approach undertaken in this study based on the following central hypothesis: that language is acquired by practicing jargons in social games within constructed thought styles (Sensevy et al., 2019; Fleck, 1935). The reading and writing activities integrated into the sequence were thus closely linked to a scientific practice: that of writing a laboratory report.

For the writing activity, students were asked to imitate, as closely as possible, a pre-prepared laboratory report, in order to write a report of the protocol they had designed to measure the diameter of a tennis ball. They were strongly discouraged from using their own writing style.

Situating the Laboratory Report

At this stage of the sequence, as regards didactic activity focussing on student productions, students had participated in two or more oral expression pair-work activities. The writing activity which will be investigated, was sandwiched between these oral pair-work activities, the reading activity described below, and the final oral, extended roleplay and write-up activity.

This section is organised in the following manner. A description of the preparatory reading activity in part one of the laboratory report lesson will be detailed. This will include a presentation of the classroom documents and some detail as to the joint action of their origin. Next, a brief description of the writing activity in part two of the lesson will be outlined, followed by a presentation of a student pair-work written output produced during the activity. After this preliminary description of the lesson's activities and the related documents, a didactic analysis of the laboratory report writing activity will be organised in the following manner. First an *a priori* analysis of the potential epistemic capacities that the activity could develop. Second, an analysis of the potential epistemic capacities that can be seen to be progressing in the student output presented in relation to this *a priori* analysis. Third, an analysis of the non-integrated potential epistemic capacities in the student pair-work output: the English teacher's correction of the student pair-work output, followed by the associate physics professor's correction, will serve as useful analytical tools to this end. Finally, an outline of some possible alternative didactic scenarios, termed counterfactuals in the JATD, as well as a consideration of possible future consequent research questions.

Description of the Laboratory Report Lesson: Activity One

The laboratory report is positioned as the third lesson of the sequence. It is designed to target the more formal, grammatically accurate jargon of the domain. In the first activity of the lesson, students are presented with a list of the different elements to be included in a laboratory report (Science Report, document A below), and a model laboratory report (extracts in document B below), which includes each of the elements specified in the Science Report (document A), but in the wrong order. They are asked to link the elements from the list in the Science Report (document A) with its corresponding text in the laboratory report (extracts document B, and full document Appendix B). For example, in the documents below, they should link number 11 (the Conclusion) to the text which corresponds to A in the mixed-up laboratory report (document B)), next, 4 (the Objectives) to the text in B, and 12 (the Closing Remarks) to the text in C. This learning game, which is designed to introduce the students to the laboratory report, can be described as follows: ‘matching the defined content of a laboratory report with its corresponding text so as to actively use reading skills to explore the jargon and thought style of a laboratory report in English. Gain awareness of the form and function of each constituent element of the document.’

The following questions (Gruson, 2019 and the existing body of work in the JATD, e.g. Sensevy et al, 2015), are an effective means of analysing the didactic interest of the activity. Q1. How does the contract (the *already-there*) enable the students to successfully tackle the problem presented in the situation? Q2. How does the structure of the milieu (the symbolic structure of the problem posited) enable students to construct new knowledge? (Gruson, 2019, p. 130). (Author’s translation)

In answer to question one, the students’ existing ability to read and understand English, together with their experience of using translation software, generally ensure that they have the means to decipher the texts. They also have some existing knowledge of activities within the laboratory report genre, as they are required to produce descriptions of laboratory work in French. A full, detailed laboratory report might be a new experience, at least for some.

In answer to question two, how does the structure of the milieu enable students to construct new knowledge, the situation is designed as follows: for the students to successfully participate in this game they are constrained to read both documents closely and actively. That is to say, they are constrained to understand the jargon of a protocol within the social game of writing a laboratory report, in English, which entails, for example, recognising the difference in function and form between an abstract and a conclusion. To do this, students would need to become aware of the fact that the former is succinct and informative and the latter is detailed and persuasive: an abstract should inform the reader as quickly as possible as to the overall purpose, method and results of an experiment, whereas a conclusion should persuade the reader of the validity of its results based on the rigour and detail presented. The structure of the milieu enables the students to gain more awareness of these differences. It also constrains them to read actively in English and potentially contribute to a more long-term improvement of their reading skills.

Class Documents

Document A was produced by the English teacher in discussion with the associate physics professor. The latter was frequently disappointed with the organisation and lack of detail in students' laboratory reports. The teachers worked together to define the lay-out and content of an ideal laboratory report which culminated in the production of document A.

Document A: Science Report

Science Report: Understanding and Using the Scientific Method

One of the main skills that a scientist will learn is that of communication. If a scientist is unable to present information in a concise and understandable form then they will encounter problems in their professional life

Reports must contain the following components in this order:

The first and last names of the group members

1. Title

2. Abstract/summary
The summary is the material condensed to its main points but it should be sufficiently self-contained to enable the reader, who may be doing a literature-search, to decide whether or not to read the full report.

What did you set out to do or find?
What general method did you use/apply?
What assumptions were made?

*What parameters/special conditions did you work within?
How successful were you?
What are your principal conclusions?*

3. Introduction

*Setting the scene, background info etc.
Objectives of the experiment.*

The introduction is the 'scene setting' and is an elaboration of the summary. More detailed information may be included but the introduction should still be brief background to the exercise, explaining why it was performed, the way it was conducted and an outline of results expected

4. Aims/ Objectives:

5. Theory/Prerequisite: (pertinent previous scientific knowledge or observations)

6. Hypothesis

What 'you think' will be the final outcome of the experiment. This is generally based on prior knowledge or observations. In other words, you are not just pulling this 'out of thin air'; you have some logical reason for thinking this. If you have no prior knowledge of the concept, you will need to do research before making a hypothesis.

7. Context/Tools (describe the conditions in detail and the tools used, materials list etc.)

A figure or two, carefully labelled and somewhat schematic is usually sufficient to help the reader to imagine the general set-up.

8. Procedure/Experimental method/protocol

(Describe the protocol. Use numbered steps for your procedure. Someone else should be able to repeat your experiment using your instructions. *A statement of the various tasks necessary to complete the study. Ignore details which are just instructions.*

Direct style	If you are more confident, integrate the passive
Place the pitot-static tube against one wall of the pipe and record the dynamic pressure indicated on the manometer. Record the pressure again at 5mm intervals across the diameter until the tube touches the opposite pipe wall. Repeat this at the five stations marked along the pipe.	A pitot-static tube was traversed across the pipe at several axial positions, each time recording the dynamic pressure profile.
Apply an initial load of 5 kN and set the extensometer to zero. Increase the load by increments of 2 kN to a maximum of 30 kN, recording the extension at each step. Repeat the procedure with reductions in load until reaching the initial load again.	The specimen was loaded incrementally throughout the elastic region, recording the extensions for both loading and unloading steps.

9. Experimental results and calculations (Include any figures, tables and equations. All measurements and units must be included)

10. Estimation of the measurement uncertainty/Discussion of results

This is the most important part of the report. Explain reasonably any errors that are evident or any departures from accepted values which are clear, but be careful to avoid elaborate justifications of errors when the limitations on equipment and your technique really *prevent* highly accurate results, i.e. do not blame the equipment for everything! REMEMBER: You probably do everything thoroughly ONCE. If you came back next day and did it all again would you expect exactly the same data? Don't expect miraculous accuracy.

11. Conclusion.

This is a written summary of what was actually learned from doing the experiment. The conclusion will either support or reject the proposed hypothesis.

(i). Paragraph One: In your own words describe the purpose of the experiment.

(ii). Paragraph Two: Restate your hypothesis and your reasoning for this prediction. Summarize the lab procedure. Explain the set-up.

(iii). Paragraph Three Describe the outcome of the experiment and how it relates to your hypothesis (supports or rejects); discuss your sources of error. Refer to your data tables, graphs, etc. in assessing the data because actual data from your observations is a 'must' in forming a conclusion. From your analysis, point out certain trends or patterns that support your conclusion.

12. Closing remarks

Explain exactly what was/was not accomplished or learned from doing the lab.
What suggestions could you make to get more accurate results?

The origin of document B below is a joint action between the English teacher and the associate physics professor. The English teacher went to the physics teacher's home in the evening (a pertinent detail as we shall see) to observe her execute an experiment to measure the diameter of a tennis ball using two methods: one using the ball's shadow, the other its photograph. The physics associate professor and the English teacher then cooperatively produced a laboratory report detailing her experiment which was integrated into the teaching sequence as part of the laboratory report lesson. The document below is an extract from this integrated version and the complete version can be found in Appendix B.

Document B: Extract of Mixed-Up Laboratory Report

A

This report presents two experiments to determine the diameter of a tennis ball, the first with the use of a shadow projection method and Thales' theorem, the second with the use of a photograph of a tennis ball, a ruler and the mathematical rule of three. The experiment also sought to estimate the level of accuracy of each experiment and to compare their results. The methods used were simple in order to highlight the importance of good procedure in reducing the degree of uncertainty.

Depending on the brand, the diameter of a tennis ball varies between 6.56 and 6.86 so an efficient procedure should give results within this range. The first procedure was conducted in a living room very late in the evening in poor lighting conditions. A torch was shone on a tennis ball, and both the torch and the ball were positioned so as to ensure the shadow on the wall opposite was exactly perpendicular to the source of light and ball. Thales' theorem was used to calculate the diameter of the ball (see figures 1 and 2). The second procedure used a photograph of a tennis ball with a ruler positioned approximately at the height of the ball's radius (see figure 6) which was used as a scale.

The results of the two experiments are as follows: the first procedure $d = (6.0 \pm 0.6)$ cm, and the second procedure $d = (6.6 \pm 0.7)$ cm. As the diameter of a tennis ball is known to be between 6.54–6.86 cm it can therefore be concluded that both sets of results have a relatively high level of inaccuracy. This was thought to be due to problems of lighting and parallax.

B

i) to determine the diameter of a tennis ball ii) to use Thales' theorem to magnify the dimension to be measured (without a lens); iii) to use a photograph and ruler to measure the diameter iv) to estimate the accuracy of each measurement v) to compare the obtained results.

C

A number of possible improvements could be introduced to improve the accuracy of the projected shadow protocol:

- The use of a much more powerful torch (smaller if possible) could have been used in order to avoid penumbra
- The use of set squares and spirit levels (with wooden boards) would have been better to measure TB and TS (with a friend to avoid parallax)
- The removal of furniture close to the screen and the positioning of the torch closer to the ball would have better magnified the ball's shadow.
- The shadow of the ball could have been measured with sunlight in the summertime (the 21st of June when the sun is at its highest position in the sky)
- The use of a lens to create an infinite light source (in a practical laboratory)

Answers to Activity One

A = 11. The Conclusion

B = 4. The Objectives

C = 12. The Closing Remarks

Description of the Laboratory Report Lesson: Activity Two

The time required to complete activity one, the reading activity, is approximately 30 minutes. Following this activity, the students use the laboratory report document (in the right order, Appendix B) as a model to write their own laboratory report. Their report will be a detailed description of the experiment they had themselves executed to measure the diameter of a tennis ball. They are instructed to write their reports on a Drive document. This is shared with the English teacher and the associate physics professor and corrected after the lesson, first by the English teacher, then by the physics teacher. The learning game, designed to develop students' scientific written English, can be described as follows: 'imitate and adapt the style and structures of a model laboratory report so as to imitate the jargon and thought style of a practicing physicist writing a report in English; develop awareness and use of pertinent phrases and structures in English whilst avoiding direct translations from French. Gain awareness of the function and form of each constituent element of a laboratory report.'

As before, it is useful to consider the question 'How does the contract (the students' existing knowledge, the *already-there*) enable the students to successfully tackle the problem presented in the situation?' At this stage of the sequence the students have researched and used a range of jargon to describe their chosen protocol. In the actual execution of their protocols they have been confronted with the rigour and detail necessary to successfully design an experimental set-up and execute an experiment. They have calculated their measurement result and evaluated their measurement uncertainty (the jargon of the practice in italics will be discussed in detail later). This knowledge will now be re-invested in the laboratory report writing activity.

Again, we shall consider the question 'How does the structure of the milieu (the symbolic structure of the problem posited) enable students to construct new knowledge?'

The students ought not to simply copy the model laboratory report. They must imitate its style and adapt the model to their own needs: the laboratory report describes and compares two different models, whereas the students must describe only one procedure, and one that is different to those described in the laboratory report. In imitating whilst adapting and re-writing, the students should progress in the use and understanding of the jargon of the domain, as well as the form and function of the different components of a laboratory report. They are also constrained to actively use written English and to engage in an imitative process designed to contribute to a more long-term improvement of their written expression.

As knowledge of basic physics as a practice is required and considered to be already acquired by the students (that is, it is considered to be part of the contract in JATD terms), it is not the focus of the learning game in this CLIL sequence which is taught in class by a language teacher, not a physics teacher. However, as we shall see, scope for progress in the field of physics will be encountered by the students. This is due, at least to some extent, to the fact that a practice and its jargon are necessarily interlaced.

Extracts from a Student Pair-work Production with Corrections

The effectiveness of the above defined learning games will be gauged by comparing traces of developing targeted epistemic capacities in the students' written production with those defined in the *a priori* analysis (Table 10). To this end, four extracts taken from an example of a student laboratory report (written in pairs) within the context of activity two can be found below. Each extract is first presented with the corrections of the English teacher in italics, then again with the added corrections of the associate physics professor in bold typeface. Comments by the associate physics professor added to the side of the Drive document are indicated by '*' and added below the pertinent extract in bold typeface too.

The example of student work presented is that of two students from the class in 'The Genesis of a Thought-Style'.

Extract 1a: Student Production + English Teacher's Correction in Italics

1	I.	<u>Title:</u> Measuring the diameter of a tennis ball using its circumference
2	II.	<u>Summary</u>
3		
4		This report presents an experiment to determine the diameter of a tennis ball using a thread <i>which is wrapped around the ball to determine the</i> and
5		Circumference of the ball = $2 \times \pi \times$ Radius of the ball
6		This report also sought to estimate how accurate the <i>measurement experiment</i> is and therefore also to <i>estimate</i> determine the uncertainty
7		The result of the experiment was a diameter of (6.8 ± 0.5) cm which is within the range
8		of official diameters for tennis balls.
9		
10		
11		The conclusion is that this method can give satisfactory results.

Extract 1b: Student production + English Teacher's Correction in Italics and Physics Professor's in Bold Typeface

14		10/20 but again, I would give a F. They do not do their <u>maths</u> to calculate the uncertainty
15		or they were never <u>tought</u> about how to do it ?
16	II.	<u>Summary</u>
17		
18		This report presents an experiment to determine the diameter of a tennis ball using a thread <i>which is wrapped around the ball to determine the</i> and Circumference of the ball = $2 \times \pi \times$ Radius
19		This report also sought to estimate how accurate the <i>measurement experiment</i> is and therefore
20		also to <i>estimate</i> determine the uncertainty
21		The result of the experiment was a diameter of $(6.8 \pm 0.5^*)$ cm which is within the range of
22		official diameters for tennis balls.
23		
24		The conclusion is that this method can give satisfactory and quick results.

* Far too high

Extract 2a: Student Production + English Teacher's Correction in Italics

25 IX Experimental results and calculations

26

27 The different results of this experiment are reported on the following ~~next~~ Table:

28

Experiments	Diameters (\pm uncertainty) in cm
Exp 1	6.84 \pm 0.5
Exp2	6.81 \pm 0.5
Exp 3	6.83 \pm 0.5

29

30 *This is an error we discussed last week: you cannot have a*

31 *more accurate measurement (in the hundredths) than your*

32 *estimated uncertainty (in the tenths)*

33 So we chose 6.84 \pm 0.5 since the diameter (and so the circumference) seemed the most

34 realistic.

Extract 2b: Student Production + English Teacher's Correction in Italics and Physics Professor's in Bold Typeface

35 IX Experimental results and calculations

36

37 The different results of this experiment are reported on the *following* ~~next~~ **Table 1:**

38 **Table 1: summary of the results obtained for 3 measurements.**

Experiments	Diameters (\pm uncertainty) in cm
Exp 1	6.84 \pm 0.5
Exp2	6.81 \pm 0.5
Exp 3	6.83 \pm 0.5

39 *This is an error we discussed last week: you cannot have a more accurate measurement (in the*

40 *hundredths) than your estimated uncertainty (in the tenths) EXACTELY!!!!*

41 So we chose 6.84 \pm 0.5 since the diameter (and so the circumference) seemed the most realistic.

Extract 3a: Student Production + English Teacher's Correction in Italics

42 X Estimations of the measurement uncertainty & discussion of results

43

44 After several measurements, different results were obtained, *which* they can be explained by

45 multiple factors :

46

- 47 • Firstly, because we haven't done the best protocol suited for this experiment
- 48 • Secondly, the materials used for the experiment are basic, they're not *standard proper*
- 49 • Thirdly, the thread can't be tightly wound around the ball because it isn't *supple*
- 50 enough.

51

52 Uncertainty:

53

- 54 • ± 0.1 mm? because of the mm's graduations on the ruler.
- 55 • ± 0.2 because it's hard to tell whether we properly wound ~~up~~ the thread *around* ~~on~~ the
- 56 widest part of the ball.
- 57 • ± 0.2 because the thread isn't *very* ~~that~~ *supple*.

Extract 3b: Student Production + English Teacher's Correction in Italics and Physics Professor's in Bold Typeface

58 X Estimations of the measurement uncertainty & discussion of results

59

60 After several measurements, different results were obtained, *which* they can be explained by

61 multiple factors :

62

- 63 • Firstly, because we haven't done the best protocol suited for this experiment
- 64 • Secondly, the materials used for the experiment are basic, they're not *standard proper*
- 65 • Thirdly, the thread can't be tightly wound around the ball because it isn't *supple*
- 66 enough.

67

68 Uncertainty:

69

- 70 • ± 0.1 mm? because of the mm's graduations on the ruler.
- 71 • ± 0.2 because it's hard to tell whether we properly wound ~~up~~ the thread *around* ~~on~~ the
- 72 widest part of the ball.
- 73 • ± 0.2 because the thread isn't *very* ~~that~~ *supple*.
- 74 • **Please do the maths !!!! It is simpler and RIGHT !!! the uncertainty following**
- 75 **this this protocol, if you do few experiments (5 or 6 or more) and you take the**
- 76 **2 highest obtained values for C (to be sure you measure at the "equator" of the**
- 77 **ball), then is 1mm reading the ruler (0.5 mm at the start and the same at the**
- 78 **end) divided by Pi ΔD is about 0.3mm=0.03cm though you wrote in the**
- 79 **summary $\Delta D=0.5$ that is more than 10 times too high. Anyone can measure**
- 80 **anything : the most difficult thing is to calculate or estimate the accuracy of the**
- 81 **measurement. You really failed on that point. The good thing is that you picked**
- 82 **up the quickest , the most precise and fair method, though your protocol can**
- 83 **be improved.**

Extract 4a: Student Production + English Teacher's Correction in Italics

84	XI	<u>Conclusion</u>
85		
86		The report presents an experiment to determine the diameter of a tennis ball, <i>which it</i> uses
87		the <i>measur</i> ement of the circumference of a ball and the simple formula that is : $C=2\pi R$
88		
89		The official diameter of a tennis ball usually ranges from 6.56 to 6.86; if our experiment is <u>efficient</u>
90		we should get results within this range.
91		The procedure was undertaken in an English classroom at around 11am, a thread was used to
92		measure the circumference of the ball then the $C=2\pi r$ formula was used to determine the
93		diameter.
94		
95		The result of the experiment was is $6.84\pm 0.5\text{cm}$, (<i>not possible, see above</i>) this result
96		is within the range of official diameters for tennis balls. Some of our results were quite close to
97		this one, thus it can be concluded that this experiment is a <i>fairly bit</i> accurate although it
98		could be even more accurate if more scientific tools were used.

Extract 4b: Student Production + English Teacher's Correction in Italics and Physics Professor's in Bold Typeface

99	XI	<u>Conclusion</u>
100		
101		The report presents an experiment to determine the diameter of a tennis ball, <i>which it</i> uses the
102		measurement of the circumference of a ball and the simple formula that is : $C=2\pi R$
103		
104		The official diameter of a tennis ball usually ranges from 6.56 to 6.86 UNIT ??????? ; if our
105		experiment is efficient we should get results within this range.
106		The procedure was undertaken in an English classroom at around 11am *, a thread was used to
107		measure the circumference of the ball then the $C=2\pi r$ formula was used to determine the
108		diameter.
109		The result of the experiment was is : (6.84±0.5) <u>cm</u> , (<i>not possible, see above</i> I agree) this result is
110		within the range of official diameters for tennis balls. Some of our results were quite close to this
111		one, thus it can be concluded that this experiment is a <i>fairly bit</i> accurate although it could be even
112		more accurate if more scientific tools ** were used.

* What is the importance of this experimental detail?

** These are perfect and adequate tools

General Didactic Analysis of the Laboratory Report Writing Activity

Table 10 is a general *a priori* analysis of the system of epistemic capacities (Gruson, 2019) inherent in the laboratory report writing activity that the students could potentially develop in the situation presented. The separation of the epistemic capacities into three separate columns is a somewhat artificial representation of the epistemic potential of the activity. As stated earlier, language is not considered to be separate from its context in this study. However, for the purpose of clarification, a separation of the different aspects of a given epistemic capacity will be useful for this analysis. In practice, each of these columns is very much interlinked to the others and any manifestation of a given capacity would include aspects of the other columns. For example, the text in bold typeface, featured in both the physics as a practice column and the jargon column, is an indication of the inseparability of a practice from its practice language (Collins, 2011).

Table 10

Analysis of Systems of Epistemic Capacities (8.5)

System of Epistemic Capacities (qualitative aspect of English)	System of Epistemic Capacities (<i>jargon- the practice language</i>)	System of Epistemic Capacities (physics as a practice)
<p>Written expression in English:</p> <ul style="list-style-type: none"> • No basic typical errors (e.g. experience instead of experiment, a measure instead of a measurement, for measure instead of to measure, incorrect use of the defined article “the”, forgetting the “s” on the third person singular etc.) • Correct prepositions, word form and register • Use of the correct tense/aspect in English: the present simple to describe the steps in a protocol, the past simple for the description of an actual experiment executed in the past, the conditional to discuss possible alternatives. • Use of the grammatical preferences of scientific English: the passive form, abstract nouns in place of verbs (e.g. the importance, improvements), of verbs of abstract relation (e.g. be, have, represent). 	<p>Record and represent the experiment and the data in a meaningful way.</p> <p>Using the <i>jargon</i> and <i>thought style</i> of a practicing physicist (a connoisseur of the practice) to present a detailed description of an experiment in the established, codified form of a laboratory report: present the experimental set-up, the protocol, the data and the results clearly.</p> <p>Be aware of the form and the function of each part of a laboratory report in the use of written language to achieve a fit between symbolisation and the experienced world.</p> <p>Use of the appropriate <i>jargon</i> (e.g. “to determine the diameter”, “to evaluate the uncertainty”, “the accuracy of the measurement”, “wrap a thread around a ball to determine the circumference”, “use the formula $C=2\pi R$ to determine the diameter”).</p>	<p>Describe a reliable experiment which used available equipment to measure. Choose a mathematical procedure to solve the experimental problem.</p> <p>Describe the way assumptions might affect results. <i>Identify</i> sources of experimental uncertainty and <i>evaluate</i> their impact.</p> <p>Describe efforts to <i>minimise</i> experimental uncertainty (random error).</p> <p>Make a judgement about the result of the experiment.</p> <p>Record and represent the experiment and the data in a meaningful way.</p> <p>In the <i>thought style</i> of a connoisseur of the practice, know when and where to use different aspects of scientific practice appropriately. That is to say, demonstrate the <i>seeing-as</i> and <i>grammar</i> of various practices in experimental science:</p> <ul style="list-style-type: none"> • when to calculate and how (e.g. apply appropriate formulas such as $C=2\pi R$) • when to estimate and how • where rigour is required and how to apply it • where discernment is required and how to use it <p>Use of appropriate statistical precision: neither greater nor lesser than what can be legitimately justified.</p>

Signs of the Demonstrated Use of Epistemic Capacities

Extracts 1-4 of a student production, written in the context of this activity, will be analysed in some detail. First, we shall identify in Table 11 what may be considered as signs of a demonstrated use of the epistemic capacities outlined in Table 10 above.

Table 11

Signs of Demonstrated Use of Epistemic Capacities (8.5)

Signs of the Demonstrated Use of Epistemic Capacities		
English (qualitative aspects)	Jargon (the practice language)	Physics (as a practice)
<p><u>Typical errors avoided.</u></p> <ul style="list-style-type: none"> • Third person singular with 's': 'presents' lines 4, + 86, 'ranges' line 89 • Experiment (not experience): lines 4, 9, 27, 46, 47, 89, 95, 97. • Correct use of infinitive to express 'pour faire quelque chose': to determine 4, 86, 92, to estimate 7, to measure 92. <p><u>Correct tense/aspect</u></p> <ul style="list-style-type: none"> • Present: 'the report presents' lines 4, 86. Past simple 'the result...was' line 9 'we chose...seemed' line 33 Conditional 'could be...accurate' line 98. <p><u>Grammatical preferences of scientific English</u></p> <ul style="list-style-type: none"> • Passive: 'thread...wrapped around' line 5. 'results...are reported' 27. 'results were obtained' 44, 'materials used' 47, 'Thread can't be wound' 49, 'procedure was undertaken' 91, 'Formula was used' 92. 'it can be concluded' 97. • Verbs of abstract relation: presents 4, give results 11, presents 86. • Abstract Nouns: measuring 1, the uncertainty 8, the conclusion 11, the measurement 42. 	<p><u>Clear use of the codified form of a laboratory report</u></p> <ul style="list-style-type: none"> • Title (1) – accurate description of the experiment executed • Summary (Abstract). Includes the main elements: Aim (4), Methodology (5), Result (9), Conclusion (11) • Experimental results (25). Clear presentation with the use of a table (28). <p>Correct use of the different elements composing a laboratory report suggesting an awareness of the form and function of each constituent element.</p> <p><u>Use of jargon:</u> 'to determine the diameter' line 4, 86, 'to estimate how accurate' line 7, 'a thread which is wrapped around the ball to determine the circumference' 6, 'after several measurements, different results were obtained' 44.</p>	<p><u>Execution of a rigorous protocol</u></p> <ul style="list-style-type: none"> • Description which demonstrates knowledge of the design and execution of an appropriate protocol to measure the diameter of a tennis ball (18-22) • Correct use of formula $C=2\pi R$ (19, 102, 107) • Evidence of an effort to reduce experimental uncertainty (random error): the circumference was measured several times. (41) <p><u>Signs of appropriate thought style</u></p> <ul style="list-style-type: none"> • Evaluation of the impact of experimental uncertainty: the largest circumference measurement was retained as the most realistic (28) • Records and represents the data in a meaningful way: use of a table showing three measurements (38). <p>Correct use of the different elements composing a laboratory report suggesting an awareness of the form and function of each constituent element</p>

♦ 'reported' as used here is a faux ami. This must have been overlooked by the English teacher.

As Table 11 details, the students demonstrate use of a range of targeted epistemic capacities. With regard to the qualitative aspect of the written English, there are some indicators of a confirmed B2 level (CEFR): basic errors are largely avoided, generally the correct tense/aspect is used, the consistent correct use of the infinitive to express 'pour faire quelque chose' suggests this appropriate form has been assimilated (e.g. 'to determine' 4, 'to measure' 92). There are also traces of a burgeoning use of the grammatical preferences of scientific English ('presents an experiment' 4+86, 'results were obtained' 44, 'it can be concluded' 97). Furthermore, the jargon of the scientific practice of measurement can be seen to be the very basis of the written text in the four extracts and the students' description of their protocol is in the codified form of a laboratory report with its different elements in the standard order.

As regards the practice of physics, there is evidence of correct use of targeted epistemic capacities. There is a description of an experiment which has been designed and executed using available material (18-22). An appropriate mathematical formula is applied (19, 102, 107). The report describes how some care is taken to execute the experiment in a rigorous manner by measuring the ball three times (41). The students seek to reduce the impact of random error by keeping the largest measurement (28) which indicates an understanding of the relative strengths of the circumference protocol and not just a blind application of standard practice. The results are presented in the form of a laboratory report with each of its constituent elements, and the measurement results are presented in a table (38).

Signs of Non-Integrated Epistemic Capacities

We shall now analyse the extracts in order to identify the epistemic capacities which were not yet integrated by the students (Table 12). The focus of the English teacher's correction of the document, followed by that of the associate physics professor, are important clues (Ginzburg, 1979) in relation to this question. They also provide a clue as to the possible need for clarification of the most appropriate jargon regarding the practice of physics: the underlined text indicates a correction made by the English teacher which consisted of replacing one term with another. However, the replacement term is not necessarily the most

fitting term to describe the experienced world as seen through the lens of a physicist. This led to a discussion with the associate physics professor on the correct choice of term, that is to say, they considered how they might fine-tune the jargon of the practice. This a point relevant to the question of how a joint action may function in the development of a CLIL sequence. It also highlights how the notions of jargon and thought style can be useful tools for both analysing and designing a CLIL sequence.

Table 12

Signs of Non-Integrated Epistemic Capacities (8.5)

Signs of Non-Integrated Epistemic Capacities		
English (qualitative aspects)	Jargon (the practice language)	Physics (as a practice)
<p>Grammatical errors</p> <ul style="list-style-type: none"> • A few basic errors which are not recurrent: “measurement” (not “measure” 87), “was” (not “is” 95). • Complex sentences: difficulty mastering complex sentences with “which” (5, 44, 86) <p>Register</p> <ul style="list-style-type: none"> • Replacement of a term with a synonym of a more formal, appropriate register: “following” instead of “next” (37), “very” instead of “that” 57, “standard” instead of “proper” 47, “fairly” instead of “bit” (97). 	<p>Sign of misconception of the thought style</p> <ul style="list-style-type: none"> • “at around 11 am” (106) • “...if more scientific tools were used” (98) • “not proper science tools” (47) <p>Ill-fitting <i>jargon</i>:</p> <ul style="list-style-type: none"> • “This report also sought to estimate how accurate the <i>measurement experiment</i> is <u>and therefore also to estimate <i>determine</i>* the uncertainty</u>” (7-8) <p>*This point will be discussed and contested in the analysis</p>	<p>Written Result</p> <ul style="list-style-type: none"> • Units of measurement not always specified (41, 54-57) • Incoherent: the uncertainty is not in the same decimal position as the last significant digit of the result (28, 33, 95) • Brackets missing (38, 41, 95, 109), though used in 9. <p>Uncertainty Estimate</p> <ul style="list-style-type: none"> • too high 0.5mm (22, 28, 33, 41, 78) • attempt to addition uncertainties which overestimates the impact <p>Sign of misconception of the thought style</p> <ul style="list-style-type: none"> • “...if more scientific tools were used” (98) • “not proper science tools” (47) • “at around 11 am” (106)

The teachers' corrections are useful indicators on several points. The epistemic capacities that have not as yet been fully developed by the students. The epistemic capacities of the teachers themselves with regard to their colleague's domain. Finally, the aspects of the teaching resource, developed conjointly, that could be improved to be more effective in developing the students' targeted epistemic capacities. The extracts will thus be analysed with these different points in mind.

The Qualitative Aspect of the Students' Written Production

Several corrections indicate the limits of the quality of the students' written expression. Whilst basic errors are generally avoided, the two remaining examples ('measure' for 'measurement' in line 87, 'is' instead of 'was' in line 95), suggest there is some remaining fragility as regards the quality of the students' written expression, and that the skill needs to be reinforced. Another concern is the construction of complex sentences with the use of a relative (see extract 3a for the example in line 44, 'which can' the English teacher's correction of 'they can', and extract 4a, line 86, 'which uses' to correct 'it uses'). Mastering this structure is an indicator of a more advanced level of written expression, as is identifying the correct use of register ('next' corrected by 'following' 27, 'proper' corrected by 'standard' 47, 'bit' corrected by 'fairly' 97). Analysis reveals therefore, that the students are in need of more work on written production to confirm and develop their B2 level, as might well be expected. Developing written expression in a second or foreign language is a lengthy process.

Physics as a Practice

There are several points of incoherence in the students' written result with regard to physics as a practice. At times they omit to specify the unit of measurement, as the physics professor highlights with the comment 'UNIT ??' (104), and the English teacher points out by adding 'mm?' with a question mark in line 54. In line 9 they respect the form of the written result preferred by the physics associate professor: '(6.8±0.5) cm'. That is to say, the result + the uncertainty between brackets, followed by the unit of measurement. This written result in line 9 is coherent in that the uncertainty is in the same decimal position (the tenths) as the last significant digit of the result. However, it is a far less accurate result than the

circumference method actually allows for. The students appear to recognise this in line 38 where they present a table of three measurements, the last significant digit of each being in the hundredth place ('6.84, 6.81, 6.83 cm'). These are convincing measurements for this method. The problem here, however, is that they no longer use brackets, the uncertainty of 0.5 cm is no longer in the same decimal position as the last significant digit of their result, and as we shall see, it is far too high for this protocol.

In the table in line 38, the measurements are in cm and therefore we know the '0.5' for the uncertainty of the measurement is in cm too. This corresponds to their estimated uncertainty in lines 53-57 (if we assume they are referring to mm as they forget the unit here): they estimate ± 0.1 mm uncertainty for 'graduations on the ruler', ± 0.2 mm as they were not sure they measured 'the widest part of the ball' and ± 0.2 mm because the thread wasn't 'supple'. However, this degree of uncertainty is far too high for this protocol. The comments in lines 14-15 ('I would give a F...' i.e. fail) and 74 – 83 ('Please do the maths!...') show that the physics professor was dissatisfied with the students' calculation using the formula $C=2\pi R$, as they did not apply it to their uncertainty estimate and so presented an estimate (0.5cm) which was 'far too high' (physics professor's comment) for their measurement (6.84 cm).

The teachers' comments in lines 39-40 highlight an aspect of evaluating the uncertainty of a measurement which has not as yet been fully integrated by the students: 'This is an error we discussed last week: you cannot have a more accurate measurement (in the hundredths) than your estimated uncertainty (in the tenths)'. This comment was added by the English teacher and the physics professor indicates she agrees when she writes 'exactly!'. There is a kind of logical impossibility in claiming to have a measurement which is more accurate than the degree of uncertainty: the latter indicates precisely that of which the experimenter is not sure, which necessarily will be situated on the last significant digit of the measurement. Therefore, a decision must be taken as to whether to round a measurement result up or down to the tenth or hundredth decimal place. In the case of the circumference method, which is particularly precise, it is more fitting to round up or down to the hundredth decimal place. The choice of decimal position for a measurement uncertainty, therefore, is an important clue as to what

extent a student has integrated the thought style of a practicing physicist on this point. It is very much related to the statement made by the associate professor in 'The Exploratory Lesson': '6.50 is much more accurate than 6.5. As a physicist you should know that'. The fact that these students chose a measurement uncertainty in the tenth decimal place for a measurement result in the hundredth place reveals that they have not yet fully integrated this aspect of physics as a practice. It also reveals that they have not considered the full implications of their calculated result: 0.5 cm uncertainty would mean the ball's diameter could be as much as 7.34 cm or as little as 6.34 cm. This is in contradiction to their statement copied from the model laboratory report that their result is 'within the range of official diameters for tennis balls' (i.e. 6.54 cm – 6.86 cm) in line 110.

Several explanations are possible for this unconvincing result. Firstly, the (common) error pointed out by the physics professor: the students did not divide the circumference measurement **plus** its uncertainty by pi. This was then compounded by a blind imitation of the laboratory report where the students claim they are within the official range of tennis ball diameters (as said in the model), whereas an adaptation of the model was required to use the resource effectively. In the model laboratory report, the associate physics professor also obtains a result which is beyond the official diameter of a tennis ball (6.6 ± 0.7) cm, however she states that the method has a high level of uncertainty and that therefore it is not suitable for 'obtaining results with a satisfactory level of uncertainty'. The students, however, claim their result is 'within the range of official diameters' (line 9) and that the method can give 'satisfactory results' (line 11), which is not coherent with their 0.5 cm uncertainty. A final explanation for the students' erroneous result is that the mathematical aspect of physics was ignored in this language class, and that this had a consequence on the content of the students' calculation. The epistemic potential of the sequence would thus benefit from parallel teaching by a specialist on the technical aspect of calculating the results of the protocols and measurement procedures in this sequence.

A Word on Mathematics

The issue of the potential of CLIL projects combining mathematics and foreign language learning is beyond the scope of the analysis of this thesis. However, it is worth noting an observation made during the exploration of such projects: they had proven to be challenging in terms of their potential for generating language other than mathematical jargon. Mathematics is a language in itself, and its jargon is often limited to short phrases in the simple tense, such as 'Let us assume that..', 'We have...' or 'there exists': technical terms and grammatical conventions peculiar to mathematical discourse.

This aspect of the sequence has since evolved and the preferred mathematical procedure taught during physics courses is included in the revised laboratory report in (see extract of revised report, Appendix E).

Jargon, the Practice Language

We shall now consider clues to the non-integrated epistemic capacities of the students with regard to jargon. This will lead to an investigation of the resources produced by the joint action of the teachers which proved to be in need of fine-tuning.

Jargon: Student Misconceptions

A misconception of scientific practice evidenced in the students' production is the phrase '...at around 11am' (106). The associate physics professor asks in her correction 'What is the importance of this experimental detail?' (*Extract 4b). The detail is undoubtedly an imitation of what can be read in the model laboratory report. This document specifies the time of day of the experiment in the introduction ('...at about 11pm'), and is referred to at other points, either indirectly in the procedure ('far too dark'), or again in the conclusion ('very late in the evening, in poor lighting conditions as a torch with a weak beam of light was used'). The detail was mentioned because it was likely to have had an impact on the results of the experiment. However, in the case of the students' productions, the detail was of no significance and there was no good reason for mentioning the time of day of the experiment. The students were, on this point, imitating the model laboratory report somewhat blindly, and their inclusion of an irrelevant detail in their written production is a

sign that they have not completely integrated the thought style of a connoisseur of the practice. The perception, the seeing-as, of the associate professor of physics was directed by the thought style of her domain, and as such her description of the experiment included only those details relevant to its results.

Another misconception of scientific practice evidenced in the students' production, is the phrase 'this experiment...could be more accurate if more scientific tools were used' (98). It would be more fitting to replace 'experiment' with 'measurement result' but this point will be discussed later. More striking as regards a misconception of scientific practice, is the phrase 'if more scientific tools were used'. This is a clue to a common representation of scientific practice: the more sophisticated the equipment or technology, the more scientific the practice. This misconception can be discerned once again in the conclusion in line 112 when the students claim the experiment would have succeeded better: 'if more scientific tools were used'. The associate physics professor's comment here '**These are perfect and adequate tools' indicates her disagreement with this statement.

The students' representation of scientific practice is also at odds with the epistemological position of the JATD with regard to science. As explained in Chapter 7, the work in this thesis is situated within the perspective of a renewed empiricism where scientific knowledge is seen to be produced by a scientific community sharing a specific thought style (Sensevy et al, 2008, Fleck, 1935/2008). From this perspective, 'good' scientific practice is a question of being socialised into the correct thought style and seeing-as of scientific practice. Sophisticated equipment, therefore, is no guarantee of a successful experiment if it is not used correctly in the thought style of a scientist. In other words, learning scientific practice is essentially about learning how to perceive in a particular way and how to use materials, formulas, and theories appropriately, as opposed to learning how to use sophisticated equipment.

As we can see, the clue to this misconception in the extracts of the students' output '...if more scientific tools were used' (98), is also indicated in the physics as a practice column. This is because recording and representing experiments and data in a

meaningful way is very much part of scientific practice. The Investigative Science Learning Environment (ISLE: <https://www.islephysics.net/>) include amongst their definitions of scientific abilities 'the ability to communicate scientific ideas'. The fact that this clue has its place both in the jargon column and the practice of physics column, brings to light how a jargon is organically linked to its practice. It is also intimately interwoven with the thought style which both produces and is produced by it. The question arises as to whether developing a more fitting conception of scientific practice might improve students' actual practice of physics. This issue is related to the debate explored in Chapter 7 on the question as to whether or not students' epistemological views about scientific practice would have an impact on their experimental work. In keeping with findings in other research in the JATD (Santini et al, 2018), work on improving the sequence would seek to guide students toward a more fitting conception of scientific practice. As regard this CLIL sequence, this would include work on fine-tuning the jargon of the domain in relation to the wide range of micro-steps inherent to the practice. This would be within the context of a cooperative effort between language teachers and science specialists, as the following discussion will make clear.

Jargon: Fitting Language to Practice

The implications of the following correction shall be analysed in some detail: 'This report also sought to estimate how accurate the measurement ~~experiment~~ is and therefore also to estimate ~~determine~~ the uncertainty' (8-9). The implications of this correction pinpoint how the notion of jargon can be particularly useful in analysing didactic activity as a means to honing resources and didactic activity in relation to targeted epistemic capacities. It also gives some insight into the process leading to a didactic engineering, whereby the iterative process of research-action seeks to constitute a coherent whole between actors, resources, objectives and didactic activity.

The two corrections, measurement/~~experiment~~ and estimate/~~determine~~, shall be analysed separately. The first part of the correction, 'measurement' as opposed to 'experiment', would seem to be a useful correction as it is a more fitting term. An experiment can be described as meticulous, rigorous, or detailed in that it has been elaborated and implemented by the executor with care and attention to each detail of its components. The

ISLE rubrics referred to earlier distinguish three types of experiment: the observational experiment, the testing experiment and the application experiment. The experiment executed by the students in class, and by the associate professor of physics at home, can be loosely defined (I do not argue didactic practice should follow the rubrics religiously) as an application experiment. According to the ISLE site, this entails identifying a problem to be solved, designing a reliable experiment to solve the problem, using available equipment to make a measurement, making a judgement about the results of the experiment, choosing a productive mathematical procedure for solving the experimental problem, identifying the assumptions made in using the mathematical procedure and determining the way in which the assumptions might affect the results.

In other words, an experiment is essentially a process. Returning to the correction ‘how accurate the measurement ~~experiment~~ is’, ‘measurement’, a property with an identifiable state, would appear to be a more appropriate term to be described as accurate, rather than the process of an experiment. Describing an experiment as ‘accurate’ might evoke the idea of an experiment as a formula to be applied, rather than a careful, elaborated, human process which is the reality of experimental practice. Might it be concluded that when the students termed the experiment ‘accurate’ this ill-fitting term was due to a student misconception of scientific practice?

This is impossible to know, as referring back to the model laboratory report something similar can be seen to be expressed by the teachers themselves. The abstract details how ‘the experiment sought to estimate the level of accuracy of each experiment’. Of course, it is the ‘level’ which is described as accurate here and not the experiment, but nevertheless some sense of an experiment being accurate remains. A more fitting term is thus ‘measurement’, or perhaps ‘measurement results’ as termed in the International Vocabulary of Metrology (VIM, 2012 p.32), a reference for experts in the field. It is interesting to note that this document, also talks of a ‘level of measurement uncertainty’ (VIM, p. 17).

The above considerations lead to an analysis of the second part of the correction, which deals with fine-tuning the jargon of didactic resources.

Jargon: Fine-Tuning the Didactic Resources

The second part of the correction, ‘...and therefore also to estimate ~~determine~~ the uncertainty’ (8-9) led to a focussed analysis as to the most fitting transitive verb for a measurement uncertainty: the term ‘estimate’, though appropriate at certain steps in the measurement procedure, is not necessarily the most apt term in the abstract, which is written on completion of the measurement procedure and the overall experiment. The two teachers later agreed that the students’ choice of ‘determine’ was finally more apt than ‘estimate’ in the abstract.

To explore this point further, it is useful once again to refer to the ISLE detailed rubrics. Rubric G, the ability to collect and analyse experimental data, is broken down into the following sub-abilities as regards measurement uncertainty (author’s italics): the ability to identify sources of experimental uncertainty, the ability to evaluate how identified experimental uncertainties may affect the data, the ability to describe how to minimize experimental uncertainty. The International Vocabulary of Metrology, VIM, 2012, states ‘A measurement function is also used to calculate the measurement uncertainty associated with the measured quality of Y’ on page 49, and on page 105, talks of an ‘evaluation of measurement uncertainty’. Returning to the corrections of the student output, the associate professor of physics states ‘the most difficult thing is to calculate or estimate the accuracy of the measurement’ (line 80-81).

Clearly, the most fitting transitive verb in relation to uncertainty, is very much dependent on the specific nature of the step in a measurement procedure that is being executed at a given point in time. As a consequence of this observation, the English teacher and the physics professor are currently engaged in a joint action to finely-tune the jargon in relation to the practice of the sequence. This includes, for example, re-writing the laboratory report to more closely fit each stage of the application experiment undertaken by the associate physics professor.

These observations could also be incorporated into other aspects of the sequence. For example, during ‘The Genesis of a Thought-Style’, it would be useful to clarify in work in class, that the discussion is about identifying sources of experimental uncertainty, in order to

consider how to minimize them. This would then be distinct from work in the laboratory report where students would calculate their result then evaluate the uncertainty in their measurement.

Conclusions: The Laboratory Report

The points discussed in the above analysis highlight the extent to which language and practice are intimately interwoven, a central premise of this study. As Jay Lemke states in 'Talking Science', '...the mastery of a specialized subject like science is in large part mastery of its specialized way of using language' (1990, p. 21). This is a potentially fertile field of research for joint action between specialists and language teachers as language classes provide many opportunities for students to practice the accepted patterns of scientific description, argument and writing.

A finely-tuned jargon reflects the range and complexity of scientific practice. This gives some indication of the potential of jargon to better socialise students into scientific practice through language. As we saw, the choice of terms reveals precisely the manner in which a practice can be seen to be executed at any given stage of an experimental process. This suggests the possibility of using jargon as a useful tool in both the analysis and design of didactic activity. It might reveal to what extent a student is executing each stage of an experimental process in the correct thought style. Do they appear to comprehend fully when to calculate and why? That is to say, when applying a formula such as $C=2\pi R$ to ensure mathematical accuracy. Or, depending on the preferred approach of the physicist of reference in the didactic game, in calculating an interval of reasonable values, or in applying a mathematical probability theory? Do they appear to comprehend fully when to estimate, or evaluate, and why? That is to say, when considering the balance of the impact of various uncertainties in an experiment. Do they appear to comprehend fully where rigour is required and how to apply it? That is to say, in the elaboration and execution of an experimental set-up so as to minimise the impact of random errors.

These are questions that future research might explore in the development of didactic resources to successfully socialise students into a correct thought style. This would include

researching the possibilities as to how fine-tuning the jargon of a practice might actually improve students' scientific practice.

Counterfactuals

The above analyses give some insight into the following question. To what extent were the targeted epistemic capacities institutionalised or not in the laboratory report writing activity? It is worth remembering that 'The Laboratory Report' writing activity was undertaken by students following a model laboratory report and is therefore an indication of an ongoing process of acquisition rather than of institutionalisation. This process of ongoing acquisition, together with the table detailing non-integrated epistemic capacities in the sequence, thus leads to a reflection on the subsequent didactic activities that might address these objectives.

The counterfactuals below are some reflections on various possible scenarios of didactic activity that could be tested and developed with these objectives in mind. I feel there would be many ways of developing the sequence within a LANSOD language-teaching team. There remains much unexploited potential in the sequence to explore, whilst at the same time identifying and sharing effective teaching-learning practices. This iterative, Deweyan approach is an integral aspect of the Joint Action Theory in Didactics.

Counterfactual 1: Honing Jargon to Practice

The points highlighted in the analyses regarding the precise use of jargon in relation to micro-stages of scientific practice, offer a promising terrain for the development of future didactic activities. Working closely with physicists, a range of supporting teaching resources could be developed to that end. For example, a selection of scientific scenarios might be elaborated with specialists in the field. The scenarios could be converted into activities where students would be constrained to identify and use the most appropriate terms; these would be encountered in the context of the practice in which they were embedded. An example of such potential, identified in this analysis, was the question of choosing the exact transitive verb to describe a specific stage of a measurement process: identify, calculate, estimate, evaluate, or minimise. Depending on the scenario, the notion of jargon could serve to render

more explicit what might be the more implicit aspects of scientific practice, and to integrate such insights into L2 teaching practice.

Counterfactual 2: The Qualitative Aspect of English

Teaching-learning didactic activity often associated with more traditional approaches is not precluded, on the condition that it remain subordinate to the inquiry-based approach which is an integral element of the teaching-learning approach in this study. It could be useful at this point of the sequence to introduce some specific grammar exercises. A possible scenario might be work on the passive. The teacher could outline the structure of passive sentences, then practice converting active sentences to passive sentences with the students. The students would then return to their laboratory reports and attempt to integrate the passive into their reports. Examples could be again shared with the class and the teacher, then discussed in a joint action. As the exercises are put to the service of the elaboration of the laboratory report, the activity remains in keeping with the inquiry approach.

Alternatively, or additionally, subsequent to 'The Laboratory Report' writing activity, students might be asked to share examples of their written expression with the teacher and the class. Their drive documents would be projected onto a screen, and the examples re-worked in a joint construction between the teacher and the students. Common grammatical errors or students' interrogations could be discussed and revised conjointly to accompany students in developing their L2 written expression.

Counterfactual 3: Translating

Whilst the overall structure of a laboratory report is recognisable in different languages, there are nevertheless some differences in the habits and practices between languages. For example, in French it is common to describe a past experiment in the present tense. However, in English it is standard practice to present an experiment that has actually been executed in the past tense (both these affirmations are subject to the exact phrasing of the description; they should be understood as a generalisation of what is commonly practiced). As might be expected, students tend to express their first language habits in the target language. This is one of the reasons why students were discouraged from using their

own writing style and asked to follow the model laboratory report. An activity which entailed translating French phrases or abstracts into English could be a useful activity. It might help develop an awareness of these differences in habits between languages, as well as some meta-linguistic skills.

Future Research Questions

The counterfactuals explored above might invite the reader to imagine a future research project exploring the interaction between imitative learning strategies and translanguaging learning strategies. In the process of developing L2 skills, when and where is it more effective to develop didactic activities with essentially the former or the latter approach? In this study, imitative learning strategies were mainly encouraged for written expression so as to avoid common errors, whereas translanguaging strategies were more encouraged, at certain stages, for oral expression. This was to encourage fluency and confidence. In what kind of circumstances might the contrary be effective? For example, might a student with an excellent C1/C2 level (CEFR) of written expression, benefit from experimenting their own voice once certain structures and codes were fully integrated? Or might a student with an excellent C1/C2 level of oral expression benefit from imitating more closely the oratory skills of an articulate native speaker?

In the quest to better identify effective work on developing L2 skills, these are some examples of hypotheses that could be explored in future research.

Future Research: CLIL

The discussion in this chapter raises some interesting questions with regard to CLIL practice. To what extent can the English teacher integrate the content, that is to say physics as a practice, into the language lessons? For example, she does not have the specialist knowledge to guide the students clearly on specific calculations: this is left to the physics professor (e.g. lines 74-83).

There is some debate as to the 'cut-off' point between content and language in CLIL practice. The technical aspect of physics is an indicator of the limits of 'content' in a CLIL

language classroom. Without specialist knowledge of physics, a language teacher can only seek to support the teaching of the field and cannot function as a reference for the students.

Thus said, the English teacher can be seen to stray into some technical aspects of the domain of physics at certain points: lines 30-32 and 95 when she corrects the students' uncertainty evaluation which is not in the same decimal position as the last significant figure of the measurement result, or line 54 when the students forget to specify the unit of measurement.

Similarly, the associate professor of physics can be seen to usefully stray into the language aspect of the practice. For example, in line 37 when she replaces the English teacher's correction ('following' instead of 'next') with a numbered title and caption ('Table 1: summary of the results obtained for 3 measurements'). This is an example of jargon which is more fitting to scientific practice: the joint action of the language teacher with the specialist in the field was in this way an effective means of developing specialised sequences in English. Minor errors by the physics professor (e.g. 'tought' instead of 'taught' 15, 'exactely' instead of 'exactly' 40, 'picked up' instead of 'picked' 82) illustrate the interest of a language specialist as a reference for the accuracy of the L2 explored in CLIL in sequences.

Joint action cooperative projects between domain specialists and language teachers offer prospects of fruitful areas of research. In particular, the notion of jargon, straddling as it does both language and practice, is potentially an effective tool for both designing and analysing didactic engineerings in this field of research.

8.5.1 Preliminary Conclusions with regard to the Study Research Questions

The research questions which are addressed in this study, will be considered in relation to the laboratory report analysis.

Question 1: How can the combined objectives of a conceptual understanding of scientific practice, together with work on language skills, be effectively described?
What is the role of jargon in the construction/development of a capacity?

The laboratory report analysis discussed how the notion of jargon could be useful in analysing didactic activity as a means to honing resources and didactic activity in relation to targeted epistemic capacities.

Firstly, the analysis suggested that it had the potential to render more visible the more implicit aspects of scientific practice. By exposing the micro-stages of a given epistemic capacity, such as executing scientific measurement, there is some indication of the potential of jargon to better socialise students into scientific practice through language. In revealing the extent to which a student is executing each stage of an experimental process in the correct thought style, jargon might prove to be a useful tool in both the analysis and design of didactic activity.

Secondly, it showed how the iterative process of research-action, in cooperative projects between specialists and language teachers, could contribute to a coherent whole between actors, resources, objectives and didactic activity. The notion of jargon encompasses both language and practice, and is thus a potentially effective tool for both designing and analysing didactic engineering in CLIL research.

The iterative process between oral and written activities, targeting a specific jargon and thought-style, also suggests interesting prospects for future research as regards the progression of L2 skills.

Question 2: What capacities can be identified in the didactic activity of the students participating in the case study, and what evidence is there of effective work on those capacities in the didactic activity between themselves and with the teacher?

There are an increasing number of examples of effective work on developing capacities in the laboratory report analysis, compared with the previous analyses of extracts taken from earlier lessons in the sequence. Various indicators of the quality of the written English, such as avoiding basic errors, using correct tense/aspect, and using a range of vocabulary, correspond to a confirmed B2 level (CEFR). The jargon of the scientific practice of measurement, can be seen to be the basis of the written text in the students' description of their protocol, and they respect the codified form of a laboratory report with its different elements in the standard order.

As regards the practice of physics, there is evidence of correct use of targeted epistemic capacities: designing and executing an experiment, applying an appropriate mathematical formula, executing the experiment in a rigorous manner, and seeking to reduce the impact of random error. As indicated above, the experiment is presented in a laboratory report with each of its constituent elements, and the measurement results are presented in a table.

The fact that the students executed the experiment in a rigorous manner, and that they retained the largest circumference measurement, is evidence of an appropriate thought style. There is also evidence of how the epistemic capacities require further development. Some of the statements in the report, such as, 'if more scientific tools were used', reveal an ill-fitting conception of scientific practice. Also, the fact that the students' measurement result was mathematically inconsistent, and that they chose a measurement uncertainty in the tenth decimal place for a measurement result in the hundredth place, reveals that they have not yet fully integrated this aspect of measurement uncertainty.

Question 3: What are the concrete conditions of a CLIL programme which enable students to develop a conceptual understanding of scientific practice whilst improving their English language skills?

How ought CLIL practice interweave content and language, and in what ways are these two elements then influenced by their convergence?

What are the frontiers in a given speciality that necessitate language teachers cooperating

with specialists of a body of knowledge?/ that limit the scope of language teachers in a CLIL sequence?

As stated above, the notion of jargon could serve to render more explicit what might be the more implicit (Brandom, 1998) aspects of scientific practice, and to integrate such insights into L2 teaching practice. The cooperative work on fine-tuning the didactic resources to better describe the micro-stages of scientific measurement is an example of how content and language were interwoven in this CLIL programme, each having an influence on the other.

An example of a frontier that limits the scope of language teachers in a CLIL sequence was the issue of the mathematical calculations with regard to measurement uncertainty. The students revealed some mathematical inconsistencies in their results, which might have been due to this aspect of the practice being largely ignored in the language class. Calculating measurement uncertainties requires a specialised understanding of mathematical practice (see Appendix E-the current formula in the laboratory report), which is generally not the domain of language teachers. The epistemic potential of the sequence would thus benefit from more closely aligned parallel teaching by a specialist on the technical aspect of calculating the results of the protocols and measurement procedures in the sequence.

8.6 *The Extended Roleplay*

As previously stated, a primary underlying premise of this study is that language is acquired by use in context, in social games, which are characterized by social interaction in either oral, signed or written form. The first hypothesis explored in this study is that in activating the social practice related to the question of uncertainty in measurement in physics, students will engage in its corresponding *jargon* and *thought style* and in doing so develop their English language skills.

A second hypothesis explored is that in seeking to develop students' language skills through the social game of a scientific practice, epistemic capacities similar to those of scientists engaged in that social game —the connoisseurs of the practice— will be encountered and possibly developed (Sensevy, 2011; Santini et al, 2018).

'The Extended Roleplay' is the culmination of the sequence. In this analysis, the two hypotheses above will be explored by seeking traces of students co-constructing meaning on the question of uncertainty in measurement. How and where students might be seen to be developing their English language skills will be identified as precisely as possible using JATD notions to model the didactic activity and its context. It will also seek to identify to what extent students participate in practices that can be recognised as sharing some epistemic kinship with those of expert users of the English language in the physics domain.

Of course, the practices undertaken by students in class differ to that of actual practicing physicists. Firstly, they are necessarily transposed (Chevallard, 1985) to an educational context and are therefore adapted to meet didactic objectives. Secondly, those didactic objectives are primarily concerned with developing the language aspect of scientific practice as the sequence was designed for a language class. The extended roleplay is an example of an activity adapted to an L2 classroom where students are constrained to interact so as to explore a range of language. Students discuss at length their uncertainty estimates. They are asked to classify each protocol according to their uncertainty estimate. This is an exercise which is unlikely to occur in physics laboratory work, at least not in such detail, and it is an example of how language classes can be seen to contribute to the communicative

aspect of scientific practice. It is also an example of how language classes might render more explicit what is generally more implicit in scientific practice. (Brandom, 1998)

The Social Construction of Meaning and Language Learning

As discussed in Chapter 1, the link between thought and language is complex. It involves questioning where the transition from thought to language might occur: in people's heads or in some form of interpersonal space in a meshwork of semiotic systems? (For the latter view, see Vygotsky, 1934; Mead, 1934/1974; Dewey, 1938/1997; Halliday, 1978/2004; Sensevy, Gruson & Forest, 2015). This raises some interesting questions regarding the social aspect of foreign language learning and the kinds of joint action that would be effective in its acquisition. A hypothesis explored in this study is that meaning is constructed in social spaces, and that consequently language is not a uniquely individual phenomenon. Based on this hypothesis, activities allowing for the exploration of semiotic systems are of particular interest.

The choice of a scientific field for the content aspect of the CLIL sequence was because of its potential to generate specific kinds of language games (Wittgenstein, 1953/2009): question-and-answer activities are a common feature of the language of science (Lemke, 1990). Science subjects thus provide fertile settings for resistant and transactional didactic milieus where students engage in such language games. Thus, the extended roleplay was intended to create a productive language learning milieu on two levels. First, the roleplay learning game constrained students to engage in scientific language games: asking and answering clarification questions, challenging and defending claims and exploring predictions and relationships (Duschl et al, 2007). In fact, the roleplay is essentially founded upon such exchanges. Second, the development of (L2) learning games (Sensevy, 2008) in the context of such scientific language games (Wittgenstein, 1953/2009), would create L2 semiotic learning situations (Sensevy, Gruson & Forest, 2015) which are arguably necessary to a language learning milieu. Scientific practice requires attention to detail, and agreeing upon a shared vision of reality (Fleck, 1935; Bazerman, 1988): that is to say, milieus where students would have the opportunity to develop language skills whilst engaged in the co-construction of meaning in a shared reality.

Extracts from this roleplay will be analysed in this section with a view to clarifying the semiotic systems at work throughout the didactic action.

Context

In the previous didactic analyses, the extracts described were taken from classes of first-year university students, in either maths or physics degree courses. The students in this extract are from a third-year university maths degree course. This group was chosen for a number of practical reasons: first, virtually the entire discussion was successfully filmed and is fairly audible. Second, their full engagement in the roleplay produced a range of transactions emanating from their interactions. This provided the opportunity to analyse the full complexity of the phenomena at play. The group's discussion lasted 45 minutes. The full transcription of their exchange (minus ten minutes as the group discuss organisation), can be found in Appendix F.

General Didactic Analysis

The JATD notion of a contract-milieu dialectic will serve as an analytical tool to examine the didactic phenomena in this last lesson of the four-lesson sequence where the students participate in an extended roleplay. They are expected to demonstrate the range of epistemic capacities that they have been developing during the various learning situations presented throughout the sequence. This belongs to the contract aspect of the contract-milieu dialectic. That is to say the *already-there*: a concept to denote all the existing knowledge, capacities and habits of learning available to an individual. It is from the contract that a person will muster the learning strategies available to them to explore the potential knowledge inherent in a milieu.

The learning game of the extended roleplay can be defined thus: 'conjointly negotiating meaning and knowledge around the issue of uncertainty in measurement using the jargon and thought style of a connoisseur of the practice; developing and strengthening English language skills during the joint construction of meaning.' In the roleplay, each student is compelled to describe a protocol in detail, justify the uncertainty in their measurement, and listen attentively and critically to other students' protocol descriptions. This entails

challenging, and being challenged on protocol details, as well as justifying the execution of protocols and uncertainty estimations in detail. The task of ranking the protocols, according to the degree of uncertainty in the measurement, was integrated into the roleplay so as to constrain students to explore and question the many factors contributing to a measurement result. That is to say, it served to create a resistant and transactional milieu (Sensevy, 2008) where students undertook didactic transactions in the form of their questions, explanations and justifications.

In seeking to develop strategies to successfully participate in this game, the systems of epistemic capacities presented in Table 10 (8.5) and Table 14 later could potentially be developed.

The Contract-Milieu Dialectic

As with the analyses in sections 8.2 to 8.5, the following questions (Gruson, 2019 and the existing body of work in the JATD, e.g. Sensevy et al, 2015), are an effective means of analysing the didactic interest of the activity. Q1. How does the contract (the *already-there*) enable the students to successfully tackle the problem presented in the situation? Q2. How does the structure of the milieu (the symbolic structure of the problem posited) enable students to construct new knowledge? (Gruson, 2019, p. 130 - Author's translation).

In answer to question one, the previous didactic activities in the sequence, (described and analysed in 8.2-8.5), are designed to enable students to participate in this roleplay learning game. Students have had the opportunity to practice describing a chosen protocol in detail, in the form of both oral and written expression. In previous lessons, students were constrained to develop their language skills during activities designed to develop the appropriation of the jargon and thought style of the practice of measurement in physics. Evidence as to the reality of this premise will be sought in this didactic analysis.

In answer to question two, it is structured to be a resistant and transactional milieu (Sensevy, 2008). The following are potential opportunities for developing new knowledge inherent in the roleplay activity: further enhancing confidence and fluency in oral expression, further enhancing comprehension and oral skills in exchanging and co-constructing meaning

with others, and further developing a fitting view of scientific practice during epistemic practices, such as questioning assumptions and providing detailed descriptions of protocols.

The teacher's intervention during this roleplay activity is virtually non-existent. However, this is not to say she is totally absent: she remains present on two levels. First, in the expectations and habits integrated into the contract during the didactic activity of the preceding few weeks. (Sensevy, 2008; Gruson, 2016-HDR). The class document 'Measuring Roleplay Assignment' below gives a fairly detailed indication of the nature of those expectations and habits. Second, by her continuing observation and assessment of the on-going activity. The students are expected to be fully engaged in the activity. The teacher therefore plays a role in witnessing the efforts made. This witnessing, combined with non-intervention, is a sign to be interpreted: it is a signal that the teacher considers the students to be usefully exploring the milieu and it is in this sense a validation of the students' practice. If there were not a teacher in the classroom the interactions between the students would possibly not be the same. This is not to say that such an exchange would be without didactic interest. It is rather to stipulate that the fact that the teacher can potentially hear the details of the exchange at any given moment is a factor that will have some influence on the students' behaviour and is another example of how the teacher is not totally absent.

Before proceeding to a more detailed analysis, the instructions given to the students prior to the roleplay are presented in some detail.

Class Documents

The exact instructions given to the students at the outset of the roleplay are presented in Document A below. It asks them to undertake a number of activities: first each student should present the protocol that they designed and executed to measure the diameter of a tennis ball. They should include their results and the estimate of uncertainty in their measurement. Second, the method should be challenged and questioned by the other students to determine if they find the student's method and assumptions convincing. Third, the students should then rank each method according to its degree of uncertainty (least to highest).

Document A: Roleplay Instructions

Measuring Roleplay Assignment

Demonstrate your team's scientific rigor and ability to synthesize information by compiling a report comparing several different methods to measure the diameter of a tennis ball.

Classify each method from 1 – 5 according to the accuracy of its estimated degree of uncertainty - the lowest level of uncertainty first and so on.

Stage 1 (0:10 – 0:20) **OLD GROUPS**

In pairs, clarify your conclusions on the method you used to measure the tennis ball's diameter. Are you able to explain clearly the method you used and justify your estimated degree of uncertainty?

Stage 2 (0:25 – 1:05) **NEW GROUPS**

Meetings in new groups of 4 to 5 students (45 mins)

Follow this agenda:

- State the purpose of the meeting
- A brief presentation of each method and its estimated degree of uncertainty, each presentation followed by questions and reactions from the group to clarify; as you listen decide on your classification and why
- Each person presents their classification and reasoning
- Vote to classify each method. You need to agree as a research team; you are not defending your method as the best, but objectively assessing each method.
- Assignment of a task for each person in the group on the writing up of the final report; work on a joint Drive document which should be finalized by the end of the lesson.

(One person to chair the meeting, one person to take minutes on the meeting)

Stage 3 (1:10 – 2:00) **NEW GROUPS**

Writing up of the group's final report: to be finished by the end of the lesson. The report should include:

A title and the names of each member of the group

Introduction with a statement of purpose

An *abstract* of each method with its classification

Conclusion: A statement of the classification and the team's reasoning

Following the roleplay, the students are required to produce a written summary which is executed in a shared Drive document. The written summary constrains the students to do the following: (i) use acquired jargon to describe their protocol in detail, (ii) include some elements of a laboratory report using the appropriate form and style of scientific writing, and

(iii) demonstrate the capacity to synthesise and classify the information discussed during the roleplay. This includes demonstrating an understanding of the factors which influence the results of a measurement. The written summary will not be included in this analysis. Written expression is analysed in 8.5.

Description and Preliminary Analysis of Extracts from the Extended Roleplay

The didactic analysis of the extended roleplay will be based on the detailed description below. It concerns the interactions between four students in relation to one of the students' protocol descriptions. The description is comprised of 5 extracts. Extract 1 is taken from the written summary executed after the roleplay activity. It is presented here simply to clarify the context of the exchange between the students. Extracts 2-5 concern the exchange between the students and the evolving milieu, which can be seen to be of their own making. Each extract will be followed by a preliminary analysis using the notions of contract-milieu.

The four students in the group are Jean (white shirt), Frédéric (in blue), Paul (wearing a cap) and Driss (in grey), whose protocol description, together with the exchanges it generates, will be the subject of this analysis. The extracts below describe the students' interactions, beginning at 28:32 minutes into the 45-minute roleplay. At this stage, Jean (J) has already described the 'photograph' method he used to measure the diameter of a tennis ball (lines 5 – 79, Appendix F), Frédéric (F) his 'syringe' method (lines 80 – 142, Appendix F), and Paul (P) his 'immersion' method (lines 144 – 192, Appendix F). Driss (D) is about to describe his 'home-made calliper' method (lines 195 – 241, Appendix F).

Driss used two protocols to measure the tennis ball's diameter: one using two set squares which he calls a home-made calliper method, the other using an actual calliper. His contribution to the written report at the end of the roleplay, reproduced below in extract 1, briefly presents Driss's protocols as seen from his perspective.

Extract 1: Driss's Written Summary of his Protocol

Abstract of each method:

1. Caliper method:

The goal of our experiment was to set up a home made caliper. To do it, we took 2 set-squares and we put the ball between them. Then, with a ruler, we measured the diameter of the ball and we found 6,5 cm. The uncertainty was only 1mm because of the "graduation" of the ruler. But we also thought that uncertainty could come from the set squares if they wasn't totally vertical. So we also measured the diameter of the ball with a real caliper and we also found the same result, which means our home made caliper was quite accurate.

The marks on the text indicate the teacher's corrections. These points will not be explored here (for a detailed analysis of teacher corrections see 8.5).

Driss's protocol using the set-square method with a 1mm uncertainty estimate is reasonably convincing. If the set-squares were perpendicular to the surface on which the ball was placed and parallel, the uncertainty would mainly be due to the reading of the ruler. If the ruler were graduated in mm, a 1mm uncertainty estimate is standard procedure. A point which the students do not explore in the roleplay, is the precision of the calliper as a measuring instrument compared to the set squares. A protocol using two set squares could reasonably claim to be accurate to the tenth place, as Driss states (6.5cm). A calliper, however, could reasonably give a result accurate to the hundredth place, if used correctly.

The students do explore the assumptions and predictions as to how Driss ensured the set-squares were parallel, as we shall see.

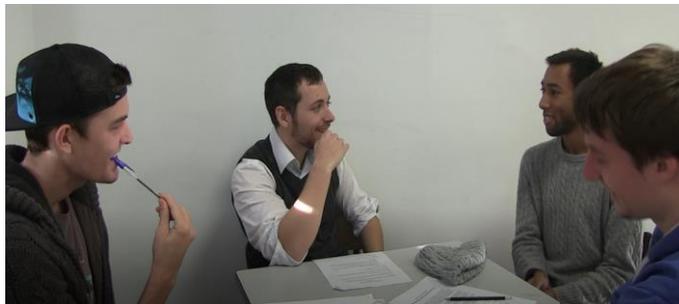
Extract 2: Driss Begins his Description

1. Driss (D): Right. Our method was (inaudible) ... home-made caliper so (inaudible)
2. Jean (J): I'd like you to explain to me exactly what it does



Frame 1: 'I'd like you to explain to me exactly what it does'

Driss is a slightly more reserved member of the group: he volunteers to speak last and has contributed slightly less than the other students. He appears to begin with a very brief description of his protocol. (speech turn 1). Jean asks him to explain further (speech turn 2).



Frame 2: Coercing Driss to contribute more

The four students laugh (Frame 2) and Jean, Frédéric and Paul turn overtly toward Driss, as if settling down to listen to him in detail at length: they appear to be coercing Driss into contributing more to the discussion than he might otherwise be inclined to do.

3. D: Calliper ou ... ('or' in French)?
4. J: yeah
5. D: it does something that er stuck the ball and then er (inaudible) ... as we don't have a



Frame 5/6: Checks understanding "Set square?"

calliper here - er we took two set square –
(*he looks at Paul to check understanding*) set
square?

6. P: *grimaces to show he doesn't know the word*
7. D: (translates) – *équerre*
8. P: ah ok
9. D: we took two set square and we stuck the ball between two set square like that (*places his two hands vertically and parallel to each other*).
10. F: ah – to make sure it's er parallel



Frame 9: "Between 2 set square"

Driss appears to ask Jean if they want him to explain further the calliper aspect of his method (speech turn 3) and Jean confirms he does (speech turn 4). Driss explains he stuck the ball between two set squares. At this stage it is not exactly clear what Driss means here. Either he compares his method to using a calliper (because of the ball being lodged between two set squares, in the same way that a calliper would lodge the ball firmly between two points), or he is talking of two methods: one with set squares, and one with a calliper. Driss looks towards Paul to check he understands the word set square (speech turn 5, frame 5). Paul shows with a grimace that he doesn't (6, frame 5/6) Driss translates the term with *équerre* (7). He continues his description of how he lodged the ball between two set squares using his hands to demonstrate the position of the set squares (speech turn 9, frame 9). Frédéric indicates that he understands Driss held the set squares in this way to ensure they were parallel to each other (speech turn 10).

11. D: yeah
12. F: ok
13. D: and then we ...
14. F: (*interrupts Driss, to address J*) For your problem – (*places a hand parallel over the table. A reference to J's method which needed something to ensure that the phone was exactly parallel to the desk to take a photo of the ball*)
15. J: *nods in agreement*



Frame 14: For your problem

Driss confirms to Frédéric that he was ensuring the set squares were parallel (speech turn 11) and continues with his description (13). He stops for a moment when Frédéric turns to Jean to say that the set square structure would have been useful in Jean's protocol too (speech turn 14, frame 14). Frédéric is referring

back to Jean's protocol set-up which Jean described at the beginning of the roleplay. Jean had used a photograph of a tennis ball with a ruler beside it (line 12, appendix F) but the method did not obtain accurate results, possibly because the phone had not been parallel to the surface on which the ball was placed. Frédéric is suggesting the phone could have been placed on two set squares to ensure it was parallel. Jean nods in agreement (speech turn 15). Both Frédéric and Jean then return their attention to Driss after this brief interruption.

Below is a preliminary analysis of this extract, using the contract-milieu dialectic, in order to clarify the various interactions between the students with regard to the potential knowledge inherent in the milieu.

It is useful to restate the objectives of the learning game so as to identify clearly the knowledge at stake at this point in the exchange: 'conjointly negotiating meaning and knowledge around the issue of uncertainty in measurement using the jargon and thought style of a connoisseur of the practice; developing and strengthening English language skills during the joint construction of meaning.'

The Already-There

Various aspects of the already-there can be identified in extract 2. First, and perhaps foremost, the students share a common background within which to negotiate meaning. They have all understood the rules of the game, a social game, whereby each of them must describe the protocol they undertook and justify the results they found. They thus share the common epistemic situational background of a cooperative game, thanks to which, other shared experience becomes possible.

Within the playing field of this cooperative game, other phenomena can be seen to emerge. For example, signs from the students to help the discussion along, either to confirm comprehension, or to signal incomprehension: that is to say already-there behavioural habits. Frames 1 – 14 show the students listening attentively to each other's contributions, whilst studying both the faces and the gestures of the speaker to better understand the meaning intended. Discourse patterns also facilitate exchange, such as Jean's requesting Driss to explain in detail 'I'd like you to explain to me exactly what it does' (speech

turn 2). This is an example of the students respecting the didactic contract by actively participating in a dialogue in order for the learning game to be effective.

There is also evidence of knowledge of English, such as the grammatically accurate structure 'I'd like' to make polite requests (speech turn 2). The beginnings of a jargon related to the field of measurement is identifiable: 'we stuck the ball between two set square' (speech turn 9), 'to make sure it's er parallel' (speech turn 10).

This jargon is also evidence of the students' knowledge of physics as a practice. As we saw in 8.2 to 8.5, the students have participated in the common epistemic practice of designing a suitable protocol with available material and with a productive mathematical procedure. They have sought to identify and minimise experimental uncertainties. They have recorded and represented their results in a recognized scientific way in a laboratory report and are now reporting the details of their results. This practice is included in the already-there at this stage of the sequence.

The Resistances and Transactions of the Milieu

A student not knowing a specific term at a given moment is a common occurrence in the roleplay and is a clear example of how the milieu proves to be resistant. In this extract for example, Paul intimates by a grimace (6) that he does not understand the term 'set square'. Driss translates the term for him with 'équerre' (7). This term is later used by Paul, as we shall see in extract 4 (speech turn 29). Driss also uses his hands to symbolically represent the set square material used in his set-up. This prompts Frédéric to state 'ah - to make sure it's er parallel'. At this point he is introducing an appropriate form of jargon into the milieu to express verbally what Driss had introduced symbolically with his hands. This is an example of a resistance in the milieu leading to a transaction between the students which both constructs and transforms the milieu. The question of material being parallel will be explored further by the group from this point on.

Co-constructed Meaning

At this stage of Driss's contribution, the students appear to have constructed a shared general understanding of his protocol. This can be deduced from Frédéric's interjection to refer back to Jean's photograph method (14). This is another method which will not be analysed here. It serves to offer a clue as to how Frédéric imagines Driss's protocol: the group had previously discussed the need for a structure that would allow a phone to be maintained parallel to the surface on which the ball being photographed was placed (Appendix F, lines 27,28). Frédéric therefore imagines Driss's structure as allowing for this. Jean appears to agree with a nod (15). Based on Frédéric's comment, it can be deduced that the students share a common general representation of Driss's set up as a parallel structure.

Extract 3: Challenging and Defending Claims

Following Frédéric's reference to the exchange earlier in the roleplay, Driss continues with the description of his protocol.

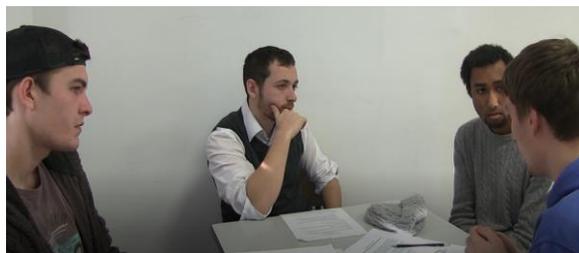
16. D: and then we took a ruler and with the ruler we measured the diameter of the ball
17. F: *asks a question* (inaudible)
18. D: yeah. Erm so the uncertainty came just from the ruler so we just had 1mm uncertainty and we found something like 6.4 or 5 that er that was good. And then we er we took a real calliper – we did the first experiment however we took a real calliper and measured the diameter of the ball and it was the same that er we took so ... (inaudible)
19. F: how could you be sure that the ball can't be pressed by the calliper when you measure because if you press it the ball is er flexible and the diameter .. ?? and er the ball is not really spheric and the diameter change in the manner of how you put the ball between the (*places two hands parallel to each other*).
20. D: In fact, in the beginning we tried to put the ball between the two set square, the ball er ...
21. F: came out
22. D: yeah, yeah came out. So er we really tried to fix it and er the moment when we fix it we know that we were er we were .. ? (inaudible)



Frame 20: We tried to put the ball between two set square

Driss continues with his description. He says they measured the diameter of the ball with a ruler - this probably means they measured the distance between the two set squares with a ruler (16). He says they estimated 1mm for the uncertainty on reading the ruler. He says they found 6.4 or 5. (18). Perhaps he says 6.4 or 5 depending on whether or not he includes his 1mm uncertainty estimate. He does not specify the unit of measurement but undoubtedly means cm. He says they then used a real calliper to measure the ball's diameter and that this gave the same measurement (speech turn 18). Frédéric asks him how they ensured they were not compressing the ball when they lodged it in the calliper as the diameter would change if the ball were compressed (speech turn 19). Driss explains this had been a problem and that when they first measured the ball it came out (20, frame 20). He does not find the verb "come out" himself. Frédéric guesses what he wants to say and completes his sentence with "came out" (21). Driss confirms this is the term he needs and uses it to continue explaining something about the moment they lodged the ball (22) but he is again interrupted by Frédéric who challenges an aspect of his protocol.

23. F: nods. I think er if the ball is er out of the calliper that's because the diameter you measure is a little er a little more than *(struggles for words, slaps the palm of his hand)* ..the real diameter is a little more than ...



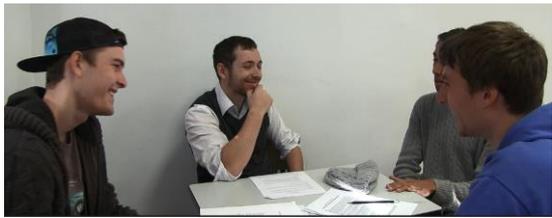
Frame 23: Slaps hand as struggles for words

Frédéric responds to Driss's idea of fixing the ball. He thinks that if the ball came out during measurement it is an indicator that he was slightly underestimating its diameter (frame 23, speech turn 23). He can't find the words to finish his sentence and he slaps his hands as if physically trying to get the words out. In this example, neither Frédéric nor the other students produce the term which eludes him

24. D: maybe but ... the method was good because after we checked *(the suffix -ed pronounced /id/ instead of /t/)* on the website



Frame 25: Checked (tʃɛkt)!

<p>25. Teacher: Checked (tʃekid)! (passing by repeats the mispronunciation with surprise) checked (tʃekt) the result, checked (She corrects the pronunciation twice)</p> <p>26. D: We checked (tʃekt) the result (the students laugh) on some website about er ball tennis and er</p> <p>27. F: yeah 6.5 and 6.8 (uses fingers to demonstrate a range between the two)</p> <p>28. D: yes exactly</p>	 <p style="text-align: center;">Frame 26: Caught out</p>
<p>Driss defends the validity of his protocol and its results by saying that he checked the diameter of a tennis ball using references on the internet which confirmed his results were in the right range (24). He mispronounces “checked”, pronouncing the suffix -ed as “id” instead of “t”. The teacher passing by hears the mistake and corrects him (25). Driss integrates the correction and repeats his statement with the correct pronunciation (26). The students appear to be surprised by an interjection from the teacher beyond their circle (frame 25). Jean, Frédéric and Paul find the situation amusing (26).</p>	

The Already-There

The students continue to practice behavioural habits (listening and observing attentively) and discourse habits that facilitate the interactive exchange of the roleplay. Driss describes his protocol in more detail (16,18,22). He is challenged by Frédéric (19, 23). The students’ English, in terms of the quality of their expression, is sufficient to be able to evoke a range of situations using different structures and jargon. For example, the correct use of the preterit for the past (took, measured 16, found 18, tried 20), Modulation, (could you be sure 20). Driss mispronounces the suffix -ed in ‘checked’ (speech turn 24): he is corrected by the teacher who generally does not intervene to correct errors. This is a sign that she expected the correct pronunciation of -ed to be part of the contract, the *already-there*. A range of appropriate jargon (‘did the first experiment’ (18), ‘measured the diameter’ (18), ‘ball can’t be pressed by the calliper’ (19)), acquired in the weeks preceding the roleplay, is introduced into the milieu. The questioning and defending of the empirical validity of Driss’s results can be considered as an exchange undertaken in an appropriate scientific thought style in that it is based on reasoning related to the specific experimental detail of the set-up (speech turns 18-23). (Bazerman, 1988).

The Resistances and Transactions of the Milieu

Once more the milieu proves to be challenging in terms of vocabulary. Frédéric cannot find the term which eludes him in speech turn 23, and slaps his hand in frustration (frame 23). Driss lacks the term he needs to complete his sentence in 20 'we tried to put the ball between the two set square, the ball er ...'. Again, this resistance becomes a transaction between the students, as Frédéric is able to provide Driss with the term he needs (21): 'came out'. Through the joint action of Driss and Frédéric, the term is integrated into the milieu as Driss then uses the term himself (speech turn 22).

During Driss's contribution, the students engage in asking and answering clarification questions which lead them to explore and transform the didactic milieu. The milieu is both constructed by the students' questions and answers, and rendered more resistant by those same questions. For example, when Frédéric challenges Driss by postulating that his protocol underestimates the ball's diameter because it compresses the ball (19, 23), Driss has to spontaneously respond to his question.

Driss's expression in 16 and 18 is pre-prepared and demonstrates an ability to reproduce language. Frédéric's probing questions in 19 and 23 demonstrates Frédéric's ability to mobilize language spontaneously to question Driss's description. Frédéric's questions then constrain Driss to respond, without preparation, and to produce a spontaneous, appropriate use of the target language.

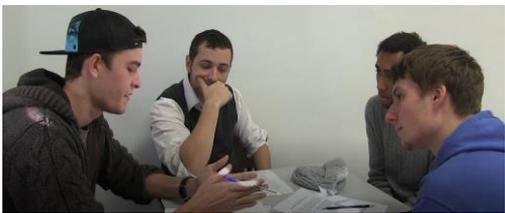
The spontaneous mobilizing of language resources is a necessary step in the appropriation of an L2. The students' exchanges form a transactional milieu where the targeted knowledge (strengthening of language skills) is the object of the transactions between them as they seek to spontaneously mobilize their language resources. Through these transactions the students can be seen to explore beyond the contract – the *already-there*. That is to say, they go beyond a pre-prepared use of language and are constrained to use the target language spontaneously. In other words, to the unknown in the milieu. This spontaneous use of language can be seen as the demonstration of efforts to strengthen language skills. It is made possible by participating in the social game of exploring the jargon and thought style of measurement in physics.

Certain aspects of Driss's practice are undertaken in what might be considered to be a non-scientific thought style. The habit of checking on internet to be sure of the validity of an experimental result can be seen as the consequence of an ill-fitting understanding of experimental science. It is not challenged at this point and is therefore unexplored potential within the milieu. Also, the group does not challenge or explore the assumption that a calliper would produce a result which was accurate to the tenth place (speech turn 18). This instrument, if used properly, should easily produce a result which is accurate to the hundredth place. This is a very important aspect of physics as a practice, and harks back to the associate physics professors' comment in the exploratory lesson: '6.50 is much more accurate than 6.5 as a physicist you should know that'.

Co-constructed Meaning

A fairly common occurrence in the roleplay are examples of students 'pooling' vocabulary. Frédéric providing Driss with the term he lacked (*came out*, 21) is an example. This is, on one level, an illustration of a transactional milieu, as the students trade one of the objects of knowledge at stake: vocabulary. It is also a clue as to how meaning is co-constructed in the group, as it demonstrates how Frédéric and Driss are literally sharing the same vision of the discussed set-up. Frédéric is able to provide Driss with the term he lacks because he is following Driss's representation of events and thus can guess the term he lacks. Again, the symbolic/material milieu would appear to help this process: Driss had used his hands to represent the two set squares (frame 20) just before Frédéric volunteered the term '*came out*' in speech turn 21.

Extract 4: Asking and Answering Clarification Questions

<p>29. Paul (P): The two set square – set square? <i>(looks at Driss for confirmation the right word)</i></p> <p>30. Driss (D): yeah yeah</p> <p>31. P: ... have to be erm very parallel. How can you be sure that they are er ...?</p>	 <p>Frame 31: 'The two set square ...'</p>
<p>Following Driss's description of the protocol he had devised to measure a tennis ball's diameter, Paul asks Driss to justify a detail in the protocol. Driss's method involved lodging the ball between two set squares, both of which, to give an accurate measurement, must be parallel in a rigorous set up. Paul wants Driss to explain how he ensured that the set squares were parallel (Speech turn 31). He begins tentatively by checking that "set square" is the correct term (speech turn 29). This is because he discovered the term "set square" from Driss's protocol description (speech turns 5), when Driss translated the term with "équerre" for him (7): it is thus a new term for Paul. Driss confirms it is the right term (speech turn 30). Paul then continues with his question of asking Driss how he was sure his set squares were parallel (speech turn 31).</p>	
<p>32. D: (Laughs) er we took er a <i>(looks around the room to find an example of what he wants to say. Struggles to find the word)</i> ... not a book... Because they are on lines <i>(uses hands to demonstrate lines)</i>.</p>	 <p>Frame 32: '...they are on lines ...'</p>
<p>Driss laughs as he struggles to find the term to describe what he had used to ensure the set squares were parallel. It appears to be a common object in a classroom as he looks around the room to find an example of the object to show the other students what he used. He does not find an example: he states it was not a book (speech turn 32), which helps the other students to understand that it must be similar to a book. He adds "they are on lines" meaning the set squares were placed on lines and he uses his hands to demonstrate lines (frame 32).</p>	
<p>33. Frédéric (F): Ah a copybook!</p> <p>34. D: yeah, a copybook. So, it was true the set square was on lines.</p>	 <p>Frame 33 'A copybook!'</p>
<p>The clue 'book' and 'lines' help Frédéric to realise what Driss is referring to (speech turn 33) and he exclaims "A copybook!" (a term often used in French schools for the notebooks that pupils use to note down an English lesson). Driss confirms the term copybook (speech turn 34), and returns to Paul's question by explaining the set squares were placed on the lines of the copybook to ensure they were parallel. Frédéric</p>	

rotates his fingers rapidly in a spinning motion on each side of his temples, perhaps suggesting the term had somehow popped up in his head (Frame 33).

35. P: ... and how can you be sure the lines in the copybook are really parallel? (*Said with a smile as it is not a serious question*)
36. D: Ah that's not my problem. That's another thing (*the students laugh*)



Frame 35: 'How can you be sure ...?'

Paul continues, somewhat humorously, by asking Driss to explain how he can be sure that the lines on the copybook were parallel (speech turn 35). The four students laugh (Frame 35). Paul's question is an example of a number of exchanges, during the roleplay, which serve to create a feeling of light humour and goodwill between the students.

A question that Driss could have been asked, was how it would have been possible to align two set squares perfectly on the lines of a notebook. Though it would have been possible to align perfectly one set square on the line of a copybook, and to lodge the ball against this set square, it is unlikely that the second set square, lodged against the other side of the ball, would also have been exactly aligned on another line of the copybook. This would be to assume that the tennis ball's diameter was an exact distance between two lines of a copybook. Perhaps Driss could have justified that the second set square was aligned using a nearby line used as a reference.

The Already-There

As the roleplay progresses, certain elements can be seen to move from the milieu to become part of the contract as a result of previous transactions. For example, the term 'set square' used by Paul in speech turn 29. Paul learnt the term from Driss who translated it for him (speech turn 6), following Driss's own use of the term in his protocol description (speech turn 5).

This might also be the case for the structure 'how can you be sure?' used in speech turn 31 and 35 by Paul. Similar structures were used previously by Frédéric in speech turn 10 ('to make sure it's er parallel'), and speech turn 19 ('how could you be sure'). However, at the beginning of the roleplay Frédéric did not appear to master

this structure as he used a clumsy expression 'How did you do to be really parallel?' (Appendix F, line 24). Therefore, Frédéric himself may have integrated this term from elsewhere. Perhaps from Jean ('Are you sure ...' Appendix F, line 183). Alternatively, the fact that he is required to mobilise his language skills to participate in the roleplay, may be enabling him to better use and access his grammatical knowledge of English. In other words, he may be accelerating the links between his own cognitive activity and language production.

In the interaction between Paul and Driss the issue of the set squares being parallel is raised again. Paul asks Driss to explain how he ensured his two set squares were parallel: 'P: ... have to be erm very parallel. How can you be sure that they are er ...?' (speech turn 31).

This issue can be seen to have passed from the milieu into the contract (the *already-there*) and to be transforming the milieu in the process. The question of instruments being parallel, and being sure that they are so, was part of the milieu-problem in extract 2, whereas it is more a part of the contract in extract 4.

This kind of attention to detail regarding the experimental set-up is specific to experimental science. Concern for the question can be considered as a practice sharing some epistemic kinship with practicing scientists.

The Resistances and Transactions of the Milieu

This new milieu continues to be challenging in terms of vocabulary: though Driss wants to reply that he ensured his set squares were parallel by placing them on the lines of a copybook/notebook, he lacks the term notebook/copybook. Frédéric appears to guess from Driss's symbolic representation of the lines of a notebook/copybook with his hands (frame 32), as well as the reference to a book (speech turn 32), the term that Driss is looking for. Frédéric interjects with 'Ah a copybook!' (speech turn 33). Driss responds: 'yeah, a copybook. So, it was true the set square was on lines.' (speech turn 34).

As with the term 'set square', the term 'copybook' is another example of a resistance, becoming the object of a transaction between the students in the milieu.

The point of the virtual impossibility of both set squares being placed on the lines of a notebook/copybook is still not as yet explored.

Co-constructed Meaning

The visual fixation of a symbolic representation of an object/set-up, whilst thinking, appears to be one of the factors helping other members of the group to guess an interlocutor's missing vocabulary. For example, 'copybook', as we saw above, emerging from the exchanges in speech turns 32-34. This would suggest that, as a result of their interactions, the students construct a shared collective representation of the experimental details discussed.

There is also a particular shared thought style explored by the students with attention to the rigorous details specific to experimental science. At this stage of the discussion this is mainly limited to ensuring that the set squares are parallel. However, Frédéric (extract 3, speech turn 23) has already introduced another issue regarding Driss's set-up: the question of the tennis ball being compressed as it is held by measuring instruments. This issue is not as yet shared by the group. He will finally succeed in bringing this point into the milieu in extracts 5a to 5c, thanks to the transactions between the students using a symbolic milieu to represent a material milieu. This included hands or pencils to represent set squares, and a hat to represent a tennis ball, as we shall see.

Exploring Alternatives

Frédéric wants to suggest an alternative way of using the measuring instruments in Driss's protocol. His suggestion is presented in detail in extracts 5a-5c below. Frédéric thinks this idea will minimize the uncertainty in the measurement linked to the difficulty of identifying the widest part of the ball (which corresponds to the ball's diameter). He argues that Driss's method might slightly underestimate the diameter of the ball, as lodging the ball between the calliper (or the set squares – it is not clear which method Frédéric is referring to) would have entailed slightly compressing it. It is not possible to say whether or not Frédéric is right in suggesting his method would have obtained more accurate results. It would be necessary for Frédéric to actually execute the protocol he suggests. Also, it is highly unlikely a protocol using set squares could have obtained a more accurate result than one obtained with

a calliper, on condition the calliper were used correctly. The details of Driss’s use of a calliper are not sufficiently clear to ascertain if this were the case in his protocol. However, the questioning, challenging and exploring are in themselves evidence of an appropriate scientific thought style, as well as excellent opportunities for exploring language.

In the extracts described below, Frédéric is trying to communicate his suggestion to the group but this requires three attempts. The interactions between the four students, as they attempt to see ‘eye-to-eye’ on the sense of Frédéric’s contribution, will be analysed closely. Each of the three attempts is described separately below.

Extract 5a: Exploring Alternatives - First Attempt

<p>37. F: instead of putting the set square like this (Frame 37: places his two hands parallel to each other, outer edge on the desk, fingers directed away from himself) why don’t you put it like this (Frame 37b: places outer edge of hands along an imaginary line, wrists bent at an angle of 90°, palms facing toward himself, tips of fingers pointing to each other) erm, you’ll be sure .. er you’ll be sure because of the (forms a spherical shape with his hands)</p>	 <p>Frame 37a: ‘Instead of putting the set squares like this’</p>  <p>Frame 37b: ‘Why don’t you put it like this’</p>
<p>Frédéric suggests an alternative way of using the set squares: he does this first by representing the two set squares with his hands lengthways (Frame 37a), then by turning his hands at a 90° angle to his wrists, to suggest placing the set squares either side of the tennis ball (Frame 37b).</p>	
<p>38. P: if you do this you have to know the centre of the ball because you have to put the square on .. the .. (Frame 38: he demonstrates the two set squares as his two hands turned at an angle of 90° at the wrist, the tips of the fingers facing toward the imaginary ball).</p>	



Frame 38: 'It has to be the centre' (29:30)

Paul imitates the same positioning of the set squares (Frame 38), but questions the usefulness of such an operation, arguing that it would be necessary to know where the centre of the tennis ball was for this to be successful. He appears to have misinterpreted Frédéric's suggestion and it is not easy to discern how valid his point is from a physics point of view. His question does serve to indicate to Frédéric that his idea is not yet clear to the others and that he needs to find a way to help them better visualise his suggestion.

The Already-There

There are various behavioural habits and discourse habits that can be considered as part of the contract in extract 5a: the students engage in challenging each other's assumptions about how best to use the set squares in Driss's set-up. They can also be seen to use a range of structures and jargon. For example, jargon such as 'putting the set square like this' (37), or the interrogative form 'why don't you.' (37), or the conditional 'if you do this, you have to know... the centre of the ball' (38).

Frédéric and Paul continue to use symbolic representations of an absent material milieu to transact with the group (frames 37a, 37b, 38). This is possible thanks to the common epistemic background of considering the factors which contribute to the uncertainty of a measurement and how to reduce them, played out within the context of a cooperative game.

The Resistances and Transactions of the Milieu

Paul and Frédéric do not share a common representation of Frédéric's suggestion. Neither the symbolic representation of the set-up material, nor the jargon and range of grammatical structures they do have, are sufficient at this stage to construct a shared understanding of Frédéric's idea. This is probably because it is a new idea and represents something of a rupture with the previous line of questioning and reasoning in the group as to how to ensure the set squares are parallel. Frédéric's suggestion creates a more resistant milieu with regard to the issue of using Driss's material as efficiently as possible. Frédéric is constrained to explain his idea more clearly and the other students are constrained to remain attentive to his explanation.

Extract 5b: Exploring Alternatives - Second Attempt

39. F: with the, **with the set square**, (*Frame 39a: he takes two pencils and places them upright on the table facing each other*) you put the ball progressively and **when the distance is at the maximum** you have the **diameter** (*Frame 39b: as he says maximum he gradually widens the space between the two pencils whilst maintaining them parallel to each other and on an imaginary line. He looks at the other students to check comprehension but they show by their blank faces that they have not followed his reasoning*). You understand?



Frame 39a: "with the set square"



Frame 39b: “when the distance is at the maximum”

Frédéric explains his idea again, this time using two pencils to represent the set squares (39a). He widens the distance between the two pencils to symbolise how he would use the set squares in his method (39b). The other students show by their blank expressions (frame 39b) that they still have not understood what he wants to suggest.

Co-Constructed Meaning

Throughout extracts 5a-5c, there are regular signs from all of the students. This enables a semiosis process within their joint action. Eye-contact and facial expressions to indicate comprehension or non-comprehension are very much a part of the group communication. Frames 39a shows the students listening attentively to Frédéric whilst studying the symbolic representation of the material set-up that Frédéric wishes to communicate. The students' blank expression in frame 39b indicate to Frédéric that they still have not understood his suggestion.

Extract 5c: Exploring Alternatives - Third Attempt

40. P takes the two pencils. F indicates to him that he wishes him to maintain them upright as he had just done in his demonstration. Then, with P holding the pencils upright, F takes a woollen hat and rolls it into the shape of a ball (Frame 40).



Frame 40: Gesturing with hands (29:51)

Frédéric explains his idea yet again, this time using another student to help him demonstrate physically his idea, and using the pencils and a hat to symbolise Driss's measuring instruments. He asks Paul to hold the two pencils upright whilst he uses a rolled-up hat symbolising the tennis ball (Frame 40).

41. F: You put it (Frame 42: he passes the ball – the hat- through the space between the pencils)
42. Jean (J): **Oh Okay!** (Frame 42: his face lights up in comprehension as the ball – the hat – passes through the two pencils)
43. F: so, you put it, it's becoming bigger and at the maximum you have the diameter
44. D: yeah, ok



Frame 42: speech turn 42 'Oh Okay!!'

Frédéric succeeds in getting the other students to understand his idea of measuring the ball several times (represented by the woollen hat rolled into the shape of a ball) as it passes through the set squares (represented by the upright pencils), the widest point being the best indicator of the most accurate measurement of the ball's diameter (Frame 42).

Co-Constructed Meaning

The students' faces finally light up in comprehension in frame 42, accompanied by 'Ah Okay!' in speech turn 42, to indicate that they have now understood Frédéric's idea

The time it takes for the other students to understand Frédéric's suggestion may be due to a number of factors. Perhaps his lack of vocabulary at certain points, though he does successfully represent symbolically what he cannot say with words: for example, his hands to represent lengthways (frame 37a), and widthways (frame 37b). A more likely explanation is that this idea represents a rupture with the previous issue explored in the contract (parallel set squares) and therefore it requires more time to be fully grasped. Many human exchanges are helped along by an interlocutor half-guessing what is about to be said. When a contribution is unexpected and somewhat original, it takes longer for interlocutors to jointly construct the sense of the message, as might be expected.

This passage was chosen precisely for this reason. It was with the objective of finding clues as to the way language might be constructed and developed in the semiotic systems typical of a language classroom (Sensevy, Gruson, & Forest, 2015).

The successful integration of Frédéric's seeing-as, is the result of a cooperative group effort to construct meaning. This begins with a question from Paul (speech turn 38) which allows Frédéric to realise some aspect of his seeing-as is not clear, and to give him the impetus to describe his idea more visually. He uses the pencils as props to demonstrate the widening distance between the set squares. He realises from Jean's, Driss's and Paul's faces (frame 39b) that his seeing-as is still not accessible to the other students. He is thus compelled to render his suggestion even more visually accessible in order for it to be understood. He then engages Paul in his demonstration by indicating to him that he should hold the pencils, and takes Driss's hat to symbolise a tennis ball which he passes through the widening pencils/set squares. These moves, together with the students' fixed attention on his visual representation, mean that his seeing-as becomes accessible to the group.

The alternative method that Frédéric suggests in the extracts above is an example of approaching a problem in a particular thought style. A common misconception of scientific

practice is that it is primarily founded on sophisticated equipment, as discussed in 8.5 in the laboratory report analysis. However, Frédéric’s approach, which entails taking several measurements of the various items in the set-up whilst in movement, is sophisticated in method but simple as regards the material. It is arguably based on a more fitting conception of scientific practice. This might also explain the time it takes to integrate the particular thought style implicit in his suggestion.

Global Didactic Analysis of the Extended Roleplay

The choice of a scientific field for the content aspect of this CLIL sequence was due to its potential to generate pertinent question-and-answer dialogues, which are a common feature of the language of science (Lemke, 1990). The Extended Roleplay is the culmination of the sequence. It was devised so as to constrain students to engage in a number of dialogical forms inherent in scientific practice: asking and answering clarification questions, challenging and defending claims, and exploring and predicting (empirical) relationships (Duschl et al, 2007). Table 13 summarises examples of students engaging in such dialogue in extracts 2-5c presented above.

Table 13

Question and Answer Dialogues

Asking clarification questions	Answering clarification questions	Challenging claims	Defending claims	Exploring predictions and relationships
<p>2 Jean: I’d like you to explain to me exactly what it does</p> <p>10 Fréd: ah – to make sure it’s er parallel?</p> <p>19 Fred: how could you be sure that the ball can’t be pressed by the calliper when?</p> <p>29/31 Paul: have to be erm very parallel. How can you be sure that they are er?</p>	<p>9 Driss: we took two set square and we stuck the ball between two set square like that</p> <p>22 Driss: yeah, yeah came out. So er we really tried to fix it and er the moment when we fix it we know that we were er we were</p> <p>32 Driss: Because they are on lines</p>	<p>23 Fred: nods. I think er if the ball is er out of the calliper that’s because the diameter you measure is a little er a little more than</p> <p>35 Paul... and how can you be sure the lines in the copybook are really parallel?</p> <p>37 Paul: if you do this you have to know the centre of the ball because</p>	<p>24 Driss: maybe but ... the method was good because after we checked</p> <p>39 Fréd: with the with the set square, (he takes two pencils and places them upright on the table facing each other) you put the ball progressively</p>	<p>14 Fréd: (<i>interrupts Driss, to address J</i>) For your problem</p> <p>37 Fred: instead of putting the set square like this</p> <p>39 Fréd: with the with the set square, (he takes two pencils and places them upright on the table facing each other) you put the ball progressively</p>

These questions, together with their answers, were the dialogical transactions which functioned as the pillars of the learning game from which to explore the didactic milieu. The didactic milieu is where each of the individuals have the opportunity to practice developing their fluency, accuracy and confidence in using English. It is the frequent struggle of being confronted with the need to develop language skills that leads to progress in a language, as a person confronts and explores their personal links between thought and language. However, this struggle is only possible in the context of a cooperative action within a social game. This is termed an epistemic capacity in JATD.

The JATD as an Analytical Framework

A disadvantage of the table above, is that in separating the type of reasoning or activity from the knowledge at stake, it is not easy to identify the epistemic value of a statement. For example, speech turn 35 ‘... and how can you be sure the lines in the copybook are really parallel?’ (Paul) might appear to be simply an evaluation question. Through the lens of the description of the didactic analysis, other aspects of its content become visible. It is a question that has already been asked several times and is said in humour. It does not introduce any new epistemic stake into the milieu as far as the practice of physics is concerned. This is because this point has already been debated and to some extent resolved (Driss in speech turn 32: ‘Because they are on lines’). Driss’s answer is a valid justification of the parallelism of the set squares, though it does not resolve the issue of the diameter of the tennis ball not corresponding exactly to the distance between two lines of a notebook/copybook. Paul’s comment (35) thus functions in the students’ exchanges as a recognition of pertinent vocabulary and hints at an epistemological issue as to what can be considered to be ‘true’ in an experimental set-up. The humour is based on the prospect of an infinite, impossible quest to determine what is ‘true’.

Likewise, the true epistemic value of Driss’s justification ‘Because they are on lines’ (32) is invisible when presented in a table separately from its context. This statement could appear to be simply informative equivalent to telling somebody the time of day. The JATD framework analysis renders visible the epistemic interest of his statement. It can be discerned that he is justifying the rigor of his protocol by the fact that he ensured the set

squares were parallel in placing them on the lines of a notebook. It is a geometry-based justification linking the parallelism of the measuring instruments with the accuracy of the measurement and it is a position which is in keeping with an appropriate scientific thought style. However, as we saw earlier, this leaves unexplained how both set squares could be placed exactly on lines.

Similarly, Paul's question in speech turn 38 ('if you do this, you have to know... the centre of the ball') is useful to the group in that it encourages Frédéric to better explain his idea. The didactic description reveals it is not of interest as regards improving the experimental set-up that Frédéric proposes: the centre of the ball is not relevant to his proposition. It is a statement which functions, therefore, as a kind of car jack in the cooperative game, enabling the students to continue co-constructing meaning in exploring the milieu. Though it does not widen the epistemic scope of Frédéric's proposition as regards physics as a practice, it does create a new resistance in the milieu from which the students can explore developing their language skills.

Tables of categories such as the example above are often used in preparing programmes or evaluations and can be useful tools. However, as the above examples illustrate, they can deform substantially the import of didactic action by not situating the activity in its didactic, epistemic and even epistemological context.

In categorising the action of the students separately from the epistemic potential of the milieu, this form of categorisation hinders a full description of the moves of the students in relation to the knowledge at stake.

The Contract-Milieu Dialectic and the Cooperative Game

In the lessons preceding the extended roleplay, students acquired the jargon and behavioural habits necessary to participate effectively in the group exchange. They designed and executed a protocol to measure the diameter of a tennis ball and sought how to minimise the uncertainty in their measurement. They participated in pair-work activities describing their efforts and in doing so developed their English language expression. They also produced written descriptions of their protocols using the scientific format of the laboratory report (see

8.2-8.5). They therefore had both a common epistemic background (some understanding of the factors contributing to the uncertainty of a measurement), and a common epistemic practice (they had all executed a protocol), which included the behavioural habits of working in pairs or small groups to develop their L2 skills. This had enabled them to acquire a range of jargon associated with the practice of measurement which they could then reinvest in the cooperative game of presenting, evaluating and ranking protocols in a group discussion. The relation contract-milieu was in this way sufficiently well balanced for learning to occur. A transactional milieu emerged from the students' cooperation where they were able to co-construct meaning thanks to this common background.

Meaning-Making and Cooperative Action

Within the nooks and crannies of the didactic activity of the extended roleplay is a nodal-like system of epistemic capacities where L2 learning might emerge. As we saw in the analysis, a resistance in the milieu, such as the common problem of lacking vocabulary, obliges the participants to cooperate to achieve mutual comprehension. This form of cooperation is an important stage in L2 acquisition (and language learning in general, including a first language). It is the opportunity for a learner to gradually link together the various clues in a given context in order to apprehend its sense. This is a complex process as meaning is something of a moving target that is co-constructed and constantly evolving. For this reason, it is also an opportunity for a learner to contribute to the evolving meaning and in so doing, develop their L2 expression. These kinds of interactions become possible within the context of a common background where a range of epistemic capacities may emerge. Table 14 below seeks to lend some insight into the various moves involved in an effective didactic activity of this type.

Table 14

Co-Constructing Meaning in Mini-Groups

Behaviour facilitating the emergence of a safe, courageous space		
Subject	Inter-personal Space	Social
<ul style="list-style-type: none"> • Taking turns when appropriate and ending conversation when appropriate • Helping the discussion along: confirming comprehension, inviting others to speak. • Using social conversation/humour to facilitate communication in the group. <p>Oral Comprehension</p> <p>Signal that you do or do not follow an interlocutor, as well as the interactions between third parties in the group discussion</p>	<p>The cooperative co-construction of an interpersonal space: a courageous yet safe space, where a semiotic system can function effectively, and where individuals feel comfortable in exploring their personal cognitive links between thought and language.</p>	<ul style="list-style-type: none"> • Group facilitation of turn-taking • Group attentiveness, and signs of interest in the speaker’s intervention (eye-contact, body-language, breathing patterns). • Establishing a feeling of group friendliness and goodwill • A shared understanding of the objectives of the learning game. • Shared enthusiasm to communicate <p>Oral Comprehension</p> <p>Group awareness and necessary adaptation according to different individual’s reception of ideas, but also different individual’s needs (frame 16): allowing time for confirmation of comprehension (speech turns 9 -16), recognizing the need for all members of a group to show understanding.</p>
Discourse patterns generating cooperative exchanges		
<ul style="list-style-type: none"> • Initiate discourse • asking and answering clarification questions • challenge and defend claims • explore relationships in predictions and results • Evaluate (interactively) each student’s protocol and uncertainty estimate. 	<ul style="list-style-type: none"> • A shared, or partially shared, understanding of the significance of each type of intervention: the style of discussion and reasoning that is effective in the pursuit of a shared understanding of empirical claims. <p>Establishment of agreement about the validity of ideas.</p>	<ul style="list-style-type: none"> • As a group, convene on the overall direction and sense of the discourse, established by the different interventions of the group members.

The cooperative, co-construction of language		
<p>Flexible language use when lacking vocabulary oneself:</p> <ul style="list-style-type: none"> • the skill of conjuring expedient terms • the skill of communicating according to one's own limitations • Practices of translating, miming, and symbolizing <p>Flexible language use adapting to interlocutor(s) limitations: Explaining in some alternative, comprehensible fashion</p>	<p>A pooling of resources:</p> <ul style="list-style-type: none"> • sharing vocabulary, structures. • sharing stimulation of cognitive activity conducive to strengthening the links between thought and language 	<p>Generating an enthusiasm of each individual's desire to communicate and to be understood. Creating the motor which stimulates the cognitive activity necessary to produce and develop thought and language.</p>
Language (widest sense) enabling the cooperative, co-construction of meaning/reality		
<p>Contributing to the discussion using the language games detailed in table 11:</p> <p>Persuading colleagues to see a situation differently</p>	<p style="text-align: center;">Co-constructed meaning</p> <p style="text-align: center;">A social, negotiable product of interaction</p> <p>A shared, or partially shared, perception of reality:</p> <ul style="list-style-type: none"> • Establishment of agreement about the truth of symbolic objects. • The convening of a shared thought style (on a fitting execution/conception of scientific practice) • An epistemic language game • An epistemic scientific practice game 	<p>As a group, convene on the overall 'reality' emerging from the different interventions of each member of the group.</p>

The Extended Roleplay: Conclusion

Participating in the role-play required the students to make various epistemic, and even epistemological commitments. For example, Frédéric in speech turn 19 'how could you be sure that the ball can't be pressed by the calliper when ...?'. The context of this statement shall be briefly outlined: Frédéric is reacting to Driss's protocol using two set squares to measure the tennis ball's diameter. Frédéric suggests that fixing the ball between the two set squares would slightly compress the ball and so distort the result. His contribution thus includes an epistemic and epistemological engagement: that a better measurement can be obtained by being careful to avoid this error, and that a protocol and its instruments are an integral part of a measurement result. He contributes this idea amongst others to the discussion, and when he lacks the language skills to present his ideas clearly, the group cooperatively overcome the resistances of the milieu to find the necessary jargon and symbolism to co-construct shared meaning.

A condition of the extended roleplay producing epistemically-dense interactions of this kind, was the students feeling sufficiently authorized to engage in such epistemic and epistemological commitments. This was a result of certain habits (Dewey, 1938) being introduced early into the language classroom, where participation and engagement were strongly encouraged. For example, as detailed in 8.2, the sequence begins with students being immediately asked to devise a protocol and to describe it to a partner in the targeted L2 language. The difficulties encountered are not 'errors' or inadequacies, but opportunities to research and integrate the jargon of the practice. In the Enhancing Fluency Extract in 8.4, students are assessed on the basis of preparation, engagement and participation and not uniquely their level of English. In this way, all students are sure of succeeding on condition that they are fully-engaged with their own learning process.

A full analysis of this aspect of the sequence is beyond the scope of this thesis. It is nevertheless, one of the necessary elements of this kind of didactic activity, together with the imperative of a common epistemic, situational and practice background, and an accurately developed contract-milieu equilibration.

8.6.1 Preliminary Conclusions with regard to the Study Research Questions

The research questions which are addressed in this study will now be considered with regard to the extended roleplay analysis.

Question 1: How can the combined objectives of a conceptual understanding of scientific practice, together with work on language skills, be effectively described?
What is the role of jargon in the construction/development of a capacity?

The JATD notion of a contract-milieu dialectic was used as an analytical tool to examine the didactic phenomena in the extended roleplay. The milieu of the roleplay could be seen to be a resistant and transactional milieu (Sensevy, 2008; Gruson, 2018), where students undertook didactic transactions in the form of their questions, explanations and justifications. The various resistances in the milieu, whether it be vocabulary or representations of physics as a practice, led to transactions between the students which both constructed and transformed the milieu.

The spontaneous mobilising of language resources is a necessary step in the appropriation of an L2. The notion of a resistant and transactional milieu served as a useful tool in describing how the students' exchanges could serve to strengthen language skills: the spontaneous mobilisation of language resources became the object of the transactions between them. Through these transactions the students can be seen to explore beyond the contract —the *already-there*. That is to say, they go beyond a pre-prepared use of language and are constrained to use the target language spontaneously. As the roleplay progresses, certain elements can be seen to move from the milieu to become part of the contract as a result of such transactions. That is to say, they become habits of action.

The notion of student-originator, denoting didactic phenomena emanating from students' own productions, is useful for indicating the students' contribution to the milieu-problem in the extended roleplay. The notion of contract-milieu equilibrium highlights how the students' transactions are only possible in an accurately assessed balance between the contract and milieu.

Question 2: What capacities can be identified in the didactic activity of the students participating in the case study, and what evidence is there of effective work on those capacities in the didactic activity between themselves and with the teacher?

In this last lesson of the sequence, the students can be seen to engage in effective work on a range of epistemic capacities within the joint action of the group, without the teacher. The student Driss describes a protocol in detail and justifies the uncertainty in his measurement using a jargon and thought style which can be seen to bear an epistemic kinship to a connoisseur of the practice. That is to say, an attention to detail regarding the experimental set-up which is specific to experimental science: this approach can be considered to demonstrate some epistemic kinship to the practice of scientists.

The other students listen attentively and critically to Driss's description and challenge him to justify the details of the execution of his protocol. In engaging in this social game, the students can be seen to demonstrate knowledge of the jargon of physics as a practice, expressed in English. The quality of their expression is sufficient to be able to evoke a range of situations using different structures and jargon.

Certain aspects of Driss's practice are undertaken in what can be considered to be a non-scientific thought style. For example, checking the diameter of a tennis ball on the internet, or not explaining how both set squares could be placed on the lines of a notebook.

This limitation is to some extent explored in the joint action of the group when the students engage in challenging assumptions about how best to use the set squares in Driss's set-up. When they lack the language skills to present ideas clearly, the group cooperatively use symbolic and material representations of their ideas. This, together with certain behavioural habits (listening and observing attentively), and certain discourse habits (asking and answering questions), enables them to co-construct meaning as a group.

This ability to engage in the co-construction of meaning with others can be considered to be an epistemic capacity to be developed as regards language acquisition. The cooperative game of challenging and justifying the assumptions leading to a measurement result can be

considered to bear an epistemic kinship to the peer review process in academia (the connoisseurs of scientific practice).

Question 3: What are the concrete conditions of a CLIL programme which enable students to develop a conceptual understanding of scientific practice whilst improving their English language skills?

How ought CLIL practice interweave content and language, and in what ways are these two elements then influenced by their convergence?

What are the frontiers in a given speciality that necessitate language teachers cooperating with specialists of a body of knowledge?/ that limit the scope of language teachers in a CLIL sequence?

The task of ranking the protocols according to the degree of uncertainty in the measurement was integrated into the roleplay so as to constrain students to explore and question the many factors contributing to a measurement result. This is an exercise which is unlikely to occur in physics laboratory work, at least not in such detail: it was an activity allowing for the exploration of semiotic systems (Sensevy, Gruson & Forest, 2015), which can be considered as necessary to a language learning milieu.

This exploration was possible thanks to certain common elements in the students' experience: they shared the same situational background of a cooperative game, and the same exploration of a recognisable thought style (that of experimental science). In this way, they shared a common background from within which they could seek to negotiate meaning. This common background can be added to the list of conditions necessary for this CLIL sequence; that is to say a CLIL sequence founded on student-originator productions in the exploration of a semiotic system.

Another condition of the extended roleplay, in order for it to produce epistemically-dense interactions in a challenging milieu, was the students feeling sufficiently authorised to engage in such epistemic and epistemological commitments. This was a result of certain habits (Dewey, 1938) being introduced early into the language classroom. Participation and engagement were strongly encouraged and difficulties encountered were not 'errors' or inadequacies, but opportunities to research and integrate the jargon of the practice. Students

were assessed on the basis of preparation, engagement and participation, and not uniquely their level of English. In this way, all students were sure of succeeding on condition that they were fully-engaged with their own learning process.

Together with the imperatives of a common epistemic, situational background, and an accurately developed contract-milieu equilibrium, the confidence of students to participate fully in the roleplay was another necessary condition of this kind of didactic activity.

Chapter 9: Findings and Discussion

The origin of this study was a desire to develop language courses that would somehow inspire and empower students to be capable of autonomously, and successfully, pursuing their subsequent on-going language learning. In other words, to educate students in the widest sense of the term, so that they would acquire a culture of language learning.²⁷

As discussed in Chapter 1, this thesis is based on the premise that a language has meaning in context, that is to say a cultural context. This means that for language learning to occur, the target language must be encountered and developed within a context that would give it meaning. To that end, a challenging, intensive CLIL programme was developed based on the scientific culture of measurement. The hypothesis underlying the study, was that in exploring the language and practice related to this field, students would develop useful habits for successful future language learning experiences.

It is beyond the scope of this research to determine to what extent, if indeed at all, this initial objective was achieved. Firstly, because this long-term goal is unlikely to be achieved on the basis of a four-week course: a much longer coursework period would be required to be able to test this hypothesis meaningfully. If students proved to be unsuccessfully pursuing on-going language learning it would not be possible to know if this were due to an ineffective programme or an insufficiently long programme. Secondly, establishing any conclusion on this point would require some kind of investigation of students' long-term language learning experiences: such an investigation was not undertaken in this study, though it is a question that could be pursued in future research.

What is investigated in this thesis are the details and the impact of the programme that was developed with this ultimate goal in mind. The students were presented a range of situations that were orchestrated in such a way as to ensure that they would be constrained to explore, collaboratively, various milieu-problems in the *jargon* and *thought style* of a scientific practice. This was based on the hypothesis that in the effort to master a social game

²⁷ See the JATD glossary for the full list of notions used by the Didactique Pour Enseigner (DpE) educational community working toward this educational goal: <http://tacd.espe-bretagne.fr/glossaire/>

based on scientific practice, they would develop the necessary language resources to succeed in that social game, as well as a culture of language learning. To that end, multiple activities were designed which provided opportunities for students to co-construct meaning in English whilst acquiring the *jargon* and *thought style* of the practice of measurement.

From the didactic analyses in this study, it has been possible to determine the capacities that students can be seen to demonstrate or be developing by the end of the sequence. It is also possible to discuss whether or not they could be considered to be developing a culture of language learning by the nature of the language learning habits they were practicing.

Three main research questions were considered at the end of each of the didactic analyses from 8.2 to 8.6. These questions shall briefly be restated here.

Question 1: How can the combined objectives of a conceptual understanding of scientific practice, together with work on language skills, be effectively described?

Question 2: What capacities can be identified in the didactic activity of the students participating in the case study, and what evidence is there of effective work on those capacities in the didactic activity between themselves and with the teacher?

Question 3: What are the concrete conditions of a CLIL programme which enable students to develop a conceptual understanding of scientific practice whilst improving their English language skills?

Question 1 will first be considered separately, in order to clarify some aspects of this question. It will then be considered conjointly with question 2 as in reality the two are difficult to separate.

9.1 General Conclusions

Question 1: How can the combined objectives of a conceptual understanding of scientific practice, together with work on language skills, be effectively described?

The JATD notions and descriptors are vital tools for addressing the research questions of this thesis and for the empirical analysis which led to its general conclusions.

The preliminary conclusion at the end of each didactic analysis (8.2 – 8.6) outlined how the JATD notions are used in relation to each didactic analysis.

Classroom practice is complex: how and where learning occurs in a classroom environment is not easy to determine. Learning a language is equally complex: the kinds of classroom learning environments that might be conducive to effective language learning is a question of considerable scope. Any attempt to address these challenging, multifaceted issues must entail correspondingly challenging, multifaceted answers. A starting point which the Joint Action Theory in Didactics framework assumes as a given is that a scientific investigation of such questions begins with empirical reality: that is to say, close inspection of what is actually happening in classrooms in relation to the knowledge taught.

To this end, the constantly developing JATD descriptive notions offer the means to finely describe classroom practice vis-à-vis a given body of knowledge. They offer the possibility of engaging in a pertinent presentation and discussion of the issues and questions arising in classroom activity.

Jargon and Thought Style

A description of the main notions used in this study can be found in Chapter 2, including the two notions of particular importance in this study, *jargon* and *thought style*. As they were essential notions for investigating this CLIL sequence, their import will be considered further here.

Firstly, as regards the construction of the sequence, the notions served to highlight the common thread weaving together the different activities throughout the programme. The first lesson began with the practical task of devising a protocol to measure the diameter of a tennis ball, and to research the jargon necessary to describe this protocol in detail. Students communicated using jargon in context: for example, in response to the teacher's questions 'How can you be sure you are exactly in the centre of the ball? How tight did you pull the wire/string/thread? How many times did you measure the ball? Which measurement did you take? Did you take the average of the measurements or the widest measurement? Which is best? Ok so you divided the circumference by pi - what about the uncertainty?' (Genesis of a Thought Style 8.3). In this way, students gradually acquired the beginnings of a jargon associated with the practice of scientific measurement. The practical measurement activity produced different results which raised the issue of uncertainty in measurement. In the next activity, students discussed the reasons for their different results. This brought them to consider an integral aspect of the thought style of a practicing scientist, which includes appreciating the fact that a measurement cannot be separated from its context; that there is no such thing as a 'true value'.

Within the detailed analysis of the genesis of a thought style extract (8.3), the notions of jargon and thought style thus rendered visible how the different activities in the lesson were directed toward a coherent body of knowledge. How the language needs encountered in the practical activity (the jargon) were integral to the more epistemological questions encountered in the discussion of the results (the thought style). This is an example of how the notions served to function as a guiding principle in the analysis of the language (jargon) and associated body of knowledge (thought style) inherent in each of the milieus analysed in this study.

Secondly, as regards the analysis of the sequence, another example can be seen in 'The Extended Roleplay'. The didactic analysis (8.6) showed how it was important to be able to situate didactic activity within the epistemic and epistemological context of the knowledge at stake in order to gauge its validity. For example, in the discussion between the students when Paul asks Driss '... have to be erm very parallel. How can you be sure the ...?' (Paul, speech turn 29), Driss replies 'Because they are on lines', speech turn

32). Driss's statement could appear to be simply informative, the equivalent of telling somebody the time of day. However, this geometry-based justification, linking the parallelism of the measuring instruments with the accuracy of the measurement, revealed a reasoning which was in keeping with an appropriate scientific thought style. The notions are in this way useful tools for situating classroom practice in relation to its epistemic and epistemological context: a recognisable thread between the different elements, but also a means of gauging both the validity and the distance of student claims in relation to the knowledge at stake.

For this reason, the notions promise to be useful tools for elaborating future CLIL projects. This would entail devising activities to construct the jargon of a particular cultural practice whilst simultaneously situating that jargon within the context of its corresponding thought style. In this way, the language activities of a CLIL programme would be sure to be linked to the body of knowledge to which that jargon contributed and from which it emerged.

Question 2: What capacities can be identified in the didactic activity of the students participating in the case study, and what evidence is there of effective work on those capacities in the didactic activity between themselves and with the teacher?

This question will mainly be considered by comparing the capacities identified in the CLIL sequence with the capacities demonstrated in the Exploratory Lesson. This will give a useful indication of the impact of the sequence. Both 'The Exploratory Lesson' and the final sequence sought to construct knowledge related to the subject of uncertainty in measurement but with very different results. Using the JATD descriptors it has been possible to identify the different outcomes as regards students' capacities.

Again, direct answers to this question can be found in the preliminary conclusion at the end of each didactic analysis. The answer to question 2 will entail the use of JATD notions and descriptors and so also responds to question 1.

9.2 The Exploratory Lesson in Comparison to the CLIL Sequence

In 'The Exploratory Lesson' (8.2), students were introduced to the jargon and thought style of scientific measurement whilst discussing the meaning and import of an MIT video with an English teacher and a physics associate professor. There was little evidence of students being able to transfer the jargon and thought style encountered in the MIT video in subsequent group-work. The didactic analysis showed that this was due to the teachers inaccurately assessing the contract (this is to be expected when exploring new material). Their design of the learning game was also not adapted to group-work: it did not require the production of jargon as a successful strategy for participating in the game, despite the production of jargon being the intended goal. Apart from the occasional smatterings of jargon during discussion with the English teacher about the MIT video (e.g. 'When it is a solid object... it is not possible...er... to change er...the size of this object er because ... it is horizontal or vertical' speech turn 8), there is little or no evidence of effective work on students developing capacities in 'The Exploratory Lesson'.

Following this observation, the sequence was redesigned and reworked in an iterative process until a satisfactory first lesson was developed. 'The Genesis of a Thought Style' is an extract taken from this lesson where the didactic activity was founded on a more accurately assessed contract. Students were gradually introduced to the jargon and thought style of scientific measurement, in English, in a plurilingual environment. This was by means of a discussion concerning the factors contributing to measurement uncertainty: the implication of this discussion was that there is not a 'true value' in scientific measurement. This understanding of measurement can be considered as evidence of a developing appropriate thought style, that is to say an epistemic capacity. In this respect, the students' reflections demonstrated an epistemic kinship to that of connoisseurs of the practice. The students also worked closely with the teacher in deciding upon the decimal position of their answers. This explorative work undertaken in the decimal activity contrasts with the statement '6.50 is much more accurate than 6.5' in 'The Exploratory Lesson', which did not give rise to further discussion. It is evidence of effective work, an epistemic capacity, related to determining the correct significant figure in a measurement result.

In lesson 3 the students worked on a formal laboratory report where an increasing number of examples of effective work on developing capacities could be identified. The jargon of the scientific practice of measurement was the basis of the written text in the students' description of their protocol, and they respected the codified form of a laboratory report, with its different elements in the standard order.

The laboratory report didactic analysis also brought to light certain epistemic capacities which had the potential to be developed further. For example, a general B2 English level (CEFR) which necessitated ongoing support and further refinement. Also, some of the statements in the report, such as, 'if more scientific tools were used', revealed an ill-fitting conception of scientific practice. As regards physics, the students' measurement result was mathematically inconsistent. This might be explained by two possibilities: either that they had not yet fully integrated this vital aspect of the thought style of a practicing physicist, or, a more likely explanation, that they did not think to integrate mathematical precision convincingly into their productions as this aspect of physics was largely ignored in the language class. This finding indicates the sequence would benefit by being more closely related to work done in science classes so that the students would know how to better integrate their knowledge of specialist fields into their productions in English.

In the final lesson of the sequence, within the joint action of a small group and without the teacher, the students can be seen to engage in effective work on the range of epistemic capacities identified in Table 15.

Table 15

Demonstrated Ongoing Development of Epistemic Capacities in the Extended Roleplay

Signs of Integration of Epistemic Capacities		
Qualitative aspect of English	Jargon- the practice language	Physics as a practice
<p>Accuracy: A range of appropriate structures, with varying accuracy, which demonstrate an ability to evoke nuances of tense, aspect and function.</p> <p><u>The past</u>: so the uncertainty <u>came</u> just from the ruler so we just <u>had</u> 1mm uncertainty and we <u>found</u> something like 6.4 or 5 that er that was good. And then we er we <u>took</u> a real calliper – we <u>did</u> the first experiment however we took a real calliper and <u>measured</u> the diameter of the ball and it was the same that er we <u>took</u> so... (8.6, speech turn 18)</p> <p><u>Modal form to express obligation</u>: because you <u>have to put</u> the square on .. (8.6, speech turn 38)</p> <p><u>Conditional to evoke cause and effect</u> 'if you do this you have to know the centre of the ball because ...' (8.6, speech turn 38)</p> <p><u>The aspect be+ing for a changing, moving reality</u></p> <p><i>it's becoming bigger</i> (8.6, 43)</p> <p><u>Interrogative form</u> 'how could you be sure that the ball can't be pressed by the calliper' (8.6, 19)</p> <p>Fluency: Engaged discussion (8.6, 1 – 44) which is not unduly hampered by hesitations.</p>	<p>Design and describe a reliable experiment, which used available equipment to measure: present the experimental set-up, the protocol, the data and the results clearly. Jean, lines 5-79, Frédéric lines 80-142, Paul lines 144-192, Driss lines 195-241. (Appendix F)</p> <p>Describe the way assumptions might affect results. <i>Identify</i> sources of experimental uncertainty and <i>evaluate</i> their impact. E.g. 'how could you be sure that the ball can't be pressed by the caliper when you measure...?' (8.6 speech turn 19)</p> <p>Describe efforts to <i>minimise</i> experimental uncertainty (random error). E.g. 'instead of putting your set square like this ...' (8.6, speech turn 37)</p> <p>Make a judgement about the result of the experiment: (8.6, Discussion 1 - 44)</p>	<p>Choose a mathematical procedure to solve the experimental problem. E.g. $4/3 \pi$ (Appendix E, line 160)</p> <p>Use of appropriate statistical precision: neither greater nor lesser than what can be legitimately justified.</p> <p>E.g. 'so we just had 1mm uncertainty and we found something like 6.4 or 5' speech turn 18.</p> <p>Demonstrate the <i>seeing-as</i> and <i>grammar</i> of various practices in experimental science: each student's protocol evaluated by the group including their uncertainty estimate. (1- 44)</p>
<p>Co-constructing meaning</p>		
<p>Range: A sufficient range of <i>jargon</i> to be able to describe and explore assumptions and hypotheses; some complex sentences. Scientific jargon to express a scientific worldview. E.g. The set squares have to be parallel (8.6, 31), instead of putting the set squares like this (8.6, 37), you have to know the centre of the ball (8.6, 38), when the distance is at the maximum you have the diameter (8.6, 43). Scientific argumentation to establish agreed upon representations of 'reality'. E.g. Frédéric's three attempts to represent an alternative measuring technique (speech turns 8.66, Extracts 5a-5c).</p>		

Table 15 is a summary of the effective work on epistemic capacities identified by the didactic analysis of the Extended Roleplay. In engaging in a social game questioning the assumptions leading to a measurement result, the students can be seen to demonstrate knowledge of the jargon and thought style of physics as a practice, expressed in English. In participating in this cooperative game of challenging and justifying the assumptions leading to a measurement result, the students can also be considered to engage in practices which demonstrate an epistemic kinship to the peer review process in academia (the connoisseurs of scientific practice).

As the didactic analysis in 8.6 revealed, the students' L2 limitations are explored in the joint action of the group. When they lacked the language skills to present ideas clearly, they pooled vocabulary and also cooperatively used symbolic and material representations of their ideas so as to co-construct meaning.

This ability to engage in the co-construction of meaning with others can be considered to be an epistemic capacity (to be developed) as regards language acquisition.

The students' language skills and understanding of scientific measurement are fruitful, though not exceptional. However, they can be seen to be in a process of autonomous, on-going learning. This hidden yet essential goal of the sequence, can be considered to be an epistemic capacity. It is a result of the habits of action integrated into the sequence with regard to the student-originator condition underlying much of the didactic activity.

To summarise, a range of epistemic capacities can be seen to be worked on effectively in the CLIL programme. Table 15 used to analyse the final lesson in the sequence, presents examples of the capacities demonstrated in this lesson. At this stage of the sequence, the content and language can be seen to be fused. The capacities identified can be summarised as demonstrating the use of the jargon and thought style related to the practice of scientific measurement. There is scope for the further development and refinement of those epistemic capacities, but examples of students co-constructing meaning autonomously can be considered as signs of their developing useful habits for successful future language learning experiences. In other words, a culture of language learning.

This range of demonstrated epistemic capacities contrasts strongly with the students' inability to participate in the learning game in the exploratory lesson.

Having identified the different results of the Exploratory Lesson and the CLIL sequence as regards students' demonstrated capacities, we shall now consider the factors which led to these different results, as determined by the didactic analyses.

Explaining the Differences: Resistant Milieus

Both the Exploratory Lesson and the Extended Roleplay were seen to have resistant milieus, but whereas the former did not lead to effective work on student capacities, the latter was explored by the students to work on a range of developing capacities. The didactic analyses determined the factors which accounted for this fact. The differences between the two milieus will be summarised here using the JATD descriptors.

In the Exploratory Lesson (8.2), the Joint Action Theory in Didactics' notions of contract—the *already-there*— and milieu, were effective tools for identifying the structural inefficiencies in the learning games in relation to the targeted objectives. A gap between the contract and the milieu was shown to be a fundamental flaw in the design of the group-work learning game. The milieu was resistant, in that it resisted students' investigation of its inherent knowledge, as the students were seen to be unable to develop strategies to overcome those resistances due to the gap between the contract and milieu being too great. For example, when the student Pascal tried to describe his measuring protocol, he lacked the jargon necessary and the two teachers had to constantly intervene to contribute vocabulary to bolster the activity so as to ensure it did not grind to a halt.

The JATD notion of contract-milieu was also used as an analytical tool to examine the didactic phenomena in 'The Extended Roleplay'. The milieu of the roleplay could be seen to be a resistant and transactional milieu (Sensevy, 2008; Gruson, 2019), where students undertook didactic transactions in the form of their questions, explanations and justifications. The milieu of the extended roleplay was resistant in that the students were constrained to seek strategies to go beyond their existing knowledge (the *already-there*), so as to participate fully in the learning game. That is to say, they were constrained to mobilise various epistemic

capacities, including new knowledge, in order to co-construct meaning in the roleplay. The example presented below illustrates how a resistance in the milieu led to a transaction between the students which both constructed and transformed the milieu (see 8.6 for a further examples).

Paul intimates by a grimace (6) that he does not understand the term 'set square'. Driss translates the term for him with 'équerre' (7). This term is later used by Paul (speech turn 29). Driss also uses his hands to symbolically represent the set square material used in his set-up. This prompts Frédéric to state 'ah - to make sure it's er parallel'. At this point he is introducing an appropriate form of jargon into the milieu to express verbally what Driss had introduced symbolically with his hands. The question of material being parallel will be explored further by the group from this point on.

In this way, the various resistances in the milieu, whether due to a lack of vocabulary or the challenge of better representing physics as a practice, led to transactions between the students which both constructed and transformed the milieu.

The resistant and transactional milieu of 'The Extended Roleplay', can be contrasted with the resistant and non-transactional milieu of 'The Exploratory Lesson'. In the latter, students encountered resistances which rendered them literally speechless. They were not armed in the contract, nor by the nature of the learning game itself, to rise to the challenge and mobilise language to overcome these resistances. The students in 'The Extended Roleplay', in contrast, were well-armed to overcome the resistances they encountered and to develop the epistemic capacities necessary to do so: i.e. co-construct meaning in developing L2 skills and a thought style that can be recognised as demonstrating an epistemic kinship to that of connoisseurs of the practice.

In contrast to the heavily resistant milieu of 'The Exploratory Lesson', the milieu of 'The Extended Roleplay' proved to be both resistant and transactional, despite all the epistemic capacities involved in the complex social game of measurement being targeted at once. This was because the didactic activity necessary to develop the different systems of epistemic capacities inherent in the roleplay had already been undertaken. Students were now in a

position to participate successfully in the roleplay learning game which targeted a unified system of epistemic capacities.

Explaining the Differences: Redesigning in an Iterative Process

Following the observation that the students were unable to participate successfully in 'The Exploratory Lesson', the sequence was redesigned and reworked in an iterative process until a satisfactory first lesson was developed.

In the group work situation presented in 'The Exploratory Lesson', the students did not have the necessary jargon to describe a measurement process. Thus, in the re-worked sequence they were given the opportunity to first research and practice the necessary jargon before being confronted with this activity. Furthermore, the situation in 'The Exploratory Lesson' of describing one's actions whilst measuring at the same time was seen to be difficult to manage. Thus, in the re-worked sequence students were asked to first describe, then enact, in an adapted learning game: they described a protocol for another student to execute, then changed roles.

In general, students were seen to lack fluency and to need time to integrate the question of uncertainty in measurement. Hence, a home assignment was integrated into the sequence where they were asked to re-design a protocol. This gave them the opportunity to include their uncertainty estimate, and to practice their fluency describing a protocol. They were then asked in class to again describe a protocol to a partner, as we saw in 'The Enhancing Fluency Extract'.

Students were seen to consistently struggle to produce a laboratory report that satisfied the associate professor of physics. This led to the decision to provide students with a model laboratory report so that they would be constrained to include all the required elements. The teachers engaged in a cooperative action to produce a suitable model which was then integrated into the sequence.

To conclude, when students were confronted with an obstacle to acquiring the knowledge at stake, the learning games were re-designed and reworked in an iterative, often cooperative process. This process continued until a satisfactory learning situation could be

presented where students would become enabled to access new knowledge. This approach was used in conjunction with the joint action of the teacher and students which shall be considered next.

Explaining the Differences: The Joint Action

The nature of the didactic activity that was undertaken to prepare the students for the roleplay is fully presented and analysed in detail from 8.2 – 8.6. These analyses show that a key factor contributing to the various aspects of the social game of measurement being clarified was the joint action between the teacher and the students in constructing knowledge. This too was an essential element in the students developing the capacity to overcome the resistances in the extended roleplay milieu and to develop strategies which led them to acquire new knowledge. To better understand the role this factor played, a few examples of this joint action will be presented here, again using the JATD descriptors.

In the re-designed, first lesson of the CLIL sequence, students began with a learning game which enabled them to acquire and actively use the jargon of scientific measurement. They were asked to devise a protocol to measure the diameter of a tennis ball using whatever material available to hand. This involved encountering the jargon embedded within a practice. They then had to describe their protocol to a partner who had to execute that same protocol whilst listening to instructions.

In 'The Genesis of a Thought Style' (8.3) following this activity, the teacher and the students, engaged in a *joint action* as they went about mapping out the milieu-problem. The dialectic of reticence/expression revealed a pattern in the teacher's moves which showed her harnessing all the existing knowledge in the classroom (the jargon and thought style of the previous activity, the students' existing knowledge of the issue of uncertainty/measurement and of their language learning skills/expression etc.) so as to integrate the *already-there* into the teaching objectives. In this way, she actively constructed the milieu-problem in a joint action with the students. The students' contributions, and the teacher's reactions to those contributions, functioned as signs in a semiotic system to explore that milieu-problem.

Another example of the role of joint action between the students and the teacher can be seen in 'The Enhancing Fluency Exchange'. In this extract, two different patterns can be discerned in the teacher's moves with regard to the students' productions: she is 'reticent' (expressively reticent) with regard to Walid (i.e. she corrects him rarely, thereby tacitly recognising his efforts to progress are effective), and 'expressive' (relatively) with regard to Pedro (i.e. she corrects him more frequently, thereby indicating where he needs to focus to progress). The notion of didactic equilibration served to identify the guiding principle with regard to these moves: the learning game challenges the students to practice and reinforce their fluency. The teacher can be seen to maintain a didactic equilibration according to the existing level of expression of each student so that they can continue to progress accordingly.

'The Genesis of a Thought Style' is an example of joint action to construct the milieu-problem. 'The Enhancing Fluency Extract' is an example of joint action to construct the student's knowledge, in this case the students' fluency in English.

These two factors, that is to say re-designing in an iterative process and the processes of joint action, explain why students were better able to overcome resistances in 'The Extended Roleplay' compared to 'The Exploratory Lesson'.

The descriptors and notions of the JATD have enabled the identification of the capacities worked on by students during the CLIL sequence. They have also served to identify the factors contributing to their development. This leads to the third research question considered in this thesis.

9.3 The Conditions of the CLIL Programme

During the experimentation and analysis of the CLIL programme, a number of necessary conditions of a CLIL programme of this type became apparent. The third and final research question of this study, stated below, addresses this question. Each of the conditions identified will be presented in detail.

Question 3: What are the concrete conditions of a CLIL programme which enable students to develop a conceptual understanding of scientific practice whilst improving their English language skills?

1. Epistemic Potential

The programme in this study sought to engage students in an inquiry-based learning approach where sufficient opportunities would arise to develop and strengthen the culture of language learning. This required a subject of sufficient *epistemic depth* (Wegner et al., 2020) to withstand persistent investigation and yet continue to produce new knowledge. The subject of uncertainty in measurement proved to be a fruitful topic in this respect which could be exploited further in future research.

2. Cooperative Action with Specialists

Given the epistemic depth of a suitable subject, that is its complexity, an effective programme required both specialist knowledge of that subject (in the case of this programme, specialist knowledge of scientific measurement), and specialist knowledge of language teaching. Another condition of the CLIL programme which became apparent, therefore, was the *cooperative action* between specialists in a field, together with that of language teachers.

This cooperative action ensured the connoisseur's knowledge of the subject was combined with the language teacher's focus on the linguistic socialisation inherent in the field. It was the language teacher who ensured the practice language of the domain (the jargon) was exploited to develop L2 skills and a culture of language learning.

The English teacher would not have been able to develop the project alone without the measuring activity suggested by the physics lecturer, as well as her guidance as regards the thought style of a physicist. The physics lecturer would not have been able to develop the project alone, (for CLIL purposes), as she would not have known how to orchestrate class activity to focus on L2 skills. Both teachers were necessary to the project, with each teacher functioning as the guarantor of the knowledge in their field.

Discussion regarding the vital aspect of the cooperative action between the two teachers will be presented in more detail further on.

3. The Introduction of Jargon within the Context of its Practice

The premise that language is organically linked to practice (Collins 2011) leads to a third condition of CLIL practice emerging from this study: the *jargon* corresponding to a given practice (Sensevy et al., 2019) must be *introduced within the context of its practice*, albeit transposed for language learning purposes. An anecdote from the early stages of this CLIL programme serves to illustrate this point. At the beginning of the 4-week sequence, in an exercise designed to explore existing knowledge in the class, students were asked to write a few words on the term ‘uncertainty’ and what it suggested to them: students discussed ecological concerns, worries about the election of Donald Trump and future career prospects, but none of them mentioned uncertainty in measurement. It was only in the context of scientific measurement that the term came to be understood as intended, that is to say, as part of the jargon of scientific measurement with its associated thought style.

Detailed descriptions of how jargon was introduced into the sequence within the context of its practice can be found in 8.2 – 8.6. Table 16 gives a general indication of the various points in the 4-lesson sequence where jargon was introduced within the context of a scientific practice. This was in a form transposed to suit L2 learning, of which more will be said later.

Table 16

Introduction of Jargon in Context

<p style="text-align: center;">Scientific Abilities (Investigative Science Learning Environment (ISLE) site)</p>	<p style="text-align: center;">Sequence Activity</p>
<p><u>Ability to design & conduct an application experiment</u></p> <ul style="list-style-type: none"> • Is able to design a reliable experiment that solves the problem • Is able to use available equipment to make measurements • Is able to make a judgment about the results of the experiment • Is able to choose a productive mathematical procedure for solving the experimental problem • Is able to determine specifically the way in which assumptions might affect the results <p><u>Ability to collect and analyse experimental data</u></p> <ul style="list-style-type: none"> • Is able to identify sources of experimental uncertainty • Is able to evaluate specifically how identified experimental uncertainties may affect the data • Is able to describe how to minimize experimental uncertainty and actually do it • Is able to record and represent data in a meaningful way <p><u>Ability to communicate scientific ideas</u></p> <ul style="list-style-type: none"> • Is able to communicate the details of an experimental procedure clearly and completely • Is able to communicate the point of the experiment clearly and completely 	<p>Lesson 1, opening activity: design a protocol to measure the diameter of a tennis ball using available material</p> <p>Assignment: design a new protocol and evaluate the uncertainty of the measurement.</p> <p>Lesson 3: Write a laboratory report to describe the protocol and its results. Conclusion + discussion of results.</p> <p>Lesson 3: Lab report as above</p> <p>Lesson 4: Roleplay, discuss, challenge, justify uncertainty evaluation</p> <p>Lesson 1: Describe and execute a protocol in pairs.</p> <p>Lesson 2: Describe a new protocol, target fluency</p> <p>Lesson 3: Written expression. See Scientific Written Language table.</p> <p>Lesson 4: Roleplay to describe, defend, justify a protocol, and to question, challenge protocols.</p>

4. The Condition of Jargon being Encountered in its Dialogical Form

Jargon is inherently dialogical in nature, emerging as it does from discussions within a community of practice surrounding a particular field. This reality led to another underlying condition adhered to in this study: *the introduction of jargon within the context of a dialogue* (in the widest sense of the term) in order to be better grasped.

As we saw from 8.3-8.6, students demonstrated an increasing assimilation of a range of jargon in the 4-lesson sequence. In 'The Genesis of a Thought Style' they were seen to be practicing numbers and decimals in English (8.3, speech turns 2, 8, 10, 12, 14, 16). Prior to this they had been researching the jargon they needed to describe their own protocol, or had used it during interactions with the teacher (e.g. 'How can you be sure you are exactly in the centre of the ball? How tight did you pull the wire/string/thread? How many times did you measure the ball?' 8.3).

In the Enhancing Fluency extract, they can be seen to be acquiring jargon whilst describing/listening to the protocol of a classmate (e.g. 'so we just, we just have to measure the diameter of the mark's ball... the ball's mark in the dough' 8.4.).

In the Laboratory Report, they can be seen to explore more formal jargon (e.g. 'to determine the diameter' line 4, 8.5) and finally, (v) during the Extended Roleplay, they can be seen to be engaged in co-constructing meaning using a range of acquired jargon (e.g. 'Erm so the uncertainty came just from the ruler so we just had 1mm uncertainty and we found something like 6.4 or 5', speech turn 18, 8.6). This can be especially appreciated when compared to the dearth of appropriate jargon available to students in the Exploratory Lesson.

It was concluded in this study that the introduction of jargon via the interactions and discussion of terms in relation to its associated practice and thought style is an effective, or even necessary method in developing second and foreign language acquisition. Its introduction in a dialogical form enabled an understanding of the thought-style of the practice in which the jargon was embedded and which gave it shape. Future research might explore to what extent this is a necessary condition of all lexical work.

5. Well-Designed Orchestrated Situations

Didactic activities must be designed in such a way so as to enable an effective exploration of the jargon and thought style of a practice. This requires *the design of situations* (e.g. enhancing fluency pair-work, 8.3, written laboratory report 8.5, extended roleplay, 8.6), which entail students producing output as a strategy for participating successfully in a particular learning game. A CLIL sequence of this type must therefore include learning games which explore semiotic systems requiring such strategies: they can be considered as a necessary aspect of language learning. Thus, an additional condition of a CLIL sequence, as explored in this study, is that they should include situations allowing for the exploration of semiotic systems, i.e. a language learning milieu (Sensevy, Gruson & Forest 2015).

6. A Common Background

For students to be able to explore semiotic environments in order to develop their L2 skills, a *common background* is necessary. This is a condition of CLIL practice, as experimented in this study, which was explored in detail in 8.6 (The Extended Roleplay): here the students were seen to share a common situational background (the cooperative learning game of the roleplay), and a common epistemic background (the details of a convincing protocol to measure the diameter of a tennis ball, the question of how to ensure a protocol reduced random error, the question of deciding on the ranking of protocols according to the degree of uncertainty in the measurement). It also included the common or shared exploration of a recognisable thought style (that of experimental science).

7. Student-Originator Productions

The condition of introducing jargon within a practice marries well with another condition integrated into the design of this study: the active engagement of students in using the target L2 language in inquiry-based programmes. Much of the didactic activity in the sequence is therefore founded, on *student-originator productions* (exploring the jargon and thought style of uncertainty in measurement) in what can be termed a dialogical form. That is to say, in activities involving some form of interactive engagement:

discussing/explaining/describing with others: this was to allow for maximum opportunity to actively develop L2 skills.

This spontaneous mobilising of language resources is a necessary step in the appropriation of an L2. The notion of a resistant and transactional milieu thus served as a useful tool in describing the kind of didactic environment where this becomes possible

8. An Adequately Assessed Contract-Milieu

For these situations to be effective, they must be designed in such a way as to ensure that the student-originators share a common background, as we saw earlier. They must also be founded on an *accurately assessed contract-milieu equilibrium*. As the didactic analysis of 'The Exploratory Lesson' (8.2) highlighted, a situation founded on student productions with an inaccurately assessed contract-milieu equilibrium is not effective. 'The Extended Roleplay' proved to be more effective as students' already-there was adequate to explore the milieu. It was also sufficiently robust for the students to be able to use the resistances which arose in the milieu as learning opportunities. For example, when they pooled vocabulary (set square, calliper, copybook, came out) and certain structures and ideas ('How can you be sure they are parallel? Instead of putting your set squares like this ...' 8.6).

9. Confident Students

A final condition of a CLIL sequence, such as that explored in this study, is that students must be fully engaged and sufficiently *confident to make epistemic commitments*. In 'The Genesis of a Thought Style', students suggested factors to explain the different measurement results of a tennis ball's diameter. In 'The Enhancing Fluency Extract', students described the protocols of their own invention. In 'The Laboratory Report', students rendered explicit the details of their protocol and justified their results. In 'The Extended Roleplay', students challenged and defended the validity of various protocols. Students were able to do this as they had acquired or reinforced the confidence necessary to make such epistemic commitments. This was a result of certain habits (Dewey, 1938) being introduced early into the language classroom.

Participation and engagement were strongly encouraged and difficulties encountered were not 'errors' or inadequacies, but opportunities to research and integrate the jargon of the practice. This confidence can be considered a final condition of a CLIL sequence such as that explored in this study.

The CLIL Conditions in Summarised Form

The conditions discussed above can be reduced to a list. This raises the question as to the use this list might serve. As discussed earlier, efforts to analyse didactic action outside of its epistemic, and even epistemological context, can be problematic. However, this list is not intended as a checklist (though it might be a useful starting point in a CLIL project). Rather, it serves to identify, succinctly, a general overview of the results of this CLIL experiment.

- (i) Sufficient epistemic potential for an inquiry-based milieu
- (ii) Cooperative development between language teachers and specialists of a given field
- (iii) The introduction of jargon within the context of its practice
- (iv) The condition of jargon being encountered in its dialogical form
- (v) Orchestrated situations allowing for the exploration of semiotic systems (which can be considered as necessary to a language learning milieu).
- (vi) A shared background in didactic activities (e.g. the shared situational background of a cooperative game for 'The Extended Roleplay'. The common epistemic background of 'The Genesis of a Thought Style' and 'The Extended Roleplay').
- (vii) Student-originator productions with a maximum of opportunity to develop L2 skills (in exploring jargon and thought style)
- (viii) Teacher interactions and learning situations based on an adequately assessed contract-milieu equilibrium.
- (ix) Student confidence to engage in epistemic commitments

9.4 Cooperative Action and the Interweaving of Content and Language

As stated on a number of occasions, this CLIL programme emerged from a cooperative action. Following the exploratory lesson experiment, the physics associate professor and the language teacher engaged in a cooperative project to produce the CLIL sequence. The JATD descriptors render visible a range of interwoven aspects of content and language resulting from this cooperative action. As this cooperative action was an essential and founding component of the sequence, its impact will be considered in more detail.

Emanating from the teachers' cooperative action was the close association of the practice of measurement with its practice language: content and language were interwoven into every level of the sequence. For example, in the didactic activities (e.g. devising protocols, writing up results), and in the productions (e.g. laboratory reports, discussions challenging and defending uncertainty estimations), as well as in the cooperative production of teaching resources. This was a result of the teachers engaging in multiple exchanges in the goal to combine the objectives of both fields.

The laboratory report (Appendix B) is an example of such a resource. It continues to evolve as a consequence of the teachers' ongoing communication, and is an example of interwoven content and language. Similarly, 'The Extended Roleplay' is an example of how the convergence of English with physics transformed the latter: the focus of a typical roleplay in a physics classroom would not necessarily ensure each participant discussed their protocol and results at length, whereas 'The Extended Roleplay', and many of the activities preparing for the roleplay, were designed with this intended goal.

A question arising from the research was the potential to explore jargon as a means of better socialising students in scientific practice. The laboratory report analysis discussed how the notion of jargon could be useful in honing resources and didactic activity in relation to targeted epistemic capacities. It argued that the specific use of the various verbs related to uncertainty (determine, minimise, calculate, estimate) could render more explicit certain implicit aspects of what is involved in an uncertainty estimation. At the same time this could serve to better socialise students into the associated thought style of a connoisseur of the practice.

Much remains to be investigated in future research on this point. The notion of jargon, straddling as it does both language and practice, is potentially an effective tool for both designing and analysing didactic engineerings in CLIL research.

9.5 Obstacles to Integrating Content

Some obstacles were encountered by the English teacher as regards the integration of content into the sequence.

Varying Practices

The jargon of a field can vary from one sub-community to another, and even from one individual to another. This was discussed with the example of the terms ‘uncertainty’ and ‘error’ (see 8.3) when the associate physics professor explained that she did not always agree with the views of some colleagues in her field regarding the use of these terms:

English Teacher: ‘when do you prefer to talk about error rather than uncertainty? When you talk about rounding up the error, I have the impression you’re still talking about uncertainties?’

Physics professor: ‘That’s true. You’re right. Some people say that we should not talk about errors, because “errors can be corrected...” I do not think so. Only systematic errors can be (and you have to figure out that there are some). Errors can have different origins and in real life, there are some compensations.’

The position undertaken in this study was to adopt the jargon and approach of the expert in the field working cooperatively on the project. Exploring the variances in jargon within the field was considered too challenging given the constraints of the project. A frontier encountered by the language teacher in this CLIL programme therefore, was the question of the divergent practices, regarding the uncertainty of a measurement, within the community of physicists.

It would be possible to explore this question in future research as the origin of this divergence opens up the issue of the nature of scientific practice. This would require a longer programme. It would also need to include specialists with differing practices. Such research

would be an opportunity to explore in greater detail the epistemological origins underlying the field, in particular the link between the empirical and the theoretical, as explored in chapter 7.

Mathematics

Just as an individual physicist's jargon might vary, so might their use of mathematics as a tool in their practice. In fact, during this study it was seen to vary between the time of the origin of the sequence and its later version (Appendix E, extract of revised laboratory report), due to the associate professor's ongoing investigation of how best to transpose this aspect of physics practice. This is another example of a frontier that CLIL language teachers might encounter: the issue of mathematical calculations with regard to measurement uncertainty. As we saw in 8.5, the students revealed some mathematical inconsistencies in their results. This was probably due to this aspect of the practice being largely ignored in the language class as it required too specialised an understanding of mathematical practice. Again, the epistemic potential of the sequence could benefit from this important aspect of uncertainty in measurement being more greatly integrated into the teaching. This would require the content of the sequence being more closely aligned with specialists' teaching on the technical aspect of calculating results.

9.6 Discussion and Future Research

This study hopes to contribute to future CLIL research in a number of ways. First, by illustrating how the theoretical and methodological JATD framework can be an effective tool for analysing CLIL practice. In particular, the notions of jargon and thought style promise to be a useful means of ensuring that the essential elements of a CLIL programme (of the type presented in this study) are included in its design, whatever the domain explored. It remains for this conclusion to be tested in future programmes of this type.

Second, there are a number of questions arising from the results of the study which could be interrogated further. On a micro level, there is the scope to further hone didactic resources to enable students to fine-tune their L2 skills. For example, students' written expression and the finer grammatical points encountered in the writing of the laboratory report. How might this aspect of the students' practice be effectively reinforced and confirmed? It would be interesting to experiment how nuanced work on grammatical structures might be integrated into this CLIL programme. The approach to language in Systemic Functional Linguistics might also offer interesting possibilities for the development of didactic resources in the context of such CLIL programmes.

On a macro level, the didactic content could be widened in scope in order to better include the objectives of the specialist subject. As we saw, the mathematical, technical aspects of uncertainty in measurement could not be fully explored and integrated into this sequence. It would be interesting to explore how this aspect of physics practice could be better included, without making the error of ignoring the language needs of the class. A related question is how CLIL programmes might seek to integrate jargon which is more closely-fit to specialists' practice, and whether this more closely-fit jargon might then contribute to understanding that practice. Another research possibility is that of opening up the sequence to explore its more epistemological concerns regarding the nature of scientific practice itself, though this again would require close interaction with specialists.

One final point. As was mentioned earlier, a guiding principle central to the elaboration of this project was the following: when students encountered an obstacle to acquiring whatever knowledge was at stake, the question addressed in response to that obstacle was

not 'what is the problem with the student?', but rather 'what is the problem with the learning situation/game/joint action?' In other words, learning situations/games/joint actions were analysed so as to identify how they could be better designed. How they could arm students to deal with the resistance encountered, and in this way enable them to engage in transactions leading to the integration of new knowledge. This fundamental position, with regard to the analysis of classroom practice, might be considered to be what Engeström et al (2012) term a 'germ cell':

The following four characteristics are essential qualities of a germ cell that may lead to an expansive theoretical concept: (a) the germ cell is the smallest and simplest initial unit of a complex totality; (b) it carries in itself the foundational contradiction of the complex whole; (c) the germ cell is ubiquitous, so commonplace that it is often taken for granted and goes unnoticed; (d) the germ cell opens up a perspective for multiple applications, extensions, and future developments. (p.3)

The smallest, simplest unit here is the starting assumption: that there is always a way for a given knowledge stake to be acquired. The foundational contradiction within it is its potential for the opposite assumption: that the students are not actually able to acquire that knowledge. This foundational assumption will necessarily pervade the didactic activity as a whole, to the point of being unnoticed. In addressing, this germ cell, future developments become possible. In other words, when students are confronted with an obstacle to learning, the assumption that a way forward is possible will likely lead to a way being found.

Résumé Long

Cette étude a été menée dans le secteur des LANGues pour Spécialistes d'Autres Disciplines (LANSAD). Elle explore d'un pont de vue didactique l'enseignement-apprentissage d'une matière par l'intégration d'une langue étrangère (EMILE), généralement connue par l'acronyme CLIL (Content and Language Integrated Learning). Elle se situe dans le cadre de la théorie de l'action conjointe en didactique (TACD) et s'interroge sur les conditions spécifiques d'un programme CLIL conçu pour des étudiants en sciences dans une université française.

Une courte séquence d'enseignement-apprentissage, en 4 séances, a été élaborée par deux enseignantes travaillant en coopération : une enseignante-chercheuse (HDR) de physique et une professeure d'anglais. Le programme est fondé sur les principes de l'approche par problème (APP) et sur une démarche d'enquête (Dewey, 1938 ; Sensevy, 2011). Les étudiants se sont vus présenter une série de situations orchestrées de manière à les contraindre à explorer, en coopération, la pratique de la mesure dans les sciences expérimentales.

En accord avec certains fondements épistémologiques de la TACD, la théorie du langage qui constitue l'arrière-plan de cette étude correspond à la conception de Wittgenstein (le 'deuxième'). Autrement dit, le langage est considéré comme étant composé de jeux de langage au sein de formes de vie qui produisent certains styles de pensée (Fleck, 1935/2008) et certaines manières de voir (Wittgenstein, 1953/2004). Ces manières de voir – des voirs-comme - à la fois produisent et sont produites par le jargon (Sensevy, Gruson et Le Hénaff, 2019) qui est considéré comme la composante linguistique d'un jeu social.

Le concept de jargon ne se limite pas au vocabulaire : il inclut une compréhension du contexte de la pratique dans laquelle il s'inscrit et qui lui donne forme. Apprendre une langue donc n'est pas simplement apprendre des mots, mais toute une culture, une grammaire de l'action qui est intégrée dans notre usage du langage. Il en suit que, pour apprendre une langue, il faut l'apprendre dans le contexte d'une pratique afin de la découvrir dans sa forme de vie.

Pour permettre aux étudiants d'explorer une forme de vie scientifique en lien avec leur Licence, la notion d'incertitude dans la mesure a été choisie pour le 'Contenu' (la matière) de ce projet CLIL. C'est une notion de science expérimentale qui est souvent simplifiée ou mal comprise par les étudiants. La séquence d'enseignement-apprentissage a donc été conçue autour d'une activité de mesure au cours de laquelle les étudiants doivent concevoir un protocole ou une procédure de base pour mesurer le diamètre d'une balle de tennis. L'exploration de cette question a nécessité le développement d'un style de pensée/jargon approprié à ce jeu social et à sa forme de vie.

Cette séquence fait l'objet d'une analyse clinique dans le cadre de ce travail doctoral. Nous chercherons à caractériser l'action didactique produite en classe et à déterminer l'effectivité des pratiques relatives au potentiel épistémique de la séquence. Sur la base de l'analyse empirique de l'activité didactique en cours, les traces d'une compréhension conceptuelle de la mesure en tant que pratique scientifique, ainsi qu'un travail effectif sur les compétences linguistiques, sont recherchées dans l'action didactique.

L'organisation du Manuscrit

Notre manuscrit comporte quatre parties. Dans la première partie, le contexte général de l'étude est décrit. Elle commence par une synthèse des recherches actuelles sur l'enseignement-apprentissage des langues secondes et étrangères et elle situe notre étude à la fois épistémologiquement et par rapport aux développements actuels en didactique des langues. Elle présente ensuite un résumé des principales recherches CLIL et présente, sous forme synthétique, les questions qui se posent à ce jour en ce qui concerne cette approche. Cette première partie est complétée par une présentation du contexte institutionnel de l'étude et une description générale de la séquence CLIL qui est au cœur de ce travail.

La deuxième partie est dévolue à l'exposé du cadre théorique et méthodologique de ce projet, la TACD. Les principales notions de la TACD sont décrites, en particulier les notions de jargon et de style de pensée. L'approche méthodologique de la TACD, telle qu'elle est mise en œuvre dans cette recherche, est explicitée. Notre démarche est composée de plusieurs éléments : des descriptions épaisses (Ryle, 1949/2009) de la pratique didactique filmée en classe, l'analyse des enjeux épistémiques de la séquence CLIL, et enfin, la modélisation et

l'analyse de l'effectivité des pratiques décrites relativement aux enjeux épistémiques identifiés. Pour contextualiser davantage ces éléments, d'autres données sont présentées et décrites : les productions des élèves, la communication entre les deux enseignantes et les ressources didactiques issues de leur travail coopératif.

La troisième partie présente deux analyses épistémiques de la séquence. La première est un aperçu de l'origine historique de la science expérimentale et de son style de pensée, tel qu'il est exprimé dans l'anglais scientifique écrit. La seconde est un aperçu du débat actuel dans l'enseignement des sciences sur la nature de la pratique scientifique elle-même, et par rapport à la question spécifique de la mesure scientifique.

La dernière partie, la quatrième, comprend l'analyse empirique de cette étude et nos conclusions. Cinq situations différentes de pratique en classe sont décrites puis analysées finement avec certaines notions de la TACD que nous présentons ci-après. Une série d'activités didactiques CLIL sont ainsi étudiées et remises en question en détail, et les composantes de cette pratique CLIL sont identifiées.

Les Questions de Recherches

Nous avons formulé trois questions de recherche pour aborder cette problématique que nous explicitons ci-après.

Question 1 : Comment peut-on décrire efficacement les objectifs doubles d'une compréhension conceptuelle de la pratique scientifique et d'un travail sur les compétences linguistiques ?

L'étude s'appuie sur une série de notions, développées au sein de la TACD, pour décrire en détail l'activité didactique et ses enjeux. Quelques notions-clés sont particulièrement importantes dans les descriptions denses (Ryle, 1943) de la pratique en cours : la double dialectique contrat-milieu et réticence-expression, le jeu d'apprentissage, le jeu épistémique (Santini et al., 2018), et les systèmes de capacités épistémiques (Gruson, 2019).

Un rôle central est attribué au discours dans cette pratique CLIL. Ainsi, les notions de *jargon* et de *style de pensée* (Sensevy et al., 2019) permettent d'analyser l'imbrication du

contenu (c'est-à-dire l'acquisition d'une conception appropriée de la mesure en tant que pratique scientifique) et de la langue (c'est-à-dire l'acquisition de compétences en anglais en tant que langue étrangère) dans la construction conjointe des connaissances dans la pratique en classe.

Pour donner un exemple, la première leçon a commencé par la conception d'un protocole pour mesurer le diamètre d'une balle de tennis, et cette activité a nécessité la recherche du jargon nécessaire pour décrire ce protocole en détail. Ainsi, les étudiants ont communiqué en utilisant le jargon en contexte : par exemple, en réponse aux questions de l'enseignant « *Comment pouvez-vous être sûr(s) d'être exactement au centre de la balle ? Dans quelle mesure avez-vous tiré sur le fil/la ficelle ? Combien de fois avez-vous mesuré la balle ? Quelle mesure avez-vous prise ? Avez-vous pris la moyenne des mesures ou la mesure la plus large ? Laquelle est la meilleure ? Ok, donc vous avez divisé la circonférence par π - qu'en est-il de l'incertitude ?* » ('Genesis of a Thought Style', p.123).

De cette façon, les étudiants ont progressivement acquis les bases d'un jargon associé à la pratique de la mesure scientifique. L'activité pratique de mesure a produit différents résultats qui ont soulevé la question de l'incertitude dans les mesures. Dans l'activité suivante, les étudiants ont discuté des raisons de leurs différents résultats. Cela les a amenés à considérer un aspect fondamental du style de pensée d'un scientifique connaisseur pratique (DpE, 2019) : c'est-à-dire l'appréciation du fait qu'une mesure ne peut être séparée de son contexte, qu'il n'existe pas de « vraie valeur ».

Question 2 : Quelles capacités peuvent être identifiées dans l'activité didactique des étudiants participant à l'étude de cas, et quelles preuves existe-t-il d'un travail effectif sur ces capacités dans l'activité didactique conjointe avec l'enseignant ?

La TACD se situe dans une conception de la pratique scientifique qui voudrait contribuer au développement d'un *nouvel empirisme* (Sensevy & Santini, 2006 ; Sensevy et al., 2008). Selon cette position, une conception appropriée de la pratique scientifique serait de la considérer comme une modélisation d'une relation entre l'abstrait et le concret, le

conceptuel et l'empirique (Sensevy et al., 2008 ; Sensevy 2011 ; Hacking, 1983 ; Cartwright, 1999 ; Buffler et al., 2009). Le travail dans des systèmes sémiotiques qui organisent la perception au sein de descriptions concrètes peut mener les étudiants à se rendre davantage sensibles au processus de concrétisation de l'abstrait que peut représenter l'activité scientifique. Par conséquent, une activité didactique qui cherche à co-construire un style de pensée où la pratique scientifique est vue sous cet angle est considérée comme une pratique ayant une parenté épistémique avec le jeu épistémique (Santini et al., 2018) de la pratique savante (DpE, 2019).

De même, le travail au sein d'un système sémiotique (Sensevy, Gruson & Forest, 2015 ; Gruson, 2019), où les mots, les gestes et les expressions prennent vie dans la co-construction du sens, doit également être considéré comme une pratique ayant une parenté épistémique avec un jeu épistémique lors de l'acquisition d'une langue seconde/étrangère. Une hypothèse sous-jacente à l'étude était la suivante : en explorant la langue et la pratique liées à ce domaine, les étudiants développent des capacités utiles pour de futures expériences d'apprentissage des langues. En d'autres termes, il s'agissait d'éduquer les étudiants, au sens le plus large du terme, afin qu'ils acquièrent une *culture de l'apprentissage des langues*.²⁸

À partir des analyses didactiques de cette étude, il a été possible de déterminer les capacités que les étudiants étaient en train de développer à la fin de la séquence. Des preuves d'un travail effectif sur ces capacités sont mises en évidence dans l'analyse empirique de l'activité didactique du chapitre 8.

Dans la dernière séance de la séquence, lors d'un travail en mini groupes, sans enseignant, on peut voir les étudiants s'engager dans un travail effectif sur les diverses capacités épistémiques identifiées dans le Tableau 17 ci-dessous.

²⁸ Une glossaire des notions développées au sein de la TACD : (<http://tacd.espe-bretagne.fr/glossaire/>).

Tableau 17

Les signes d'intégration des capacités épistémiques dans le jeu de rôle

Signes d'intégration des capacités épistémiques		
Aspect qualitatif de l'anglais	Jargon - la langue de pratique	La physique en tant que pratique
<p>Précision : Une gamme de structures appropriées, avec une précision variable, qui démontrent une capacité à évoquer des nuances de temps, d'aspect et de fonction.</p> <p>La fluidité : Discussion engagée (8.6, 1 - 44) qui n'est pas indûment entravée par des hésitations.</p>	<p>Concevoir et décrire une expérience fiable, qui utilise les équipements disponibles pour mesurer : présenter clairement le dispositif expérimental, le protocole, les données et les résultats. Jean, lignes 5-79 ; Frédéric lignes 80-142 ; Paul lignes 144-192 ; Driss lignes 195-241. (Annexe F)</p> <p>Décrire la manière dont les hypothèses peuvent affecter les résultats. <i>Identifier les sources d'incertitude expérimentale et évaluer leur impact.</i> Par exemple, «comment pourriez-vous être sûr que la balle ne peut pas être compressée par le pied à coulisse lorsque vous mesurez... ? » (8.6 Tour de parole 19)</p> <p>Décrire les efforts déployés pour <i>minimiser l'incertitude</i> expérimentale (erreur aléatoire). Par exemple, « au lieu de mettre votre équerre comme ceci... » (8.6, Tour de parole 37)</p> <p>Porter un jugement sur le résultat de l'expérience : (8.6, Discussion Tours de parole 1 - 44)</p>	
	Co-construction du sens	<p>Choisir une procédure mathématique pour résoudre le problème expérimental. Par exemple, $4/3 \pi$ (Annexe F, ligne 160)</p> <p>Utiliser une précision statistique appropriée : ni plus ni moins que ce qui peut être légitimement justifié.</p> <p>Par exemple, « nous avons juste une incertitude de 1mm et nous avons trouvé quelque chose comme 6,4 ou 5. »</p> <p>Démontrer la <i>vision</i> et la <i>grammaire de</i> diverses pratiques en science expérimentale : le protocole de chaque élève évalué par le groupe, y compris leur estimation de l'incertitude. (Tours de parole 1- 44)</p>
<p>Gamme : Un éventail de <i>jargon</i> suffisant pour pouvoir décrire et explorer des hypothèses. Quelques phrases complexes. Jargon scientifique pour exprimer une vision du monde scientifique.</p> <p>Par exemple : les équerres doivent être parallèles (8.6, 31), au lieu de les placer comme ceci (8.6, 37), vous devez connaître le centre de la balle (8.6, 38), quand la distance est au maximum vous avez le diamètre (8.6, 43).</p> <p>Argumentation scientifique pour établir des représentations convenues de la « réalité ». Par exemple, les trois tentatives de Frédéric pour représenter une technique de mesure alternative (8.6, extraits 5a-5c).</p>		

Tableau 17 est un résumé d'exemples de travail effectif, voire efficace, sur les capacités épistémiques identifiées par l'analyse didactique du jeu de rôle à la fin de la séquence. En s'engageant dans un jeu social mettant en question les hypothèses menant à un résultat de mesure, on peut voir les étudiants démontrer leur connaissance du jargon et du style de pensée de la physique en tant que pratique, exprimée en anglais. En participant à ce jeu coopératif de remise en question et de justification des hypothèses conduisant à un résultat de mesure, on peut également considérer que les étudiants s'engagent dans des pratiques qui démontrent une parenté épistémique avec la pratique savante à plusieurs niveaux : premièrement, ils/elles participent à un jeu social qui ressemble au processus d'évaluation par les pairs dans le milieu universitaire. Deuxièmement, ils/elles développent une conception appropriée de la pratique scientifique où il n'y a pas de « mesure juste ». Troisièmement, ils/elles inscrivent leur activité dans un système sémiotique (Sensevy et al., 2015) essentiel à l'apprentissage d'une langue. Finalement, ils/elles acquièrent *une culture de l'apprentissage des langues*.

Dans le jeu d'apprentissage de « The Extended Roleplay », les différentes résistances du milieu, qu'elles soient dues à un manque de vocabulaire ou au défi de mieux représenter la physique en tant que pratique, ont conduit à des transactions entre les étudiants qui ont à la fois construit et transformé le milieu. Par exemple, dans le tour de parole 6 (8.6), Paul laisse entendre par une grimace qu'il ne comprend pas le terme « set square ». Driss traduit pour lui le terme par « équerre » (7). Ce terme est utilisé par la suite par Paul (tour de parole 29). Driss utilise également ses mains pour représenter symboliquement l'équerre utilisée dans son installation. Cela incite Frédéric à dire « ah - pour être sûr que c'est en parallèle ». À ce stade, il introduit une forme de jargon appropriée dans le milieu pour exprimer verbalement ce que Driss avait introduit symboliquement avec ses mains. La question du parallélisme des instruments sera examinée plus en détail par le groupe à partir de ce moment.

L'analyse didactique a également mis en lumière certaines capacités épistémiques qui pourraient être développées davantage. Par exemple, le travail sur le rapport de laboratoire a révélé un niveau d'anglais général B2 (CECR) qui a nécessité un soutien continu et qui pourrait bénéficier d'un approfondissement supplémentaire. En outre, certaines déclarations

du rapport, telles que « si d'outils plus scientifiques étaient utilisés », ont révélé une conception inadaptée de la pratique scientifique. En ce qui concerne la physique, le résultat des mesures des étudiants était mathématiquement incohérent. Cela pourrait s'expliquer par deux possibilités : soit qu'ils n'avaient pas encore totalement intégré cet aspect essentiel du style de pensée d'un physicien en exercice, soit, ce qui est plus probable, qu'ils n'avaient pas pensé à intégrer de manière convaincante la précision mathématique dans leurs productions, cet aspect de la physique étant largement ignoré en classe de langue. Cette constatation indique que la séquence gagnerait à être plus étroitement liée au travail effectué dans les cours de sciences afin que les étudiants sachent comment mieux intégrer leurs connaissances des domaines spécialisés dans leurs productions en anglais.

En résumé, on peut constater qu'une série de capacités épistémiques sont développées efficacement dans le cadre du programme CLIL. À ce stade de la séquence, nous pouvons constater que le contenu et le langage sont étroitement entrelacés. Les capacités identifiées peuvent être résumées comme démontrant l'utilisation du jargon et du style de pensée liés à la pratique de la mesure scientifique. Il est possible de développer et d'affiner davantage ces capacités épistémiques, mais les exemples d'étudiants qui co-construisent un sens de manière autonome peuvent être considérés comme des signes du développement de capacités utiles pour de futures expériences d'apprentissage des langues réussies. En d'autres termes, comme des traces d'entrée dans une culture de l'apprentissage des langues.

Au cours de l'expérimentation et de l'analyse du programme CLIL, un certain nombre de conditions nécessaires à un programme CLIL (de ce type) sont apparues. La troisième et dernière question de recherche de cette étude, présentée ci-dessous, aborde ce sujet.

Question 3 : Quelles sont les conditions concrètes d'un programme CLIL qui permettent aux étudiants de développer une compréhension conceptuelle de la pratique scientifique tout en améliorant leurs compétences en anglais ?

Chacune des conditions identifiées est présentée ci-dessous :

1. Le potentiel épistémique

Le programme de cette étude clinique a cherché à engager les étudiants dans une approche d'apprentissage basée sur une enquête présentant des opportunités suffisantes pour développer et renforcer la culture de l'apprentissage des langues. Il fallait pour cela un sujet suffisamment *dense sur le plan épistémique* (Wegner et al., 2020) pour fournir matière à une enquête persistante qui permette de produire de nouvelles connaissances. Le sujet de l'incertitude des mesures s'est avéré être un sujet fructueux à cet égard, qui pourrait être exploité davantage dans le cadre de recherches futures.

2. L'action de coopération avec des spécialistes

Étant donné la densité épistémique d'un sujet approprié, c'est-à-dire sa complexité, une séquence efficace exige à la fois une connaissance spécialisée de ce sujet (dans le cas qui nous intéresse, une connaissance spécialisée de la mesure scientifique), et une connaissance spécialisée de l'enseignement des langues. Une autre condition du programme CLIL qui est donc apparue est la nécessité d'une *action coopérative* entre les spécialistes d'un domaine, et des professeurs de langues.

3. L'introduction du jargon dans le contexte de sa pratique

Le postulat selon lequel la langue est organiquement liée à la pratique (Collins 2011 ; Sensevy et al., 2019) conduit à une troisième condition de la pratique CLIL qui émerge de cette étude : le *jargon* correspondant à une pratique donnée (Sensevy et al., 2019) doit être *introduit dans le contexte de sa pratique*, bien que transposé à des fins d'apprentissage des langues.

4. L'introduction du jargon sous sa forme dialogique

Le jargon est par nature dialogique ; il émerge des discussions au sein d'une communauté de pratiques entourant un domaine particulier. Cette réalité a conduit à une autre condition sous-jacente à laquelle cette étude a adhéré : *l'introduction du jargon dans le contexte d'un dialogue* (au sens le plus large du terme) afin d'être mieux appréhendé.

5. Des situations conçues adéquatement

Les activités didactiques doivent être conçues de manière à permettre une exploration efficace du jargon et du style de pensée d'une pratique. Cela nécessite *la conception de situations* (par exemple, améliorer l'expression au sein d'un travail en binôme dans l'analyse 8.3, rédiger un rapport de laboratoire dans 8.5, s'investir dans un jeu de rôle dans 8.6), qui impliquent que les étudiants produisent des résultats, traces du système stratégique qu'ils ont mis en place pour participer avec succès à un jeu d'apprentissage. Une séquence CLIL de ce type doit donc inclure des jeux d'apprentissage qui explorent des systèmes sémiotiques nécessitant de telles stratégies : ils peuvent être considérés comme un aspect crucial de l'apprentissage des langues. Ainsi, une condition supplémentaire d'une séquence CLIL, telle qu'explorée dans cette étude, est qu'elle doit inclure des situations permettant l'exploration de systèmes sémiotiques, soit un milieu suffisamment résistant pour favoriser l'apprentissage des langues (Sensevy, Gruson & Forest 2015).

6. Un contexte commun

Pour que les étudiants puissent explorer les environnements sémiotiques afin de développer leurs compétences en LE, il est nécessaire qu'ils/elles disposent d'un *arrière-plan commun*. C'est une condition de la pratique CLIL, telle qu'elle a été expérimentée dans cette étude, et telle qu'elle est explorée en détail en 8.6 (« The Extended Roleplay ») : ici, les étudiants ont été considérés comme partageant un contexte situationnel commun (le jeu d'apprentissage coopératif lors du jeu de rôle), et un contexte épistémique commun (les détails d'un protocole convaincant pour mesurer le diamètre d'une balle de tennis, la question de savoir comment garantir qu'un protocole réduit l'erreur aléatoire, la question de décider du classement des protocoles en fonction du degré d'incertitude de la mesure). Ce jeu de rôle comprenait également l'exploration commune ou partagée d'un style de pensée reconnaissable (celui de la science expérimentale).

7. Productions des élèves-origines

La condition de l'introduction d'un jargon au sein d'une pratique est dépendante d'une autre condition intégrée dans la conception de cette étude : l'engagement actif des étudiants dans l'utilisation de la langue cible dans des séquences d'enseignement-apprentissage basées sur un processus d'enquête. Une grande partie de l'activité didactique de la séquence est donc fondée sur des *productions d'élèves-origines* (exploration du jargon et du style de pensée appartenant à l'incertitude dans les mesures) sous ce que l'on peut appeler une forme dialogique. Autrement dit, dans des activités impliquant une certaine forme d'engagement interactif : discuter/expliquer/décrire avec d'autres : il s'agissait de donner aux étudiants de multiples occasions de développer activement leurs capacités en LE.

En effet, cette mobilisation spontanée des ressources linguistiques est une étape nécessaire dans l'appropriation d'une LE. La notion de milieu résistant et transactionnel (Gruson, 2019) a donc servi d'outil utile pour décrire le type d'environnement didactique où cela devient possible.

8. Une équilibration contrat-milieu

Pour que ces situations soient efficaces, elles doivent être conçues de manière à ce que les élèves-origines partagent un arrière-plan commun, comme nous l'avons vu précédemment. Elles doivent également être fondées sur un *équilibre contrat et le milieu, qui doit être estimé avec précision*. Comme l'a souligné l'analyse didactique de « The Exploratory Lesson » (8.2), une situation fondée sur des productions d'étudiants dont l'équilibre entre le contrat et le milieu est mal estimé ne permet pas aux étudiants d'élaborer des stratégies efficaces pour accéder le savoir en jeu.

9. Des étudiants confiants

Une dernière condition concernant une séquence CLIL, telle que celle explorée dans cette étude, est que les étudiants doivent être pleinement investis et suffisamment en *confiance pour prendre des engagements épistémiques*.

Obstacles à l'intégration des contenus

La professeure d'anglais a rencontré quelques obstacles en ce qui concerne l'intégration du contenu dans la séquence. Le jargon d'un domaine peut varier d'une sous-communauté à l'autre, et même d'un individu à l'autre. Cela a été discuté avec l'exemple des termes « incertitude » et « erreur » (voir 8.3) lorsque l'enseignante-chercheuse de physique a expliqué qu'elle n'était pas toujours d'accord avec les opinions de certains collègues de son domaine concernant l'utilisation de ces termes.

Tout comme le jargon d'un physicien peut varier, l'utilisation des mathématiques comme outil dans sa pratique peut également varier. C'est un autre exemple de frontière que les enseignants de langues CLIL pourraient rencontrer : la question des calculs mathématiques en ce qui concerne l'incertitude des mesures. Comme nous l'avons vu au point 8.5, les étudiants ont révélé certaines incohérences mathématiques dans leurs résultats. Cela était probablement dû au fait que cet aspect de la pratique était largement ignoré dans la classe de langue car il nécessitait une compréhension trop spécialisée de la pratique des mathématiques. Là encore, le potentiel épistémique de la séquence pourrait bénéficier d'une meilleure intégration de cet aspect important de l'incertitude dans les mesures dans l'enseignement. Cela nécessiterait que le contenu de la séquence soit plus étroitement aligné sur l'enseignement des spécialistes notamment en lien avec l'aspect technique du calcul des résultats.

Discussion et Perspectives de Recherche Future

Cette étude entend contribuer à la future recherche CLIL de plusieurs façons. Premièrement, en illustrant comment le cadre théorique et méthodologique de la TACD peut être un outil efficace pour analyser la pratique CLIL. En particulier, les notions de jargon et de style de pensée promettent d'être un moyen utile pour s'assurer que les éléments essentiels d'un programme CLIL (du type de celui présenté dans cette étude) sont inclus dans sa conception, quel que soit le domaine exploré. Il reste, toutefois, à mettre à l'épreuve cette conclusion dans de futurs projets de ce type. Enfin, cette étude a également pour objectif de

contribuer aux recherches sur les dispositifs coopératifs, comme celui décrit dans cette recherche doctorale, qui nous paraissent être des terrains fructueux pour le développement de futurs projets CLIL.

List of Tables

Table 1: CEFR Conversion Table	44
Table 2: AMU Student Results 2013-2018.....	46
Table 3: Estimating Uncertainty: Problem-Solving and Learning-by-Doing in English and Physics.....	48
Table 4: Synoptic Table of the Uncertainty Sequence: Lesson Organisation	49
Table 5: The 'Point' and 'Set' Paradigms (Buffler et al., 2003)	88
Table 6: Part One: System of Epistemic Capacities (8.2).....	104
Table 7: Part Two: System of Epistemic Capacities (8.2)	112
Table 8: Systems of Epistemic Capacities (8.3): English and physics	130
Table 9: Links between the Model Answer and Class Activity.....	137
Table 10: Analysis of Systems of Epistemic Capacities (8.5).....	175
Table 11: Signs of Demonstrated Use of Epistemic Capacities (8.5).....	176
Table 12: Signs of Non-Integrated Epistemic Capacities (8.5)	178
Table 13: Question and Answer Dialogues (8.6).....	222
Table 14: Co-Constructing Meaning in Mini-Groups	226
Table 15: Demonstrated Ongoing Development of Epistemic Capacities (8.6).....	240
Table 16: Introduction of Jargon in Context	249
Tableau 17 : Les signes d'intégration des capacités épistémiques dans le jeu de rôle	264

List of Acronyms

AoA: Action-oriented Approach

ASP : Anglais de Spécialité

ATD: Anthropological Theory of the Didactic

CLIL: Content and Language Integrated Learning

EMILE : Enseignement d'une Matière par l'Intégration d'une Langue Étrangère

ESP: English for Specific Purposes

FLTL: Foreign Language Teaching and Learning

GUM: Guide to the Expression of Uncertainty in Measurement

JATD: Joint Action Theory in Didactics [TACD]

L2: Langue Seconde/ Étrangère

LANSAD: LANGues pour Spécialités d'Autres Disciplines

LANSOD: LANGuages for Specialists of Other Disciplines

LE : Langue Étrangère

LSP: Language for Specific Purposes

S/FL: Second and Foreign Language

SLA: Second Language Acquisition

SLTL: Second Language Teaching and Learning

TACD: Théorie de l'Action Conjointe en Didactique [JATD]

TAD : Théorie Anthropologique du Didactique

VIM: International Vocabulary of Metrology

References

- Abell, S. K., & Lederman, N. G. (Eds.). (2007). *Handbook of research on science education*. Lawrence Erlbaum Associates.
- Abell, S. K., Appleton, K., & Hanuscin, D. L. (2013). *Handbook of Research on Science Education*. Taylor and Francis.
<https://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=801729>
- Allie, S., Buffler, A., Campbell, B., & Lubben, F. (1998). First-year physics students' perceptions of the quality of experimental measurements. *International Journal of Science Education*, 20(4), 447–459. <https://doi.org/10.1080/0950069980200405>
- Artigue, M. (2020). Didactic Engineering in Mathematics Education. In S. Lerman (Ed.), *Encyclopedia of Mathematics Education* (pp. 202–206). Springer International Publishing. https://doi.org/10.1007/978-3-030-15789-0_44
- Atkinson, D. (1998). *Scientific discourse in sociohistorical context the philosophical transactions of the Royal Society of London 1675-1975*. Lawrence Erlbaum.
<http://www.vlebooks.com/vleweb/product/openreader?id=none&isbn=9781410601704>
- Baetens Beardsmore, H. (Ed.). (1993a). *European models of bilingual education*. Multilingual Matters.
- Banks, D. (2012). Diachronic ESP: At the interface of linguistics and cultural studies. *ASp*, 61, 55–70. <https://doi.org/10.4000/asp.2738>
- Banks, D. (2016). *The Birth of the Academic Article: Le Journal des Sçavans and the Philosophical Transactions, 1665-1700*. Equinox Publishing Ltd.
- Banks, D. (2017). The extent to which the passive voice is used in the scientific journal article, 1985–2015. *Functional Linguistics*, 4(1). <https://doi.org/10.1186/s40554-017-0045-5>
- Banks, D. (2019). *Birth of the Academic Article :Le journal des scavans and the philosophical transactions, 1665-1700*. Equinox Publishing Ltd.
- Bazerman, C. (1988). *Shaping written knowledge: The genre and activity of the experimental article in science*. University of Wisconsin Press.
- Billeter, J-F. (2011). *Un paradigme*. Paris : Alia.
- Billeter, J-F. (2017). *Esquisses*. Paris : Alia.
- Bloomfield, L. (1933). *Language*. University of Chicago Press.
<http://hdl.handle.net/1959.9/524847>
- Bloor, T. (2019). *Signs of Thought Styles: The Gestures and Objects of Jargon*. La TACD en question, questions à la didactique. Rennes. [274](https://tacd-</p></div><div data-bbox=)

- Bloor, T., & Gruson, B. (2019). Agir dans et avec l'anglais pour travailler une notion en physique à l'université. In *Didactique pour enseigner*.
- Bourdieu, P. (1987). *Choses dites*. Editions de Minuit.
- Brandom, R. (2001). *Making it explicit: Reasoning, representing, and discursive commitment* (4. print). Harvard Univ. Press.
- Brousseau, G. (2004a). *Théorie des situations didactiques : Didactique des mathématiques, 1970-1990*. La Pensée sauvage, éditions.
- Brudermann, C., Mattioli, M.-A., Roussel, A.-M., & Sarré, C. (2016). Le secteur des langues pour spécialistes d'autres disciplines dans les universités françaises : Résultats d'une enquête nationale menée par la SAES1. *Recherche et Pratiques Pédagogiques En Langues de Spécialité - Cahiers de l'APLIUT, Vol. 35 N° spécial 1*.
<https://doi.org/10.4000/apliut.5564>
- Buffler, A., Allie, S., & Lubben, F. (2001). The development of first year physics students' ideas about measurement in terms of point and set paradigms. *International Journal of Science Education*, 23(11), 1137–1156. <https://doi.org/10.1080/09500690110039567>
- Buffler, A., Lubben, F., & Ibrahim, B. (2009). The Relationship between Students' Views of the Nature of Science and their Views of the Nature of Scientific Measurement. *International Journal of Science Education*, 31(9), 1137–1156.
<https://doi.org/10.1080/09500690802189807>
- Bunch, G. C. (2016). *Secondary science teaching for English learners: Developing supportive and responsive learning contexts for sense-making and language development*. Rowman & Littlefield
- Cammarata, L., & Tedick, D. J. (2012). Balancing Content and Language in Instruction: The Experience of Immersion Teachers. *The Modern Language Journal*, 96(2), 251–269.
<https://doi.org/10.1111/j.1540-4781.2012.01330.x>
- Canale, M., & Swain, M. (1980). Theoretical Bases of communicative Approaches to Second Language Teaching and Testing. *Applied Linguistics*, 1(1), 1–47.
<https://doi.org/10.1093/applin/1.1.1>
- Campbell, R., & Wales, R. (1970). The Study of Language Acquisition. *New Horizons in Linguistics*. Penguin.
- Carol, R. (2015). La didactique de l'enseignement bilingue : Enseignement disciplinaire et langage. *Recherches En Didactique Des Langues et Des Cultures*, 12(3).
<https://doi.org/10.4000/rdlc.973>
- Cartwright, N. (1999). *The dappled world: A study of the boundaries of science*. Cambridge University Press.
- Caussarieu, A., & Tiberghien, A. (2017). When and Why Are the Values of Physical Quantities

- Expressed with Uncertainties? A Case Study of a Physics Undergraduate Laboratory Course. *International Journal of Science and Mathematics Education*, 15(6), 997–1015. <https://doi.org/10.1007/s10763-016-9734-x>
- Cenoz, J., & Gorter, D. (2017). Minority languages and sustainable translanguaging: Threat or opportunity? *Journal of Multilingual and Multicultural Development*, 38(10), 901–912. <https://doi.org/10.1080/01434632.2017.1284855>
- Chalmers, A. (2013). *What Is This Thing Called Science?* University of Queensland Press.
- Chaplier & O'Connell, C., Anne-Marie. (2015). ESP/ASP in the Domains, of Science and Law in a French Higher Education Context: Preliminary reflections. *The European English Messenger*, *The European English Messenger Winter 2015*(24 (2)), 61–76.
- Chevallard, Y. (1985a). *La transposition didactique : Du savoir savant au savoir enseigné*. Pensée sauvage.
- Chevallard, Yves. (1989). On Didactic Transposition Theory: Some Introductory Notes. *International Symposium on Selected Domains of Research and Development in Mathematics Education (Bratislava, 3-7 Août 1988.)*
- Chevallard, Yves. (2012, July). Teaching Mathematics in Tomorrow's Society: A Case for an Oncoming Counterparadigm. *12th International Congress on Mathematical Education*, Seoul, Korea.
- Chomsky, N. (1957). Logical structures in language. *American Documentation*, 8(4), 284–291. <https://doi.org/10.1002/asi.5090080406>
- Chomsky, N. (1965/1995). *Aspects of the theory of syntax* (19. pr). MIT Press.
- Collectif Didactique pour enseigner. (2019a). *Didactique pour enseigner*. Presses Univ.de Rennes.
- Collectif Didactique pour enseigner. (2020). *Enseigner, ça s'apprend*. Presses Univ. de Rennes.
- Collins, H. (2011). Language and practice. *Social Studies of Science*, 41(2), 271–300. <https://doi.org/10.1177/03063127111399665>
- Collins, H. (2018) Studies of Expertise and Experience. *Topoi*, 37 (1), 66-77.
- Compton, A. H., & Simon, A. W. (1925). Measurements of β -Rays Associated with Scattered X-Rays. *Physical Review*, 25(3), 306–313. <https://doi.org/10.1103/PhysRev.25.306>
- Conseil de l'Europe. (2000). *Cadre européen de référence pour les langues : apprendre, enseigner, évaluer*. <https://www.coe.int/fr/web/common-european-framework-reference-languages>
- Coyle, D. (2007). Content and Language Integrated Learning: Towards a Connected Research Agenda for CLIL Pedagogies. *International Journal of Bilingual Education and*

- Bilingualism*, 10(5), 543–562. <https://doi.org/10.2167/beb459.0>
- Coyle, D., Hood, P., & Marsh, D. (2010). *CLIL: Content and language integrated learning*. Cambridge University Press.
- Crosnier, E., & Décuré, N. (2018). Parler ou ne rien dire : La prise de parole en classe d'anglais Lansad. *Recherches En Didactique Des Langues et Des Cultures*, 15(2). <https://doi.org/10.4000/rdlc.3062>
- Cummins, J., & Davison, C. (Eds.). (2007). *International handbook of English language teaching*. Springer.
- Cummins, J., & Hornberger, N. H. (Eds.). (2008). *Bilingual education* (2nd ed). Springer.
- Dalton-Puffer, C. (2007). *Discourse in content and language integrated learning (CLIL) classrooms*. John Benjamins Pub.
- Dalton-Puffer, C. (2011). Content-and-Language Integrated Learning: From Practice to Principles? *Annual Review of Applied Linguistics*, 31, 182–204. <https://doi.org/10.1017/S0267190511000092>
- Dewey, J.(1922). *The nature of principles. Human Nature and Conduct: An Introduction to Social Psychology*. 238-247 New York: Modern Library.
- Dewey, J. (1997). *Experience and education* (1. ed). Simon & Schuster.
- Dewey, J. (1998). *How we think: A restatement of the relation of reflective thinking to the educative process*. Houghton Mifflin.
- Dewey, J., Nagel, E., & Boydston, J. A. (2008). *The collected works of John Dewey. [...] Vol. 12: The later works, 1925 - 1953 1938; [logic: the theory of inquiry]*. Southern Illinois Univ. Press.
- The Douglas Fir Group. (2016). A Transdisciplinary Framework for SLA in a Multilingual World. *The Modern Language Journal*, 100(S1), 19–47. <https://doi.org/10.1111/modl.12301>
- Ducheyne, S. (2005). Bacon's Idea and Newton's Practice of Induction. *Philosophica*, 76, 115–128. <https://www.philosophica.ugent.be/wp-content/uploads/fulltexts/76-6.pdf>
- Duschl, R. (2008). Science Education in Three-Part Harmony: Balancing Conceptual, Epistemic, and Social Learning Goals. *Review of Research in Education*, 32(1), 268–291. <https://doi.org/10.3102/0091732X07309371>
- Engeström, Y., Kajamaa, A., & Nummijoki, J. (2015). Double stimulation in everyday work: Critical encounters between home care workers and their elderly clients. *Learning, Culture and Social Interaction*, 4, 48–61. <https://doi.org/10.1016/j.lcsi.2014.07.005>
- Engeström, Y. (2008). *From teams to knots: Activity-theoretical studies of collaboration and learning at work*. Cambridge University Press.

- Engeström, Y., Nummijoki, J., & Sannino, A. (2012). Embodied Germ Cell at Work: Building an Expansive Concept of Physical Mobility in Home Care. *Mind, Culture, and Activity*, 19(3), 287–309. <https://doi.org/10.1080/10749039.2012.688177>
- Etkina, E. (2015a). Millikan award lecture: Students of physics—Listeners, observers, or collaborative participants in physics scientific practices? *American Journal of Physics*, 83(8), 669–679. <https://doi.org/10.1119/1.4923432>
- Etkina, E. (2015b). Millikan award lecture: Students of physics—Listeners, observers, or collaborative participants in physics scientific practices? *American Journal of Physics*, 83(8), 669–679. <https://doi.org/10.1119/1.4923432>
- Eurydice, (2006). Comisión Europea, & Dirección General de Educación y Cultura. (2005). *Content and Language Integrated Learning (CLIL) at School in Europe*. Eurydice. Viewed 23 November 2020. http://www.indire.it/lucabas/lkmw_file/eurydice/CLIL_EN.pdf
- Farrington, B. (1964). *The philosophy of Francis Bacon: An essay on its development from 1603 to 1609* (1. publ). Univ. Press.
- Firth, A., & Wagner, J. (1997). On Discourse, Communication, and (Some) Fundamental Concepts in SLA Research. *The Modern Language Journal*, 81(3), 285–300. <https://doi.org/10.1111/j.1540-4781.1997.tb05480.x>
- Fleck, L., Trewn, T. J., Merton, R. K., & Bradley, F. (1934/2008). *Genesis and development of a scientific fact* (Repr. 11. Aufl). Univ. of Chicago Press.
- Fleck, L., Jas, N., Löwy, I., & Latour, B. (1934/2008). *Genèse et développement d'un fait scientifique*. Flammarion.
- Flick, L. B., & Lederman, N. G. (Eds.). (2006). *Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education*. Springer.
- Foucault, M. (1969/2005). *L'archéologie du savoir*. Gallimard.
- Gao., X, A., (2019) The Douglas Fir Group Framework as a Reference Map for Language Teacher Evaluation. *The Modern Language Journal*. <http://doi.wiley.com/10.1111/modl.12526>
- Gajo, L. (2007a). Enseignement d'une DNL en langue étrangère : De la clarification à la conceptualisation. *Tréma*, 28, 37–48. <https://doi.org/10.4000/trema.448>
- Gajo, L. (2007b). Linguistic Knowledge and Subject Knowledge: How Does Bilingualism Contribute to Subject Development? *International Journal of Bilingual Education and Bilingualism*, 10(5), 563–581. <https://doi.org/10.2167/beb460.0>
- Garfinkel, H., Lynch, M., & Livingston, E. (1981). I.1 The Work of a Discovering Science Construed with Materials from the Optically Discovered Pulsar. *Philosophy of the Social Sciences*, 11(2), 131–158. <https://doi.org/10.1177/004839318101100202>
- Ginzburg, C. (1979). Clues: Roots of a Scientific Paradigm. *Theory and Society*, 7(3), 273–288.

- Grangeat, M. (2010, August). Effects of expert teachers' collaboration on their conceptualisations and practices towards inquiry-based methods in science teaching. *European Conference on Educational Research*.
- Gross, A. G. (2006). *Starring the text: The place of rhetoric in science studies*. Southern Illinois University Press.
- Gross, A. G. (2016). The Limits of the Rhetorical Analysis of Science. *Poroi*, 12(1). <https://doi.org/10.13008/2151-2957.1244>
- Gruson, B. (2006a). *L'enseignement d'une langue étrangère à l'école et au collège : vers une meilleure compréhension des situations didactiques mises en œuvre : analyse comparative de l'action de deux professeurs de CL2 et de deux professeurs de sixième*. Doctoral thesis. Rennes 2
- Gruson, Brigitte. (2006b). Agir, interagir et rétroagir : Analyse de la pratique d'un professeur de CM2 et de ses élèves lors d'une situation de « pairwork »—Première partie. *Carrefours de l'éducation*, pp.69-81.
- Gruson, B. (2008). Analyse de situations de compréhension de l'oral au CM2: Pistes de réflexion pour l'enseignement et la formation. *Éla. Études de linguistique appliquée*, n° 151(3), 327. <https://doi.org/10.3917/ela.151.0327>
- Gruson, B., Forest, D., & Loquet, M. (2012). *Jeux de savoir : Études de l'action conjointe en didactique*. Presses universitaires de Rennes.
- Gruson, B. (2019). *L'action conjointe en didactique des langues : Élaborations conceptuelles et méthodologiques*. Presses Univ. de Rennes.
- Hacking, I. (1983). *Representing and intervening: Introductory topics in the philosophy of natural science*. Cambridge University Press.
- Hall, Prof. J. K., Hellermann, J., & Pekarek Doehler, S. (2011). *L2 Interactional Competence and Development*. Channel View Publications. <http://public.eblib.com/choice/publicfullrecord.aspx?p=4844888>
- Hall, J. K., (2016). A Usage-Based View of Multicompetence. Cook, V. & Wei, L. *Cambridge Handbook of Linguistic Multicompetence*. pp. 183-206. Cambridge University Press.
- Hall, J. K., (2018). The Contributions of conversation analysis and interactional linguistics to a usage-based understanding of language: expanding the disciplinary framework. *The Modern Language Journal*. Vol. 103, pp. 80-84.
- Hall, J. K. (2019a). The Contributions of Conversation Analysis and Interactional Linguistics to a Usage-Based Understanding of Language: Expanding the Transdisciplinary Framework. *The Modern Language Journal*, 103, 80–94. <https://doi.org/10.1111/modl.12535>
- Hall, J. K. (2019b). The Contributions of Conversation Analysis and Interactional Linguistics to a Usage-Based Understanding of Language: Expanding the Transdisciplinary

- Framework. *The Modern Language Journal*, 103, 80–94. <https://doi.org/10.1111/modl.12535>
- Halliday, M. A. K., & Matthiessen, C. M. I. M. (2004). *An introduction to functional grammar* (3rd ed). Oxford University Press.
- Hymes, D. (1966). On “Anthropological Linguistics” and Congeners. *American Anthropologist*, 68(1), 143–153. <https://doi.org/10.1525/aa.1966.68.1.02a00160>
- Hymes, D. H. (1996a). *Ethnography, linguistics, narrative inequality: Toward an understanding of voice*. Taylor & Francis.
- Ingold, T. (2017). *Anthropology and/as education: Anthropology, art, architecture and design*. Routledge.
- Jameau, A., & Le Hénaff, C. (2018). Content and Language Integrated Learning. Teaching in Science: A didactic analysis of a case study. *Review of Science, Mathematics and ICT Education*.
- Joffredo-Le Brun, S., Morellato, M., Sensevy, G., & Quilio, S. (2018). Cooperative engineering as a joint action. *European Educational Research Journal*, 17(1), 187–208. <https://doi.org/10.1177/1474904117690006>
- Kelly, G. J., & Licona, P. (2018). Epistemic Practices and Science Education. In M. R. Matthews (Ed.), *History, Philosophy and Science Teaching* (pp. 139–165). Springer International Publishing. https://doi.org/10.1007/978-3-319-62616-1_5
- Kind, P., & Osborne, J. (2017a). Styles of Scientific Reasoning: A Cultural Rationale for Science Education?: STYLES OF SCIENTIFIC REASONING. *Science Education*, 101(1), 8–31. <https://doi.org/10.1002/sce.21251>
- Kind, P., & Osborne, J. (2017b). Styles of Scientific Reasoning: A Cultural Rationale for Science Education?: STYLES OF SCIENTIFIC REASONING. *Science Education*, 101(1), 8–31. <https://doi.org/10.1002/sce.21251>
- Koschmann, T. D. (Ed.). (2011). *Theories of learning and studies of instructional practice*. Springer.
- Kramsch, C. J. (Ed.). (2002). *Language acquisition and language socialization: Ecological perspectives*. Continuum.
- Kuhn, D. (1993). Science as argument: Implications for teaching and learning scientific thinking. *Science Education*, 77(3), 319–337. <https://doi.org/10.1002/sce.3730770306>
- Kuhn, T. S. (1996a). *The structure of scientific revolutions* (3rd ed). University of Chicago Press.
- Kuhn, T. S. (1996b). *The structure of scientific revolutions* (3rd ed). University of Chicago Press.
- Lakoff, G., & Johnson, M. (2003). *Metaphors we live by*. University of Chicago Press.

- Lantolf, J. P. (Ed.). (2000b). *Sociocultural theory and second language learning*. Oxford Univ. Press.
- Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, 29(4), 331–359. <https://doi.org/10.1002/tea.3660290404>
- Lederman, N. G., (2007). Nature of Science: Past, Present and Future. *Handbook of Research on Science Education*. Routledge.
- Lederman, N. G., & Abell, S. K. (2014). *Handbook of Research on Science Education*. Routledge.
- Lederman, N. G., Schwartz, R., & Abd-El-Khalick, F. (2015). Nature of Science, Assessing of. In R. Gunstone (Ed.), *Encyclopedia of Science Education* (pp. 694–698). Springer Netherlands. https://doi.org/10.1007/978-94-007-2150-0_12
- Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Ablex Pub. Corp.
- Lewis, C., & Perry, R. (2017). Lesson Study to Scale Up Research-Based Knowledge: A Randomized, Controlled Trial of Fractions Learning. *Journal for Research in Mathematics Education*, 48(3), 261–299. <https://doi.org/10.5951/jresmetheduc.48.3.0261>
- Llinares, A., Morton, T., & Whittaker, R. (2012). *The roles of language in CLIL*. Cambridge University Press.
- Lyster, R. (1987). Speaking Immersion. *Canadian Modern Language Review*, 43, 701–717.
- Lyster, R., & Ranta, L. (1997). CORRECTIVE FEEDBACK AND LEARNER UPTAKE: Negotiation of Form in Communicative Classrooms. *Studies in Second Language Acquisition*, 19(1), 37–66. <https://doi.org/10.1017/S0272263197001034>
- Marsh, D. (1994). Bilingual Education & Content and Language Integrated Learning. International Association for Cross-cultural Communication, Language Teaching in the Member States of the European Union. *Lingua, University of Sorbonne*.
- Marsh, D., Maljers, A., & Hartiala, A.-K. (2001a). *Profiling European CLIL classrooms: Languages open doors*. University of Jyväskylä.
- Marsh, D., Maljers, A., & Hartiala, A.-K. (2001b). *Profiling European CLIL classrooms: Languages open doors*. University of Jyväskylä.
- Mead, G. H., & Morris, C. W. (1934/1974). *Works of George Herbert Mead. Vol. 1: Mind, self, and society: from the standpoint of a social behaviorist* (19. impr). Univ. of Chicago Press.
- Mohan, & Van Naerssen. (1997). Understanding Cause-Effect: Learning Through Language. *ERIC*.
- Monrad-Krohn, G. H. (1947). The Prosodic Quality of Speech and its Disorders: (A Brief

- Survey from a Neurologist's Point of View). *Acta Psychiatrica Scandinavica*, 22(3–4), 255–269. <https://doi.org/10.1111/j.1600-0447.1947.tb08246.x>
- North, B., & Piccardo, E. (2016). Developing illustrative descriptors of aspects of mediation for the Common European Framework of Reference (CEFR): A Council of Europe project. *Language Teaching*, 49(3), 455–459. <https://doi.org/10.1017/S0261444816000100>
- North, B., & Piccardo, E. (2017). Mediation and the social and linguistic integration of migrants: Updating the CEFR descriptors. In J.-C. Beacco, H.-J. Krumm, D. Little, & P. Thalgott (Eds.), *The Linguistic Integration of Adult Migrants / L'intégration linguistique des migrants adultes*. De Gruyter. <https://doi.org/10.1515/9783110477498-011>
- North, B., Goodier, T., & Piccardo, E. (2018). *CEFR Companion Volume with New Descriptors* Ed. du Conseil de Europe. rm.coe.int/cefr-companion-volume-with-new-descriptors-2018/1680787989
- Oliveira, A. W., Akerson, V. L., Colak, H., Pongsanon, K., & Genel, A. (2012). The implicit communication of nature of science and epistemology during inquiry discussion. *Science Education*, 96(4), 652–684. <https://doi.org/10.1002/sce.21005>
- Peirce, C. S., & Welby, V. (1977a). *Semiotic and significs: The correspondence between Charles S. Peirce and Lady Victoria Welby*. Indiana University Press.
- Peirce, C. S., & Welby, V. (1977b). *Semiotic and significs: The correspondence between Charles S. Peirce and Lady Victoria Welby*. Indiana University Press.
- Phelps, L. W., (1988). *Composition as a human science: contributions to the self-understanding of a discipline*. Oxford University Press.
- Piccardo, E., & Europarat (Eds.). (2011a). *Parcours d'évaluation, d'apprentissage et d'enseignement à travers le CEFR*. Conseil de l'Europe
- Piccardo, E., & Europarat (Eds.). (2011b). *Pathways through assessing, learning and teaching CEFR*. Council of Europe.
- Piccardo, E. (2014). *From Communicative to Action-oriented: a Research Pathways*. https://www.researchgate.net/publication/338177979_Piccardo_E2014From_Communicative_to_Action-oriented_a_Research_Pathways
- Piccardo, E. (2016). La diversité culturelle et linguistique comme ressource à la créativité. *Voix Plurielles*, 13(1), 57–75. <https://doi.org/10.26522/vp.v13i1.1370>
- Piccardo, E., & North, B. (2016). *Developing illustrative descriptors of aspects of mediation for the CEFR*. Ed. du Conseil de l'Europe.
- Piccardo, E., & North, B. (2019). *The action-oriented approach: A dynamic vision of language education*. Multilingual Matters.
- Pokrivčáková, S. (2015). *CLIL in Foreign Language Education: E-textbook for foreign*

- language teachers*. Constantine the Philosopher University in Nitra.
- Puren, C. (1988/1996). Histoire des méthodologies de l'enseignement des langues. *CLE International*. <https://www.christianpuren.com/mes-travaux/1988a/>
- Puren, C. (2006g). De l'approche communicative à la perspective actionnelle. *FIPF-CLE International*, pp.80-81. <http://www.christianpuren.com/mes-travaux-liste-et-liens/2006g/>
- Roussel, S., Joulia, D., Tricot, A., & Sweller, J. (2017). Learning subject content through a foreign language should not ignore human cognitive architecture: A cognitive load theory approach. *Learning and Instruction*, 52, 69–79. <https://doi.org/10.1016/j.learninstruc.2017.04.007>
- Roussel, S., & Tricot, A. (2017). Emile/CLIL, EMI vs TCC: Des espaces de recherche si proches et si lointains. *Alsic*, Vol. 20, n° 3. <https://doi.org/10.4000/alsic.3126>
- Ryle, G. (2009). *Collected papers*. Routledge.
- Santini, J., Bloor, T., & Sensevy, G. (2018). Modeling Conceptualization and Investigating Teaching Effectiveness: A Comparative Case Study of Earthquakes Studied in Classroom Practice and in Science. *Science & Education*, 27(9–10), 921–961. <https://doi.org/10.1007/s11191-018-0016-6>
- Schegloff, E. A., Jefferson, G., & Sacks, H. (1977). The Preference for Self-Correction in the Organization of Repair in Conversation. *Language*, 53(2), 361. <https://doi.org/10.2307/413107>
- Sensevy, G. (1994). *Institutions didactiques, régulation, autonomie : une étude des fractions au cours moyen*. <http://www.theses.fr/1995AIX10002>
- Sensevy, G., Mercier, A., & Schubauer-Leoni, M.-L. (2000). Vers un modèle de l'action didactique du professeur. À propos de la Course à 20. *Recherches En Didactique Des Mathématiques*, 20(3), 263-304. [http://blog.espe-bretagne.fr/sensevy/Sensevy_et_al%20\(2000\)%20Modele_action_professeur.pdf](http://blog.espe-bretagne.fr/sensevy/Sensevy_et_al%20(2000)%20Modele_action_professeur.pdf)
- Sensevy, G., Schubauer-Leoni, M.-L., Mercier, A., Ligozat, F., & Perrot, G. (2005). An Attempt to Model the Teacher's Action in the Mathematics Class. *Educational Studies in Mathematics*, 59(1–3), 153–181. <https://doi.org/10.1007/s10649-005-5887-1>
- Sensevy, G., & Mercier, A. (2007). *Agir ensemble : L'action didactique conjointe du professeur et des élèves*. *PUR*, 225.
- Sensevy, G., Tiberghien, A., Santini, J., Laubé, S., & Griggs, P. (2008). An epistemological approach to modeling: Cases studies and implications for science teaching. *Science Education*, 92(3), 424–446. <https://doi.org/10.1002/sci.20268>
- Sensevy, G. (2011). *Le sens du savoir : Éléments pour une théorie de l'action conjointe en didactique*. De Boeck.
- Sensevy, G. (2012). Le jeu comme modèle de l'activité humaine et comme modèle en théorie

- de l'action conjointe en didactique. Quelques remarques. *Nouvelles Perspectives En Sciences Sociales*, 7(2), 105–132. <https://doi.org/10.7202/1013056ar>
- Sensevy, G., Forest, D., Quilio, S., & Morales, G. (2013). Cooperative engineering as a specific design-based research. *ZDM*, 45(7), 1031–1043. <https://doi.org/10.1007/s11858-013-0532-4>
- Sensevy, G., Gruson, B., & Forest, D. (2015a). On the Nature of the Semiotic Structure of the Didactic Action: The Joint Action Theory in Didactics Within a Comparative Approach. *Interchange*, 46(4), 387–412. <https://doi.org/10.1007/s10780-015-9266-2>
- Sensevy, G., Santini, J., Cariou, D., & Quilio. (2018). Preuves fondées sur la pratique, pratiques fondées sur la preuve : Distinction et mise en synergie. *Éducation et Didactique*, 12(2018/2), 111–125.
- Sensevy, G., & Bloor, T. (2019). Cooperative Didactic Engineering. In Steve Lerman (Ed.), *Encyclopedia of Mathematics Education* (pp. 1–5). Springer International Publishing. https://doi.org/10.1007/978-3-319-77487-9_100037-1
- Shapin, S. (2010). *Never pure: Historical studies of science as if it was produced by people with bodies, situated in time, space, culture, and society, and struggling for credibility and authority*. Johns Hopkins University Press.
- Silver, N. (2012). *The signal and the noise: Why so many predictions fail--but some don't*. Penguin Press.
- Stoddart, T., Pinal, A., Latzke, M., & Canaday, D. (2002). Integrating inquiry science and language development for English language learners. *Journal of Research in Science Teaching*, 39(8), 664–687. <https://doi.org/10.1002/tea.10040>
- Stuewer, R. H. (1975). *The Compton effect: Turning point in physics*. Science History Publications.
- Šulistová, J. (2013b). The Content and Language Integrated Learning Approach in Use. *Acta Technologica Dubnicae*, 3(2), 47–54. <https://doi.org/10.1515/atd-2015-0018>
- Swain, M., & Lapkin, S. (1995). Problems in Output and the Cognitive Processes They Generate: A Step Towards Second Language Learning. *Applied Linguistics*, 16(3), 371–391. <https://doi.org/10.1093/applin/16.3.371>
- Swain, Merrill. (2000). The output hypothesis and beyond: Mediating acquisition through collaborative dialogue. In *Sociocultural theory and second language learning* (pp. 97–114).
- Swain, Merrill, & Lapkin, S. (2013). A Vygotskian sociocultural perspective on immersion education: The L1/L2 debate. *Journal of Immersion and Content-Based Language Education*, 1(1), 101–129. <https://doi.org/10.1075/jicb.1.1.05swa>
- Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory* (1. ed). Springer.
- Tan, R. (2014). *Asian Scientist Magazine*.

<https://www.asianscientist.com/2014/10/columns/scientists-mind-ethos/>

- Tardieu, C. (2010). Votre B1 est-il mon B1 ? L'interculturel dans les tests d'évaluation en Europe. *Recherches En Didactique Des Langues et Des Cultures*, 7(2). <https://doi.org/10.4000/rdlc.2301>
- Terrier, L., & Maury, C. (2015). De la gestion des masses à une offre de formation individualisée en anglais-LANSAD: Tensions et structuration. *Recherche et Pratiques Pédagogiques En Langues de Spécialité - Cahiers de l APLIUT*, Vol. XXXIV N° 1, 67–89. <https://doi.org/10.4000/apliut.5029>
- The Douglas Fir Group. (2016). A Transdisciplinary Framework for SLA in a Multilingual World. *The Modern Language Journal*, 100(S1), 19–47. <https://doi.org/10.1111/modl.12301>
- Tiberghien, A., Cross, D., & Sensevy, G. (2014). The evolution of classroom physics knowledge in relation to certainty and uncertainty: THE EVOLUTION OF CLASSROOM PHYSICS KNOWLEDGE. *Journal of Research in Science Teaching*, 51(7), 930–961. <https://doi.org/10.1002/tea.21152>
- Trníková, J. (2015). *Primary CLIL*. 45–59.
- Tsai, C.-C. (1999). Laboratory exercises help me memorize the scientific truths? A study of eighth graders' scientific epistemological views and learning in laboratory activities. *Science Education*, 83(6), 654–674. [https://doi.org/10.1002/\(SICI\)1098-237X\(199911\)83:6<654::AID-SCE2>3.0.CO;2-Y](https://doi.org/10.1002/(SICI)1098-237X(199911)83:6<654::AID-SCE2>3.0.CO;2-Y)
- Tyler, A., Huang, L., & Jan, H. (Eds.). (2018). *What is applied cognitive linguistics? Answers from current SLA research*. De Gruyter Mouton.
- Van Lier, L. (2004). *The ecology and semiotics of language learning: A sociocultural perspective*. Kluwer Academic; Distributors for North America, Central and South America, Kluwer Academic.
- Venturini, P., & Amade-Escot, C. (2011, September). Teacher's activity analysis within a didactic perspective. *European Science Education Research Association Conference 2011*. <https://halshs.archives-ouvertes.fr/halshs-00918747>
- VIM (2012). International vocabulary of metrology. Basic and general concepts and associated terms. 3rd Edition.
- Vygotsky, L.S., (1962). *Thought and Language*. The M.I.T. Press
- Wegner, A. (2012). Seeing the Bigger Picture. *International CLIL Research Journal*, Vol 1 (4). <http://www.icrj.eu/14/article3.html>
- Wegner, A., Hudson B., & Loquet, M. (in press). *Epistemic Quality of Language Learning in a Primary Classroom in Germany*.
- Wenger, E. (2008). *Communities of practice: Learning, meaning, and identity*. Cambridge Univ. Press.

- Whitehead, J. (n.d.). Creating a Living Educational Theory from Questions of the Kind “How do I Improve my Practice?” *Cambridge Journal of Education*, Vol. 19, No.1,1989, pp. 41-52 <http://actionresearch.net/writings/livtheory.html>
- Whitehead, J. (2008). Using a living theory methodology in improving practice and generating educational knowledge in living theories. *Educational Journal of Living Theories*, 103–126.
- Whyte, S. (2016). Who are the Specialists? Teaching and Learning Specialised Language in French Educational Contexts. *Recherche et Pratiques Pédagogiques En Langues de Spécialité - Cahiers de l APLIUT, Vol. 35 N° spécial 1*.
<https://doi.org/10.4000/apliut.5487>
- Wittgenstein, L., Anscombe, G. E. M., Hacker, P. M. S., & Schulte, J. (1957/2009). *Philosophische Untersuchungen =: Philosophical investigations* (Rev. 4th ed). Wiley-Blackwell.
- Wittgenstein, L. (1996). *Le cahier bleu et le cahier brun*. Gallimard.
- Wojciech, S., (2019). Ludwik Fleck. The Stanford Encyclopedia of Philosophy (Winter 2019 Edition). Edward N. Zalta (ed.).
<https://plato.stanford.edu/archives/win2019/entries/fleck/>
- Yasuda, S. (2011). Genre-based tasks in foreign language writing: Developing writers’ genre awareness, linguistic knowledge, and writing competence. *Journal of Second Language Writing*, 20(2), 111–133. <https://doi.org/10.1016/j.jslw.2011.03.001>
- Yeught, M. V. der. (2016). Protocole de description des langues de spécialité. *Recherche et Pratiques Pédagogiques En Langues de Spécialité - Cahiers de l APLIUT, Vol. 35 N° spécial 1*. <https://doi.org/10.4000/apliut.5549>
- Zanten, A. van (Ed.). (2008). *Dictionnaire de l’éducation*. Presses universitaires de France.
- Zierer, K., & Seel, N. M. (2012). General Didactics and Instructional Design: Eyes like twins A transatlantic dialogue about similarities and differences, about the past and the future of two sciences of learning and teaching. *SpringerPlus*, 1. <https://doi.org/10.1186/2193-1801-1-15>

List of Appendices

Appendix A: Uncertainty sequence: teachers' notes and *a priori* analysis

Appendix B: Complete laboratory report (1st version)

Appendix C: Questionnaire following The Exploratory Lesson

Appendix D: Enhancing-fluency exchange: listening worksheet

Appendix E: More recent formula to calculate uncertainty

Appendix F: Transcription of the extended roleplay

Appendix A

Uncertainty sequence: teachers' notes and *a priori* analysis

Cette situation, conçue par une professeure de physique et une professeure d'anglais, vise à renforcer deux notions très importantes dans la prise des mesures : l'exigence de prendre en compte la notion d'incertitude dans toutes les mesures, et l'importance d'un protocole rigoureux pour réduire au maximum l'incertitude dans les mesures. Les étudiants sont amenés étape par étape, à communiquer en anglais dans la langue de spécialité relative à ce domaine. Au fur et à mesure qu'ils approfondissent leur compréhension des différents enjeux au cœur du projet, ils acquièrent en même temps, en anglais, le niveau de langue, à l'oral et à l'écrit, nécessaire pour la maîtrise du domaine concerné ; un enjeu principal de la séance est d'expérimenter la perspective actionnelle, c'est-à-dire la notion selon laquelle c'est en agissant dans et avec la langue qu'on développe des compétences dans cette langue.

Séance 1

Objectifs

Compétences communicatives langagières

Compétences scientifiques

<p>EO, EE B1 Mener à bien une description d'un protocole comme une succession linéaire de points</p> <p>Planification Prévoir et préparer la façon de communiquer les points importants qu'on veut transmettre en exploitant toutes les ressources disponibles.</p>	<p>Mettre en œuvre une démarche scientifique en élaborant un protocole.</p> <p>Comprendre la nécessité de l'incertitude dans les mesures ; comprendre l'aspect subjectif dans l'estimation des incertitudes et par ce biais comprendre qu'il faut développer son sens pratique dans une bonne démarche scientifique.</p>
---	--

Activité 1

Travail en binôme– Consigne : élaborer un protocole pour mesurer le diamètre d'une balle de tennis avec les moyens disponibles dans la salle. Il faut décrire le protocole avec suffisamment de détails pour qu'un autre étudiant puisse exécuter l'expérience et obtenir les mêmes résultats.

'Working in pairs you're going to elaborate a protocol to measure the diameter of a tennis ball using instruments available in class - be careful to note down your results.'

Distribution de balles de tennis et d'une fiche d'instruction (ci-après) :

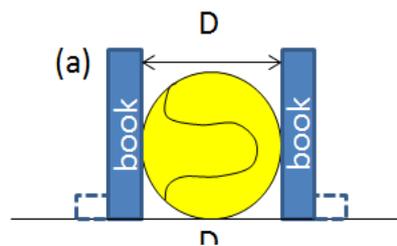
Instruction worksheet	
	Imagine an experiment to determine the diameter of a tennis ball using material available in the classroom.
	Research all the vocabulary necessary in order to be able to explain your protocol step by step to another student.
	The student who listens to your protocol should be able to carry out the same experiment and obtain the same results.
Materials	
Procedure/protocol (number each step)	
Results	

NB Il peut être utile d'amener un peu de matériel de base, tel que des équerres ou du fil, mais en général les étudiants ont l'initiative de s'adapter à leur environnement en utilisant par exemple, le fils de leurs écouteurs, l'équerre du voisin etc., ce qui est préférable.

Les étudiants réfléchissent à deux sur un protocole adapté : les échanges sont en français dans un premier temps. Le/la professeur(e) circule et, selon les besoins, veille aux points suivants : rassurer les étudiants sur la bonne compréhension de la consigne ; aider avec la recherche du vocabulaire ; corriger la prononciation ; corriger les faux-amis ; vérifier que les étudiants décrivent le protocole avec suffisamment de détails.

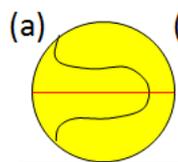
Dans ces circonstances, la plupart d'entre eux vont proposer l'une des deux méthodes suivantes, ou bien une variante de celles-ci :

- A) Méthodes à une dimension : la détermination de D se fait en mesurant la distance entre les deux parois intérieures des prismes droits.



- B) Méthode de la mesure de la **circonférence** \mathcal{C} : elle peut se faire avec un fil ou une ficelle

$$\mathcal{C} = \pi D \text{ et donc } D = \mathcal{C} / \pi$$



NB : A ce stade, nous n'avons pas encore parlé de l'incertitude dans les mesures : certains étudiants vont peut-être soulever cet aspect de l'exercice et il faut les encourager à le faire et les féliciter d'y avoir pensé.

Dans le même sens, si d'autres protocoles sont proposés il faut les encourager à condition qu'il soit possible de mener l'expérience en cours. De manière générale, c'est bien d'encourager la diversité d'approches pour que la classe entière puisse explorer un maximum d'idées et de vocabulaire.

Vocabulaire qui doit émerger de l'activité (liste non-exhaustive)

Verbes : align, attach, fix, insert, lodge, remove, squeeze, turn, twist, slide, wind around.

Outils : hard-backed books, protractor, rigid object, ruler, set square, string, thread, wire.

Termes mathématiques : circumference, graduations, height, length, parallel, perpendicular, squared, radius, width.

Autre : front-view, back-view, side-view, aerial view, eyesight, naked eye.

Exemples d'erreurs de prononciation et d'accent tonique à prévoir ou à corriger fréquemment

Cir'cumference, 'Measure, 'parallel, 'ruler, 'surface, suffix -ed, wind (verbe)

Grammaire

A ce stade les échanges se font essentiellement au présent simple, ce qui convient très bien pour un protocole scientifique.

Erreurs à corriger à chaque occasion : « for + base verbale » à la place de l'infinitif comme mauvaise traduction de « pour faire ... ». Savoir distinguer entre « measure » le verbe et « measurement » le nom.

Problèmes éventuels

Des compétences de recherche peu développées : ex. « rapporteur » traduit sur Google traduction comme « reporter » au lieu de « protractor » ; faire la démonstration d'utiliser plusieurs logiciels de traduction, puis vérifier sur Google Image pour savoir si le terme est juste.

La non prise en compte de l'incertitude dans les mesures : la deuxième partie du cours sert à souligner l'importance de l'incertitude dans les mesures : noter d'éventuelles anomalies qui sont la conséquence de cet oubli (ex. résultats improbables, résultats très divergents, résultats qui changent même avec la même méthode et la même personne *). Ces exemples serviront pour souligner l'importance de l'incertitude dans les mesures.

Des protocoles qui dépassent les connaissances du professeur de langue : à encourager en vérifiant que l'étudiant peut expliquer clairement en anglais son raisonnement.

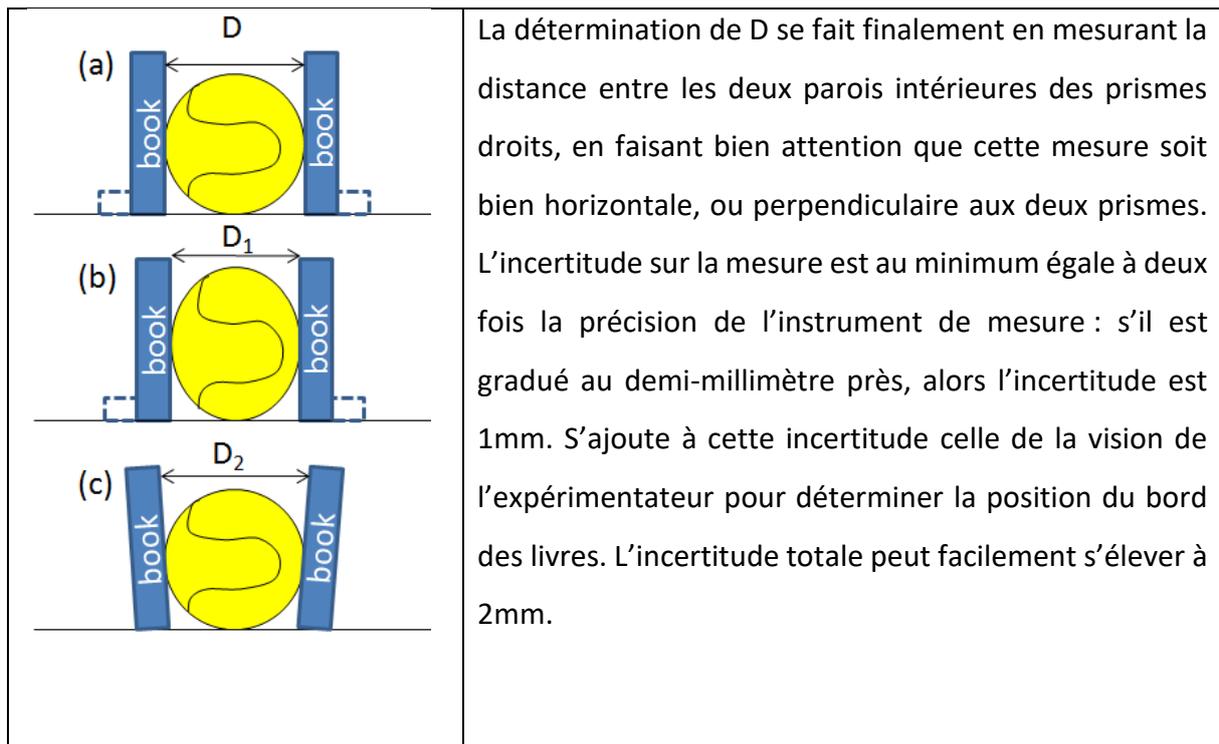
Le/la professeur(e) circule et interroge les étudiants sur leur raisonnement afin de les guider vers un protocole plus rigoureux.

Pour la méthode A, des questions du type suivant seront utiles :

How did you ensure the book/set square/ruler/box was exactly perpendicular to the table? Where did you check your right angles? Were you careful about parallax? Have you included that in your written protocol? How can you be sure of fixing the ball without squeezing it? Doesn't that increase your uncertainty? How many times did you take the measurement? Was it always the same person?

A) Méthodes à une dimension : la détermination de D se fait en mesurant la distance entre les deux parois intérieures des prismes droits.

Figure 1 : utilisation d'un prisme droit afin de mesurer le diamètre d'un objet sphérique : (a) méthode pertinente ; (b) problème de trop forte compression de la sphère induisant une sous estimation de son diamètre ($D_1 < D$) ; (c) mauvais positionnement des prismes droits induisant ici une surestimation de D ($D_2 > D$).



B) Méthode de la mesure de la **circonférence** \mathcal{C} :

Elle peut se faire avec un fil ou une ficelle, en faisant un ou plusieurs tours. Attention, l'incertitude de la mesure va dépendre de la position du fil sur la balle (sur son équateur ou non, voir figure 2 (c,d)) et du diamètre du fil (ficelle, figure 3 (g,h)).

$$\mathcal{C} = \pi D \text{ et donc } \Delta \mathcal{C} = \pi \Delta D \text{ et finalement } \Delta D = \Delta \mathcal{C} / \pi$$

On peut aussi faire plusieurs tours pour diminuer l'incertitude sur D (n tours divisent l'incertitude sur D par n mais peuvent rajouter une erreur sur la valeur cherchée, donc on aura une meilleure précision mais sur une valeur fautive !). Attention il ne faut pas utiliser une ficelle de gros diamètre et rester près de l'équateur de la balle (figure 2 (e,f)). Si on repasse au même endroit avec une ficelle épaisse on augmente la valeur du diamètre de la balle que l'on veut mesurer au cours de l'expérience.

On suppose que le fil ou la ficelle sont inextensibles, et sont incapables de comprimer localement la balle.

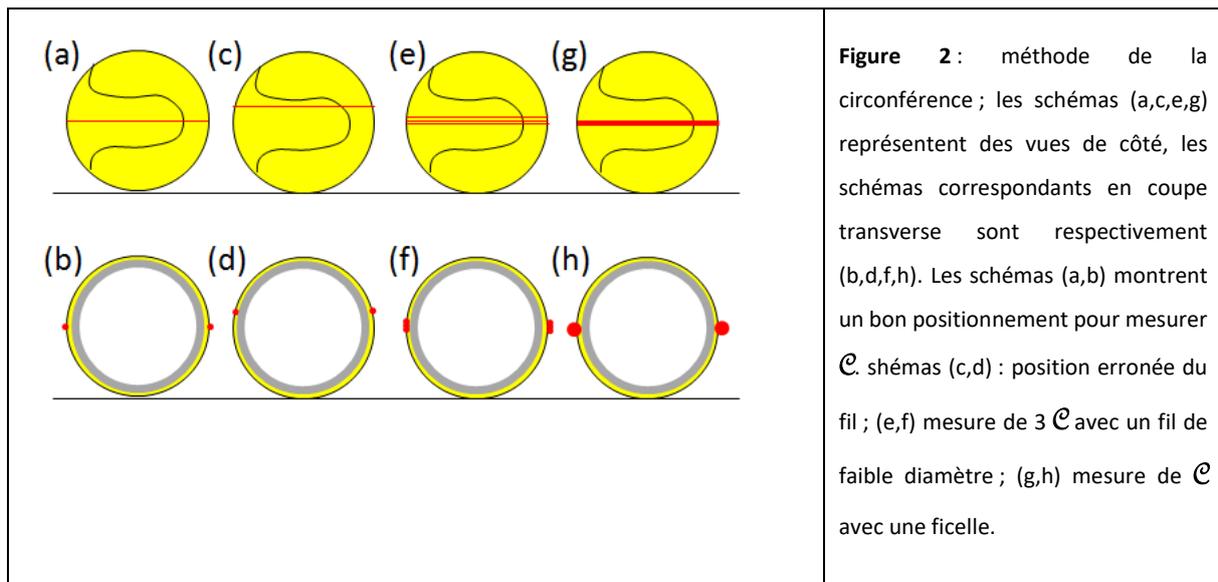


Figure 2 : méthode de la circonférence ; les schémas (a,c,e,g) représentent des vues de côté, les schémas correspondants en coupe transverse sont respectivement (b,d,f,h). Les schémas (a,b) montrent un bon positionnement pour mesurer \mathcal{C} . schémas (c,d) : position erronée du fil ; (e,f) mesure de $3\mathcal{C}$ avec un fil de faible diamètre ; (g,h) mesure de \mathcal{C} avec une ficelle.

Pour la méthode B des questions du type suivant aideront les étudiants à clarifier leur raisonnement et à mieux décrire leur protocole :

How can you be sure you are exactly in the centre of the ball? How tight did you pull the wire/string/thread? How many times did you measure the ball? Which measurement did you take? Did you take the average of the measurements or the widest measurement? Which is best? Ok so you divided the circumference by pi – what about the uncertainty?

Problèmes éventuels

Les étudiants ont tendance à seulement prendre en compte le niveau d'incertitude associé à la lecture de l'appareil de mesure. Il faut tenter de poser des questions qui les poussent à prendre en considération tous les facteurs qui pourront avoir un impact sur les résultats de leur protocole, ce qui les amène à adopter une meilleure démarche scientifique aussi bien qu'un niveau de langue plus précis et détaillé.

Des protocoles qui dépassent les connaissances du professeur de langue : les pousser à expliquer leur raisonnement. Souvent, ce sont des étudiants qui ont des bases scientifiques plus solides et qui produisent des exemples intéressants.

Activité 2

Consignes :

Vous allez décrire votre protocole de sorte qu'un autre étudiant puisse refaire l'expérience en suivant vos instructions et en utilisant le même matériel. Ne donnez pas vos résultats dans un premier temps afin de les comparer avec les résultats obtenus par l'interlocuteur qui suit votre protocole.

Une fois que les étudiant.e.s ont marqué leur résultats au tableau, le/la professeur.e mène une discussion à partir des résultats inscrits au tableau, afin de faire ressortir des phénomènes qui révèlent l'importance des incertitudes dans les mesures. Soulevez les questions :

- Comment expliquer des résultats différents ?
- En Physique, 6.5 cm peut être égal à 6.4 cm ou 6.6 cm, comment est-ce possible ?

(On cherche à faire exprimer l'importance de l'incertitude : des résultats différents peuvent être expliqués par des protocoles et praticiens différents d'où vient la nécessité de cerner son niveau d'incertitude ; cela permet de comparer des résultats d'expériences différentes où $6.4 \pm 0.1 \text{ cm}$ sera comparable à $6.5 \pm 0.1 \text{ cm}$.)

Voir texte DPE p.237-239 pour un exemple de cette étape

Activité 3 : Worksheet (ou autre, au choix)

Protocol and uncertainty: pre-discussion worksheet
1. What is the degree of uncertainty for the measurement of a height when the measuring instrument is graduated in increments of 1mm and 0.5mm respectively?
2. To what extent is 6.50 more precise than 6.5 and why?
3. Translate "0,5mm" -
4. Pronounce (i) "measure", (ii) "determine", (iii) "surface"

5. Translate : Racine carré, au carré, à la puissance trois, à la puissance dix, numérateur et dénominateur d'une fraction

6. (a) Experimental uncertainties should be rounded to one significant figure
(b) Experimental uncertainties could be rounded to one significant figure

7. What is the problem here? (9.82 ± 0.2138) cm

.....

Protocol and uncertainty: pre-discussion worksheet

1. What is the degree of uncertainty for the measurement of a height when the measuring instrument is graduated in increments of 1mm and 0.5mm respectively?

In general, for increments of 1mm the degree of uncertainty would be 1mm (0.5mm for each end of the measuring instrument) and for increments of 0.5mm the uncertainty would be 0.5mm (0.25mm for each end of the measuring instrument). However, this is not to say the degree of uncertainty is only dependent on the measuring instrument – other factors may be more important

2. To what extent is 6.50 more precise than 6.5 and why?

It is more accurate to the hundredths place as the zero informs us that the measure was made accurate to that last digit which had a value of zero. We don't know if 6.5 is rounded up or down.

3. Translate “0,5mm” -

“0.5mm” insist on decimals. Quick revision of point, dot, full-stop, period – different ways of saying “.”

4. Pronounce (i) “measure”, (ii) “determine”, (iii) “surface”

(i) /'meʒə/, (ii) /dɪ'tɜ:mɪn/, (iii) /'paɪ/ (iv) /'sɜ:(r)fɪs/, (v) /'ju:lə(ɪ)/

5. Translate : Racine carré, au carré, à la puissance trois, à la puissance dix, numérateur et dénominateur d'une fraction

Vocabulary: square root, squared, to the power of three, ten to the power of three, numerator and denominator of a fraction

6. (a) *Experimental uncertainties should be rounded to one significant figure*
(b) Experimental uncertainties could be rounded to one significant figure

7. What is the problem here? (9.82 ± 0.2138) cm

The last significant figure in any stated answer should usually be of the same order of magnitude (in the same decimal position) as the uncertainty.

Homework : Travail pour la semaine suivante

Travail en mini-groupe (3 – 6 personnes selon le nombre de personnes dans la classe entière.)

Distribuer worksheets 1 – 6

Consigne : A partir de l'indice sur la fiche, élaborer un protocole pour mesurer le diamètre d'une balle de tennis en estimant le niveau d'incertitude dans la mesure. **Faites l'expérience du protocole que vous avez choisi et notez vos résultats.**

Ceci peut être fait en groupe de 4 ou bien 2 x 2 afin de comparer les résultats des binômes au sein de leurs propres mini-groupes. Il est préférable de laisser les étudiants s'organiser selon leurs affinités et ce qui est pratique pour la communication entre eux.

Le choix du protocole reste plutôt souple mais il est important que chaque groupe travaille sur une méthode différente afin de pouvoir mettre en place un jeu de rôle pour l'évaluation finale : il est souhaitable d'informer les étudiants de cette évaluation finale afin qu'ils travaillent l'activité avec cet objectif à l'esprit.

NB : Il se peut qu'un groupe propose la méthode de la projection de l'ombre de la balle. Il est préférable d'éviter l'exploration de cette méthode car elle sera utilisée et explicitée dans la séance 3 en tant que modèle pour l'expression écrite quand les étudiants feront un rapport de laboratoire.

Si un groupe tient à refaire l'une des deux méthodes déjà explorées, c'est tout à fait possible, voire préférable pour les étudiants en difficulté. Aussi, si un groupe propose une autre méthode que celle proposée sur leur fiche, c'est aussi possible : l'essentiel est que ce choix soit fait après discussion dans le nouveau mini-groupe et que le groupe soit réellement capable de mettre l'expérience en œuvre, soit pendant le cours, soit chez eux ; l'enthousiasme du groupe est important.

Worksheet 1, 2, 3, 4, 5, 6:

The impact of protocols in experiments on uncertainties

Describe an experiment that you have decided to carry out to measure the diameter of a tennis ball. You must include in your description your protocol, the material you used and the problems you encountered and what you did to avoid them.

Specify the degree of uncertainty you expect to encounter measuring the diameter and give the result of your work with the correct written form: $D = (x \pm \Delta x)$ unit length (i.e. cm, mm etc.).

(NB: The number of significant figures written for x must correspond to the degree of uncertainty estimated.)

Explain in a detailed manner the basis of your estimation and what you did to reduce it to a minimum.

One-dimensional methods

Group 1) Hint: dough

Group 2) Hint: A photograph, a spirit level and ruler

Group 3) Hint: String or thread (*si besoin, voir ci-dessus*)

Group 4) Hint: hard-backed books or square sets (*si besoin, voir ci-dessus*)

Two-dimensional method

Group 5) Hint: ImageJ (free software)

Three-dimensional method

Group 6) Hint : transparent overflow vessel

Ci-après les méthodes proposées et les facteurs à prendre en compte pour chaque méthode :

Group 1) Hint: dough

Méthode de **l’empreinte** : il s’agit d’enfoncer la balle dans un matière molle (pâte à sel, pâte à pain, pâte à pizza, sable humide dans un bac, argile etc.) dont la surface aura été préalablement rendue bien plane, bien lisse, jusqu’à une profondeur plus grande que sa mi-hauteur, de l’enlever, et de mesurer le diamètre de l’empreinte laissée, comme le montre la figure 2. L’incertitude de mesure est du même ordre de grandeur que la méthode du prisme droit si elle est bien exécutée (on retire bien perpendiculairement la balle sans bouger sur les côtés). Attention à l’effet de parallaxe pendant la mesure.

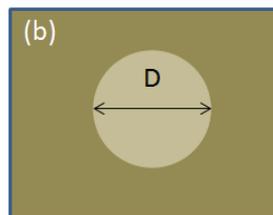
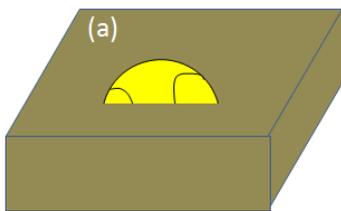


Figure 2 : méthode de l’empreinte. (a) la balle est enfoncée profondément ; vue 3D ; (b) vue aérienne de l’empreinte après retrait de la balle.

Le/la professeur(e) circule et interroge les étudiants sur leur raisonnement afin de les guider vers un protocole plus rigoureux. Pour cette méthode, des questions du type suivant seront utiles :

How did you manage to push the ball far enough and at the same time be able to pull the ball out without altering the mould? Were you careful about parallax? Have you included that in your written protocol? How did you manage to make a dough of the right consistency? How many times did you take the measurement? Was it always the same person?

Group 2) Hint: A photograph, a spirit level and ruler

Méthode de la **photographie avec échelle** : ici la balle peut être prise en photographie sous n’importe quel angle, on doit toujours imager un disque, il n’y a pas de problème de parallaxe. Celui-ci n’intervient que pour mesurer son diamètre sur l’image, si l’instrument gradué (la règle) n’est pas perpendiculaire à l’axe optique (figure 3 (c-d)) de l’appareil photographique. De plus la balle et la règle doivent être à la même distance de l’appareil photographique ; il faut donc tester quelle erreur engendre le positionnement de cette règle comme le montre la figure 3 (a-b). Tout l’art d’estimer une incertitude sur une mesure expérimentale est de « traquer » toutes les erreurs possibles engendrées par un protocole, et de vérifier si telle ou telle étape de ce protocole ne fausserait pas la valeur finale recherchée, en s’en écartant plus ou moins significativement.

La figure 4 représente schématiquement comment on peut s’y prendre pour déterminer le diamètre D de la balle sur une photo connaissant l’échelle de celle-ci.

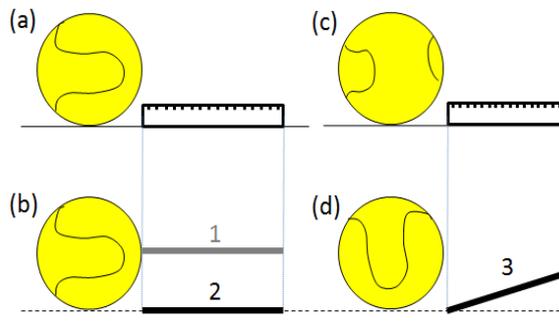


Figure 3 : méthode photographique. Pour que cette méthode donne une valeur du diamètre D avec une incertitude minimale, il faut que la règle donnant l’échelle de l’image soit bien positionnée vis-à-vis de la balle (comme la position 1). Les positions (2) et (3) peuvent donner des valeurs de D respectivement sous-estimée et surestimée. Les schémas (a) et (c) sont des vues de côté, les schémas (b) et (d) sont des vues aériennes.

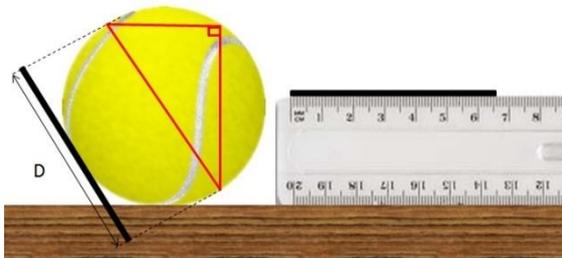


Figure 4 : photographie de la balle avec la règle qui sert d’échelle. Le diamètre de la balle sur cette photo est déterminé par le tracé d’un triangle rectangle (un point du bord du disque (de la balle à des dimensions) : l’hypoténuse est alors le diamètre du disque. Celui-ci est reporté sur l’image de la règle, qui donne un diamètre D de $(6.6 \pm 0.1)\text{cm}$.

Le/la professeur(e) circule et interroge les étudiants sur leur raisonnement afin de les guider vers un protocole plus rigoureux. Pour cette méthode, des questions du type suivant seront utiles :

Where did you position the ruler in relation to the ball? Were you careful about parallax? How did you go about converting the diameter of the ball in the photograph to the diameter of the ball in reality?

Group 3) Hint: String or thread – description dans la séance 1 (si besoin, voir ci-dessus)

Group 4) Hint: hard-backed books or square sets – description dans la séance 1 (si besoin, voir ci-dessus)

Group 5) Hint: ImageJ (free software)

Méthode à deux dimensions (surface du disque correspondant à l'image de la balle)



Figure 7 : logos de 2 logiciels gratuits de traitement d'images.

La photo de la méthode groupe 2 précédente peut être exploitée dans des logiciels gratuits comme GIMP ou ImageJ (figure 7) qui permettent de déterminer le rayon équivalent de n'importe quelle surface. Il suffit de détourer celle-ci. Le protocole de détourage (largeur du trait choisi) va entraîner une erreur sur la surface totale S du disque égale à $S=\pi(D/2)^2$. Il faut bien sûr changer cette largeur de trait (au moins la doubler) pour estimer l'incertitude sur la valeur de la surface ΔS qui va se répercuter sur celle du diamètre. On pourra aussi faire plusieurs détourages pour vérifier la reproductibilité des résultats (petite étude statistique).

$$\Delta S = (2\pi/4) D \Delta D \text{ et donc } \Delta D = 2\Delta S / (\pi D)$$

Le/la professeur(e) circule et interroge les étudiants sur leur raisonnement afin de les guider vers un protocole plus rigoureux. Pour cette méthode, des questions du type suivant seront utiles :

Where did you position the ruler in relation to the ball? Did you take a front, side or aerial view to take the picture? How did you convert the measurement of the ball in the image to the diameter of the ball in reality? Were you careful about parallax? How many times did you take the measurement? Was it always the same person?

Group 6) Hint : transparent overflow vessel

Méthode à trois dimensions

Il s'agit de déterminer le volume V d'eau déplacée par l'immersion de la balle (figure 8). Il faut supposer que la balle est imperméable et comme elle flotte, il faut trouver un système pour la maintenir au fond du récipient, ou du moins pour l'immerger. La précision sur V est donnée par la graduation du récipient. Si le récipient est équipé d'un «trop plein», avec un

réceptif de récupération étroit et gradué finement (disponible en laboratoire de chimie), l'incertitude sera encore meilleure (disponible en laboratoire de chimie).

On pourra avoir besoin de la notion de conversion, si le ΔV est en ml, il faut le convertir en mm^3 ou cm^3 pour pouvoir calculer ΔD en mm ou en cm....Il faut alors savoir qu'un centimètre cube est égal à un millilitre et que un centimètre cube est égal à 1000 millimètres cube.

$$V = \frac{4\pi D^3}{24} \text{ et donc } V = \frac{\pi D^3}{6} \text{ et donc } \Delta V = \frac{3 D^2 \Delta D \pi}{6} = \frac{\pi D^2 \Delta D}{2} \text{ et donc } \Delta D = \frac{2 \Delta V}{\pi D^2}$$

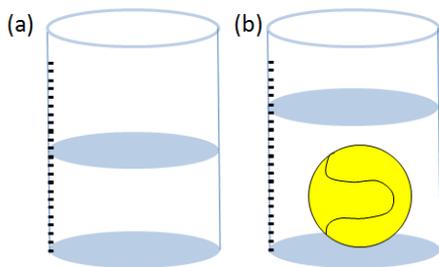


Figure 8 : méthode du volume. La différence de hauteur du niveau de l'eau donne un volume égal à celui d'une sphère de diamètre D . Une hypothèse forte d'imperméabilité de la balle est nécessaire. Le problème de maintien de la balle immergée est à résoudre (balle lestée ou immersion en appuyant dessus avec un objet de volume connu, ou on mesure le niveau de départ avec une objet en partie immergée jusqu'à un repère donné, etc.).

Le/la professeur(e) circule et interroge les étudiants sur leur raisonnement afin de les guider vers un protocole plus rigoureux. Pour cette méthode, des questions du type suivant seront utiles :

How did you keep the ball in the water? How did you manage the problem of meniscus (a curve in the upper surface of liquid contained in an object)? How many times did you take the measurement? Did you dry out the jar between each measurement?

Une autre méthode possible est la méthode du pied à coulisse (ci-après) mais comme la méthode de la projection de l'ombre, elle aussi est à éviter pour des raisons pratiques : à condition d'utiliser l'instrument correctement elle est beaucoup plus précise que les autres méthodes et de ce fait nuit à la discussion lors de l'évaluation finale. Il peut être intéressant pour savoir la mesure la plus précise possible du diamètre de la balle afin de le comparer avec des résultats obtenus par les autres méthodes : souvent l'un des groupes auront l'initiative de le faire.

Méthode directe **du pied à coulisse** :

Si l'écartement du pied à coulisse le permet, la mesure du diamètre doit pouvoir se faire au 3/100 de mm, sans compter la possible compression de la balle par l'instrument. Si l'instrument possède un système de débrayage, la mesure va se faire au pire au dixième de mm. Sinon elle se fera au pire au 5/10 de mm (à cause d'une légère compression).

Vocabulaire qui doit émerger de l'activité (liste non-exhaustive)

Verbes : align, attach, fix, insert, lodge, remove, squeeze, turn, twist, slide, wind around.

Outils : calliper, hard-backed books, protractor, rigid object, ruler, set square, string, thread, wire.

Termes mathématiques : circumference, graduations, height, length, parallel, pi, perpendicular, squared, radius, right-angle, width.

Autre : eyesight, front-view, back-view, side-view, aerial view, meniscus, naked eye

Useful phrases : In the context of our investigations, In general, the, the more accurate the results, As more weight is added,, In addition you will need these items, To achieve the most accurate measurements, make sure ...is on a level surface, You will need the following items, Things you will also need, You can increase accuracy even further by + verbING, The tips below will, This is designed to be used..., This demonstrates how, Repeat this process..(and Before/After repeating +verbING), Note: to prevent... , When measuring + base verbale, Do not allow..., Be sure to check..., Make sure

(Cette liste de vocabulaire peut être imprimée au dos du document ci-après, ou rajoutée au tableau pendant l'activité afin d'enrichir les productions proposées par les étudiants eux-mêmes)

Problèmes éventuels

Les étudiants ont tendance à seulement prendre en compte le niveau d'incertitude associé à la lecture de l'appareil de mesure. Il faut tenter de poser des questions qui les poussent à prendre en considération tous les facteurs qui pourront avoir un impact sur les résultats de leur protocole, ce qui les amène à adopter une meilleure démarche scientifique aussi bien qu'un niveau de langue plus précis et détaillé.

Des protocoles qui dépassent les connaissances du professeur de langue : les pousser à expliquer leur raisonnement. Souvent, ce sont des étudiants qui ont des bases scientifiques plus solides et qui produisent des exemples intéressants.

Dans la notation $D = (x \pm \Delta x)$, le nombre de chiffres significatifs écrits pour x doit être en adéquation avec l'incertitude estimée, or souvent les étudiants proposent des résultats du type : (6.5 ± 0.03) cm ; ce résultat n'est pas logique. On ne peut pas estimer un niveau d'incertitude encore plus précis que la mesure elle-même. C'est une erreur assez commune (peut-être les étudiants pensent qu'en étant plus précis ils/elles sont plus « scientifiques »). Le travail de la séance 2 sur les chiffres significatifs cherche à remédier cette fausse conception.

Non enrichissement du vocabulaire et tendance à rester au niveau d'expression B1

Il faut pousser les étudiants à s'exprimer avec des structures plus riches et un niveau de réflexion plus approfondi en proposant des structures plus élégantes ; c'est souvent l'occasion de corriger des fautes grammaticales : le prétérit à la place du present perfect, le conditionnelle uniquement pour parler de ce qu'on aurait pu faire et non pas pour la description du protocole qui sera au présent (cars toujours le même) ou au prétérit comme une description d'une expérience faite dans le passé.

Séquence : Estimating uncertainty

Résumé de la séance 1 : travail en binômes pour élaborer un protocole pour mesurer le diamètre d'une balle de tennis en estimant le degré d'incertitude dans sa mesure.

Séance 2

Objectifs

Compétences communicatives langagières	Compétences scientifiques
<p>EO, EO en interaction, EE B1 – B2</p> <p>Mener à bien une description détaillée d'un protocole en justifiant l'estimation de son niveau d'incertitude par des points pertinents.</p> <p>Coopération à visée fonctionnelle Spéculer sur les différents moyens pour améliorer son protocole et sur son impact possible sur le niveau d'incertitude.</p> <p>Faire clarifier : poser des questions pour vérifier ou clarifier des points équivoques.</p> <p>CO B2 Comprendre les idées principales d'une intervention complexe dans son domaine de spécialisation.</p>	<p>Mettre en œuvre une démarche scientifique en élaborant un protocole pour faire une mesure et en estimant le niveau d'incertitude de cette mesure.</p> <p>Cerner des erreurs possibles dans un protocole ; améliorer le protocole afin de réduire au minimum ces erreurs ; faire une estimation de la valeur de l'incertitude de sa mesure.</p> <p>Ecrire un résultat : en lien avec l'estimation de l'incertitude ; un seul chiffre significatif sur l'incertitude ; ne pas oublier les unités.</p> <p>Comprendre la démarche de Walter Lewin (vidéo MIT) par rapport à ses outils, son expérience, son hypothèse et le degré d'incertitude qu'il prend en compte.</p>

Activité 1

Travail en binômes – Contrôle formatif : expression orale en interaction

Objectif :

-faire progresser les étudiants en expression orale : chaque séance inclut des créneaux où les étudiants doivent se communiquer exclusivement en anglais.

-faire réfléchir, ou encore mieux, faire découvrir l'impact d'un protocole sur le niveau d'incertitude dans une mesure par les résultats qui émergent de cette activité ; les différents protocoles impliquent des niveaux d'incertitude plus ou moins importants.

Consignes :

«Describe your protocol to another student in English. Describe your protocol twice, the first time concentrating your efforts on the fluent expression of your description, the second time concentrating on your partner's full comprehension of your protocol; he or she should note down the details on the Enhancing Fluency Worksheet.

Activité 2

Visionnage d'un extrait d'un Massachusetts Institute of Technology (MIT) OpenCourseware : l'objectif de l'extrait est de rappeler l'exigence de prendre en compte la notion d'incertitude dans toutes les mesures. Pour faire comprendre cela, Walter Lewin met en place une expérience pour mesurer la hauteur, debout et allongé, d'un des étudiants qui assiste à son cours.

Transcription de l'extrait

Now all important in making measurements, which is always ignored in every college book, is the uncertainty in your measurement. Any measurement you make without any knowledge of the uncertainty is meaningless, I will repeat this, I want you to hear it tonight at 3 o'clock when you wake up, any measurement you make without a knowledge of its uncertainty is completely meaningless. My grandmother used to tell me that, at least she believed it, that someone who is lying in bed is longer than someone who stands up, and in honour of my grandmother today I'm going to bring this to a test. I have here a set-up where I can measure a person standing up and a person lying down, it's not the greatest bed, but lying down. I have to convince you about the uncertainty in my measurement because

a measurement without knowledge of the uncertainty is meaningless and therefore what I will do is the following. I have here an aluminium bar and I make the reasonable, plausible assumption that when this aluminium bar is sleeping, when it is horizontal, that it is not longer than when it is standing up. If you accept that we can compare the length of this aluminium bar with this set-up and with this set-up. At least we have some kind of calibration to start with. I will measure it, you have to trust me, during these three months we have to trust each other, so I measure here 149.9 cm. However, I would think that - this is the aluminium bar, this is in vertical position, 149.9 - but I would think that the uncertainty of my position is probably 1 mm. I can't really guarantee you that I did it accurately any better - so that's the vertical one. Now we're going to measure the bar horizontally for which we have a set-up here. The scale is on the other side, so now I measure the length of this bar - 150.0 horizontally - 150.0 again plus or minus 0.1 centimetre, so you will agree with me that I am capable of measuring plus or minus one centimetre, that's the uncertainty of my measurement. Now if the difference in lengths between lying down and standing up, if that were one foot, we would all know it, wouldn't we? You get out of bed in the morning, you lie down and get up and you go clunk and you're one foot shorter, and we know that that's not the case. If the difference were only one millimetre we would never know. Therefore, I suspect that if my grandmother was right, that it's probably only a few centimetres, maybe an inch, and so I would argue that if I can measure the length of a student to one millimetre accuracy that should settle the issue. So I need a volunteer. You're the volunteer? Ok, what is your name? Zak. Ok Zak- nice day today Zak, yeah? You feel all right? Your first lecture at MIT. I don't. Ok man. Stand there - ok 183.2 stay there, don't move. Zak - this is vertical - what did I say 18? Only one person - three? Come on 183.2 and an uncertainty of about 0.1 centimetres. And now we are going to measure him horizontally. Zak I don't want you to break your bones so we have a little step for you here. Put your feet there - oh let me remove the aluminium bar - watch out for the scale that you don't break that because then it's all over. Ok I'll come on your side, I have to do that- yeah, yeah relax - think of this as a small sacrifice for the sake of science all right? Ok you good? You're comfortable? You're really comfortable
right?
Wonderful
You're ready? Ok 185.7 - stay where you are. 185.7 - I'm sure - we first make the subtraction right - 185.7 plus or minus 0.1 centimetres - oh that is 2.5 plus or minus 0.2 centimetres. You are about one inch taller when you sleep than when you stand up. My grandmother was right. She's always right. Can you get off here

Le document ci-après accompagne le visionnage de l'extrait : son objectif est d'aider les étudiants à comprendre l'extrait, il incite une réflexion sur le protocole utilisé dans le cours MIT et son impact sur l'incertitude des mesures prises

Worksheet: The impact of protocols on accuracy

(i) As you listen, identify the terms for the following:

Hypothèse faible	
Expérience	
Précision	
Vérifier	
Dispositif expérimental	
Appareil de mesure	

(ii) Listen to the video and decide if the following statements are true or false:

- Any measurement you make without knowledge of the uncertainty is meaningless
- According to Walter Lewin's grandmother, someone lying in bed is shorter than someone standing up
- It is a reasonable assumption that an aluminium bar has exactly the same length horizontally as vertically
- The difference in length between lying down and standing up is one foot (30.48cm)
- Horizontally, Zak measures (183.2 ± 0.1) cm
- Zak is (2.5 ± 0.2) cm longer lying down than standing up

(1 inch = 2.54cm, one foot = 30.48cm):

(iii) Watch the extract again and note down Lewin's results for the measurement of both the bar and Zak.

	Aluminium bar	Zak
Vertically		
Horizontally		
Result	uncertainty	difference in height

Any comments?

(iv) How could Walter Lewin improve the protocol of his experiment?

(hint: compare results)

(hint: shock-absorbant soles)

(hint: parallax)

(v) On which of the two criteria below does Lewin base his degree of uncertainty?

- His reading of the measuring instrument
- The accuracy of the measuring instruments

(vi) Make a list of the subjective and objective factors that might influence measurement uncertainty.

Subjective factors:

Objective factors:

Ci-après le même document avec une idée générale des réponses attendues :

Worksheet: The impact of protocols on accuracy

(i) As you listen, identify the terms for the following:

Hypothèse faible	Assumption (reasonable)
Expérience	experiment
Précision	accuracy
Vérifier	check
Dispositif expérimental	Set-up
Appareil de mesure	Measuring instrument

(ii) Listen to the video and decide if the following statements are true or false:

- Any measurement you make without knowledge of the uncertainty is meaningless **T**
- According to Walter Lewin's grandmother, someone lying in bed is shorter than someone standing up **F**
- It is a reasonable assumption that an aluminium bar has exactly the same length horizontally as vertically **T**
- The difference in length between lying down and standing up is one foot (30.48cm) **F**
- Horizontally, Zak measures $(183.2 \pm 0.1)\text{cm}$ **F**
- Zak is (2.5 ± 0.2) cm longer lying down than standing up **T** – (maybe; according to Lewin)

(1 inch = 2.54cm, one foot = 30.48cm):

(iii) Watch the extract again and note down Lewin's results for the measurement of both the bar and Zak.

	Aluminium bar	Zak
Vertically	$(149.9 \pm 0.1)\text{cm}$	$(183.2 \pm 0.1)\text{cm}$
Horizontally	$(150.0 \pm 0.1)\text{cm}$	$(185.7 \pm 0.1)\text{cm}$
Result	± 0.1 cm uncertainty	$2.5 \pm 0.2\text{cm}$ difference in height

Any comments? Notice that he adds together the vertical uncertainty measure and the horizontal uncertainty measure for Zak but not for the bar. Should lead to discussion that probably because there are more factors creating uncertainty for a person than a bar.

(iv) How could Walter Lewin improve the protocol of his experiment?

(hint: compare results)

(hint: shock-absorbant soles)

(hint: parallax)

(v) On which of the two criteria below does Lewin base his degree of uncertainty?

- His reading of the measuring instrument
- The accuracy of the measuring instruments

He appears to be basing it on the accuracy of the instruments – or maybe his reading of the instruments. It's not really clear – a kind of general estimation of the impact of these factors.

(vi) Make a list of the subjective and objective factors that might influence measurement uncertainty.

Subjective factors: eyesight, mood (some days you feel more confident than others that you have identified all the pertinent factors). Experience; setting-up the experiment frequently would improve skills.

Objective factors: parallax, equipment, lighting, shoes, and other factors linked to the experimental protocol. What is a protocol? It is related to the choice of the set-up and how you use it.

Le travail avec l'extrait du cours MIT et la fiche qui l'accompagne devrait permettre de mieux intégrer les points suivants dans ce qui se passe en cours :

- Intégrer du vocabulaire utile pour le projet et éviter certains faux-amis (ex. experience)
- Encourager les étudiants à utiliser « accurate » à la place de « precise » ce qui est important en physique :

(Common definition -Wikipedia: In the fields of [science](#), [engineering](#) and [statistics](#), the accuracy of a [measurement](#) system is the degree of closeness of measurements of a [quantity](#) to that quantity's true [value](#).^[1] The precision of a measurement system, related to [reproducibility](#) and [repeatability](#), is the degree to which repeated measurements under unchanged conditions show the same [results](#).^{[1][2]} Although the two words precision and accuracy can be [synonymous](#) in [colloquial](#) use, they are deliberately contrasted in the context of the [scientific method](#).)

- Distinguer entre 'measure' (verbe) et « measurement » (nom)
- Faire comprendre la nécessité de prendre en compte les incertitudes dans les mesures.
- Amener les étudiants à une réflexion sur l'impact des protocoles sur les incertitudes.

Worksheet (verso) :

Réflexion sur la langue/critères de choix en physique

(vii) Choose the sentence which is most appropriate and explain why:

(Remember, the objective is to determine if Zak is taller lying down than standing up; the goal is not necessarily to determine the student's exact height.)

- a. He should have measured the student at least twice
- b. He could have measured the student at least twice

- a. The measuring tool should be held straight
- b. The measuring tool could be held straight

- For Nike shoes
- a. The student should have taken off his shoes
 - b. The student could have taken off his shoes

- For wooden clogs
- a. The student should take off his shoes
 - b. The student could take off his shoes

- a. Walter could take 2mm as the uncertainty value on Zak's height
- b. Walter should take 2mm as the uncertainty value on Zak's height

- a. Walter should check both the horizontal and vertical head-level with a set square
- b. Walter could check both the horizontal and vertical head-level with a set square

(viii) What other options can you suggest to improve the protocol of the experiment?

Ci-après le même document côté verso avec une idée générale des réponses attendues :

Réflexion sur la langue/critères de choix en physique

(vii). Choose the sentence which is most appropriate and explain why:

(Remember, the objective is to determine if the student is taller lying down than standing up; the goal is not necessarily to determine the student's exact height.)

- a. He should measure the student at least twice
 - b. **He could measure the student at least twice** (Could is more appropriate as it is one of a number of options)
-
- a. **The measuring tool should be held straight**
 - b. The measuring tool could be held straight

For Nike shoes

- a. **The student should take off his shoes**
- b. The student could take off his shoes

For Dutch wooden clogs

- a. The student should take off his shoes
- b. **The student could take off his shoes**

- a. **Walter could take 2mm as the uncertainty value on Zak's height**
- b. Walter should take 2mm as the uncertainty value on Zak's height

Et tu peux répondre could car il le fait en son âme et conscience, et peut penser qu'il n'arrive pas à lire une position au 0.5mm pres mais à 1mm pres.

- a. **Walter should check both the horizontal and vertical head-level piece with a set square**
- b. Walter could check both the horizontal and vertical head-level pièce with a set square (répondre should, sinon il sous estime son incertitude finale...il l'a peut etre fait mais pas sous les yeux des étudiants)

(viii). What other options can you suggest to improve the protocol of the experiment?

He could ask another person to check his measurement

Problèmes éventuels

Niveau de compréhension faible de certains étudiants : à chaque professeur d'adapter son enseignement selon le niveau général du groupe et son savoir-faire ; il est possible par exemple de vérifier la bonne compréhension des points principaux en français à la fin de l'exercice ; déposer le document sur la plateforme pour qu'ils puissent le regarder à nouveau. Cependant, le but de l'extrait n'est pas de se focaliser trop longtemps sur la compréhension orale mais de rester dans la dynamique du problem-solving en collaboration.

Une certaine confusion peut émerger de l'exercice : par exemple, 'it's false to say it's a reasonable assumption that the aluminium bar has the same length horizontally as vertically because of the uncertainty'. Ce genre d'intervention est plutôt une excellente occasion de clarifier ces points : l'incertitude est par rapport à notre lecture de l'appareil de mesure, ou la précision de l'appareil, et non pas sur l'aluminium bar. Rassurer les étudiants qu'ils/elles auront l'occasion de clarifier leur compréhension de ces notions lors du pairwork. Remercier l'étudiant qui a osé proposer cette réponse afin d'encourager un environnement où on n'a pas peur de montrer ce qu'on a pas compris. Très important.

Technique : les vidéos projecteurs sont parfois capricieux -prévoir de déposer l'extrait sur la plateforme.

Séquence : Estimating uncertainty

Résumé de la séance 2 : travail de révision sur des différents points importants dans la séquence : vocabulaire, prononciation, facteurs pertinents à l'estimation de l'incertitude, chiffres significatifs.

Travail en mini-groupes pour élaborer un protocole pour mesurer le diamètre d'une balle de tennis en estimant le degré d'incertitude dans sa mesure.

Séance 3

Objectifs

Compétences communicatives langagières	Compétences scientifiques
<p>EO, EO en interaction, EE B1 – B2</p> <p>Mener à bien une description détaillée d'un protocole en justifiant l'estimation de son niveau d'incertitude par des points pertinents.</p>	<p>Mettre en œuvre une démarche scientifique en élaborant un protocole pour faire une mesure et en estimant le niveau d'incertitude de cette mesure.</p>
<p>EE B2 : Coopération à visée fonctionnelle</p> <p>Ecrire un rapport de laboratoire, clair et détaillé, d'une expérience menée en mini-groupes.</p>	<p>Mettre en œuvre une démarche scientifique en écrivant un rapport de laboratoire claire et détaillé.</p>
<p>Faire une synthèse :</p> <p>l'évaluation d'informations empruntés à des sources diverses.</p>	

Activité 1 (option)

Warm-up *Un quart d'heure pour faire le point sur la séance précédente : les étudiants se mettent d'accord sur les résultats/vocabulaire de leur expérience : le professeur circule pour répondre aux diverses questions ou de reconnaître et féliciter les efforts fournis.*

Activité 2

Travail en classe entière : *les étudiants ont deux documents : (i) un descriptif de tous les éléments qui composent un rapport de laboratoire, (ii) un rapport de laboratoire complet d'une expérience menée pour mesurer le diamètre d'une balle de tennis avec la méthode de la projection de son ombre.*

Objectifs

Faire lire en détail un rapport de laboratoire afin d'intégrer et reproduire le modèle ; amener les étudiants vers une meilleure compréhension de tous les différents aspects de la mise en œuvre d'une démarche scientifique ; mener à bien une expérience et de la décrire correctement dans un langage scientifique ; améliorer le vocabulaire et la complexité des phrases à l'écrit.

Consigne : 'Here is a description of all the different elements of a laboratory report from the abstract to the closing remarks (document (i)). This second document is a complete laboratory report but the different components are not in the right order. Match the subtitle of each element of the report to its corresponding part in the laboratory report.

Science report: understanding and using the scientific method

One of the main skills that a scientist will learn is that of communication. If a scientist is unable to present information in a concise and understandable form then they will encounter problems in their professional life

Reports must contain the following components in this order:

The first and last names of the group members

1. Title

2. Abstract/summary

The summary is the material condensed to its main points but it should be sufficiently self-contained to enable the reader, who may be doing a literature-search, to decide whether or not to read the full report.

What did you set out to do or find?

What general method did you use/apply?

What assumptions were made?

What parameters/special conditions did you work within?

How successful were you?

What are your principal conclusions?

3. Introduction

Setting the scene, background info etc.

Objectives of the experiment.

The introduction is the 'scene setting' and is an elaboration of the summary. More detailed information may be included but the introduction should still be brief background to the exercise, explaining why it was performed, the way it was conducted and an outline of results expected

4. Aims/ Objectives:

5. Theory/Prerequisite: (pertinent previous scientific knowledge or observations)

6. Hypothesis

What 'you think' will be the final outcome of the experiment. This is generally based on prior knowledge or observations. In other words, you are not just pulling this 'out of thin air'; you have some logical reason for thinking this. If you have no prior knowledge of the concept, you will need to do research before making a hypothesis. Also, explain exactly 'why you think this'. **REMEMBER!** There is no right or wrong answer. It's strictly what 'you think' and 'why you think this'.

7. Context/Tools (describe the conditions in detail and the tools used, materials list etc.)

A figure or two, carefully labelled and somewhat schematic is usually sufficient to help the reader to imagine the general set-up.

8. Procedure/Experimental method/protocol

(Describe the protocol. Use numbered steps for your procedure. Someone else should be able to repeat your experiment using your instructions. A statement of the various tasks necessary to complete the study. Ignore details which are just instructions.)

Instruction Sheets	Laboratory Report
Place the pitot-static tube against one wall of the pipe and record the dynamic pressure indicated on the manometer. Record the pressure again at 5mm intervals across the diameter until the tube touches the opposite pipe wall. Repeat this at the five stations marked along the pipe.	A pitot-static tube was traversed across the pipe at several axial positions, each time recording the dynamic pressure profile.
Apply an initial load of 5 kN and set the extensometer to zero. Increase the load by increments of 2 kN to a maximum of 30 kN, recording the extension at each step. Repeat the procedure with reductions in load until reaching the initial load again.	The specimen was loaded incrementally throughout the elastic region, recording the extensions for both loading and unloading steps.

9. Experimental results and calculations (Include any figures, tables and equations. All measurements and units must be included)

10. Estimation of the measurement uncertainty/Discussion of results

This is the most important part of the report. Discuss the significance of graphs, of the numerical solutions and of the differences which may be seen between results which have come from distinct methods (theory or measurement?). Take care to point out peculiarities that may not be obvious. Explain reasonably any errors that are evident or any departures from accepted values which are clear, but be careful to avoid elaborate justifications of errors when the limitations on equipment and your technique really *prevent* highly accurate results, i.e. do not blame the equipment for everything! REMEMBER: You probably do everything thoroughly ONCE. If you came back next day and did it all again would you expect exactly the same data? Don't expect miraculous accuracy.

11. Conclusion.

This is a written summary of what was actually learned from doing the experiment. The conclusion will either support or reject the proposed hypothesis.

(i). Paragraph One:

In your own words describe the purpose of the experiment.

(ii). Paragraph Two:

Restate your hypothesis and your reasoning for this prediction.

Summarize the lab procedure.

Explain the set-up.

(iii). Paragraph Three

Describe the outcome of the experiment and how it relates to your hypothesis (supports or rejects) ; discuss your sources of error

Refer to your data tables, graphs, etc. in assessing the data because actual data from your observations is a 'must' in forming a conclusion.

From your analysis, point out certain trends or patterns that support your conclusion.

Closing remarks

Explain exactly what was/was not accomplished or learned from doing the lab.

What suggestions could you make to get more accurate results?

Document (ii) (Mixed-up laboratory report – page 1 only as example)

A

This report presents two experiments to determine the diameter of a tennis ball, the first with the use of a shadow projection method and Thales' theorem, the second with the use of a photograph of a tennis ball, a ruler and the mathematical rule of three. The experiment also sought to estimate the level of accuracy of each experiment and to compare their results. The methods used were simple in order to highlight the importance of good procedure in reducing the level of uncertainty.

Depending on the brand, the diameter of a tennis ball varies between 6.56 and 6.86 so an efficient procedure should give results within this range. The first procedure was undertaken in a living room very late in the evening in poor lighting conditions. A torch was shone on a tennis ball, each of which was positioned so as to ensure the shadow on the wall opposite was exactly perpendicular to the source of light and ball. Thales' theorem was used to calculate the diameter of the ball (see figure 1 and 2). The second procedure used a photograph of a tennis ball with a ruler positioned approximately at the height of the ball's radius (see figure 6) and was used as a scale.

The results of the two experiments are as follows: the first procedure $d = (6.0 \pm 0.6) \text{ cm}$, and the second procedure $d = (6.6 \pm 0.7) \text{ cm}$. As the diameter of a tennis ball is known to be between **6.54–6.86 cm** it can therefore be concluded that both set of results have a relatively high level of inaccuracy. This was thought to be due to problems of lighting and parallax.

B

i) to determine the diameter of a tennis ball ; ii) to use Thales' theorem to magnify the dimension to be measured (without a lens) ; iii) to use a photograph and ruler to measure the diameter iv) to estimate the accuracy of each measurement v) to compare the obtained results.

C

A number of possible improvements could be introduced to improve the accuracy of the projected shadow protocol:

- The use of a much more powerful torch (smaller if possible) in order to avoid penumbra
- The use of set squares and spirit levels (with wooden boards) to measure TB and TS (with a friend to avoid parallax)
- The removal of furniture close to the screen and the positioning of the torch closer to the ball in order to better magnify the ball's shadow.
- To measure the shadow of the ball with sunlight in the summertime (the 21st of June when the sun is at its highest position in the sky)
- The use of a lens to create an infinite light source (in a practical laboratory)

Les étudiants auront le temps de mettre le rapport dans le bon ordre afin d'être amenés à plonger dans le document et de bien prendre connaissance de tous les différents aspects d'un rapport de laboratoire complet.

Le document complet, corrigé, se trouve en Appendix B :

Problèmes éventuels

Difficulté à comprendre les consignes de l'exercice : les consignes de cet exercice sont plutôt compliquées donc souvent il faut les répéter plusieurs fois et donner des exemples de réponses pour la classe entière et ensuite c'est souvent utile de circuler pour vérifier que tout le groupe a bien compris.

Des questions surprenantes : de manière générale les étudiants sont très concentrés et actifs pendant cette activité. C'est aussi l'occasion de vérifier la bonne compréhension de chaque individu pendant que la classe est occupée : ce qui peut révéler des fausses conceptions surprenantes : ex « je ne vois pas comment calculer l'incertitude avec des maths comme elle fait dans le modèle ». C'est l'occasion d'expliquer que l'incertitude est incluse dans le calcul fait avec la formule de Thales, mais qu'il n'y avait pas un calcul pour l'incertitude même. Si le professeur de langue n'est pas en mesure de clarifier ce point, il faut encourager l'étudiant à chercher par d'autres moyens : soit les autres étudiants, soit le professeur de physique, soit des tutoriels sur youtube etc.

Activité 4

En suivant le modèle ci-dessus, les étudiants rédigent un rapport de laboratoire afin de décrire en détail l'expérience qu'ils ont menée en mini-groupe. Ils travaillent en collaboration en mini-groupe sur un document drive commun aux membres de chaque groupe.

Appendix B

Complete laboratory report (1st version)

1. Measuring the diameter d of a tennis ball using a projected shadow and a photograph

2. Abstract

This report presents two experiments to determine the diameter of a tennis ball, the first with the use of a shadow projection method and Thales' theorem, the second with the use of a photograph of a tennis ball, a ruler and the mathematical rule of three. The experiment also sought to estimate the level of accuracy of each experiment and to compare their results. The result of the shadow projection method was (6.0 ± 0.6) cm and though this partly overlaps with the $6.54\text{--}6.86$ cm diameter of a tennis ball used in official tournaments, it nevertheless suggests a high level of inaccuracy. This was probably due to parallax, an inaccurate set-up and poor lighting. The photograph method obtained the result $d = (6.6 \pm 0.7)$ cm which was a more accurate result but still with a relatively high level of uncertainty. The conclusion is that neither method is very suitable for obtaining results with a satisfactory level of uncertainty.

3. Introduction

This report describes two experiments designed to determine the diameter of a tennis ball and the level of uncertainty for each method. The methods used were simple in order to highlight the importance of good procedure in reducing the level of uncertainty. Both experiments were conducted in a living-room, at about 11 pm, using material available in a typical home, as shown in figure 1.

4. Objectives: i) to determine the diameter of a tennis ball ; ii) to use Thales' theorem to magnify the dimension to be measured (without a lens) ; iii) to use a photograph, a ruler and a set square to measure the diameter iv) to estimate the accuracy of each measurement v) to compare the obtained results.

5. Prerequisites: Thales' theorem as shown in figure 2, and notions of the impact of a punctual or spread source of light, as explained in figure 3. The mathematical rule of three to calculate with the use of proportionality.

6. Hypothesis

The diameter of a tennis ball varies between 6.56 and 6.86, possibly depending on the brand and age of the ball.

7. Context/Tools

The following items are required, as displayed in figure 1; A tennis ball ; two empty yogurt pots (to be used as a ball/ torch lamp stands, using the hollow disk at their base), flat surfaces of the same height (the top of 2 CD storage units), a torch, adhesive tape (to fix both the torch onto the yogurt pot stand and the stand onto the furniture's surface), a 5m long tape measure (graduated in mms).



Figure 1: picture of the main items needed for the shadow method to measure the diameter d of a tennis ball.

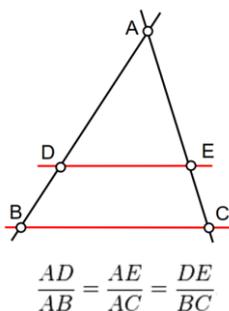


Figure 2: Thales' theorem; note that the straight lines in red should be parallel, so that the following ratios are equal.

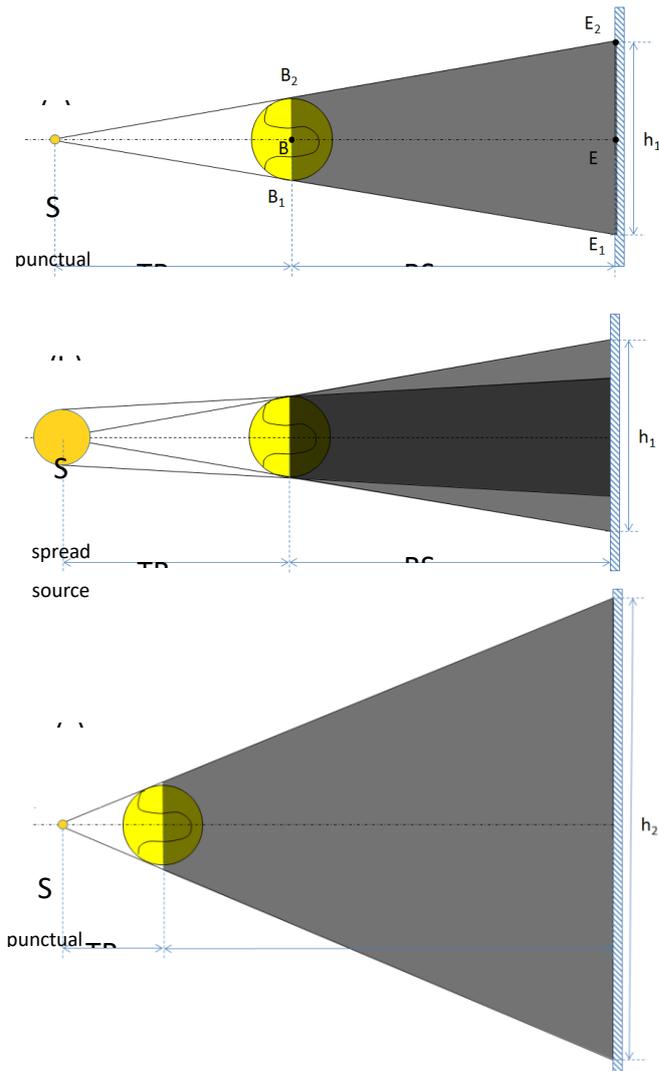


Figure 3: the projected shadows of a tennis ball B using either a punctual source of light S (a,c) or a spread source (b) on a screen E. Note that the size of the projected shadow greatly depends on the distance between the source of light and the ball (the closer, the bigger) for a given source-screen distance. By analogy with figure 2, Thales' theorem can then be re-written in (a) replacing A, D, B, E, C by S, B₁, E₁, B₂, E₂ respectively.

8. Procedure/Protocol:

(i) A torch and a ball were positioned as displayed in figure 4. Particular attention was given to place both the torch and the ball in such a way as to ensure that the projected light was perpendicular to the wall; if this were not so the shadow would no longer be a dark disk but an ellipse and it was therefore necessary to check this step before any measurements could be taken.



Figure 4: views of the set up; left, side view; right, axis view.

(ii) The torch-ball distance was chosen so as to be able to see the shadow on the white wall (screen); if the torch and the ball had been too close, the furniture next to the screen would have impeded the vision of a complete image (shadow).

(iii) The lighting of the ball had to be finely adjusted. An object of a known size was placed close to the wall which was later photographed and numerically treated to determine D. This diameter D of the shadow was also measured directly on the wall despite the poor lighting conditions (far too dark).

(iv) As there was a blurred zone (penumbra) separating the central part of the shadow and the outer edges, the measurement was taken in-between the two zones to minimize error.

(v) The distance between the facing walls (including the screen) was measured with the folding ribbon ruler, and with the use of the squares of the tiles on the ground, and in two steps as the distance was greater than 5m. Both CD parallelepiped storage units were identical which facilitated the measurement of the distances between the torch and the ball, and the distance between the ball and the screen (white wall in figure 4). All the obtained-values are given in table 1, with their corresponding estimated uncertainties. Note that it is difficult to measure distances alone without the use of a spirit level and with problems of parallax, even for short distances like TB.

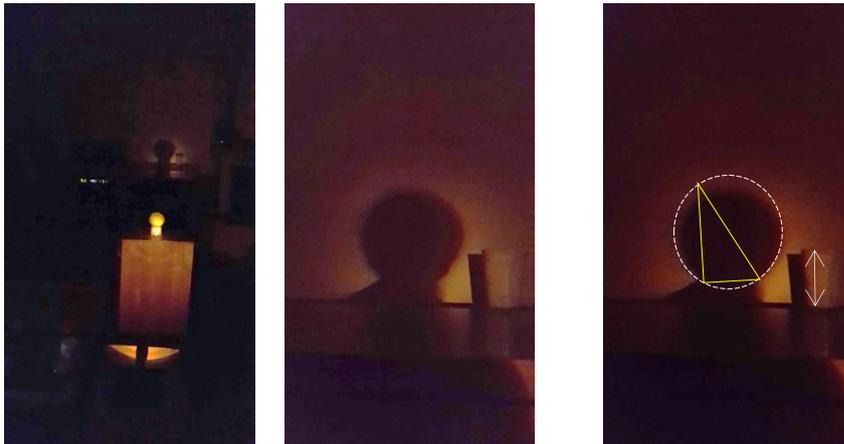
9. Experimental results:

The diameter D of the ball’s shadow measured directly on the wall was: $D = (22.5 \pm 0.5)$ cm. This measurement was taken three times and was within a 22-23cm range.

The photographs displayed in figure 5 were taken with an android cell phone (Samsung). The disk shadow could then be guessed and the white glass (the height of which is (10.4 ± 0.1) cm) close to the wall was used as a scale; D could thus be determined at $10.4/4 \times 8.1 = 21.06$ cm.

I eventually chose to take $D = (23 \pm 2)$ cm.

Figure 5: photographs taken with an android cell phone during the experiment; a) on the left, lighting adjustments; b) centre, the ball’s shadow on the screen; c) on the right, the measurement of the diameter of the shadow, thanks to b).



The distances used to apply Thales’ theorem are given in blue in table 1. To calculate d (the diameter of the tennis ball), the diameter of the shadow disk D which is (BC in figure 2 or E_1E_2 in figure 3), had to be measured. **Table 1: the distances between (i) the torch and the ball (TB) and (ii) the torch and the screen (TS).**

opposite walls	wall opposite the screen and torch	torch and ball (TB)	ball and screen (BS)	torch and screen (TS)
(509.7±0.5) cm	(114±1) cm	(104±1) cm	(292±2) cm	(396±2) cm

Thus, $d/D=TB/TS$ and eventually, the analytical expression of the ball’s diameter is

$$d = D \times TB / TS \quad (1)$$

numerical application: $d = 23 \times 104 / 396 = 6.04040404 \text{ cm}$

10. Estimation of the measurement uncertainty:

Let's take the logarithm of (1), which gives:

$$\ln(d) = \ln(D) + \ln(TB) - \ln(TS) \tag{2}$$

Let's calculate the derivative of (2), this gives:

$$d(d)/d = dD/D + d(TB)/TB - d(TS)/TS \tag{3}$$

Let's take the upper bound of (3) introducing 'deltas'

$$(\Delta d)/d = (\Delta D)/D + (\Delta TB)/TB + (\Delta TS)/TS$$

Eventually, $\Delta d = d \times [(\Delta D)/D + (\Delta TB)/TB + (\Delta TS)/TS]$ (4)

numerical application: $\Delta d = 6 \times [2/23 + 1/104 + 2/396] = 0.61384042 \text{ cm}$

Tennis ball diameter: $d = (6.0 \pm 0.6) \text{ cm}$

As it is known that the official diameter should be in the **6.54–6.86 cm** (2.57–2.70 inches) range, it can be concluded that this ball may have a diameter of the official tennis ball class. Nevertheless, the value range is slightly low; it can thus be concluded that the measurement's **uncertainty was underestimated** (the protocol and tools were not well adapted). An estimated error of at least 5% would have been more realistic as there was only one person manipulating the set-up (there were many problems of parallax and poor lighting). The results would probably have been more accurate with the use of a spirit level and a longer measuring tape. Also an optics bench and a diaphragm to sharpen the contrast of the ball's shadow would have been useful. A transparent screen would have avoided the problem of parallax when reading the measure.

The second method as a quick comparison: a photograph of a ball and a ruler as a scale. The graduation of the ruler is in 1 mms so the uncertainty will be at the minimum $0.5 \times 2 = 1 \text{ mm}$; but if the ruler is NOT well placed, the uncertainty will be significantly higher, as demonstrated in figure 6.

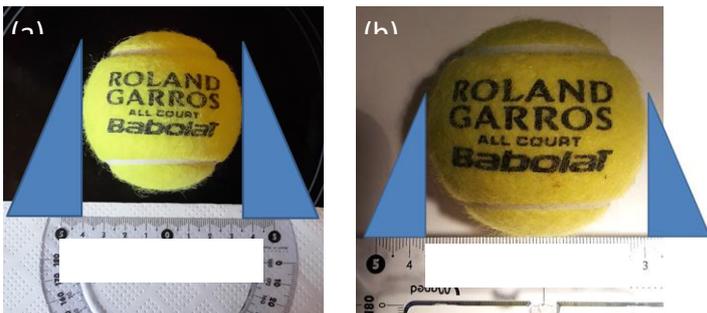


Figure 6: two pictures of a tennis ball taken with an android cell phone; a) the ruler is placed on the table, with the ball. b) the ruler is placed above the level of the table, as parallel as possible to the surface of the table) at a height which corresponds to the approximate radius of the tennis ball.

An error of about 3.3 cm (which is approximately the radius of the ball) with the positioning of the ruler induces an error of up to 0.9 (0.9=7.5-6.6) cm for d value. Let's assume that the position of the ruler was not exactly at a height corresponding to the radius of the tennis ball but was off by 0.2 cm (which is a low estimate; it could even have been 0.5 cm). Assuming that the error on the scale is linear, the error on d would then be 0.7 cm (respectively about 2 cm!!!). Again, this one dimensional protocol is not very suitable but it is more accurate than the previous protocol.

Eventually, we can estimate $d = (6.6 \pm 0.7) \text{ cm}$ if we feel optimistic.

11. Conclusion

This report presents two experiments to determine the diameter of a tennis ball, the first with the use of a shadow projection method and Thales' theorem, the second with the use of a photograph of a tennis ball, a ruler and the mathematical rule of three. The experiment also sought to estimate the level of uncertainty of each experiment and to compare their results. The methods used were simple in order to highlight the importance of good procedure in reducing the level of uncertainty.

Depending on the brand, the diameter of tennis balls vary between 6.56 and 6.86 so an efficient procedure should give results within this range. The first procedure was undertaken in a living room very late in the evening in poor lighting conditions as a torch with a weak beam of light was used. The torch was shone on a tennis ball, each of and both the torch and the ball were positioned so as to ensure the shadow on the wall opposite was exactly perpendicular to the source of light and ball. Thales' theorem was used to calculate the diameter of the ball (see figure 2 and 3). The second procedure used a photograph of a tennis ball with a ruler positioned approximately at the height of the ball's radius (see figure 6) and was used as a scale.

The results of the two experiments are as follows: the first procedure $d = (6.0 \pm 0.6) \text{ cm}$, and the second procedure $d = (6.6 \pm 0.7) \text{ cm}$. As the diameter of a tennis ball is known to be between **6.54–6.86 cm** it can therefore be concluded that both sets of results have a relatively high level of uncertainty. This was thought to be due to problems of lighting and parallax in the first protocol and to the position of the ruler in the second. The level of uncertainty is rather high in both protocols though the results of that of the second are more accurate.

A number of possible improvements could be introduced to improve the accuracy of the projected shadow protocol:

- The use of a much more powerful torch (smaller if possible) in order to avoid penumbra, or the use of a large powerful torch with a diaphragm
- The use of set squares and spirit levels (with wooden boards) to measure TB and TS (with a friend to avoid parallax)
- The removal of furniture close to the screen and the positioning of the torch closer to the ball in order to better magnify the ball's shadow.
- To measure the shadow of the ball with sunlight in the summertime (the 21st of June when the sun is at its highest position in the sky)
- The use of a lens to create an infinite light source (in a practical laboratory)
- The use of an optics bench in order to measure the lengths more accurately.

Appendix C

Questionnaire following The Exploratory Lesson

Donner un exemple précis de quelque chose que vous avez appris ou mieux compris grâce à cet exercice.

S'agit-il d'une compétence ou d'une connaissance plutôt scientifique ou linguistique, ou un peu les deux ?

Expliquez ce que vous avez appris ou mieux compris concernant les protocoles, suite à cet exercice.

Quel est l'intérêt de ce genre d'exercice, selon vous ?

Comment l'améliorer ?

Appendix D

Enhancing-fluency exchange: listening worksheet

	Ours	Theirs	Differences
Materials used (specify)	e.g. ruler, ...		
How they undertook the reading of the measurement (any pertinent details)	e.g. They measured the diameter x times (this might help to identify random error)		
Potential uncertainty inherent in the material	e.g. The books are not hard-backed so difficult to keep stable		
Potential uncertainty inherent in the protocol	e.g. the two books must be perpendicular to the flat surface and parallel to each other. To check this we ...		
New verbs (if you can't catch the word, note the sound)			
New nouns (if you can't catch the word, note the sound)			

- 1. Student A:** Explain your protocol in detail without interruption. Be careful to specify where you saw potential uncertainty in your measurement.
- Student B:** Listen carefully to student A describe his or her protocol, without interrupting. As you listen, note down in the table any of the above requested information that you can identify. Try to be aware of new vocabulary too.
- 2.** Without conferring, change roles and either listen or describe according to your new role.
- 3.** Now compare tables and discuss the reasons for your differences. Following this exchange, integrate any ideas that you think may improve your protocol and any new vocabulary that might improve your descriptio

Appendix E

More recent formula to calculate uncertainty

$$\mathbf{x = y^n}$$

$$\text{Ln}(x) = \text{Ln}(y^n) = n \text{Ln}(y) \rightarrow dx/x = n dy/y \rightarrow \frac{\Delta x}{|x_{\text{best}}|} = |n| \frac{\Delta y}{|y_{\text{best}}|}$$



or more?

$$\mathbf{q = (x \cdot y \cdot z) / (u \cdot v \cdot w)}$$

$$\frac{\Delta q}{|q_{\text{best}}|} = \sqrt{\left[\frac{\Delta x}{|x_{\text{best}}|}\right]^2 + \left[\frac{\Delta y}{|y_{\text{best}}|}\right]^2 + \left[\frac{\Delta z}{|z_{\text{best}}|}\right]^2 + \left[\frac{\Delta u}{|u_{\text{best}}|}\right]^2 + \left[\frac{\Delta v}{|v_{\text{best}}|}\right]^2 + \left[\frac{\Delta w}{|w_{\text{best}}|}\right]^2}$$

It is less than the sum of the fractional uncertainties

$$\mathbf{q = x + y + \dots + z}$$

$$\frac{\Delta q}{|q_{\text{best}}|} = \sqrt{\Delta x^2 + \Delta y^2 + \dots + \Delta z^2}$$

It is less than the sum of the uncertainties

1

Appendix F

Transcription of the extended roleplay

- 1 **Extended Roleplay Exchange**
- 2 The following is a description of the exchange.
- 3 Film 1: 00:21 - 16:23
- 4 F: well shall we start?
- 5 J: Yeah ok. I'm going to present my method. The method of the group I was in. Erm So er the thing the idea we had was
6 let's take a picture of ~~of~~ the tennis ball because the tennis ball is a sphere and a sphere is not very practical to determine
7 the diameter it's easier with a circle. So basically, we needed we, needed to prediction the dimension and the easiest thing
8 to do was to er to take a picture of the tennis ball. So, we put the tennis ball on a surface. We used a spirit level to check
9 that the surface of the ball was flat and we took a photo and that's when maybe the incertitude the uncertainty is very high
10 because it can be easier to take a picture that was er the phone need to be strictly parallel to the surface in order for the
11 projection to be right, else we wouldn't get a circle or would get an ellipse or something like that. So, this is something that
12 is kind of hard to do but I think the uncertainty is not that high. So, we took a picture with our phone parallel to the surface.
13 We had a photo with the tennis ball which is now a circle, ok, we print it out. And then, So, we got our circle on the paper.
14 And now we can construct the ~~centre~~ of the circle, ok, with a compass and a ruler. For example, what we did was taking two
15 chords of the circle and we constructed the perpendicular bisector of each chord and the intersection of these two lines
16 ~~were~~ was the ~~centre~~ of the circle. I forgot to mention that when the photo was took we also add next to the tennis ball we
17 add a ruler because of course when you take the photo you can zoom in you can zoom out so you need a scale, so we also
18 add a ruler next to it. And then. So now we have our printed-out photo, we have the ruler we have the ~~centre~~ of the circle
19 ok so we measure ~~the~~ the radius of the circle. We've got the number, it's not the real radius of the circle because of course as
20 I said you can zoom in and zoom out it's not the good measurement but we've got the ruler, we measure 1cm on the ruler
21 and then with proportionality you can guess you can compute the real radius of the circle. So basically, the uncertainty is
22 very high as I said I think when we take the photo because so we need the surface to be ~~flat~~ we used a spirit level to check if
23 it was flat but you really need to be strictly parallel to the surface as er
- 24 Frédéric: how did you do to be strictly parallel?
- 25 J: We did it as good as we could. Because I don't know maybe we could have done a little better but I don't know how
26 exactly strictly parallel to the surface
- 27 F maybe by taking a structure (he demonstrates with his hands an imaginary structure going straight up from the table to
28 what would be about the height of the phone).
- 29 J: Yeah ~~yeah~~
- 30 F and you put it (demonstrates placing the phone at the top of the imaginary structure) er not performing by a human.
- 31 J: It's true. We could have managed to do something like that but we didn't have the courage but (laughs) it would have
32 been possible and the uncertainty would have been ~~less~~ I think. Erm but then the construction of the ~~centre~~ of the circle is
33 exact as if you manage to take a point of the circle exactly but our eyes' accuracy must be good enough you've got the
34 uncertainty due to the ruler you use the graduation is 1mm so the uncertainty is half a millimeter I think that the accuracy
35 of the eye for taking points on the circle is at least an half millimeter too. As for the uncertainty of taking the picture I
36 decided subjectively to take 1 mm because I had no idea how to compute this uncertainty. So basically, for the radius we
37 had an uncertainty of 2mm which means that for the diameter we had an uncertainty of 4mm. And we found er we found
38 er ... our result wasn't good at all I don't know why but we found something like the tennis ball had a diameter of 8cm
- 39 F: ok smiling
- 40 J: ~~Plus~~ or minus 4mm
- 41 Other students inaudible
- 42 J: I guess but what's strange is that on the picture with the ruler next to it you can see even with your eyes without making
43 any projection er without making any construction of the ~~centre~~ of the circle you can guess that it's about 8cm so I don't
44 know. I didn't have the ball in my hand so I don't know I just had the photo and printed it out but we found 8cm
- 45 P: maybe it's a big ball
- 46 J: Yeah, that's what I thought too I think it's the most plausible er everyone laughing
- 47 F: you did it on only one ball

48 Yeah and I didn't even see the ball myself.

49 F: only the photograph

50 J: I just had the photograph so I don't know; I don't think it's six and a half cm because you can really see on the picture that
51 it's about 8cm

52 F maybe it depends on the high of the ball when your photograph was taken

53 Of course it does but there is the ruler next to it and therefore...yeah .. the proportionality and even without the
54 proportionality you can see that on the ruler it's about 8cm. You can see that the ball is between 5.5cm and 13.5 so about
55 8. I don't know.

56 F that's tragic because I think that the diameter of the ball is between 6 and 7 cm something like that, not more than that.

57 J: It depends er if the ball is a ball for kids or something like that. But I didn't see the ball so I couldn't

58 F: the ball wasn't the ball like er inaudible (pointing to the cupboard where the balls are kept)

59 J: I don't know I didn't see the ball so

60 P: and when the ball inaudible

61 J: It was a photographie take by a colleague but I er wasn't here two weeks ago

62 P: he bought it or he took it from (indicating the cupboard from where the balls were distributed.)

63 J: Oh no it was given here. It's weird, it's weird (all laughing)

64 F: it's very strange

65 J: But it's my method anyway. It doesn't change the method.

66 F: the ball can't be really totally spheric. So maybe there is er there are some er disparities in the ball
67 (shrugs.)

68 But then if we don't consider the ball as a sphere how do you define the diameter? (opens hands in questioning gesture)

69 F: yeah.

70 So the question er – I think we assume that er

71 F: by taking an average (lots of gesticulating: uses hands in what maybe represents several chords of the circle) by taking an
72 average of the different (inaudible word, maybe sphere, and uses fingers to represent quotation marks).

73 J: Oh ok – purses his lips appearing to indicate grudging agreement. Yeah, maybe we could do something like that but I
74 think it's almost a sphere.

75 P: Maybe the ball was wet and so it was bigger than... (indirect reference to another method where this was the case) the
76 students laugh

77 J: I don't know either. I didn't take the photo, I didn't see the ball so

78 F: ok

79 But the method is what I suggested and I think it can work. Maybe we didn't get the ? we took a very poor photograph

80 F so we wanted to measure the diameter of the tennis ball by filling water in the ball until the ball is full to have the internal
81 volume of the ball. So we count how much how many syringes injected it and then we cut a piece of the ball to have the
82 thickness of the ball

83 J: Of course

84 F to add it the syringe ??the number of times we had. So we did it last week near the blackboard. So we had two syringe
85 one for 5ml graduated every tenth of ml and one of 1ml graduated every hundredth er of millilitres so very accurated
86 instruments. Erm we put 34ml er 74ml in the ball and at this moment the ball started to drop of water. So some drops of
87 water

88 D:(looks confused)

89 J: it leaked – the water was (explains to the student who didn't understand what F meant)

90 D: oh ok

91 F the water was out. So, we couldn't continue the experiment because when we get 5ml and 2 came out it's not correct so
 92 we decided to stop the experiment here. Erm we approximated water lost at 1ml because we had one syringe of 1 ml so we
 93 see what it represent we saw what it represent

94 P is it possible to close the door because with the sun I cannot see anything – thank you

95 F: after that we cut the ball with the knife and with a caliper we graduated at tenth of millimetres we measured the
 96 thickness of the ball and we had 5.2mm of thickness and after calculations with a formula of a poly?? supposing the ball is
 97 totally spheric we had 6.23cm so which is not too far from the reality however we have a big uncertainty because we put in
 98 er 5, no 8 syringe of 5ml and er I don't know I don't remember and ere po po pop ..and 34 syringe from 1ml because
 99 when we were at 40 we thought that it would be ok 34, we, at 40 we thought it would be full (gesticulates can't find the
 100 words) and not po po... ok so the uncertainty was multiplied by ??(44?) so that was very big. With an uncertainty for
 101 the big syringe of 0.2ml because it's inaudible ... so 0.2 for each syringe, for the small syringe 0.01 per two per 34

102 J yeah

103 F: and for the sliding caliper

104 J: sliding?

105 F (gesticulates sliding by sliding one hand in front of the other) and whispers in French the translation (coulissant)

106 D: translates caliper – Pied à coulisse

107 J: oh ok

108 F : to measure (indicated thickness with fingers) the as it was calibrated at 10ml we had an uncertainty of hundredth so at
 109 the end at the beginning 0.02ml and as we approximated the water lost by the ball by the ball at 1ml we have finally 1.80cm
 110 of ?

111 J: 1.80cm of degree of incertitude

112 F: of degree of incertitude – uncertainty

113 J: uncertainty

114 F: so that's er ... even if our results are not so far from the reality, with the uncertainty it's very approximative

115 D/ inaudible

116 F: near to 2cm and so the diameter could be 4cm or 8cm. Our result is coherent however with the uncertainty er we have
 117 not really result

118 P you did well your experiment if you have a good result but a big

119 F however we thought that when the ball lost some drops of water the ball isn't full, wasn't full

120 J how the water got out of the ball

121 F we did a little ... of the ball (shows diagram) water took this trajectory in the ball and we notched (?) the ball to insert the
 122 syringe and so the ball wasn't er there isn't water on the ball – I don't have – and er as we continue to inject we feeled we
 123 felt water ..(film stops here)

124 **Film 2: 0:00 – 16:06**

125 F: the back of the ball (using hands to form a sphere-like shape like the ball) ... so the water began to leak (using hands
 126 to demonstrate the dripping of water from the ball)

127 J: yeah. But when do you assume that the ball is full of water. When do you know that it is

128 F: We heard when we injected the ball some er some er Phitt (makes a sound of escaping air – the students laugh) from the
 129 ball which er signified that the air came out of the ball. And we could also shake the ball to feel the water moving, So we
 130 could control the ball was full or not and when we stopped it it was not totally full. There is there was er some place
 131 however, inaudible.. it was not possible to continue the experience because the uncertainty would be bigger and bigger

132 J: and so you need to ... estimate the volume, that is not taken by er by water

133 F: yeah. We wanted to do this however when we we make the water go out from the ball to cut the ball... (inaudible)
 134 there wasn't only water - there was some piece of the ball in .. the ball ... was er ... erm, dégradé, (damaged said in
 135 French). Er (struggles for words. Inaudible). So er it, it would be very difficult to measure the quantity (pronounced
 136 quantité) of air we had in when we stopped. Erm po, po, pop ... (turns pages of laboratory report as reflects on how to
 137 continue).

138 J: So you've got er good results but bad ...

139 F: Good results however we have uncertainty of,

140 J: Basically it's the opposite of (students laugh) think want to say the result should be less certain
 141 than the uncertainty)

142 F: Yeah (laughs) of course.

143 Pause J opens in hands toward P and D to give them the floor

144 P: Ok my turn so our experiment used also water. We er we take a bowl of water (sounds similar to ball for the
 145 students) - a bowl of water (he articulates carefully to check they understand)

146 J: yeah, ok all the students laugh

147 P: a bowl of water that we know the volume – we can take any container, a graduated container. So we know the volume of
 148 this container and er we hammer in the ball two needles (repeats quietly you know hammer in) and we put the ball on the
 149 bowl (for French speakers ball and bowl sound the same) so the ball is

150 J: the ball on the ball (uses his hands as if moving a ball from one spot to another)

151 P: yeah -all the students laugh – the ball on the bowl (insists on bowl) on the container

152 J: in

153 P: in the container – entirely.

154 P: So the volume er

155 J: in the water

156 P: yeah yeah in the water. So the volume increases. So we took the difference of the first volume and the final volume ...
 157 and this difference give us the volume of the ball. (hesitates, consults laboratory report) ...

158 J: then you use I guess the same formula as (indicates towards F)

159 P: Yeah erm, after this we just have to use the formula of a sphere

160 F: $4/3 \pi$

161 P: that people use - and so we can found the diameter of the ball but so in this experience there is not too much
 162 uncertainty because we just have to measure two things. The first volume of the water in the bowl laughs in the container
 163 and the second measure of the volume in the container with the ball so there is two uncertainties but we took 1ml of
 164 uncertainty because our graduated container for example is not very accurate so we don't have a lot of uncertainty but
 165 they are pretty big. Erm

166 J: but it's er easy to reduce this uncertainty by taking a more graduated

167 P: we can but it's hard to found it's not

168 J: yeah it's not easy to found to find at all

169 P: ok. There is_u so ... we did two experiments because this is the first one and in the second one before to put the ball in
170 the container with water we put it in an other container with water because the coating will absorb water and so the
171 volume er not the volume but if we put the first time if the a ball is er completely dry

172 F: the ball absorb water

173 P: yeah, the ball will absorb water and so you can make some er

174 F: uncertainty

175 P: yeah uncertainty pretty big. So we put it on another container so the ball will absorb water in this container and then we
176 put it on the graduated container to evaluate the difference in volume. So with the first experiment we found_{er} ??cm and
177 the second one 6.4 so it's not a big difference

178 F: Maybe the uncertainty is very different

179 P: we took the same uncertainty for the both experiments because the uncertainty on the absorbing by the coating of the
180 ball is er ..

181 F: very difficult

182 P: So in the ??? we had 0.8 cm pretty big you can reduce by more graduating of ...??? Container. Erm pause Any questions?

183 J: Just one. Are you sure that the diameter of the ball once put in water doesn't change at all?

184 F: Ah! (Raises index finger and nods to show he finds the question relevant).

185 P: the diameter? When you put?

186 J: Once it absorbs the water. It's a sphere is exactly the same or did it maybe_u (F scratches his head thinking)

187 F: the volume er can't change even if the ??? inaudible_u sphere

188 J: (thinks for a moment and concedes agreement) Er_u yeah that's true (reflects for a moment again) ... that's true_u

189 P: I don't think – It's just that the, that the ... the ... the water will absorb water but the

190 F: it doesn't depend from the mass so er (waves hands in the air)

191 J: I think you're right

192 D: inaudible. The ball when you're inaudible ... wet

193 F: ok_u (turning to D –

194 go ahead)

195 D: Right. Our method was inaudible ... home-made caliper so inaudible

196 J: I'd like you to explain to me exactly what it does

197 D: Calliper ou_u

198 J: yeah

199 D: it does something that er stuck the ball and then er (inaudible) ... as we don't have a calliper here? er we took two set
200 square – (he looks at another student to check understanding) set square?

201 P: grimaces to show he doesn't know the word

202 D: (translates – équerre)

203 P: ah ok

204 D: we took two set square and we stuck the ball between two set square like that (places his two hands vertically and
205 parallel to each other).

206 F: ah – to make sure it's er parallel

207 D: yeah

208 F: ok

209 D: and then we ...

210 F: addressing J) For your problem – places a hand parallel over the table. A reference to J’s method which needed
211 something to ensure that the phone was exactly parallel to the desk to take a photo of the ball)

212 J: nods in agreement

213 D: and then we took a ruler and with the ruler we measured the diameter of the ball

214 F: asks a question (inaudible)

215 D: yeah. Erm so the uncertainty came just from the ruler so we just had 1mm uncertainty and we found something like 6.4
216 or 5 that er that was good. And then we er we took a real calliper – we did the first experiment however we took a real
217 calliper and measured the diameter of the ball and it was the same that er we took so ... inaudible

218 F: how could you be sure that the ball can’t be pressed by the calliper when you measure because if you press it the ball is
219 er flexible and the diameter .. ?? and er the ball is not really spheric and the diameter change in the manner of how you put
220 the ball between the (places two hands parallel to each other). In fact, in the beginning we tried to put the ball between the
221 two set square, the ball er

222 F: came out

223 D: yeah, yeah came out. So er we really tried to fix it and er the moment when we fix it we know that we were er we were...
224 ? inaudible

225 F: nods. I think er if the ball is er out of the caliper that’s because the diameter you measure is a little er a little more than
226 (struggles for words, slaps the palm of his hand) the real diameter is a little more than ...

227 D: maybe but ... the method was good because after we checked (the suffix -ed pronounced /id/ instead of /t/) on the
228 website

229 Teacher: Checked (tʃɛkɪd)? ((passing by corrects pronunciation) checked (tʃɛkt) the result

230 D: We checked (tʃɛkt) the result (the students laugh) on some website about er ball tennis and er

231 F: yeah 6.5 and 6.8 (uses fingers to demonstrate a range between the two)

232 D: yes exactly

233 P: the two set square – set square? (looks at D for confirmation the right word)

234 D: yeah yeah

235 P: have to be erm very parallel. How can you be sure that they are er

236 D: (Laughs)er we took er a (looks around the room to find an example of what he wants to say. Struggles to find the word)
237 ... not a book. Because they are on lines (uses hands to demonstrate lines).

238 F: ah a copybook!

239 D: yeah a copybook. So it was true the set square was on lines.

240 P: and how can you be sure the lines in the copybook are really parallel

241 D: ah that’s not my problem. That’s another thing (the students laugh)

242 F: instead of putting the set square like this (places his two hands parallel to each other, outer edge on the desk, fingers
243 directed away from himself) why don’t you put it like this (places outer edge of hands along an imaginary line, wrists bent at
244 an angle of 90°, palms facing toward himself, tips of fingers pointing to each other) erm, you’ll be sure .. er you’ll be sure
245 because of the (forms a spherical shape with his hands)

246 P: if you do this you have to know the centre of the ball because you have to put the square on the (he demonstrates
247 the two set squares as his two hands turned at an angle of 90° at the wrist, the tips of the fingers facing toward the
248 imaginary ball).

249 F: with the with the set square, (he takes two pencils and places them upright on the table facing each other) you put the
250 ball progressively and when the distance is at the maximum you have the diameter (as he says maximum he gradually
251 widens the space between the two pencils whilst maintaining them parallel to each other and on an imaginary line. He
252 looks at the other students to check comprehension but they show by their black faces that they have not followed his
253 reasoning). You understand?

254 P: P takes the two pencils F indicates to him that he wishes him to maintain them upright as he had just done in his
255 demonstration. Then, with P holding the pencils upright, F takes a woollen hat and rolls it into the shape of a ball.

256 F: You put it (he passes the ball – the hat- through the space between the pencils)

257 Other students: Oh right (their faces light up in comprehension as the ball – the hat – passes through the two pencils)

258 F: so you put it it's becoming bigger and at the maximum you have the diameter

259 D: yeah ok

260 F: and by putting it like this (he places his hands again in the position with the wrists bent at 90°) you are sure that it's
261 parallel.

262 D: ok. We didn't do it like that because we forgot to do it. Yeah, you're right.

263 F: Sorry for (to P as during the demonstration the pencil had left marks on P's laboratory report).

264 Students laugh

265 D: So that's ok. Do you have any questions?

266 F: I'm going to go for notation – he looks up to check they agree-

267 J: Yeah, go ahead

268 F: so, the name of your method to identify. (looking at J)

269 J: mm, (raising his eyebrows in thought) the photograph method (F writes it down)

270 F: turns to

271 P: erm

272 F: immersion?

273 P yeah emersion

274 F: me, syringe (he looks at P for confirmation)

275 P: mm?

276 F: Syringe

277 P: yeah. He whispers syringe to himself and writes it down

278 F: and er

279 D: Caliper

280 F: caliper, even if I have a caliper (he used a caliper in his method too at one point)

281 D: a home-made caliper if you want

282 F: yeah laughs. Mais (but in French) Erm, I think that ... the less accurated is my method er because of the number of
283 J: the operations you need to do

284 F: of syringes. So I think that we need to do

285 P: but for you if had take one big syringe and one small one?

286 J: yes, with good graduation but er good capacity (holds out hands to demonstrate big size). But you can't take that er

287 F: yeah. Yeah. But we didn't know the capacity of the ball so when we were at 40 we thought that we weren't so far from

288 the reality. And er

289 D: I think they didn't learn the experiment was going to fail

290 They laugh (I don't understand this reference)

291 P: not the population. Not the good population (I don't understand this reference)

292 F: We should do the experiment two times. And the second one with a real result prepared thanks to ... we didn't have. So I

293 think that mine is the less ... accurated

294 J: at least you found something er

295 F: my results are coherent however the uncertainty

296 P: looking at J We don't know if it's your method or the ball

297 J: yeah (stretching, starting to look a little tired). I don't know myself.

298 Film 3 0:00 – 5:57

299 J: yes it was going to work. We thought it was.

300 P: Because if it's not the ball it's you

301 J: yeah. And then my method is terrible, I know.

302 D: Maybe that worked

303 F: and er, so as your results are not nice maybe, maybe the third in audible would be ...

304 D: that's ok

305 F: Between water and caliper I think it's (juggles his hands to suggest fifty fifty)

306 P: I think the caliper is more accurate because it's er it's er easier than my method

307 J: Oh (shows disagreement). I would say the ... yeah, it's easier but it's also trickier because you need to take ... it's right. I

308 don't want to say the uncertainty is er is high but I think it's hard to evaluate the uncertainty on this method because you

309 need to do ... in audible manually ... and you feel it – you feel when it's about right and it's mostly about feeling.

310 Suddenly the noise increases in the classroom as other groups are finishing.

311 F: speaks but his contribution is inaudible ... it's more difficult to read a graduation with water than with a ruler (gesticulates

312 to show reading a graduation at eye level with hand at level of his eyes and waved to level of an imaginary measurement).

313 So, I (juggles his hands from side to side to suggest there are arguments on both sides).

314 J: but this method is more scientific

315 P: it's more tricky

316 J: there is more ?? confus (to say confusion maybe)

317 D: That's true but we really wanted to do something simple and then ... inaudible ... the real caliper did exactly the same.

318 P: I thinks ... inaudible

319 F: 2 (pointing to P) and 1 (pointing to D)?

320 The students consult the role-play instruction sheet and re-read to themselves. Lots of noise as the class generally changes

321 activity.

322 F: we have to ... inaudible ... why our reasoning leads to this classification I think

323 P: ok

324 F: ... write-up ... but one report for all of us the task ... inaudible ... stage?

325 J: Yes. First we need to know what ... inaudible ... exactly ... inaudible ... what we are going to do.

326 The students continue reading in order to understand and follow the instructions.

327 F: inaudible ... the four methods ... inaudible ... Why our er ... inaudible ... leads to ... this classification, I think

328 P: inaudible

329 F: Writing up our final group report. (looking at instruction sheet). One report for all. I think the tasks ... later (raises arm
330 and pushes back imaginary task to suggest later).

331 J: As a conclusion, I think we should talk about what we talked about between the two methods because if we think about –
332 the protocol is that we need to be able to do exactly the same as it is written and I think that your protocol (indicating P) is
333 ... inaudible than yours (indicating D) but as I said I think that your method (indicating D) is the easiest and it could give us
334 the best results. It's easy you can see er

335 P: you can't really found the mistake in this caliper method so

336 D: yeah, yeah. Because it's not right, this method. It's true. I think we have the capacity as humans to do it

337 F: find the caliper

338 J but even with the two set squares you can do it as er ok. So, basically we need to write down what we said it

339 F for introduction it's like everyone in it for today (he looks at and indicates each person in turn) – we want to measure the
340 diameter bla bla bla

341 D: but maybe we just do what we say because ... inaudible

342 P: inaudible

343 J: we set the context, what we wanted to do er

344 They discuss how to organize the write up of their meeting but it is inaudible

345 F: the introduction Je le propose (I volunteer to do the introduction)

346 J: yeah ok the introduction – the big thing would be the abstract and maybe the conclusion

347 Teacher: you share the document with myself and also the physics teacher

348 P: to teacher we'll do this now?

349 Teacher: yes, otherwise you won't have enough time

350 F: I think we didn't talk of the abstract of ... inaudible to add to it with the ...? ...; and the explication on the result from this
351 consultation and the conclusion

352 J: the conclusion was the conclusion what we finally said on the classification and all the reasons for this

353 F: yeah ok

354 The students stand to go towards the computers to go onto the written part of the evaluation.

Titre : Travail coopératif entre une enseignante-chercheuse de physique et une professeure d'anglais dans le secteur LANSAD (LANGues pour les Spécialistes d'Autres Disciplines) : une étude clinique en TACD menée dans le cadre d'un projet CLIL (Content and Language Integrated Learning).

Mots clés : CLIL (Content and Language Integrated Learning) ; Travail coopératif ; LANSAD (LANGues pour les Spécialistes d'Autres Disciplines) ; TACD (Théorie de l'Action Conjointe en Didactique) ; potentiel épistémique ; incertitude dans les mesures.

Résumé : Cette thèse porte sur une séquence d'enseignement-apprentissage CLIL (Content and Language Integrated Learning) qui est le produit d'un travail de coopération entre une enseignante-chercheuse de physique et une professeure d'anglais LANSAD (LANGues pour les Spécialistes d'Autres Disciplines). En utilisant l'approche clinique de la TACD (Théorie de l'Action Conjointe en Didactique), une séquence construite autour de l'incertitude sur les mesures est analysée en détail afin d'étudier l'activité didactique produite en classe par rapport au potentiel épistémique de la séquence. L'étude identifie les conditions spécifiques de la séquence CLIL, et propose le cadre de la TACD comme outil pour le développement de futurs projets CLIL issus de travaux coopératifs.

Title : A cooperative project between an associate professor of physics and an English language teacher in the LANSOD (LANGuages for Specialists of Other Disciplines) sector: a JATD (Joint Action Theory in Didactics) clinical study of a CLIL (Content and Language Integrated Learning) programme.

Keywords : CLIL (Content and Language Integrated Learning); cooperative projects; LANSOD (LANGuages for Specialists of Other Disciplines); JATD (Joint Action Theory in Didactics); epistemic potential; uncertainty in measurement

Abstract : This thesis investigates a CLIL (Content and Language Integrated Learning) teaching and learning sequence resulting from a cooperative project between an associate professor of physics and a LANSOD (LANGuages for Specialists of Other Disciplines) English language teacher. Using the JATD (Joint Action Theory in Didactics) clinical approach, a sequence based on uncertainty in measurement is analysed in detail in order to investigate the didactic activity produced in class in relation to the epistemic potential inherent in the sequence. The study identifies the specific conditions of the CLIL sequence examined and proposes the JATD framework as a tool for developing future CLIL programmes emanating from cooperative projects.