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The Interactions between Resources, Particularly Digital Resources, and Biology Teachers' Conceptions during their Documentary Work

Eman Shaaban

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LEBANESE UNIVERSITY
Doctoral School of Literature,
Humanities & Social Sciences

**The Interactions between Resources, Particularly Digital
Resources, and Biology Teachers' Conceptions during
their Documentary Work:
Case of Teaching Genetic Determinism
at Secondary Level, Lebanon**

**A dissertation submitted for fulfillment of the
requirements for the degree of Doctor of Education**

Prepared By:

Eman Kamal Shaaban

Supervised By:

Dr. Iman Khalil & Dr. Luc Trouche

Defense on 19 December 2014

Jury:

Dr. Iman Khalil

Professor at the Faculty of Education - Lebanese University

Supervisor

Dr. Luc Trouche

Professor at IFE-ENS of Lyon - France

Co-Supervisor

Dr. Iman Osta

Professor at the School of Arts and Sciences - Lebanese American University

Discussant

Dr. Pierre Clément

Professor at Lyon1 University – France

Reader

Dr. Paula Abou Tayeh

Assistant Professor at the Faculty of Education - Lebanese University

Reader

Academic year: 2014-2015

2014-2015

LEBANESE UNIVERSITY

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*I dedicate this work to my family and all my friends who
supported me and stood by my side all these years.*

LOVE YOU ALL

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ABSTRACT

Eman Kamal Shaaban for

PhD in Education

Major: Science Education

Title: The Interactions between Resources, Particularly Digital Resources, and Biology Teachers' Conceptions during their Documentary Work: Case of Teaching Genetic Determinism at Secondary Level, Lebanon.

The purpose of this study is twofold: first, it aims to study the factors that influence the integration of digital resources in the documentary work of Lebanese biology teachers, particularly for teaching abstract and difficult concepts such as those related to genetics. Second, it aims to study the relation between the use of digital resources by teachers and their conceptions of genetic determinism, particularly from hereditarianism to epigenetics. For the purpose of this study, we have articulated two theoretical frameworks, highlighting the fruitful nature of their interaction: the “*documentational approach*” to analyze the documentary work of teachers and the “*KVP model*” to study their conceptions about genetic determinism. A mixed methodology was designed, combining quantitative studies (questionnaire) and qualitative (interviews, logbooks, schematic representations of the system of resources (SRSR) and classroom observations). This methodology highlighted the interest of critical resources and situations to infer the conceptions of teachers. The field of research involved 116 secondary biology teachers from various regions in Lebanon. Four teachers were purposefully selected for further studies, and two of them were monitored for two consecutive years. One teacher, Maya, was selected from a public school and another teacher, Tania, from a private school. The results showed that teachers in fact integrate digital resources in their teaching in order to facilitate students' understanding of abstract genetics concepts and to enrich and update their own scientific knowledge. Moreover, findings indicated that availability and accessibility of technology, time availability, collective and collaborative work, technological proficiency and attitudes towards technology are all factors that influence teachers' integration of digital resources. Results also revealed that Maya has outdated knowledge (K) on the genetic determinism reflecting her innate values (V), and has chosen in her practice (P) *critical resources* applying hereditarianism model. However, her interactions with digital resources have helped in initiating changes in her conceptions toward epigenetic. While Tania, with a dynamic system of resource and updated knowledge (K) reflecting her progressive values (V), grants a central place in her practice (P) to her digital archive that is constantly updated, and to French biology textbooks applying the epigenetic model. Thus, the relation between resources and conceptions is dialectical: teachers' conceptions affect the choice and implementation of resources on one hand and teachers' documentary work affects teachers' conceptions on the other. Implications for practice and future research are discussed.

Résumé/ Abstrait

Titre : Les Interactions entre les Ressources, Notamment Numériques, et les Conceptions des Enseignants de biologie au cœur de leur Travail Documentaire: le Cas de L'enseignement du Déterminisme Génétique, dans le Secondaire, au Liban.

Cette étude comprend deux objectifs: premièrement, elle vise à étudier les facteurs qui influent sur l'intégration de ressources numériques dans le travail documentaires d'enseignants de biologie au Liban, plus particulièrement pour l'enseignement de notions abstrait et difficiles comme celles liées à la génétique. Deuxièmement, elle vise à étudier les relations entre l'usage de ressources numériques par les enseignants et leurs conceptions concernant le déterminisme génétique, en particulier de l'héréditarisme de l'épigénétique. Aux fins de cette étude, nous avons articulé deux cadres théoriques, mettant en évidence le caractère fructueux de leurs possibles interactions: « *l'approche documentaire* » pour analyser le travail documentaire des enseignants, et « *le modèle KVP* » pour étudier leurs *conceptions* sur le *déterminisme génétique*. Une méthodologie mixte a été conçue, combinant des études quantitatives (questionnaire) et qualitatives (entretiens, journaux de bords, représentations schématiques de systèmes de ressources (RSSR) et des observations de classe). Cette méthodologie mis en évidence l'intérêt de *ressources et situations critiques* pour inférer les conceptions des enseignants. Le terrain de recherche a impliqué 116 enseignants de biologie du secondaire de diverses régions libanaises. Quatre enseignants ont été sélectionnés pour des études plus approfondies et deux parmi eux ont été surveillés pendant deux années consécutives. Un enseignant, Maya, a été choisi dans une école publique et un autre enseignant, Tania, dans une école privée. Les résultats ont mis en évidence que les enseignants intègrent des ressources numériques dans leur enseignement pour favoriser la compréhension, par les élèves, de concepts abstraits en génétique et pour enrichir et mettre à jour leurs connaissances scientifiques. En outre, les résultats ont indiqué que la disponibilité et l'accessibilité de la technologie, la disponibilité du temps, le travail collectif et collaboratif, la maîtrise technologique et les attitudes envers la technologie sont autant des facteurs qui affectent l'intégration, par les enseignants, de ressources numériques. Les résultats ont également révélé que Maya, a des connaissances non mises à jour (K) sur le déterminisme génétique reflétant ses valeurs inné (V), a choisi dans sa pratique (P) des ressources critiques appliquant le modèle héréditariste. Cependant, ses interactions avec les ressources numériques ont permis un début d'évolution de ses conceptions vers l'épigénétique. De son côté, Tania, avec un système de ressource dynamique et des connaissances actualisées (K) reflétant ses valeurs progressiste (V), accorde une place centrale dans sa pratique (P) à ses ressources numériques mises à jour de façon continue, et de manuels de biologie françaises basés sur le modèle épigénétique. Les résultats ont ainsi montré que la relation entre les ressources et les conceptions est dialectique: les conceptions des enseignants affectent leur choix de ressources d'une part et le travail documentaire des enseignants affecte leurs conceptions d'autre part. Les implications pour la pratique et les futures recherches sont discutées

ملخص عن الدراسة

العنوان: التفاعل بين الموارد ، خاصة الرقمية منها، مع مفاهيم (Conceptions) أساتذة مادة علوم الحياة خلال عملهم التوثيقي (Documentary work): حالة تدريس الحتمية الوراثية في المرحلة الثانوية، لبنان.

الهدف من هذه الدراسة مزدوج: أولاً، تهدف الى دراسة العوامل التي تؤثر على دمج الموارد الرقمية في العمل التوثيقي لأساتذة مادة علوم الحياة في لبنان، وخاصة لتدريس المفاهيم المجردة والصعبة مثل تلك المتعلقة بعلم الوراثة. ثانياً، تهدف الى دراسة العلاقة بين استعمال الأساتذة للموارد الرقمية ومفاهيمهم تجاه الحتمية الوراثية، خاصة التحول من الوراثة (Hereditarianism) الى التفاعل (Epigenetics). لتحقيق هدف الدراسة، قمنا بدمج إطارين نظريين لتسليط الضوء على طبيعة تفاعلهم المثمرة: "Documentational approach" لتحليل العمل التوثيقي للأساتذة و "KVP Model" لدراسة مفاهيمهم حول الحتمية الوراثية. كما تم تصميم منهجية مختلطة، تجمع بين البحث الكمي (استبيان) والنوعي (مقابلات، مفكرة "logbook" ، رسم بياني لمجموعة الموارد "SRSR" ومشاهدات صفية). أبرزت هذه المنهجية أهمية الموارد والحالات الحيوية لاستنتاج مفاهيم الاساتذة. شمل مجال البحث 116 أستاذاً يدرّسون مادة علوم الحياة في المرحلة الثانوية من مختلف المناطق اللبنانية. تم اختيار اربعة اساتذة لمزيد من الدراسات، كما تم متابعة اثنين منهم لمدة سنتين متتاليتين: استاذة من مدرسة رسمية، مايا، واستاذة اخرى، تانيا، من مدرسة خاصة. أظهرت النتائج أنّ الأساتذة في الواقع يستعملون الموارد الرقمية في التعليم وذلك لكي يسهلوا عملية استيعاب التلاميذ للمفاهيم المجردة الخاصة بعلم الوراثة ولإغناء معرفتهم العلمية وتحديثها. علاوة على ذلك، أظهرت النتائج ان توافر وإمكانية استعمال التكنولوجيا والوقت المتاح والعمل الجماعي والتعاون والمهارة التكنولوجية والموقف تجاه التكنولوجيا، كلها عوامل تؤثر في إدماج الموارد الرقمية. وكشفت النتائج ايضا ان المعرفة العلمية لدى مايا غير محدثة (K) وهي تعكس قيمها الفطرية (V)، كما انها اختارت في الممارسة العملية (P) موارد حيوية تطبق النموذج الوراثي. ومع ذلك، فقد ساهمت التفاعلات بينها وبين الموارد الرقمية ببداية تغير في مفاهيمها نحو التفاعل. في حين، تانيا تملك نظاماً ديناميكياً من الموارد ومعرفة محدثة (K) تعكس قيمها التقدمية (V)، كما انها تمنح في ممارستها العملية (P) مكاناً مركزياً لأرشيفها الرقمي، الذي يتم تحديثه باستمرار، وكذلك للكاتب الفرنسية التي تطبق النموذج التفاعلي. وهكذا فإن العلاقة بين الموارد والمفاهيم هي جدلية: مفاهيم الأساتذة تؤثر على اختيار واستعمال الموارد من جهة، والعمل التوثيقي للأساتذة يؤثر على مفاهيمهم من جهة اخرى. وكذلك تمت مناقشة التوصيات للممارسة والدراسات المستقبلية.

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CHAPTER I

“PROBLEMATIQUE”

This chapter presents an introduction of the “problematique” of this study. First, a background (§ 1.1) of the research topic is presented and then a discussion of the purpose (§ 1.2), rationale (§ 1.3) and significance (§ 1.4) of the study is presented. The chapter concludes with a brief outline of the current study (§ 1.4).

1.1. Background

This section presents a background of the study, specifically in terms of the difficulty of genetics concepts among students (§ 1.1.1), the evolution of the epigenetics paradigm (§ 1.1.2), the status of epigenetics in the Lebanese context (§ 1.1.3) and the use of digital resources in science education (§ 1.1.4).

1.1.1. Difficulty of genetics concepts.

Biology like any science is dynamic and evolving whereby its knowledge is temporary and tentative. Biology teachers are challenged with teaching difficult and evolving concepts. Genetics is one field of biology that is ripe with exciting advances, social and individual relevance, and opportunities to engage students in lively discussions. Genetics is a fundamental part of biology that is relevant to everyday life; however it is considered a difficult subject in biology for both students and teachers (Bahar, Johnstone & Hansell, 1999; Bahar, Johnstone & Mahmoud, 1980; Knippels, Waarlo & Boersma, 2005; Lewis & Kattman, 2004; Lewis & Wood-Robinson, 2000; Pashely, 1994).

Studies have shown that students encounter difficulties when studying modern genetics in areas such as differences between genes and traits, gene expression, and the meiotic model (Duncan & Resier, 2007; Kindfield, 1992; Lewis & Kattmann, 2004; Lewis, Leach & Wood-Robinson, 2000a, 2000b; Marbach-Ad & Stavy, 2000;

Stewart & Van Kirk, 1990; Tsui & Treagust, 2003; Venville & Treagust, 1998). These researchers attributed student difficulties to (a) the interdisciplinary nature of genetics which requires understandings of chemical and physical interactions at the molecular level (b) the high level of reasoning needed to interpret and explain genetics information, and (c) the inability to demonstrate genetic information in lab settings. In addition, molecular genetics is particularly difficult because it is full of abstract concepts that many find difficult to visualize and it integrates several levels of structural organization, from molecules and ultra-structure to microscopic and macroscopic features.

1.1.2. Evolution of the epigenetics paradigm.

At the end of the twentieth century, scientists laid the foundation for a new genetics paradigm, namely, “epigenetics” which is the study of the interaction between human genes and their environment (Morange, 2005). This new paradigm emerged from the extensive debate between what is innate and/or acquired which ultimately resulted in the consensus that both genes and the environment are necessary and are in constant interaction (Atlan, 1999; Jacquard, 1981; Jacquard & Kahn, 2001; Kupiec & Sonigo, 2001; Lewontin, 2003). In fact, genetic concepts have significantly evolved over the last fifteen years. Unique reference to genetic determinism has been replaced by the interaction between genes and their environment (i.e., epigenetics). Atlan (1999) claimed “the end of all genetics” (“la fin du tout - génétique”) which often reduced human traits such as intellectual or musical performance with genetic determinism. The philosopher Canguilhem (1981) defined reduction of complex phenomena to simple molecular causes and the explanation of complex social features by only the human genes as a reductionist ideology in Life Science which is equivalent to fatalist ideology in society. According to him, the schema one gene → one trait- i.e. the belief that any human behavior or performance is mainly determined by genes - is reductionist, with a hereditarianism conception and probable fatalist values.

According to Mills Shaw, Van Horne, Zhang and Boughman (2008) students' most common conceptions in genetics fall into the category of patterns of inheritance. Students do not comprehend the multiple genetic and epigenetic factors that play a role in genetic regulation, and seem unable to manipulate genetic materials in laboratory settings. Also, students fail to explain how multiple factors might contribute to phenotype and always view single mutations as being the origin of one disease without mentioning any environmental influence. All these topics are modern evolving concepts in genetics that require updating of teachers' scientific knowledge and their teaching strategies.

1.1.3. Epigenetics in the Lebanese context.

The scientific evolutions related to genetic determinism of phenotype and epigenetics occurred after the implementation of the reformed Lebanese curriculum in 1997 which has not been updated till now. According to Quessada and Clément (2007) *Didactic Transposition Delay* (DTD) is the time lag between the date of publication of a scientific discovery and the date of its introduction into the educational system. Thus, there is DTD in introducing new scientific knowledge about the interaction between genotype and the environment and the paradigm of epigenetics in the Lebanese curriculum.

In the Lebanese curriculum, the concept of "gene" in secondary classes is introduced in grade 11 in the scientific section. The DNA structure is first introduced, followed by DNA replication (submicroscopic level) and the notion of the gene after introducing an experiment on transgenesis (microscopic level). Then, the process of protein synthesis is introduced to explain how a gene is translated into a protein that determines a phenotype (macroscopic level). The gene is defined as a piece of DNA that is translated into a polypeptide chain which, in turn, codes for a protein that determines a specific hereditary character, emphasizing the idea of genetic determinism of phenotype. This "classical molecular gene concept" according to which a gene is a stretch of DNA encoding a functional product, which may be a single polypeptide or RNA molecule (Griffiths & Neumann-Held, 1999), has been

recently challenged by a series of findings (e.g., split genes, alternative splicing, overlapping and nested genes, mRNA edition, and epigenetics...). Also, the biological identity of an organism is simply related to the expression of genotype; the interactions with the environment to determine our phenotype are not in the national curriculum or national biology textbooks for secondary classes (grade 11 Scientific and grade 12 Life Science).

Studies were done in Lebanon on the national Lebanese biology textbooks (Castéra et al., 2008) and on teachers' conceptions related to genetic determinism (Castéra, Munoz & Clément, 2007) in the context of the European project Biohead-Citizen, Biology Health and Environmental Education FP6-CIT2 (2004-2008). These studies proved that the ideology of hereditarianism (genes determine traits) is still very present in school textbooks as well as in teachers' conceptions.

Based on my personal experience as a secondary Lebanese biology teacher for 20 years, I have found that students experience many difficulties in central genetics' concepts. They are unable to differentiate between gene and allele or among chromosome, chromatid and DNA. Students are also unable to understand how the gene is expressed and the relationship between protein and physical attributes. For instance, they think that all human characteristics, including personality, are determined only by our genes. To overcome the obstacles and difficulties in teaching and learning genetics concepts, I sought to search for new resources and teaching strategies when addressing these concepts. In Lebanon, there is no efficient in-service teacher training program for continuous professional development specifically for public school teachers. The National Center for Educational Research and Development (CERD) organizes training sessions that public school teachers can attend for free but they are not obligatory and focus more on teaching strategies rather than updating scientific knowledge. Throughout my personal teaching experiences, I have found that implementing digital resources, like animations and videos, in teaching genetic concepts facilitates and enhances the teaching-learning process of

such concepts. The importance of digital resources in teaching biology in general and genetics in specific is discussed in the following section.

1.1.4. Use of digital resources in science education.

Nowadays, the proliferation and availability of digital and online educational resources such as software, digital textbooks, online exercises, websites, and forums, makes digital technologies an important category of resources for approaching the challenges of teaching difficult concepts (Flick & Bell, 2000). According to Bell (2001), science educators are currently using tools including: digital microscopes, simulation software, websites with simulators and data collection methods, spreadsheets, graphing calculators and presentation software. Moreover, communication tools (e.g., e-mail, video-conferencing), presentation tools (e.g. interactive whiteboards) and digital video are common to science education.

Due to the fact that science has many theoretical and abstract concepts that are difficult to understand by students, the importance of computer assisted instruction (CAI) has become more prevalent. CAI provides students with visual opportunities to learn difficult and abstract concepts. Additionally, it provides text, graph, audio, video, picture, animation and simulation within the same media (Tekbiyik, Birinci, Konur & Pirasa, 2008). According to Web (2008), using computer simulations for science teaching allows the exploration of phenomena that are too difficult or dangerous to investigate experimentally, things too small or too large to be seen and things that happen too fast or too slow for direct observation. Simulations also foster learning and help students to see different aspects of a subject and then generalize it.

The proliferation of digital resources has led to a large amount of learning and teaching materials available for teachers. Digitalization is manifested by the abundance of Internet resources on one hand and the diversity of the technological tools that can be used by teachers like software, interactive whiteboards (IWB) and USBs on the other. This evolution leads to major changes in preparation/teaching practices (Sabra & Trouche, 2011). According to many studies (e.g. Recker, 2006;

Recker, Dorward & Nelson, 2004; Recker et al., 2005), the Internet has been increasing teachers' access to a vast amount of resources in a multitude of formats. Internet resources can update teachers' scientific knowledge which is necessary in sciences, particularly in biology where scientific concepts are evolving at a rapid pace. Moreover, new technologies have made diffusion, sharing, exchange and transport of resources faster between teachers and between one medium to another.

Faced with this abundance and diversity of resources, teachers select resources among those from different technologies as well as among those "traditionally" available to them (curriculum material and books). According to Webb (2008), teachers have always developed their own resources to some extent, but now technology is enabling them to produce a wider range of material and to share them more easily. Technological developments are profoundly changing the working conditions of teachers; they generate new needs and add new complexity to the work of the teacher. While digital resources are important, the question is whether and how teachers are able to make use of these resources in their preparation/teaching practices. Thus, the major problematique of this study is: what are the consequences of interactions between biology teachers and digital resources on their teaching practices and conceptions related to genetic determinism of phenotype?

However, a simple use of online resources abundant on a variety of sites, or a simple exchange of digital resources is not enough nor does it solve the challenges of integrating technology in teaching. The effective integration of information and communication technologies (ICTs) into educational systems is a complex, multifaceted process that is influenced by many factors such as access and availability of technology, curriculum and pedagogy, institutional readiness and teacher competencies, to name a few (Haddad & Draxler, 2002).

1.2. Purpose of the Study

Based on the previous background and from my own experiences, it is evident that teachers' scientific knowledge in relation to genetic determinism needs to be

updated to be aligned with modern epigenetics conceptions. One way to do so is to use digital resources which expose teachers to up-to-date scientific information. Therefore, the purpose of this study was twofold. First, the study aimed to determine if teachers are in fact using digital resources in their preparation/teaching practices in general and in teaching genetic determinism in specific; in addition to the factors that might influence the integration of digital resources in their teaching practices. Second, the study aimed to determine whether teachers' interactions with these digital resources would lead to changes in their conceptions of genetic determinism of phenotype, particularly from hereditarianism to epigenetics.

For the purpose of this study, a combination of two theoretical frameworks was used, namely the “*documentational approach*” and the *KVP model*. The *documentational approach* (Gueudet & Trouche, 2008a, 2009) refers to the analysis of teachers' selection, appropriation, implementation and transformation of various resources - a term known as “documentary work”. According to Gueudet and Trouche (2009) and Hammoud (2012), teachers' documentary work occurs through an ongoing, evolving process called “documentation genesis”. On the other hand, teachers' conceptions were studied in terms of Clément's (2004, 2006) *KVP model* which posits that conceptions are a result of interactions among three interrelated poles: 1) Scientific knowledge (K) published by the scientific community in the form of school textbooks, academic journals, Internet websites, media...etc.; 2) Value systems (V) which refers to opinions, faiths, ideologies, and philosophical and moral positions; and 3) Social practices (P) including professional practices of teachers inside and outside the school context as well as environmental constraints and conditions. In this study, the evolution of teachers' conceptions was studied in light of the KVP interactions in their evolving documentary work.

1.3. Rationale

The present study fills a gap in the literature in Lebanon on the integration of technology in science teaching in general and genetics in specific. An exhaustive review of the literature was conducted in Lebanon between the years 1992 and 2002

by BouJaoude and Abd-El-Khalick (2004) and it showed that there are 62 empirical science education studies conducted. Surprisingly, despite the fact that many private schools in Lebanon have fully equipped computer laboratories, some of which have access to the Internet, only a single empirical study investigated ways in which computer technology could contribute to the teaching of science in Lebanon. This study (Shihab, 2000) investigated the effect of using web-based hypermedia as an alternative to textbooks on student achievement in a unit on the classification of animals.

Similarly, according to BouJaoude and El Hage (2009) based on another review done between 2002 and 2008, only two studies were published in 2007 and 2008 in the category of technology-aided instruction: one investigated the mathematization in physics laboratories that incorporated inquiry enhancing technologies (Jurdak, BouJaoude, & Ghumrawi, 2007) while the second surveyed students' and teachers' views of the advantages and limitations of using information and communication technology (ICT) (Eid, 2008). Thus, there are no studies in Lebanon about interactions between digital resources and teachers' conceptions.

In the context of a digitalization era, information and communication technology (ICT) is considered part of a wider range of available teaching resources in which teachers exchange digital files by e-mail, use digital textbooks, draw on resources found on the net and prepare digital files (Gueudet & Trouche, 2009). Therefore, it is crucial to conduct studies related to teachers' interactions with resources, particularly digital resources, and teachers' practices and conceptions. The topic of genetic determinism of phenotype is chosen because teaching the linear relation one genotype → one phenotype is limited and even dangerous. According to the study of Clément, Quessada and Castéra (2012) there is a link between innatism and intolerant attitudes as sexism or racism. The human phenotype includes not only the anatomy and physiology of any person, but also his/her appearance, illnesses and health, behavior, emotions, intelligence, skills, and any other learned competences. Most of these features are socio-cultural and cannot be reduced to genetic

determinism (Clément & Castéra, 2013). According to Castéra and Clément (2009), teaching epigenetics is a citizen challenge for the 21st century; this new paradigm in biology is a "question vive" with an important social challenge, it has important implications on biology teaching. Thus, the new challenge facing Lebanese biology teachers is how to cope with these changes and update their scientific knowledge relying on all *available resources* including digital resources. The interactions between teachers and these resources during their professional activity and the consequences of these interactions play a central role in teachers' professional development (Gueudet, Pepin & Trouche, 2012). Despite the significant influence that digital resources can have on teachers' conceptions, no study has been done in Lebanon in the context of genetic determinism.

1.4. Significance

This study can inspire curriculum designers in Lebanon to include modern topics like epigenetics which deal with interactions between genotype and the environment to determine phenotype in the reformed Lebanese biology genetics curriculum. It also emphasizes the importance of pre-service and in-service teacher training programs that focus on teachers' conceptions related to important topics like the genetic determinism of phenotype, training should introduce recent topics in genetics, like epigenetics and should emphasize on KVP interactions. Moreover, teachers should be trained to integrate ICT in their teaching practices, and to design their own digital resources based on their students' needs. Finally, by improving teachers' conceptions of genetic determinism of phenotype this will, in turn, lead to changes in students' conceptions as well. New ideas in genetics must be introduced in a more systemic manner in order to build scientifically literate citizens aware of the importance of the environment and its effect on gene expression. In fact, using digital resources will not only modify students' conceptions but also enhance their conceptual understanding and motivation and as a result their academic achievement.

1.5. Outline of the Study

This study consists of six separate chapters. This first chapter (Chapter I) presented the “Problematique” of the study.

Chapter II presents the theoretical framework to analyze teachers’ conceptions about genetic determinism of phenotype and a framework to study teachers’ interaction with digital resources. In addition it includes a review of literature related to the topic of study. This allowed for refinement of the research questions which are presented at the end of Chapter II.

Chapter III illustrates the elaborated methodology for collecting and analyzing our data. It also presents the field of the study and the cases selected.

Chapter IV presents the analysis of teachers’ responses to a questionnaire elaborated to study the current status of integration of digital resources by Lebanese biology secondary teachers. This will partially answer our research questions; in addition it allowed us to select the participants of the qualitative part of the study.

Chapter V focuses on the analysis of the data collected from the case studies while, finally, Chapter VI presents the discussions related to the research questions. It also includes future perspectives and a general conclusion.

CHAPTER II

DOCUMENTATIONAL APPROACH, KVP MODEL, LITERATURE REVIEW, AND RESEARCH QUESTIONS

This chapter presents the basic concepts of the two theoretical frameworks on which the study was based: the “*documentational approach of didactics*” (§ 2.1) and the “*KVP model*” for analysis of teachers’ conceptions about genetic determinism of phenotype (§ 2.2). Then, the interactions between the two theoretical frameworks is presented in part (§ 2.3). This is followed by a literature review related to genetic determinism and ICT integration in education (§ 2.4). Finally, the questions of research are presented in (§ 2.5).

2.1. The *Documentational Approach* of Didactics

This part presents the theoretical framework that allowed for investigating the interactions between teachers and digital resources during teachers’ professional activities. The *documentational approach* was recently elaborated by Gueudet and Trouche (2008a) in didactics of mathematics in order to comprehensively study the work of teachers inside as well as outside the classroom. In this theoretical framework, researchers study teachers’ professional evolution where the attention is focused on the resources and their appropriation and transformation by a teacher or group of teachers working together (Gueudet & Trouche, 2009). Similar issues have already been investigated by Adler (2000) who claims that mathematics teacher education needs to focus on resources in practice. The basic concepts of this approach were built based on studies done on secondary teachers of mathematics in France (Gueudet & Trouche, 2008a; Sabra, 2011) and then its scope was extended to secondary teachers of chemical sciences in France (Hammoud, 2009, 2012; Hammoud, Le Marechal & Trouche, 2010). This study applied the *documentational approach* on secondary Lebanese biology teachers and thereby supporting the idea of implementation of this approach beyond mathematics.

The basic concepts of the *documentational approach* are presented in the following sections: the resources and documentary work of the teacher (§ 2.1.1); and the documentation genesis process (§ 2.1.2).

2.1.1. The resources and documentary work of the teacher.

The meaning commonly attributed to the term “resource” in and for education is that of material resources which includes teaching aids such as textbooks, teaching software and Internet resources. Previously, resources were called “tools and technologies in mathematical didactics”. The word “resource” was introduced due to the need to consider technologies within a range of resources available for students, teachers, and teacher trainers (Gueudet & Trouche, 2008a). Various kinds of digital material are now extensively used and they can be viewed as belonging to a wider set of material (Remillard, 2005) and teaching resources (Adler, 2000). Digital resources include both media (CD-ROM or Internet sites), systems of integration (interactive whiteboards, video projection, or computer rooms), or the content in these media, particularly in Internet resources.

Adler (2010) argued for the verbalization of the word resource whereby the word is viewed as the verb “re-source” - i.e., to source again or differently where “source” implies the origin from which a thing comes or is acquired. Based on this definition, Adler (2010) offered a broad conceptualization of *available resources* which comprises a set of physical, human and cultural resources. Similarly, Gueudet and Trouche (2010) refer to a resource as all that is likely to re-source the work of teachers. In other words, a resource is everything that contributes to the teaching process including material resources, digital or not as well as socio-cultural resources, for example, interactions with students and discussions with colleagues. Thus, according to this viewpoint, student responses/reactions or advice from other colleagues in addition to books and Internet resources are all possible resources for teachers. In the broad sense of the term, a resource is anything that can be used by teachers to support teaching and learning whether during the preparation of lessons or during their implementation.

Interacting with resources is a key element in teachers' work. Documentary work covers all facets of teachers' professional activities; it takes place in a set of places outside class as well as inside class. The *documentational approach* is used to identify the influence of professional knowledge on the choice of resources and vice versa. For this purpose, this approach studies teachers' documentary work including their collection, selection, transformation, recombination, sharing and revision and implementation of resources. Documentation refers to the documentary work in addition to the outcome (documents) generated during this work. (Gueudet & Trouche, 2009)

The following section presents how the work with resources can yield a document through a documentation genesis process.

2.1.2. The documentation genesis process.

The *documentational approach* makes an essential distinction between *available resources* (textbooks, official program, digital resources, student worksheets, advice given by a colleague etc...) and a document developed by the teacher from these resources through a process called "documentation genesis". In this perspective, the *documentational approach* is inspired from the instrumental approach which proposes a distinction between artifact and instrument. According to Rabardel (1999), an artifact is a cultural and social means provided by human activity whereas the instrument is built from the artifact by a subject and results from a process named instrumental genesis along which the subject builds a scheme of utilization of the artifact for a given context. A scheme constitutes rules of action structured by implicit knowledge built through various contexts of utilization of the artifact. Applying this to the *documentational approach*, the resource refers to the artifact, the subjects are the teachers and the instrument is how the teacher builds a scheme of utilization of a set of resources across a variety of contexts. This is what is referred to as a genesis process which ultimately yields a document. The documentation genesis process refers to the instrumentalization process which conceptualizes teacher's appropriating and reshaping resources, and the

instrumentation process which captures the influence of resources on teacher's activity, as illustrated in Figure 1.

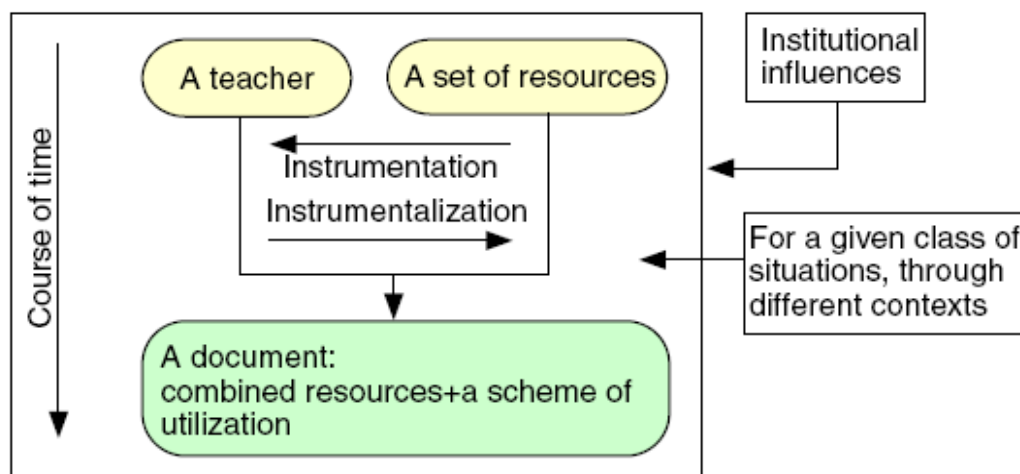


Figure 1. Schematic representation of a documentation genesis process (Gueudet & Trouche, 2009).

The documentation genesis process ultimately produces a document which simultaneously develops a new resource (made up of a set of resources selected, modified, recombined) and a scheme of utilization of this resource. The main part of the scheme is invisible and corresponds to operational invariants and the observable part corresponds to usages.

$$\text{Document} = \text{Resource} + \text{Usages} + \text{Operational Invariants.}$$

The genesis process is ongoing whereby the document gives rise to a new resource that combines other resources to be involved in new genesis. Therefore, there is a dialectical relationship between resources and the document (Gueudet, Pepin & Trouche, 2012). A document always belongs to teachers' documentation system, evolving through documentation genesis. Documentation genesis is not a transformation from resources (input) to document (output) but rather it is an ongoing process that involves appropriation and reshaping of resources. A documentation genesis induces evolutions of teachers' schemes including the rules of

action (i.e., teacher practices) and the operational invariants (i.e., teacher knowledge and beliefs). The teacher's resource system constitutes the 'resource' part of her documentation system without the scheme part; it comprises material elements and other elements that are more difficult to collect, like conversations with colleagues and student interactions. The documentation system consists of the resource system as well as the corresponding schemes. Documents produced by teachers are organized in a documentation system and the analysis of the evolution of these documentation systems permits the study of teachers' professional development. Thus, the consequences of the interactions between teachers and resources and teachers' integration of new resources play a central role in teachers' professional development specifically in terms of their knowledge and teaching practices (Gueudet et al., 2012).

This research studies teachers' interactions with resources during their professional activities outside and inside class; these resources include material resources, particularly digital resources, as well as resources that are difficult to collect.

According to the concept of the life cycle of the document elaborated by Hammoud (2012), the development of a document is a complex process with no clear beginning or end. It also essentially includes collective aspects since teachers never work in isolation but rather collectively with students or colleagues. Teachers develop their documents through interactions with students or colleagues, collect resources via the Internet and participate in various institutions or associations. Thus, the development of a document requires a set of resources and several actors. A document comes in response to a given class of situations like, in the case of this study, preparing for teaching the genetic determinism of phenotype.

Hammoud (2012) also distinguishes between mother and daughter resources. "Mother resources" are the set of resources that initiate and instigate teacher preparation while "daughter resources" are those that are produced by the documentary work of the teacher at the end of the design process to be implemented

in class (Hammoud, 2012). During the life cycle of a document, teachers search for *mother resources* either from resources that they already possess or from other resources. At this point, teachers may also ask their colleagues to seek for *mother resources* which results in a collective dimension. Then, the teacher selects and combines all these *mother resources* to design *daughter resources*. According to Hammoud (2012) based on Gueudet and Trouche (2007), *daughter resources* constitute three levels: physical media, content, and educational or didactic organization. For example, in the context of this research, physical media include students' worksheet and animations and videos about transcription and translation. As for the content, it resides in the biological concepts that are the subject of the *daughter resource* which will be analyzed in terms of conceptions about genetic determinism. Also, traces of didactic organization of this "daughter resource" can be identified whereby students are expected to answer worksheets after observing an animation which in turn leads to construction of knowledge about the topic being explained.

The design process is done in a double instrumentation and instrumentalization movement. The development of the document continues to take place in the classroom whereby the *daughter resources* are implemented and adapted according to students' feedback. Afterwards, the *daughter resources* are officially modified and then integrated into teachers' existing system of resources. Therefore, the development of a document continues throughout the life cycle and it is difficult to identify precisely at what stage of the cycle a document is built. In addition, parts of the document may not be visible, some of which might be inferred from the design and use of the daughter resource. Thus, a document is not an end result, but rather a means for creating an on-going cycle of *daughter resources*. The *daughter resource* from which a document grows and evolves over time adapts to the new constraints that may arise, it is the same for professional knowledge to face new situations, which certainly reflects on the document. The document itself gives rise in turn to new resources that will be involved with other resources and serve as a *mother resource*

for the preparation of another *daughter resource* who will give another document with respect to another class of situation for the next year or the year after.

In this study, the researcher was interested in the life cycle of the document since the purpose of the research was to investigate the interactions between teachers and resources. The resources in question are constantly revisited by the teacher, in an instrumentalization movement, the professional knowledge of the teacher is questioned by the resources, their implementation and the effects they cause and the interactions between teachers and their resources is at the heart of their teaching practices. Therefore, beyond the new resources produced while developing a document there is professional development: it is not only changes in the system of resources, but also of the knowledge and professional activity. Gueudet and Trouche (2010) consider that the development of a document has a clear productive part (the resources produced by the teacher) and a constructive part (this production is based on knowledge and product). Changes associated with professional knowledge in terms of interaction with digital resources are part of the constructive dimension.

The following section illustrates the second theoretical framework, namely the *KVP model*, used to analyze teachers' conceptions related to genetic determinism of phenotype.

2.2. KVP Model to Analyze Teachers' Conceptions

Teachers' and learners' conceptions have been addressed in many researches in didactics of science in the last twenty years (Astolfi & Develay, 1989; Clément 1998, 2010; Giordan & De Vecchi, 2002; Giordan, Girault & Clément, 2004). Researchers of didactics are interested in learners' previously held ideas related to a scientific topic and whether these previous ideas allow or inhibit the acquisition of new knowledge. These previous ideas about a certain scientific topic are called "conceptions" (Clément, 2010). It should be noted that conceptions do not indicate exactly what a student thinks, but rather they provide *inferences* about students' ideas

by giving insight into what is found in their minds on a certain topic (Clément, 1994, 2004, 2010).

Clément (1999) identified “situated conceptions” conceptions which are evident in specific situations, such as solving a task for having a dialogue. Similarly, Giordan and De Vecchi (1987) defined conceptions as “a set of explanatory, coordinated ideas, and coherent images used by learners when confronted with a problematic situation” (as cited in Castéra et al., 2008, p. 165). These conceptions emerge from the long-term memory as a result of the situation in which learners are placed. Thus, researchers can only analyze situated conceptions when it reflects a response to a question (written or oral), or an intervention in a group, or as a behavior or achievement in a specific context. In order to make accurate inferences and assumptions about a learner’s conceptions on a certain topic, it is necessary to observe that learner in various contexts in order to elicit different facets of his/her conceptions. In this study, teachers’ conceptions about the genetic determinism of phenotype was inferred after the analysis of all the data gathered in different situations (interviews, classroom observations, lesson plans, logbooks and resources utilized). This led to the use of *critical resources* and situations for the purpose of inferring teachers’ conceptions.

Furthermore, Clément (1998) proposed a new theoretical model where conceptions are analyzed in terms of interactions between three poles: 1) scientific knowledge (K); 2) social practices (P); and 3) values (V) (Figure 2). This model was first applied in the context of *Education for the Environment* to analyze the different conceptions of the actors of the educational system (students, teachers, curriculum designers, authors of books, editors and researchers) (Clément & Hovart, 2000; Cheikho & Clément, 2002). It was later generalized to analyze any conception like conceptions on a specific theme or topic (Clément 2001, 2004, 2006).

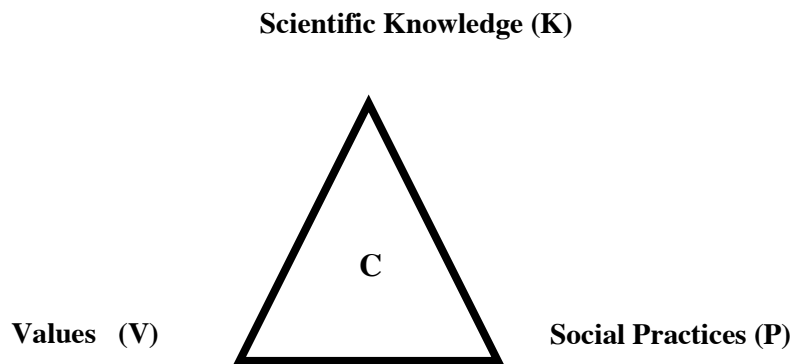


Figure 2. The *KVP model* where conceptions (C) are analyzed as interactions between the three poles K, V and P (Clément, 2006).

Scientific knowledge (K) is that which is published by the scientific community in the form of school textbooks, academic journals, Internet websites, radio or television, scientific papers, conference papers or any other resource. In the context of biological sciences, scientific knowledge is evolving at a rapid pace and thus this scientific knowledge might be controversial with existing knowledge.

As for the value systems (V), it refers to opinions, faiths, ideologies, and philosophical and moral positions. For instance, in related to the topic of human genetics in this research, values are understood to be ideologies which are considered a product of history within a scientific context (Canguilhem, 1981). As specific examples for the field of biology, Canguilhem cites “anatomism”, “reductionism”, and “the ideology of heredity,” which is also can be called “hereditarianism,” “innatism,” or even the ideology of “all genetics” (Atlan, 1999).

Finally, social practices (P) include not only professional practices of teachers within the school context (i.e., interactions with their colleagues or parent meetings) but their influential social practices as regular citizens, whether civic, religious, ethical or others. Additionally, it covers the personal practices of the actors of the educational system.

The P pole was introduced by Martinand (1986, 2000) who drew attention to the importance of taking into account social practices (P) as important references in

“didactic transposition” in connection with the knowledge to teach. The *Didactic Transposition* was first defined by the sociologist Verret in 1975 (as cited in Clément, 2006) who described the constraints for the choice of the contents to be taught. In other scientific fields, the *Didactic Transposition* is used to analyze why some scientific contents are selected to be taught (external *Didactic Transposition*, for the definition of curricula and syllabuses) and then how these contents are transposed for teaching - learning (internal *Didactic Transposition*). Chevallard (1985), using the work of Verret (1975), proposed a three-step scheme of *Didactic Transposition* as illustrated in Figure 3.

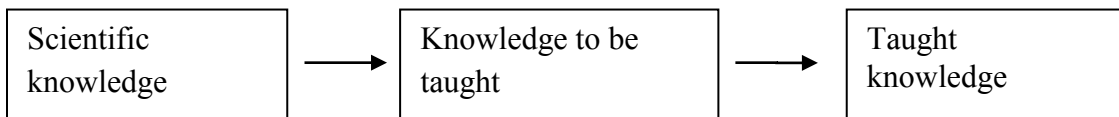


Figure 3. The three steps of *Didactic Transposition* proposed by Chevallard (1985).

Clément (2006) from his research in *Didactics of Biology* and in *Environmental Education* proposed the inclusion of KVP interactions at all levels of *Didactic Transposition*, using a modified model (Figure 4). This new model includes several additions and changes compared to the model of Chevallard (1985): it includes more than three steps to analyze more precisely the conceptions of the different actors of the educational system. One of the added levels is the different levels of science popularization, which obeys its own rules and interferes with implementation at the school level. It is the same for the realization of textbooks; it is less linear and more differentiated with a possibility of feedback between the different steps; and the KVP interactions are found at all levels of implementation. This approach is consistent with analysis of conceptions of the actors at different levels of *Didactic Transposition* by introducing the *KVP model* at each of these levels. In particular, KVP which is introduced at the references are not limited transposition “scholarly knowledge” but also include social practices and values. It is at this point that this pattern differs most from the approach of Chevallard (1985).

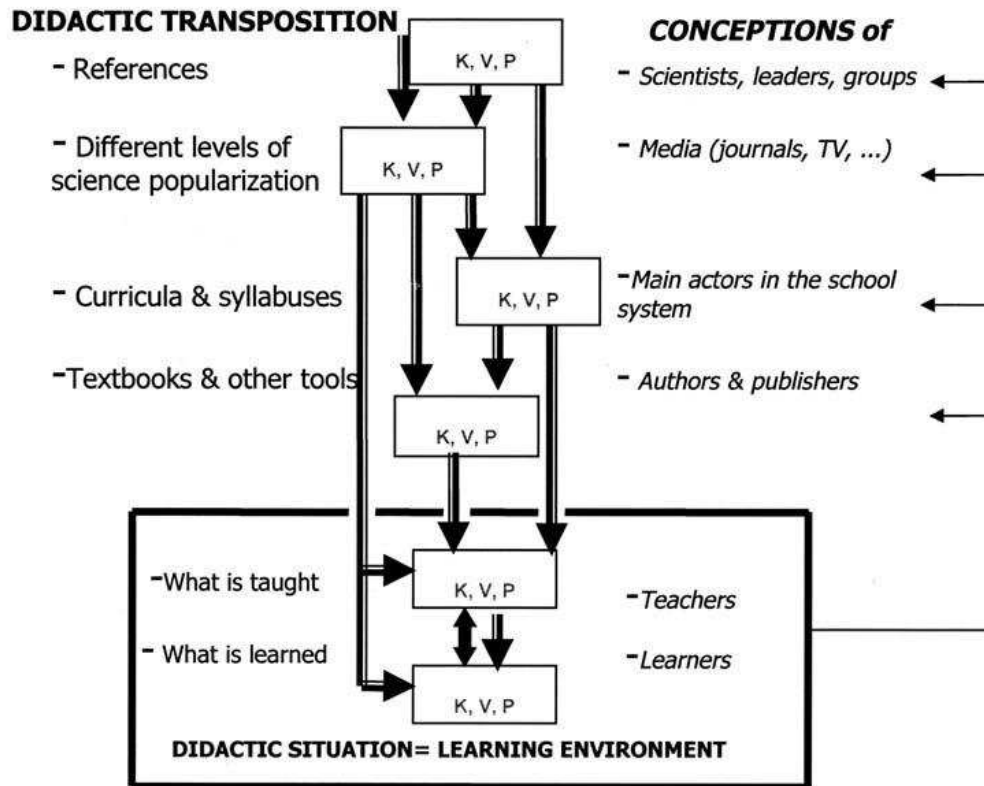


Figure 4. Schema of *Didactic Transposition* elaborated by Clément (2006) to include KVP interactions at all levels.

In order to understand the use of the *KVP model* to analyze teachers' conceptions in this study, a simple example presented in the study of Castéra et al. (2008) will be used to illustrate this point. When a textbook or a famous scientific magazine publishes an image of young children who are monozygotic twins (identical twins) to illustrate the physical resemblance between two people sharing the same genotype, this choice made by the author and/or publisher is based on scientific knowledge in genetics transmitted by the picture: the similarity between these two twins is seen from an anatomical point of view (K pole). This picture also illustrates the social practices (P pole) of the twins' parents since they dress both their children in the same way and also the social practices of the publishers who also perceive that monozygotic twins are always dressed alike. Therefore, an ideological message is also transmitted through these images in which identity is defined by hairstyle, clothes, body posture, and facial expressions and thus suggesting that these features

are programmed by the identical genotypes of monozygotic twins. The value (V) in this case is the implicit innate idea of “hereditarianism” suggesting that human cultural and social features (such as hairstyle and dress) are genetically determined.

In this study, conceptions of teachers about the relation between genotype and phenotype - genetic determinism of phenotype - was analyzed as an interaction between the three poles: scientific knowledge related to human genetics specifically the expression of genotype (K); values as either innatism that may reflect fatalist values or epigenetics that may reflect more progressive values (V); and teaching practices and social practices (school, media...) (P). The *KVP model* was not only used to analyze teachers’ conceptions but also indirectly the conceptions of researchers, textbook authors and other actors of the educational system.

The following section presents the contribution of this study to the theoretical field manifested by the articulation between the two theoretical frameworks presented above (*KVP model* and *documentational approach*) according to the purpose of the study and the research questions.

2.3. Articulation between the Two Theoretical Frameworks

In order to analyze teachers’ conceptions through their documentary work in this study, a new model integrating the documentation genesis process (Figure 1, § 2.1.2) with the *KVP model* was formed. This model was used to analyze teachers’ conceptions as KVP interactions during their search choice and appropriation of resources as well analyze the conceptions of the resources’ authors as KVP interactions and its effect on teachers’ conceptions. Thus, the researcher took into account, instead of the schemes to build a document, knowledge (K), practices (P) and values (V) of resources as well as that of institutions (school, society) interacting with KVP of teachers. The new model is illustrated in Figure 5.

A document developed by teachers during their professional activity constitutes of resources enriched from teachers’ experiences based on KVP interactions, the values (V) and knowledge (K) of teachers might be reflected through

their practices (P). The relationship between the teacher and the resources is dialectical: teachers select, appropriate and transform resources based on their conceptions (instrumentalization) and the *implemented resources* reshape teachers' activities (P), professional knowledge (K) and values (V) (instrumentation). The latter, in turn, might lead to evolution in teachers' conceptions. Moreover, the documentation genesis process develops a new resource (made up of a set of resources selected, modified, and recombined) based on teachers' KVP interactions.

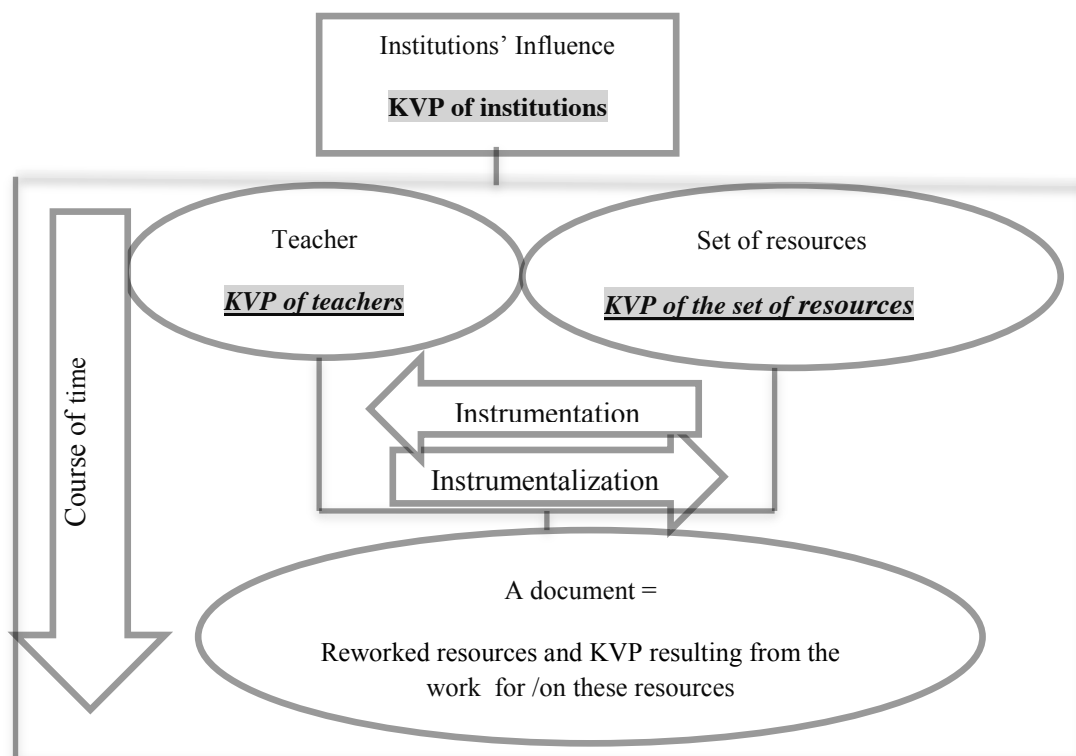


Figure 5. Schema showing a new description of the documentation genesis process integrating the *KVP model*.

In this study the researcher defined specific notions to articulate the two theoretical frameworks, “the *documentational approach* of didactics” and “the *KVP model*”, on which the study is based in order to investigate evolutions of teachers' conceptions based on their interactions with resources during their documentary work. These notions are:

- **Available resources:** Set of resources belonging to teachers' system of resources like textbooks, academic books, magazines, exams, exercises, student worksheets, digital resources downloaded from the net and Internet resources available for all teachers in school and outside school. This also includes resources elaborated by teachers or exchanged with colleagues.
- **Mobilized resources:** All the resources actually implemented or used by teachers during their preparation practices for teaching a specific topic or lesson. They can include resources from the teachers' system of resources, Internet resources, textbooks, university books...etc. Thus, the notion of *mother resources* (Hammoud, 2012) is refined to consider only the resources that are actually used to prepare the *implemented resources* in class. This notion was introduced in this study since the interest was to analyze the KVP of these resources that are directly mobilized to prepare *implemented resources*, believing that they might reflect teachers' conceptions.
- **Elaborated resources:** All resources designed by the teachers for a specific topic or lesson after selecting, combining and reshaping the *mobilized resources*. This study was specifically interested in these resources since they indicate what teachers consider as basic ideas for a certain topic and as a result might reflect their KVP related to this topic.
- **Implemented resources:** All resources actually put in action in class during teaching; they can be either *mobilized resources* or *elaborated resources*. This differs from the notion of "daughter resources" (Hammoud, 2012) since it only includes the resources implemented and adapted in class believing that this might allow us to infer teachers' conceptions based on KVP of resources.
- **Critical resources:** The resources considered essential by the teacher for the preparation and teaching of a specific topic. At the same time, they are identified after data analysis as the basic resources of teachers' system of resources mobilized, elaborated or implemented for teaching a specific topic.

All the *critical resources* were analyzed in order to infer teachers' conceptions and to investigate any evolution in these conceptions.

- **Critical situations:** Situations identified during the implementation of *critical resources* in the classroom, but they can also be raised by students' questions that require the teacher to apply new *critical resources* in the classroom. In addition, they can be induced by the researcher when asking specific questions that might reflect teachers' conceptions during interviews. The interest is in the output of these *critical situations*: a discourse, a diagram or a photo that might reflect teachers' conceptions.
- **Archive:** A set of resources utilized by teachers during their years of teaching experience; they are mobilized, elaborated or *implemented resources* in previous years. The *archive* related to the topic of genetic determinism was analyzed to infer teachers' conceptions and any evolution of conceptions based on evolution of the *archive's* resources related to this topic.

The following section presents a literature review of the studies related to the topic of research in light of the two theoretical frameworks presented above.

2.4. Literature Review

This section presents a literature review of the studies related to the topic of this research, namely, the genetic determinism of phenotype and the new paradigm of epigenetics (§ 2.4.1). Then, it presents studies related to the integration of ICT in education and the factors that might influence the integration of digital resources in teaching practices (§ 2.4.2).

2.4.1. The epigenetics paradigm and conceptions about genetic determinism.

This part discusses the evolution of the epigenetics paradigm (§ 2.4.1.1), genetic determinism as it is tackled in textbooks (§ 2.4.1.2) as well as teachers' conceptions of genetic determinism (§ 2.4.1.3).

2.4.1.1. Evolution of the epigenetics paradigm.

The term genetic determinism was formulated in the 1960s; it is currently used in biomedicine and conveys the notion that a person's physical and psychological characteristics are established by genes only. This is considered a reductionist ideology in which any biological phenomenon is seen to be determined by genetics structure (Silva, Ferrerira & Simoes, 2009). Related to this ideology, the term “genetic program” has been used for pedagogical purposes in textbooks and other resources as well as by teachers indicating that all characters are programmed by our genes.

For many years, the teaching of genetics has only been centered on the determinism of phenotype by genotype. Although this linear and deterministic representation, called the linear causal model (Figure 6), is important in explaining genetics, it is limited and even dangerous both in human biology and in general. Nevertheless, this does not mean that the genome is not important in explaining some phenotypic aspects, but to reduce all phenotypes to genetic influence is more ideological than scientific, expressing the values of “innatism” or “hereditarianism” (Clément & Castéra, 2013).

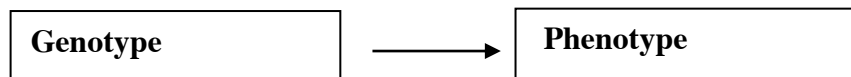


Figure 6. Schematic representation of the linear causal model of genetic determinism.

The deterministic representation of genetics (linear model) is no longer accepted by biologists (Abrougui & Clément, 1997a; Atlan, 1999; Clément, 2007; Kupiec & Sonigo, 2001; Morel & Miquel, 2001; Noble, 2007). During the second half of the 20th century, there was a debate between innate and acquired human features (nature versus nurture) based on studies in genetics about identical and fraternal human twins (Lewontin, Rose & Kamin, 1984; Schiff et al., 1982). The psychologist Zazzo (1984) indicated that identical twins tend to differ in their

behavior and psychological characteristics more than fraternal or non-identical twins; this observation was termed “the paradox of twins”. Percentages of contribution from both genotype and the environment were proposed, for instance, to explain intelligence from research on twins (the famous fraud of Burt reported by Lewontin, Rose, & Kamin, 1984). Consequently, the traditional debate *nature versus nurture* was progressively replaced by a new representation *nature and nurture*. This additional representation (genes + environment) is called the additive model (Figure 7), which is still very popular in students’ conceptions (Lewis, Leach, & Wood-Robinson, 2000a & b; Lewis, 2000 & 2004) and even in school textbooks and teachers’ conceptions (Clément & Forissier, 2001; Forissier & Clément, 2003).

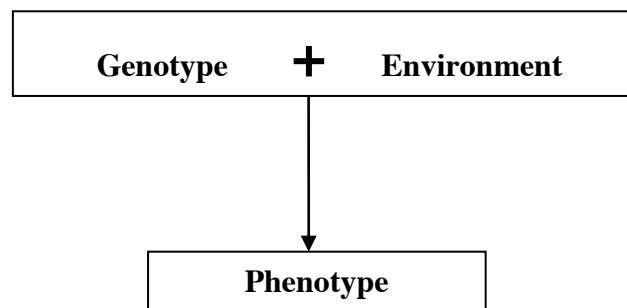


Figure 7. Schematic representation of the additive model of genetic determinism, genotype and environment responsible for phenotype.

Nevertheless, this representation is scientifically incorrect because the genes and their environment cannot be added; rather they interact, as has been demonstrated by researchers in genetics (Jacquard, 1981). When the genotype and the environment interact, it is impossible to evaluate their importance by a percentage. By the end of the 20th century, biologists claimed that the debate between nature and culture was outdated and that both are in constant interaction (Atlan, 1999; Jacquard, 1981; Jacquard & Kahn, 2001; Kupiec & Sonigo, 2001; Lewontin, 2003). Jacquard (1981) developed an analogy saying that interactions between bricks and cement are necessary to build a wall. All biologists agreed with the interactive representation (Atlan, 1999; Jacquard & Kahn, 2001; Lewontin, 2003) which is called the interactive model (Figure 8).

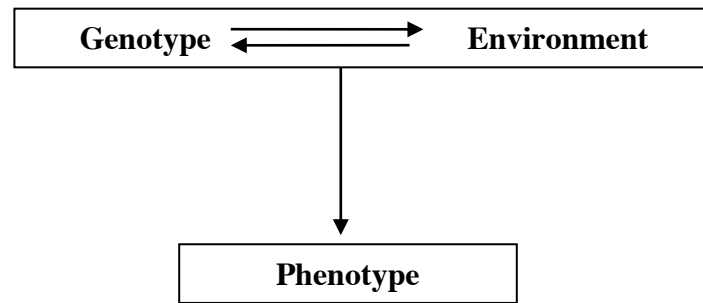


Figure 8. Schematic representation of the interactive model of genetic determinism.

It has been well accepted that although a person is born with genetic potential, metabolic and environmental factors may influence the expression of such genetic potential (Penchaszadeh, 2002). Human biological identity is a very important concept holding multiple meanings. It is partly defined of course, by our unique genome (DNA), but this identity also includes a neurological, genetic, behavioral and psychological identity (Abrougui & Clément, 1997b; Clément & Abrougui, 1996). Thus, our biological identity results from our body's interactions with its interior and exterior environment (Prochiantz, 1993). Nowadays, the interaction between human genes and their environment is called “epigenetics” (Morange, 2005). “Epigenetics” could be broadly defined as the sum of all those mechanisms necessary for the unfolding of the genetic program for development (Holliday, 2006). The strict scientific definition of “Epigenetics” (Pouteau, 2007) is only concerned with the control of the activity of genes by chemical modifications of the DNA itself (e.g., by methylation) or of proteins of the chromatin around the DNA (e.g., histone acetylating). A broader definition of “Epigenetics” is concerned with all the non-genetic processes which, in interaction with the genes, are acting to build a phenotype.

However, the interaction can be more complex than that represented in Figure 8. Forissier and Clément (2003) described three levels of interaction (Figure 9) between: 1) Genes and their environment (epigenetics) (Figure 8); 2) Phenotype and the environment, for example, when one has an accident resulting in amputation of one's leg; and 3) (1) and (2), for example, genetic manipulation or the use of a diet

without phenylalanine to correct the effects of a gene mutation that causes phenylketonuria (Jacquard, 1981).

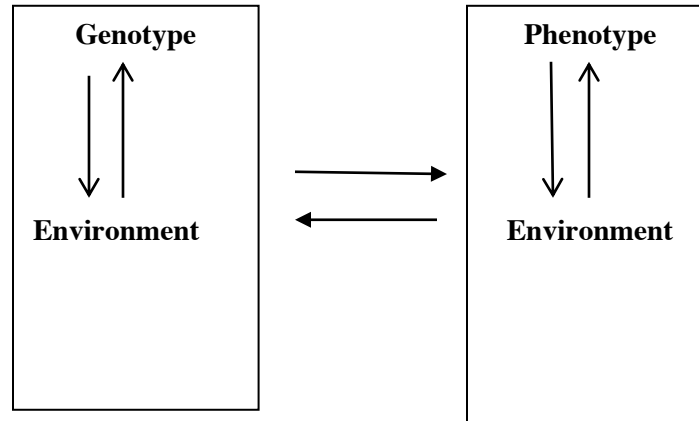


Figure 9. Schematic representation of the interactive model of genetic determinism with three interactive levels.

Another new scientific discovery related to genetic determinism is the notion that one gene can give rise to several gene products via alternative splicing, the use of more than one reading frame and/or post-translational processes. Alternatively, several genes may be involved in one single gene product (Flodin, 2007). Splicing was discovered in 1977 (Berget, Moore & Sharp, 1977; Chow et al., 1977; Gelinas & Roberts, 1977) when it became clear that the gene was not a simple unit of heredity or function, but rather a series of exons, coding for, in some cases, discrete protein domains, and separated by long non-coding stretches called introns. With alternative splicing, one genetic locus could code for multiple different mRNA transcripts. This discovery complicated the concept of the gene radically. In fact, some genes have been found to overlap one another, sharing the same DNA sequence in a different reading frame or on the opposite strand. The discontinuous structure of genes potentially allows one gene to be completely contained inside another one's intron, or one gene to overlap with another on the same strand without sharing any exons or regulatory elements (Gerstein et al., 2007). Moreover the phenomenon of *trans-splicing* (ligation of two separate RNA molecules) further complicated our

understanding (Blumenthal, 2005). There are examples of transcripts from the same gene, or the opposite DNA strand, or even another chromosome, being joined before being spliced. Clearly, the classical concept of the gene as “a locus” no longer applies for these gene products whose DNA sequences are widely separated across the genome (Gericke & Hagberg, 2007).

2.4.1.2. Genetic determinism in textbooks.

After the emergence of the new paradigm of epigenetics, several didactics of biology became interested in the definition of genetic concepts in the school environment. Previous research has shown that old genetic deterministic conceptions still prevail in school textbooks. In fact, before 2001, the interaction between genotype and environment to determine biological identity was not taught.

Recently, Quessada and Clément (2007) introduced the concept of *Didactic Transposition Delay* (DTD) which refers to the time interval between the date of publication of a scientific discovery, or formulation of a new paradigm, and the date of its introduction into an educational system (DTDP) and/or its introduction into textbooks (DTDM). For instance, following the introduction of epigenetics (Atlan, 1999; Morange, 2005), programs and textbooks were renewed differently depending on the country (Castéra et al., 2008; Clément & Castéra, 2013) and the media (Clément & Castéra, 2007). In the context of this study, DTD is studied in terms of the integration of new scientific knowledge into teachers' conceptions of genetic determinism of phenotype.

Castéra et al. (2008) studied in the context of the Biohead project how current school biology textbooks in 16 countries (including Lebanon) present the progress of genetic concepts from hereditarianism to epigenetics. The study showed that there is still an implicit idea of genetic determinism in textbooks although the notion of “genetic information” is used more. Thus, the results of Castéra et al.'s (2008) study indicated that textbook content not only conveys scientific knowledge, but also implicit messages related to values (i.e., hereditarianism). Consequently, in

accordance with the *KVP model* of Clément, there is a strong interaction between knowledge (K) and values (V).

Conceptions of genetic determinism through examples of genetic diseases

Conceptions of genetic determinism can be presented through the examples of genetic diseases in school textbooks (often found in chapters dealing with human genetics) or by the way genetic diseases are presented by teachers. A genetic disease represents a malfunction or a mutation in one or several genes and can be separated into two large categories: monogenic diseases caused by a mutation in a single gene and polygenic diseases caused by multiple genes. Therefore, some genetic diseases illustrate a simple linear genetic determinism while others clearly demonstrate interactive processes in the development of the pathological phenotype. A textbook which only cites examples of monogenic diseases like cystic fibrosis or Duchene muscular dystrophy, unintentionally conveys the message of hereditarianism. This could justify fatalism with regard to social practices in which it is believed that being healthy and successful is due to good genes. According to WHO, health is a multidimensional concept including psychological, social, economic, environmental as well as biological aspects (Castéra, Bruguière & Clément, 2008). In fact, even some monogenic diseases are influenced by the environment which can play a role in the partial or even total reversibility of the disease. For example, in the case of phenylketonuria, a special diet can completely prevent the occurrence of mental retardation.

In the case of polygenic diseases, variations in the DNA sequence are necessary but not sufficient to trigger the disease since an interaction with the environment is also required (e.g. diabetes, cancer, albinism...etc). Current scientific and medical knowledge suggests that cancer development is a multi-stage process in which a number of gene altering events are necessary to progressively transform the descendants of a normal cell into malignant cells. Cancer has a polygenic origin since its development is due to the accumulation of successive anomalies in different genes

over the course of multiple cellular generations (Séralini, 2003). The same argument holds for both Type 1 and Type 2 diabetes, which are also considered polygenic. In the case of sickle cell disease, the presence of modifier genes which regulate the severity of the disease has been acknowledged (Lobie & Elion, 1996).

In this study, the presentation of genetic diseases in resources used by teachers was used as an indicator of teachers' conceptions about genetic determinism. More specifically, teachers that present examples of genetic diseases in which genotype is the unique explanation to a pathological phenotype (reductionist model), like Duchene muscular dystrophy or cystic fibrosis, might have hereditarianism conceptions. On the other hand, teachers that illustrate examples of genetic diseases that illustrate the interaction between genes and the environment or between phenotype and the environment might have epigenetic conceptions.

Studies done on the newly published French biology textbooks after changing the French curriculum in 2007 (Castéra, Bruguière & Clément, 2008), have found that environmental influences on genetic diseases are addressed and associated to polygenic models. However, the Lebanese curriculum has not been renewed since 1997 and the national biology textbooks published in 1999 and 2000 have not been renewed yet. According to Castéra et al. (2008), the Lebanese curriculum presents only the genetic factors of hereditary diseases without mentioning any environmental influence. In fact, the results of Castéra et al.'s (2008) study further indicated that the three Lebanese biology textbooks published in 1999 and 2000, including the textbook for grade 11S, show implicit evidence of hereditarianism conceptions. The frequent occurrence of the term "genetic program" and the lack of consideration of the interaction among genotype, phenotype and the environment indicated the time delay with respect to French texts (DTD). However, ideas about epigenetics (Morange, 2005) were introduced after the implementation of the Lebanese curriculum in 1998. According to Castéra et al. (2008), this might lead to many misconceptions in genetics among Lebanese students.

2.4.1.3. Teachers' conceptions of genetic determinism.

Studies related to teachers' conceptions about genetic determinism of phenotype were conducted in Lebanon (Abu Tayeh 2003; Abu Tayeh & Clément, 1999; Castéra, Munoz & Clément, 2007), in Tunisia (Kochkar 2007; Kochkar et al. 2002) and in other countries (Clément, Quessada & Castéra, 2012). These studies highlighted a strong persistence of the ideology of hereditarianism (one gene determines one phenotype) among practicing teachers and prospective teachers in Lebanon and Tunisia. Recently, a European project Biohead-Citizen (Biology, Health and Environmental Education for better Citizenship, FP6 (2004-2008) addressed teachers' conceptions on the one hand and recognizable conceptions in textbooks on the other related to six topics including "human genetics". It included 19 countries: Portugal, France, Germany, Italy, England and Finland, Cyprus, Estonia, Hungary, Lithuania, Malta, Poland, Romania, Tunisia, Algeria, Morocco, Mozambique, Senegal and Lebanon. The theoretical framework of the project was the *KVP model* proposed by Clément (2004, 2006) and one of its aims was to analyze teachers' conceptions related to genetic determinism utilizing a questionnaire (Castéra, 2010; Castéra & Clément, 2008, 2009a, 2009b, 2010). The findings of this project indicated the presence of different trends of conceptions according to country.

Within the context of the Bio-Head project, conceptions of primary and secondary teachers on biological determinism of human personality were studied by Castéra, Munoz and Clément (2007). This study analyzed interactions between knowledge and values, and interactions that are linked with personal information of the teachers such as gender, age, occupation, field training, qualifications, and political and religious opinions. In Lebanon, several studies have analyzed the last ten years, science teachers' conceptions, especially in the context of the European project Biohead-Citizen (El Khatib, 2008). The studies showed differences in teachers' conceptions on vivid topics, including genetic determinism; they showed differences due to the type of school (public / private), the teaching language (French /English/ Arabic), teaching experience, and differences according to Lebanese regions (Khalil,

El Hage & Clément 2007; Khalil, Munoz, Clément 2007a, 2007b). The researches further showed that the conceptions of teachers related to the genetic determinism of behavior influence the choice of resources used in teaching genetics' concepts depending on their scientific knowledge (K), their beliefs and their values (V) (Castéra & Clément, 2009b, 2012).

Based on the previous literature review and on my own professional experiences, it is evident that the teaching of evolving scientific concepts like epigenetics and genetic determinism of phenotype is difficult. Teaching such concepts necessitates the use of resources other than the textbook (e.g., university books, digital resources such as Internet resources) and changes in teaching practices to integrate the new available digital resources that might enhance the teaching/learning process. According to Flick and Bell (2000), appropriate educational technologies have the potential to make scientific concepts more accessible through visualization, modeling, and multiple representations. Suitable uses of technology might enhance the teaching and learning of difficult science concepts. However, this requires teachers to understand how to use technology and how to properly integrate digital resources in their teaching practices. The following section presents a review of the literature on the importance and the effect of the use of information and communication technologies (ICT) in education.

2.4.2. Integration of information and communication technologies (ICT) in education.

Information and communication technologies (ICTs) are a diverse set of technological tools and resources used for creating, storing, managing and communicating information. For educational purposes, ICTs can be used to support teaching and learning. In the *documentational approach* of didactics, ICTs are considered part of a wider range of available teaching resources. This approach aims at studying the interactions between teachers and ICT through teachers' documentary work including looking for resources, selecting and designing tasks, planning the

sequence of implementation, carrying them out in class and managing the *available resources*. This documentary work is considered at the core of teachers' professional activities (Gueudet & Trouche, 2009). This research studies the effect of integration of ICT and digital resources on teachers' documentary work and conceptions related to genetic determinism of phenotype.

This section presents the effect of integrating ICT in education (§ 2.4.2.1), the obstacles and factors that might influence and hinder the integration of ICT in teaching practices (§ 2.4.2.2) and the status of the integration of ICT in the Lebanese curriculum in general and in biology in specific (§ 2.4.2.3).

2.4.2.1. The effect of integrating ICT in education.

According to Vajargah, Jahani and Azadmanesh (2010), ICTs can enhance the quality of education in several ways: by increasing learners' motivation and engagement, by facilitating the acquisition of basic skills and by enhancing teacher's training. Haddad and Draxler (2002) identified at least five levels of technology use in education: presentation, demonstration, drill and practice, interaction, and collaboration. Each of the different ICTs including audio/video cassettes, radio and TV broadcasts, computers or the Internet, may be used for presentation and demonstration, the most basic of the five levels. With the exception of video technologies, drill and practice may also be achieved using the whole range of technologies. On the other hand, networked computers and the Internet enable interactive and collaborative learning best. However, their full potential as educational tools will remain unrealized if they are used merely for presentation or demonstration. By using ICTs, teachers can manipulate, reshape and store their resources (instrumentalization). At the same time interactions with ICT, particularly Internet resources might influence teachers' scientific knowledge (K), values (V) and teaching practices (P).

According to Bell (2001), technology in science education might promote inquiry learning, exploration and conceptual learning and makes scientific views

more accessible to students. Thus, ICT can be implemented by science teachers for the purpose of student-centered learning which in turn might affect science teachers' practices (instrumentation). Tools science educators are currently using include: digital microscopes; simulation software; websites with simulators and data collections; spreadsheets; graphing calculators; presentation software. These tools have greatly enriched the system of resources of teachers and allowed them to appropriate their set of resources to elaborate new documents based on their professional knowledge.

Several researches have proved that animation-based activities, interactive computerized learning environments, and inquiry-based learning in genetics are highly successful in promoting conceptual understanding of many aspects of the genetic, meiotic and molecular models of genetics (Buckley et al., 2004; Cartier & Stewart, 2000; Gelbart & Yarden, 2006; Rotbain, Marbach-Ad & Stavy, 2006). According to these studies, when teachers merged student-centered activities taken from digital resources into their lessons, students were more able to understand abstract, difficult-to-grasp concepts and had more positive attitudes. Moreover, using computer simulations in science teaching allows the exploration of phenomena that are too difficult or dangerous to investigate experimentally, things too small or too large to be seen and things that happen too fast or too slow for direct observation (Webb, 2008). There is evidence that focusing on specific areas of difficulty and addressing them with carefully designed tasks using IT-based simulations can lead to productive learning (Webb, 2005, 2008).

In one case study, a biology teacher used an animation that illustrated the transcription and translation process in Real Time player in order to help students visualize the stages of protein synthesis. The process was successful and enabled students to comprehend the whole process (Goldenberg, 2011). Moreover, the introduction of basic concepts of molecular biology to students is a challenging problem. Molecular biology concepts such as protein and DNA are often blended with basic chemistry, 3-dimensional geometry, and biological relevance. Because of

the underlying complexity of these concepts, it is vital to go beyond the text and pictures that can be found in a textbook. According to Pontelli et al. (2009), teachers can benefit from certain available online resources like specific websites providing some computational tools that enable viewing and investigating molecular biological entities for teaching genetic concepts at the molecular level. Similarly, Shihab (2000) claimed that integrating hypermedia in biology lessons has a positive effect on students' science achievement. Thus, the proper integration of digital resources in teaching practices related to genetics concepts might help avoid student misconceptions and lead to conceptual change.

When inherently difficult concepts are to be presented to students, the pedagogical task of the teacher is to select appropriate teaching strategies and representations of content to address these topics. The past fifty years have witnessed exceptional advances in information technologies which have important implications for teaching science at the pre-college level (Abd-El-Khalick, 2005). This new pedagogical paradigm and this recurring and dynamic relationship between technology and pedagogy are challenging teachers to transform their practice (Hoge, 2010). Thus, ICT integration might affect teachers' practices (instrumentation) by providing them with a set of *available resources* that they can mobilize during their preparation/teaching practices. Computers serve the purpose of renewing teaching practices by managing technical computations, thus potentially promoting more conceptual understanding. In this context, the new role of the teacher is to organize and encourage interaction with the computer environment (Guin & Trouche, 1999). According to Christmann, Badgett and Lucking (1997), the impact of using IT on achievement in science may be greater than that on other subjects. IT-based resources can enable students to construct and explore their ideas and hence increase pedagogical opportunities within a constructivist framework. In student-centered pedagogy, teachers see science taught in a manner consistent with the way scientists do their work – that is, students ask scientific questions, devise methods for answering the questions, collect and organize data, reach conclusions based on that

data and share their conclusions with their peers. Furthermore, by discussing the details of the data and the various approaches to analyzing the data, students have opportunities to consider the tentative nature of scientific knowledge (Flick & Bell, 2000). These pedagogical approaches can be enhanced by integrating digital resources in teaching practices.

Moreover, interactive whiteboards (IWBs) or mobile devices wirelessly linked to a data projector can support various types of classroom interactions between students, computers and teachers (Webb, 2008). A review of the literature (Smith et al., 2005) reveals that teachers and pupils are overwhelmingly positive about the impact and potential of IWBs. Science teachers identified the main additional advantages of display technologies as the ability to display educational software, or web pages, or store their board notes and diagrams and revisit them later in the same lesson or in a subsequent lesson (Hennessy et al., 2007). The effectiveness of ICTs could be maximized, and their potentials realized by integrating such technologies into teaching practices that are consistent with constructivist pedagogy, in which students are actively engaged in their own learning. IT is mostly used to foster an environment in which students explore phenomena and concepts, generate and test ideas by hypothesizing and collecting data to adjudicate between alternative explanations, and come to build their own understanding while developing essential skills. Under this pedagogical approach, teachers transfer their role as “providers of knowledge” and assume the role of “facilitators of learning”. Teachers structure the learning environment and guide students in their efforts to learn (Abd-El-Khalick, 2005).

Sabra and Trouche (2011) argue that digitalization has influenced teaching due to proliferation of Internet resources and the diverse types of technologies that can be used by teachers (e.g., USB, IWBs and software). These modifications affect both preparation and teaching practices (instrumentation). The International Society for Technology in Education (ISTE) asserts that the Internet plays at least four important and useful roles in schools. First, the Internet provides students and

teachers with access to information that is otherwise difficult to acquire. Second, the Internet can be used as a means to communicate/collaborate with others through email, conduct collaborative projects and participate in discussion groups among many other means of communication. Third, the Internet can be used to create student and teacher websites and develop systems of digital learning objects that can play a useful role in constructivist teaching and learning. Fourth, the Internet provides opportunities for students to partake in information technology (IT) assisted project-based learning. This involvement provides students with opportunities to conduct research, use higher order thinking skills, increase their knowledge of using information technology and subject matter, and, more importantly, to become members of a community of scholars who communicate and solve problems collaboratively. Thus, the Internet is an important *available resource* that teachers can use in their practices.

Studies on the integration of new technologies in the classroom have highlighted the need for holistic research approaches suitable for capturing the wholeness of teachers' practices (Monaghan, 2004). The *documentational approach* (Gueudet & Trouche, 2009) aims at shedding light on the consequences of generalized availability of digital resources on teachers' professional activities. The attention is focused on teachers' selection, adaptation and transformation of resources. This approach considers teachers' work outside as well as inside the classroom. Accordingly, three environmental factors might influence teachers' work: institutional conditions and constraints, the use of ICT and involvement in collective work. The cases studied in the research of Sabra (2009) show that: ICT plays an important role in developing students' activities, illustrating concepts and motivating students; the Internet allow teachers to have access to lot of available online resources; and ICT easily allows the recycling, storage and exchange of resources. However, although pedagogical innovations such as IT integration could enable significant improvements in science teaching, they present a considerable challenge for teachers, teacher educators and curriculum developers. Teachers have always

developed their own resources to some extent, but now technology is enabling them to produce a wider range of types of material and to share them more easily (instrumentalization). A model for many curriculum development projects has been to bring together innovative teachers, researchers, designers and developers to explore new approaches to learning and developing materials (Webb, 2008).

Thus, as presented in the literature, ICT integration has a great influence on science education, enriching the teachers' system of resources and causing a change in their teaching practices. However the proper integration of digital resources in the educational process is complicated and many obstacles are encountered as illustrated in the following section.

2.4.2.2. Factors influencing the integration of ICT in education.

The experience of introducing different ICTs in educational settings all over the world over the past several decades suggests that the full realization of the potential educational benefits of ICTs is not automatic. The effective integration of ICTs in classrooms is a complex, multifaceted process that involves not just technology but also curriculum and pedagogy, institutional readiness, and teachers' competencies (Haddad & Draxler, 2002).

IT-assisted instruction needs to meet certain conditions. First, instructional interventions using IT should have clear and specific objectives and should be carefully and thoughtfully planned. Second, science teachers themselves should be comfortable with the technology and pedagogy in use and integrally involved in all stages of developing and implementing the IT-enhanced approaches. Indeed, technologies are as effective as the individual teachers who use them. Teachers should be trained to master technology in order to be able to use it efficiently with their students, they should develop positive attitude towards technology (Abd-El-Khalick, 2005). For example, software programs should contain the actual curriculum otherwise they will be merely supportive software programs rather than fully integrated in the actual lessons. Teachers should be encouraged to design software or

at least participate in designing software that fully integrates their lessons with computer technologies (Shihab, 2000).

According to Sabra (2009), ICTs are important resources for teachers, but they add complexity to their professional work. The inclusion of technology in education is thus an important factor in the development of professional skills. Furthermore, previous research has highlighted the slow and complex process of technology integration due to the complexity of teachers' work in technological environments (Guin, Ruthven & Trouche, 2005; Sabra, 2011) which is influenced by many factors (Ertmer et al., 2001; Levin & Wadmany, 2008; Valcke et al., 2007). Among these factors is availability and ease of access to computers and ICT resources (Hohlfeld et al., 2008; Inan & Lowther, 2010; NCES, 2000; Norris et al., 2003) Moreover, teachers who feel ready and confident to integrate technology use it more frequently in their classroom instruction (Kanaya, Light & Culp, 2005; NCES, 2000; Scheffler & Logan, 1999). Teachers' computer and software knowledge also helps them figure out the affordance of the technology and how particular software might be beneficial to student learning (Angeli & Valanides, 2009; Newhouse & Rennie, 2001; Snoeyink & Ertmer, 2002).

According to Busch (1995) and Whitely (1997), gender is also an important factor in the use of technology in which men have been found to be more competent than women in technology especially in the use of computers. Another factor influencing technology integration includes years of teaching experience. For instance, a couple of studies have indicated that recent graduates from teacher preparation programs are more technology competent and more prepared to integrate technology into classroom instruction (Jones & Madden, 2002; Mims et al., 2006; O'Dwyer, Russell & Bebel, 2004). Inan and Lowther (2010) further argued greater years of teaching negatively affects computer proficiency which in turn positively affects the integration of technology.

Osta (2005) identified many types of obstacles hindering ICT integration in education in developing countries (including Lebanon): obstacles related to policy-making, financial and managerial obstacles, obstacles related to human resources, obstacles related to curricula, and obstacles related to culture and language. The study also specified many obstacles that prevent teachers from utilizing ICT efficiently, like difficulty to reach technological tools, lack of time, and deficiency in the skills of utilizing the computer and the Internet. According to Perrault (2007), although the Internet has the potential to offer the multimodal resources they seek, teachers may not adequately access the information because they lack the necessary online search skills to efficiently find, and effectively use, online resources ranging from digital libraries to electronic discussion lists. Many teachers are convinced that the Internet can help with instructional planning and the creation of learning activities for their students (Hedtke, Kahlert & Schwier, 2001; NetDay, 2004, 2006; Recker, 2006). However, while the Internet provides new resources, the question is whether and how teachers are able to make use of these Internet resources in their instructional planning.

The Office of Technology Assessment in the U.S. Congress (1995) indicated that time is the greatest barrier to teacher's implementation and integration of instructional technology. According to studies, teachers describe their experiences with using the Internet as time consuming. They also express frustration with the quality of results and are sometimes overwhelmed when a search yields thousands of results (Hedtke, Kahlert & Schwier, 2001; Karchmer, 2001; Recker, Dorward & Nelson, 2004). According to Recker et al. (2004), the time barrier is due to the many demands on a teacher during the course of a school day, with little or no time allotted to explore instructional technology and to collaborate with other teachers about applications of this technology and integration of the technology into their teaching strategies and techniques.

Thus, Webb (2008) claims that in order for IT to fulfill its potential to enhance science education four areas need to be addressed. First, the process of

reviewing and redesigning the science curriculum for the twenty-first century needs to continue and to take full account of new technology. Second, science resource developers and educators need to be aware of the benefits of IT use and incorporate it as an important aspect of any curricular or pedagogical innovation. Third, research needs to focus on developing pedagogy in science education incorporating IT together with other pedagogical innovations. Most importantly, teachers need to be supported to explore and evaluate new uses of IT so that they can contribute to curriculum and resource development. Therefore, the decision to integrate IT into teaching is only a first step in a more engaged process of re-examining curricular goals and pedagogical approaches. Such re-examination entails several necessary aspects for the professional development of science teachers which should be catered for throughout the implementation process (Abd-El-Khalick, 2005). Teachers need to accept the fact that they cannot provide all information to their students and that their roles need to change from sources of information to facilitators of knowledge acquisition by students (BouJaoude, 2003).

2.4.2.3. ICT integration in the Lebanese curriculum.

From 1995, general reforms started on the Lebanese curriculum. One such reformation was the introduction of ICT as a separate subject under the name of “informatics”. Nonetheless, the use of ICT in education is not mentioned in the goals, objectives or activities of the reformed Lebanese curriculum implemented in 1998. Only one of the general aims of the Lebanese curriculum mentioned that we should raise a citizen that recognizes the importance of technology and can use it, improve it and interact with it in a responsible and skillful way. However, the use of these technologies in other subjects was not specifically clarified (Mounsef, 2005).

2.5. Research Questions

Given the importance of integrating technological resources in science teaching and the difficulty of teaching genetics concepts (discussed earlier), it is essential for Lebanese teachers to integrate technology in their teaching practices.

Although this is not directly required by the Lebanese curriculum, the use of technological resources is not only important for promoting student understanding but also for updating teachers' scientific knowledge so that it is aligned with modern scientific paradigms.

In the context of this study, the new scientific paradigm in question is that of epigenetics. As evident from the previous discussion, school textbooks and teachers still maintain hereditarianism views of genetics in which the influence of the environment on genotype and consequently phenotype is not considered. In order to teach epigenetics, it should be first introduced in the school curricula and textbooks and more importantly teachers' conceptions should evolve from hereditarianism towards epigenetics. One way to do so is through teachers' interaction with and integration of digital resources. Thus, the main purpose of this study was to investigate whether or not secondary Lebanese biology teachers were using digital resources in their teaching practices and the factors that influenced such an integration, or lack thereof. The second major purpose of this study was to determine whether or not teachers' interactions with digital resources during their documentary work lead to the evolution of their conceptions toward epigenetic views.

Based on the articulation between the *KVP model* and the *documentational approach* described earlier (§ 2.3) and in order to attain the research purpose, the researcher analyzed the interactions between the KVP of teachers and resources, the instrumentation and instrumentalization processes. Moreover, in order to determine teachers' professional development, the evolution of their documentary work and conceptions related to genetic determinism of phenotype due to interactions with resources, particularly digital resources, was studied.

Thus, in light of previous research presented in the literature review and based on the two theoretical frameworks, this study addressed the following questions of research:

- 1- Do secondary Lebanese biology teachers utilize digital resources in their preparation/teaching practices in general? What are the particular digital resources related to the teaching of genetics concepts?
- 2- What are the factors that influence teachers' integration of digital resources in teaching practices in general and in teaching genetics concepts in specific?
- 3- Do teachers' conceptions of genetic determinism of phenotype affect their choice and integration of resources and consequently their system of resources and documentary work?
- 4- Do teachers' interactions with resources, particularly digital resources, lead to the evolution of their documentary work and conceptions related to genetic determinism of phenotype, consequently leading to their professional development?

CHAPTER III

METHODOLOGY

This chapter presents a detailed description of the methodology including the research design (§ 3.1), the setting and participants (§ 3.2), the construction of the methodology (§ 3.3) and the different data collection tools and the procedure of their implementation (§ 3.4). Then, this chapter presents the specific methods used for analysis of all the data (§ 3.5) which is followed by a discussion of the methods implemented for validity and reliability purposes (§ 3.6).

3.1. Research Design

This study applied a sequential mixed-method approach in which a quantitative design was followed by qualitative design. The quantitative part constituted of a questionnaire (section §3.3.1) administered to Lebanese biology secondary teachers in order to investigate the current status of integration of digital resources in their preparation/teaching practices. Based on the analysis of the data collected from the questionnaire, the participants for the qualitative part were selected.

The design of the qualitative part of this research was that of a collective case study following the purposive sampling technique. The case study approach was designed for in-depth investigation of teachers' documentary work, teachers' appropriation and transformation of resources with special interest in digital resources, and the consequences of teachers' interactions with resources on their conceptions related to genetic determinism of phenotype.

The methodology was designed *a priori* based on the research questions and the theoretical frameworks. Moreover, the methodology followed was flexible as it was performed under the realistic conditions in the experimental field. According to this perspective, the methodological tools were elaborated and adapted according to the needs and conditions of the work of the teachers involved. Thus, during

implementation of this study, the structure of the methodology was constantly reorganized whereby the researcher strived to develop methodological tools that adequately answer the research questions addressed.

3.2. Setting and Participants

This part presents a description of the setting and the selection of participants used in this research. Selecting the participants consisted of four major steps: 1) selection of a large population of secondary biology Lebanese teachers based on a questionnaire in order to study the current status of integration of digital resources; 2) selection of eight teachers to be interviewed in order to distinguish relevant profiles as illustrated below; 3) application of the *reflective investigation* methodology (see § 3.3.1) during the first year on four teachers; and 4) selection of two “prototypical” teachers during the second year of the study for deeper case analysis.

At the beginning of the research, a questionnaire in the context of DOCENS project- a collaborative project between France (IFE-ENS de Lyon) and Lebanon (Lebanese University) (see §3.4.1) - was administered to Lebanese secondary biology teachers in June 2011 during the annual meeting for the discussion of the answer key of the national exams for grade 12 Life Science (LS) section. The questionnaire was administered during that occasion because it provided a convenient opportunity for a large number of secondary biology Lebanese teachers from different regions and backgrounds to be gathered in one place. A total of 250 teachers attended the meeting. The researcher distributed 200 questionnaire papers randomly at the doors to most of the attending teachers; 116 of the secondary biology teachers directly completed the questionnaire. Quantitative analysis of the teacher responses allowed for the study of the current status of integration of digital resources (see Chapter IV). Then, using descriptive statistics of the questionnaire data (§4.1.1) teachers were purposefully selected to participate in the qualitative part of the study. Teachers were chosen based on the following characteristics:

1. Grade 11 Scientific teachers since genetic is taught at this level particularly the genetic determinism of phenotype;
2. Teachers from Beirut and Mount Lebanon for the feasibility of the study since these areas are near the researcher's residence;
3. More than ten years of teaching experience. This was based on the assumption that teachers with more experience will have a more developed system of resources compared to new teachers, particularly those related to genetics and genetic determinism of phenotype;
4. Teach in schools where technological tools are available and accessible in order for the selected teachers to be able to search for and implement digital resources;
5. Teach in public and private schools, with English and French as languages of instruction, in order for the sample to be representative of the Lebanese context;
6. Have adequate technology skills (use Internet, computers at home and at school). This was considered an important factor for the integration of technology in preparation/teaching practices.
7. Finally, teachers using digital resources in their preparation and teaching practices in general and in teaching the genetic concepts and genetic determinism of phenotype. This criterion is in line with the overall purpose of the present research which is to study the consequences of digital resources on teachers' documentary work and conceptions related to genetic determinism.

Eight teachers satisfying the above mentioned criteria were contacted and interviewed during the period between September and December 2011. However, only four teachers were followed during the first year of the study (from December till June 2011-2012), since one of the eight teachers was not going to be teaching grade 11S anymore, another teacher refused to participate in the research, and two teachers did not elaborate the use of digital resources for teaching genetic concepts.

The four participating teachers were: Tania and Fadi from the same private school in Mount Lebanon. Fadi teaches the English sections and Tania teaches the French sections; Maya who teaches in a public secondary school in a village in Mount Lebanon; and Marwa who teaches in another public secondary school in Beirut. All the names are pseudonyms. Table 1 presents a comparison between the profiles of the four selected cases.

The private school in which Tania and Fadi teach contains classes from KG-12 and is well-equipped with technological tools that are easily accessible. Collective work and coordination are efficient in the school with the freedom to choose and use any textbook in addition to other resources available (books, software and animations). On the other hand, the public secondary schools where Maya and Marwa teach are equipped with technological tools but they are not easily accessible for teachers; they have to be reserved beforehand. The school contains a technology room with an interactive white board (IWB) and a computer room with an LCD. In the two public secondary schools, teachers abide by the Lebanese curriculum and utilize the national textbooks. In addition, there is no efficient coordination in these schools and no additional resources are provided for the teachers. Table 2 presents a comparison between teacher's working environment and professional activities.

During the first year of research, the study focused on the preparation and implementation of a lesson about gene expression and its relation to phenotype utilizing specific data tools (see §3.4). During the second year (from December till September, 2012-2013) in which a deeper analysis was done only two teachers (Tania and Maya) were followed. Fadi refused to continue and it was difficult for the researcher to monitor Marwa due to the school's difficult location in Beirut.

Table 1
Profile Comparison of the Four Participating Teachers

Profile	Maya	Marwa	Fadi	Tania
Teaching experience (till 2011)	16 years	25 years	19 years	10 years
Teaching language	English	English	English	French
Type of school	Public	Public	Private	Private
University degree	MS in Biology, CAPES ¹ , M2 Research in education, she is preparing a proposal for the Doctoral School (didactics of biology)	BS Biology and CAPES	BS in biology and Teaching Diploma (TD)	MS in Biology, Lebanese University. Master's Degree from USJ (Saint Joseph University) in Environmental Education. Currently a doctoral student in the field of education in USJ.

¹ Certificat d'Aptitude Pédagogique à l'Enseignement Secondaire (CAPES); English translation: Certificate of Qualification in Education for Secondary School Teaching.

Table 2
Comparison between the Professional Activities and the Working Environment of the Four Participating Teachers

Working environment and professional activity	Maya	Marwa	Tania	Fadi
Type of school	Public	Public	Private	Private
Equipment at school	LCD & IWB	LCD & IWB	LCDs available for classes	LCDs available for classes
Collective work in school	Rare (no coordination)	Rare (no coordination)	Regularly with the coordinator and other biology teachers.	Sometimes with the coordinator
Exchange of resources in school	Sometimes	Rare	Exchange of resources with other biology teachers and coordinator	Sometimes exchange of resources with coordinator
Professional activities in /outside school	None	Coordinator for intermediate classes. University assistant for medical students.	Coordinator for elementary classes. Responsible for environment club in school. Member in various environmental Committees. Science teacher trainer.	Coordinator for science projects and responsible for science club. Teacher trainer outside Lebanon.

Figure 10 shows a schema summarizing the selections of participants in this research.

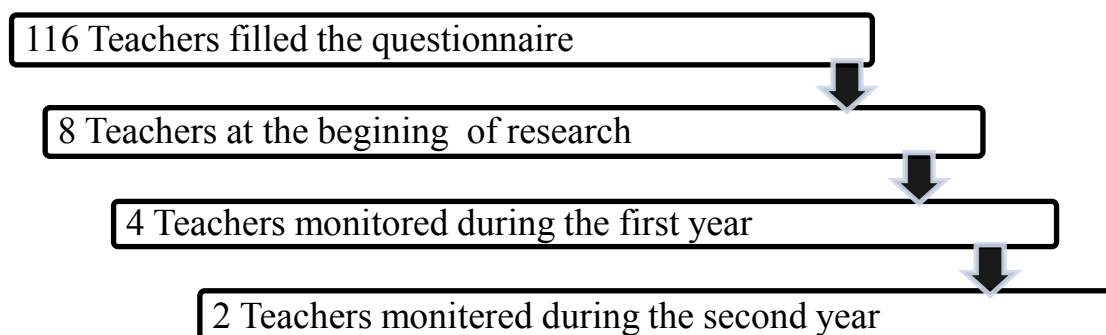


Figure 10. Summary of procedure for selection of participants.

3.3. Construction of a Methodology Based on the “*Documentational approach*” and the “*KVP Model*”

This section presents the construction of the methodology for this research. First, the methodological principles for the qualitative part of the study based on the two theoretical frameworks - the *documentational approach* to analyze teachers’ interaction with resources, particularly digital resources, and the *KVP model* to analyze teachers’ conceptions - are presented in (§3.3.1). Then, the grid elaborated for the analysis of teacher conceptions and its application to *critical resources* and the output of *critical situations* (defined in section § 2.3) is presented in (§ 3.3.2).

3.3.1. Methodological principles.

The methodological principles used in this study were inspired by the *reflective investigation* methodology elaborated for the *documentational approach* by Gueudet and Trouche (2008b) and from methods implemented in researches that apply the *KVP model* elaborated by Clément (2006). The documentary work of the four secondary biology Lebanese teachers was monitored during the preparation and explanation of genetic determinism of phenotype in grade 11S in order to investigate the evolution, if any, of teachers’ conceptions due to their interactions with digital resources. For this purpose, the following principles were used to guide the study:

- The principle of *long-term monitoring* to capture elements of stability and development in teachers' documentary work and conceptions. Two cases were monitored for two consecutive years, a relatively long enough period to identify elements of stability and any seeds of evolution of teachers' documentary work and conceptions about the genetic determinism of phenotype. Teachers' conceptions were analysed as interactions between knowledge (K), values (V) and practices (P).
- The principle of *in and out of class follow-up*. The classroom is an important place where the teaching process is implemented; it allowed the researcher to analyze how the resources were implemented and adapted in class and to observe the interaction between teachers and resources - particularly digital resources - in the classroom. These interactions reflected teachers' conceptions based on the *KVP model*. Teachers' work outside the classroom (at school, at home, in teachers training programs...) are also of great importance in order to investigate the resources utilized in their documentary work and to identify the critical *mobilized resources* that might reflect teachers' conceptions about genetic determinism.
- The principle of *collection and analysis* of the critical material resources mobilized elaborated and implemented by teachers throughout the follow-up period. Analysis of KVP of *critical resources* also allowed the inference of teachers' conceptions about genetic determinism.
- The principle of *reflective follow-up* of the documentary work. Teachers were involved in the collection of their own data since only they have access to their activities in all the relevant places and times. Teachers reflected on their own practice to enhance the structure of their activity. The reflection of the teachers on their own work and that of the researcher were complementary and enriched each other. Moreover, the teacher reflection on their own resources allowed the identification of the *critical resources* used which in turn allowed the inference of teachers' conceptions.

3.3.2. Grid for analysis of teachers' conceptions.

The following section presents the grid elaborated for the analysis of teachers' conceptions related to genetic determinism. These conceptions were based on *critical resources*, output of *critical situations* and the data collected from different tools to identify *critical resources* and situations (see section § 3.4). *Critical situations* include explanation, illustrations and answering questions in interviews and the classroom.

Several studies have proposed three models for the categorization of teachers' conceptions on genetic determinism (Agorram et al., 2010; Castéra & Clément 2009a, 2012; Forissier & Clément, 2003; Kochkar, 2007). In this study, the researcher adapted these models in order to categorize teachers' conceptions utilizing the data collected from the output of *critical situations* in addition to the *critical resources* mobilized, elaborated and implemented in class. The three models are the linear or causal model, the additive model and the interactive model. In the linear or causal model, the gene is considered a part of the chromosome, a fragment of DNA or a sequence of nucleotides. In this model, there is no mention of other epigenetic or environmental factors that might influence gene expression. According to this model, phenotype is only based on genotype without any interaction with the environment. This indicates a hereditarianism conception (H): Genotype → Phenotype.

As for the additive model, the influence of both the environment and the genotype is mentioned; however, there is no interaction between the two to determine phenotype. This was evident, for instance, when teachers mentioned percentages of influence of each of genotype and the environment. This indicates an additive conception (A): Genotype + Environment → Phenotype.

Finally, in the interactive model, the genotype is viewed to interact with the environment to determine phenotype. Here the gene is considered a hypothetical construct with a diverse material base consisting of DNA segments that take part in a developmental process. Moreover, there is an emphasis of epigenetic and

environmental factors that might influence the expression of the gene. This indicates an epigenetic conception (E): Genotype \leftrightarrow Environment \rightarrow Phenotype.

Table 3 presents the specific grid of analysis elaborated for this research to categorize teachers' conceptions as either (H), (A) or (E).

Table 3
Grid for Analysis of Teachers' Conceptions as Hereditarianism (H), Additive (A) or Epigenetics (E)

Criteria	<i>Critical resources</i> (mobilized, elaborated, implemented) and output of <i>critical situations</i>
Language utilized in resources or used by teachers	<p>Verbs: “causes”, “implies”, “gives rise to”, “controls and determines” (H); “interacts”, “regulates” (E); “adds” (A)</p> <p>Terms and specific prepositions: “genetic information” (E); “genetic language”, “genetic program” (H); “genetic information/language and environment” (A).</p> <p>Sentences: “our genes responsible for our characters” (H); “gene and/also environment are responsible for our characters” (A); “genes interact with environment to determine our phenotype” (E)</p>
Diagrams (schemas, figures) utilized in resources or drawn by teachers	<p>Diagrams: Gene \rightarrow Phenotype (H); Genotype +Environment \rightarrow Phenotype (A); Genotype \leftrightarrow Environment \rightarrow Phenotype (E)</p>
Pictures found in resources or used by teachers	<p>Identical twins having exactly the same features (H); Himalayan rabbits (E)</p>

Teachers' conceptions were inferred based on the analysis of their documentary work using the data collected from the output of *critical situations*: the schematic diagrams drawn by the teachers and their answers to specific questions related to gene and the relation between genotype and phenotype; the presentation of genetic diseases; the verbal discourse of the teacher in interviews or in the classroom while explaining, illustrating using examples or answering student questions related to specific issues about the relationship between genotype and phenotype.

3.4. Data Collection Tools and Procedures

This part presents the different data collection tools used in the research and the procedure followed for their implementation. Data was collected using several complementary instruments based on specific methodological principles for triangulation of sources. The tools used included: a questionnaire (§3.4.1), interviews (§3.4.2), schematic representations of the system of resources (SRSR; §3.4.3), logbooks (§3.4.4) and classroom observations (§3.4.5). Data collected from these tools was used to analyze teachers' documentary work in order to identify *critical resources* and situations which were in turn analyzed based on the elaborated grid (§3.3.2) to infer teachers' conceptions related to genetic determinism of phenotype.

3.4.1. The questionnaire.

A quantitative questionnaire was constructed in the context of DOCENS project (Documentation des Enseignants des Sciences) funded by the Franco-Lebanese program CEDRE (Coopération pour l'Évaluation et le Développement de la Recherche). Three doctorate students in didactics of biology, physics and mathematics with their French and Lebanese thesis directors participated in the project. The project targeted the professional development of science teachers with the ultimate goal of developing a platform to design and share resources among science teachers. The questionnaire was elaborated by the researcher in collaboration with other two doctorate students. Then, content validity of the first version of the questionnaire was determined by six expert researchers in didactics of biology (one),

physics (two) and mathematics (three). Moreover, a pilot study was done on 16 secondary biology teachers different from those who participated in the actual research. In this research, the questionnaire aimed to study current status of utilization of resources, particularly digital resources, by secondary biology Lebanese teachers and to purposefully select participants for the qualitative part.

The final version of the questionnaire (Appendix I) comprised of 33 items that mainly focused on the criteria for integration of digital resources and technology in preparation and/or teaching in general and in teaching genetic concepts in specific. The questionnaire is divided into three parts; the first and the third part were common in the theses of the three different disciplines. The first part related to the working environment of the teacher: availability and use of computers and Internet at their schools and at home; the purposes of utilization of computers and Internet; resources and software utilized and the purpose of their utilization, technological tools available at their school and the purpose of their utilization. This part is made up of 22 close-ended questions. In most of these questions, teachers were provided with a list of response categories (or checklist) and were asked to check the response(s) that apply to them.

The second part of the questionnaire related to the preparation and teaching of the gene concept. It is made up of four questions three of which are open-ended. This part is designed to know the resources utilized in teaching genetics concepts and the purpose of their utilization as well as to infer the role played by digital resources. This part is specific to this research.

The third and last part of the questionnaire pertained to demographic and background information about teachers such as their teaching experience (grade levels taught, number of years of teaching, language of instruction), educational background (degrees/certificates and ICT training sessions), gender, contact information (phone number and e-mail address), type of school, name of the school

and its location and the telephone number of the school. The questions in this part are mainly close-ended with a checklist provided for the participants.

3.4.2. Interviews.

Several unstructured and semi-structured interviews were performed at different intervals of time throughout the period of the qualitative part of the research. These interviews applied the principle of monitoring teachers' documentary work outside school. All the interviews were conducted face-to-face - i.e. in-person interviews – and followed the interview guide approach where the interviewer asked specific open-ended questions with the aim of exploring a specific topic.

During the first year of the research (2011-2012), three sets of interviews were conducted. The first set of interviews (§ 3.4.2.1) were conducted with the eight participants selected after the analysis of the questionnaire as illustrated in part (§ 3.2). After the analysis of the data collected from the first interview, four teachers were monitored during the first year of the research (two from a private school and two from a public school). A second set of interviews was conducted with the four participants at the beginning of the follow-up period before the classroom observation (§ 3.4.2.2) and then the third set of interviews was conducted with them at the end of the academic year (§ 3.4.2.3). After the preliminary analysis of the data collected from the first year, only two teachers were followed for the second year: Maya and Tania.

During the second year (2012-2013), the guidelines for the interviews were elaborated based on the preliminary analysis of the data collected during the first year. These modified interviews aimed to collect more data to answer the research questions pertaining to teachers' evolution of their documentary work and conceptions related to genetic determinism of phenotype. During the second year, another set of three interviews were done. A fourth set of interviews with Maya and Tania were conducted at the beginning of the follow-up period of the second year before classroom observation (§ 3.4.2.4). At the end of the academic year, a fifth set

of interviews was conducted with the two participants (§ 3.4.2.5). In addition, a sixth interview was conducted with Maya (§ 3.4.2.6). Figure 11 shows a schema synthesizing the interviews conducted during the duration of the research.

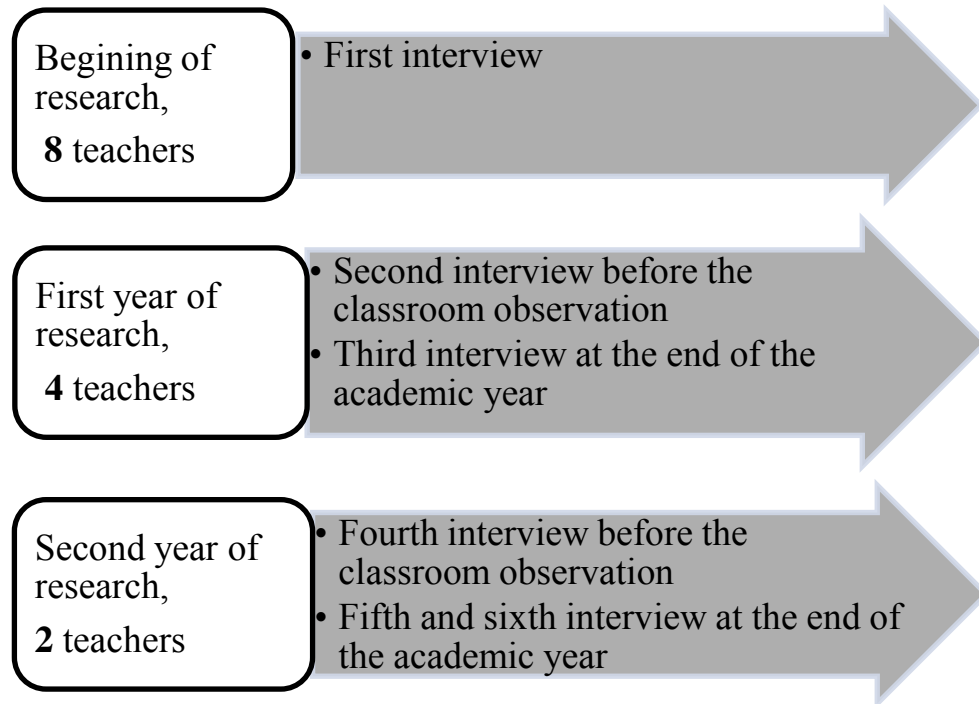


Figure 11. Schema for interviews conducted during the research

The following sections present the procedure and purpose of each set of the six interviews mentioned earlier. The first, second and third interviews were done during the first year of research (2011-2012) while the fourth, fifth and sixth interviews were done during the second year (2012-2013).

Interviews during the first year of research

3.4.2.1. First interview.

The first interviews were semi-structured and their duration varied from one hour to two hours. They were conducted in September 2011 with the eight teachers selected after the questionnaire analysis. They were qualitative interviews where the interviewer, the researcher, asked a series of open-ended, probing questions. At the

beginning of the interview, the teachers filled a short questionnaire about their personal and professional information and information about their working environment (see Appendix II). The general objectives of the first interview were:

- To validate the data of the questionnaire;
- To know the resources utilized by teachers and whether they are integrating digital resources in their teaching practices in general and specifically in teaching genetic concepts;
- To select the participants to be monitored during the first year of the study (2011-2012), after preliminary analysis of the data.

The interview consisted of 11 questions divided into two parts. The first part consisted of five items related to the general resources utilized by teachers during their preparation/teaching practices which included a general description of everything judged useful by the teachers for their documentary work. The second part consisted of six items related to the teaching of genetics and the resources implemented for that purpose. The most important resources were those related to the concept of a gene and their history (with at least one personal production) were discussed and collected. The interviews were conducted between September and December 2011 in the houses of the teachers in order to have a look at their working environment and to collect their resources. The specific interview questions and their objectives are illustrated in Appendix III.

3.4.2.2. Second interview.

Similar to the first interviews, the second interviews were semi-structured with probing questions. Their duration varied between 30-40 minutes (see Appendix IV). The interviews were conducted with the four participants at the beginning of the follow-up period of the first year between December and March 2011-2012. The general objectives of these interviews are:

- To explore the teachers' perspectives on their own teaching strategies.

- To identify and collect all the resources about genetics that they were willing to implement in the class sessions to be observed.
- To infer by crossing with other data the *critical resources* mobilized by the teachers to prepare their lesson about gene expression.
- To know from the teachers the purpose of integrating digital resources in teaching genetics concepts.

These interviews took place at the houses of the four participating teachers before the first classroom observation. This was done to minimize bias since it did not give the chance for the teachers to change their teaching strategies based on the discussion done during the interview. These interviews were composed of two parts. The first part of the interviews focused on the lesson to be observed, particularly its objectives, implementation procedure and resources to be included which were in turn collected to be analyzed. During the second part of these interviews, teachers were introduced to the logbook (§3.4.4) which they were to fill out during the follow-up period.

3.4.2.3. Third interview.

The third interviews were unstructured and lasted from 30-40 minutes. These interviews were conducted at the houses of the participants, after classroom observations of the sessions related to the explanation of genetics concepts. They were done at the end of the follow-up period of the first year between March and June 2012. The general objectives of this interview were:

- To discuss with the teachers the resources implemented in class.
- To know if the teachers were satisfied with the resources they implemented in class.
- To know the modifications that the teacher decided to do after implementing these *critical resources* in class and the reasons for their modifications.

During these interviews, the observed sessions were discussed with the teachers with a focus on what was planned and what was actually achieved in class. For this purpose, the data collected from the second interview, the grid filled during the classroom observations and the field notes taken by the researcher during the observations were all used. Moreover, the logbooks filled by the teachers were collected to be analyzed. A sample of these interviews is presented in Appendix V.

Interviews during the second year of research

3.4.2.4. Fourth interview.

The fourth interviews were semi-structured and lasted from 50 to 60 minutes. They were conducted before the classroom observations of the second year in December 2012. These interviews aimed at the following: to clarify some data collected during the academic year 2011-2012; to learn about the modifications related to the genetics concepts compared to the first year of research; to know from the teacher the new sequence to be followed in teaching genetics concepts according to the new modifications compared to the first year of research (case of Tania, see Appendix VI); to know from the teacher the scenario of implementing the resources during the academic year 2012-2013 and any modifications related to the *critical resources* elaborated and implemented during the first year (case of Maya, see Appendix VII); to know the type of interactive work done with other teachers related to the new modifications; and to learn about the organization of the system of resources by analyzing the schematic representation of the system of resources (SRSR) drawn by the teacher during this interview. Moreover, the new part added to the logbook (§ 3.4.4) was discussed and the teachers were asked to fill it out during the preparation/teaching of the genetics chapters. A comparison of the data collected from this interview, from the other tools and from the first year allowed the inference of the evolution in teachers' documentary work.

3.4.2.5. Fifth interview.

The fifth semi-structured interview was conducted at the end of the follow-up period during the second year in June, 2013 (case of Maya) and September 2013 (case of Tania). It mainly focused on scientific information about the gene, the relationship between genotype and phenotype and genetic diseases in addition to the digital resources utilized to explain them. The teachers were asked to draw a diagram that shows the relationship between genotype and phenotype and were asked to discuss how they present genetic diseases to the class and the resources they utilized to explain them (*critical situations*). Finally, the observed sessions and the changes in the digital resources implemented in class were discussed (see Appendix VIII). So the main objective was to collect data that might enable the categorization of teachers' conceptions as either hereditarianism (H) or epigenetics (E) and to infer any evolution in teachers' documentary work.

Furthermore, in the case of Tania, discussions were carried out on how she built her *archive* during her 11 years of teaching and the main resources she uses. This was done to infer the evolution of resources during building her *archive*. Then, the SRSR (§3.4.3) was discussed and she was asked to add any modifications related to her system resources compared to the first year. Finally, an exploration of the resources saved on her laptop was done in order to infer any evolution in her system of resources.

3.4.2.6. Sixth interview.

A sixth interview was conducted with Maya in October 2013 at her house. The discussion with Maya focused on the resources utilized to update her scientific knowledge related to the influence of the environment on the expression of genotype (see Appendix IX). She was asked to draw a new SRSR showing all the resources mobilized for her teaching practices, how they were organized and what the relationship between them was. A final exploration of the digital resources on her laptop and USB was done. She was also asked to show the researcher the extra notes

prepared, how they were saved and the resources used for their preparation. Finally, the activities written in the logbook were discussed with Maya. The data from this interview was compared with the all the data collected to infer any evolution in the documentary work and conceptions of Maya.

Interviews with the coordinator

Although the coordinator was not directly involved in this research, she plays an essential role in the private school of Tania and Fadi. Therefore, two interviews were also conducted with her, one at the end of the academic year 2011-2012 (at school) and another interview during the academic year 2012-2013 (at her house). The first interview was not previously prepared and aimed to infer the nature of the collective and collaborative work between biology teachers, the sequence followed in teaching genetics from grade six till grade 12 and to know the *critical resources* (textbooks, software, animations...) utilized in order to compare them with those used in public schools. On the other hand, the second interview aimed to learn about the modifications related to the genetics concepts to be implemented in the second year of follow-up (updated scientific knowledge or new topics introduced, resources, new methodologies, strategies...). Moreover, to enhance the validity of the data collected from the interviews with the two biology teachers in the same private school, the resources utilized, sequence and strategies followed and extent of collective work was compared (see Appendix X). Note that there were no general biology coordinators in the two public schools where Maya and Marwa were monitored.

3.4.3. Schematic representation of the system of resources (SRSR).

The schematic representation of the system of resources (SRSR) is a tool adopted by the *reflective investigation* methodology elaborated by Gueudet and Trouche (2010) in the “*documentational approach* of didactics”. The SRSR relies on teachers’ reflections of their own resources and documentary work by applying the principles of reflectivity and involving teachers in data collection. The SRSR

provides evidence of the linkages between resources and the activities of the teacher inside and outside the class and it also gives insight into the system of resources used by the teacher. The teachers were asked in the fourth interview at the beginning of the second year (2012-2013) to draw a schematic representation that describes the available, mobilized and *implemented resources* in their teaching practices and illustrates how those resources are organized and related. Time was given for the teachers to draw their representations and then they were asked to explain it and comment on it. Teachers were provided with a white A4 paper and colored pencils. Then, on the same drawing, the teachers were asked to specify the resources that they have utilized this year for preparation and teaching of the genetics concepts. Here teachers were provided with calc paper to be placed above the original drawing. During the final interview, teachers were given the opportunity to add or change their SRSR based on the resources actually utilized in their teaching practices during the second year of research. The general objectives behind drawing the SRSR were:

- To know how teachers present and organize the elements of their documentary work.
- To infer the components of the teachers' system of resources.
- To infer, after crossing with data from other tools, the *critical resources* utilized by the teachers in teaching genetics and particularly the genetic determinism of phenotype.
- To infer any evolution in teachers' system of resources based on the modifications inferred from the comparison of the SRSR of the first and second year of research and after crossing it with the data collected from other tools.

In other words, the SRSR was used as a tool for triangulation of the data collected pertaining to the documentary system of the teachers. The data collected from these schematic representations were then compared to what the teachers said about resources and their organization in the interviews, to the activities written in the logbook and the resources actually implemented in the classroom.

3.4.4. Logbook.

The logbook is another tool adopted from the *reflective investigation* methodology (Gueudet & Trouche, 2010). It was developed for the “*documentational approach* of didactics” in order to holistically track the documentary work of teachers inside and outside the class during the follow-up period. It applies the principle of following the teachers inside as well as outside school and the principle of reflective follow-up on the documentary work of teachers. The teachers were involved in data collection by reporting all their daily professional activities related to their preparation/teaching practices of genetics concepts in general and genetic determinism of phenotype in particular (in school, in the presence or absence of students, at home, in a library, during a training, at a conference...etc.). In the logbook, teachers were asked to specify for each activity: the time, place, actors, resources used, what was produced, what was *archived* and additional comments, if any (Appendix XI).

During the second year of research, a new part was added to the first version of the logbook adapted from Hammoud (2012). It was provided to the teachers during the fourth interview at the beginning of the second year of this study (December, 2012). In the new part, teachers were supposed to report in addition to their professional activities inside and outside school, the resources utilized, their origin, purpose of utilization, and any production utilizing these resources individually or collectively and how they were *archived* (Appendix XII). This added part aimed at inferring the resources utilized by teachers and how these resources are organized and archived. Furthermore, comparison of the data collected from the interviews and the SRSR allowed the inference of the *critical resources* mobilized, elaborated and implemented in teaching genetics concepts and genetic determinism of phenotype.

3.4.5. Classroom observations.

The classroom observations performed in this research were qualitative, naturalistic observation that involved observing all relevant phenomena and taking

extensive field notes where the researcher is said to be the data-collection instrument (Johnson & Christensen, 2008). The classroom observations align with the principle of monitoring the documentary work of teachers inside the classroom.

According to the *reflective investigation* methodology (Gueudet & Trouche, 2010), the classroom is an important place where the teaching process occurs. For this study, classroom observations allowed for the identification of the interactions among teachers, students and resources. The aim of this data collection tool was to: investigate how the teachers are implementing and adapting resources, particularly digital resources, in the classroom; compare what is planned to what is achieved in the classroom; and infer teachers' conceptions of genetic determinism of phenotype based on the *critical resources* implemented in class and on the output of *critical situations* based on the grid illustrated in section (§3.3.2). Classroom observations were done during the first and second years of the present study.

During the first year, an observation grid was filled and took into account: the organization and layout of the classroom; the activities of the teacher and students; the resources utilized by teachers with special interest in digital resources (videos, animations, PowerPoint...); the resources utilized by students; behaviors of the teacher; comments and feedback (see Appendix XIII). However, knowing that the use of video recordings is of increasing importance in educational research, video recordings of class sessions were performed during the second year of observation since the video provides a partial reconstruction in time and space of the event of interest; it also captures the verbal and nonverbal behavior of the teacher and students. The number of sessions observed varied from one case to another and they were chosen based on the purpose of the study and according to specific criteria: implementation of digital resources; realization of students' activities in class; and explanation of scientific knowledge that might allow the researcher to infer teachers' conceptions based on *critical resources* and situations.

In the first year of research, Maya was monitored for four sessions between December and February (2011-2012) during her implementation of the new digital resource that she elaborated to teach the chapter on gene expression (see Table 4). On the other hand, Tania and Fadi were observed for several sessions during the explanation of the whole genetics part (beginning March till the end of May, 2012) since they were utilizing books other than the national biology textbook and they followed a different sequence (see Tables 5 and 6, respectively). On the other hand, Marwa was observed for two sessions; one during the implementation of a digital resource that she elaborated specifically for teaching the relationship between genotype and phenotype (a slide show about protein synthesis). The second session was during which she performed a hands-on activity using worksheets prepared for students from a specific website: www.lessonplansinc.com about protein synthesis where students simulated the processes of transcription and translation and learned how proteins are built using DNA code (see Table7). Figure 12 shows a schema of the number of classroom observations performed with the four teachers during the first year.

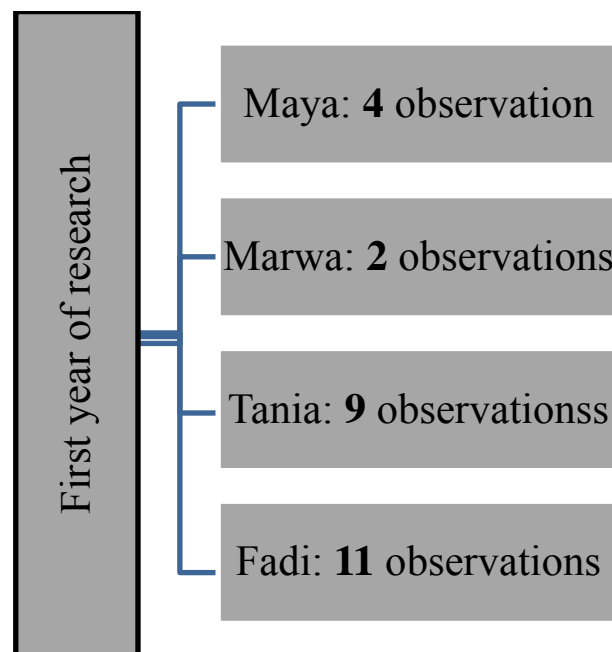


Figure 12. Schema for the number of classroom observations during the first year of research.

Table 4
Synthesis for the Classroom Observations for Maya during the Academic Year 2011-2012

Observation session	Date	Place	Title/subject	Resources utilized
First observation	20-12-2011	Technology room ²	The gene notion and its expression: -Chromosomes & DNA carriers of genetic information. -First step of protein synthesis: transcription	The slide show “genetic program and its expression” with schematic drawings and animations
Second observation	17-1-2012	Computer room (see Appendix XIV) and classroom	The gene notion and its expression: -Second step of protein synthesis: Translation (tools of translation, initiation and elongation steps)	The slide show “genetic program and its expression” with schematic drawings and animations
Third observation	7-2-2012	Computer room	The gene notion and its expression: Second step of protein synthesis: Translation (elongation and termination)	Animated figures about translation on the slide and copybook of the teacher
Fourth observation	10-2-2012	Computer room	The gene notion and its expression: Structure of protein. Relation between gene and character	The slide show, quick time movie about protein synthesis, , animation about the steps of translation Movie clip about DNA, animation about transcription, quick time movie about mitosis.

²It is equipped with IWB and LCD held on roof; computer placed on a desk table and speakers; a big chair for the teacher to sit in front of the computer; chairs for students to sit down, but no tables, no board.

Table 5
Synthesis for the Observed Sessions for Tania during the Academic Year 2011-2012

Observation session	Date	Place	Title/Subject	Resources utilized
First session	6-3-2012	Classroom (see appendix XV)	The phenotype depend on protein: -Structure of protein and its relation to function	A video about protein denaturation and a quick time movie about protein structure. Extra sheet about structure of protein
Second session	20-3-2012	Classroom	DNA and genetic information: -Structure of DNA	Three videos, an animation and a PowerPoint about DNA and genetic information.
Third session	3- 4 - 2012	Classroom	Conservation of genetic information: -DNA replication during interphase before mitosis	Two animations about the cell cycle, two similar animations about DNA replication one not commented and the second is commented, third animation about DNA replication. Students' worksheet about DNA replication
Fourth session	24-4-2012	Classroom	DNA replication: -Meselson and Stahl experiment	Animation about Meselson and Stahl experiment. Documents of the textbook
Fifth session	2-5-2012	Classroom	Protein synthesis: -Transcription, first step	Two similar animations about transcription, the first not commented and the second commented. Another animation about transcription, and students' worksheet about translation.

Sixth session	8-5-2012	Classroom	Protein synthesis: -Genetic code	PPT about genetic code, animation about early genetic engineering experiment, an animation about creating a transgenic animal. Documents of the textbook
Seventh session	15-5-2012	Classroom	Protein synthesis: -Translation, second step.	Two similar animations about translation the first is not commented and the second is commented, a third animation about translation, student work sheet.
Eighth session	16-5-2012	Classroom	-Mutation	Worksheet about mutation with application exercises was utilized in class to explain the ideas of mutation, and documents of the textbook.
Ninth session	29-5-2012	Classroom	-Relation between gene phenotype and environment: -Influence of the environment on the expression of the gene.	Documents of the French biology textbook (Bordas, 2007)

Table 6
Synthesis for the Observed Sessions for Fadi during the Academic Year 2011-2012

Observation session	Date	Place	Title/ Subject	Resources utilized
First Session	16-3-2012	Classroom (same classroom organization as Tania) (Appendix XV)	Biological identity of living organisms: -Gurdon experiment	Booklet ³ elaborated by Fadi
Second session	30-3-2012	Classroom	Chemical and physical structure of chromosomes: -chemical identification of DNA	. Booklet elaborated by Fadi
Third Session	3- 4 -2012	Classroom	chemical and physical structure of chromosomes: Physical structure of DNA	Booklet elaborated by Fadi
Fourth session	20-4-2012	Classroom	DNA replication and cell cycle	Booklet elaborated by Fadi
Fifth Session	23-4-2012	Classroom	DNA replication and cell cycle	Animation about DNA replication and the booklet

³The booklet prepared by Fadi for teaching biology in grade 11 S contains documents adapted from the National biology textbook and the French biology textbook, Bordas 2007.

Sixth session	27-4-2012	Classroom	Application exercise about DNA replication	Booklet elaborated by Fadi
Seventh session	4-5-2012	Classroom	The gene: structure and unit of information.	Booklet elaborated by Fadi
Eighth session	15-5-2012	Classroom	-Transcription: first step of protein synthesis	Booklet elaborated by Fadi
Ninth Session	18-5-2012	Classroom	-Transcription and genetic code	Booklet elaborated by Fadi animation about transcription
Tenth Session	28-5-2012		-Translation second step of protein synthesis	Booklet elaborated by Fadi
Eleventh session	29-5-2012	Classroom	-Genes and alleles Mutation	Booklet elaborated by Fadi

Table 7
Synthesis for the two Classroom Observations for Marwa Academic Year (2011-2012)

Observation session	Date	Place	Title and Subject	Resources utilized
First session	29-2-2012	Technology room equipped with interactive whiteboard and LCD)	Protein synthesis: -What are proteins and what are they needed for? -Steps of protein synthesis: transcription and translation.	PPT entitled: "Protein synthesis". Animations and Quick time movies
Second session	13-3-2013	Classroom*	Protein synthesis: Hands on activity done by students as an application on the process of protein synthesis. the activity is downloaded from the following website: www.LessonPlansInc.com	Papers, scissors, scotch tape, glue, lesson plans copied for students

* The classroom contains a big blackboard with teacher's table and chair in front. It contains four rows of two students' tables and each row contains four tables.

During the second year of the research, Maya was monitored for four periods: three periods during the implementation of the same slide show elaborated during the first year “genetic program and its expression”. This was done to track any modification or evolution in her documentary work or conceptions. The fourth period was during the explanation of genetic diseases to infer her conceptions based on how she presents the topic (*critical situations*) and her use of *critical resources*.

As for Tania, she was monitored for two sessions: one during which students were presenting projects about the Cancerization process utilizing digital resources that they elaborated; and the second session when Tania was explaining Cancerization utilizing the documents of the new biology French textbook (Bordas, 2011). This topic was chosen because it is newly integrated in the program of grade 11S and to infer teachers’ conceptions related to genetic determinism based on how cancer is explained in class (*critical situation*). Figure 13 shows a schema of the number of classroom observations performed with Maya and Tania during the second year of research.

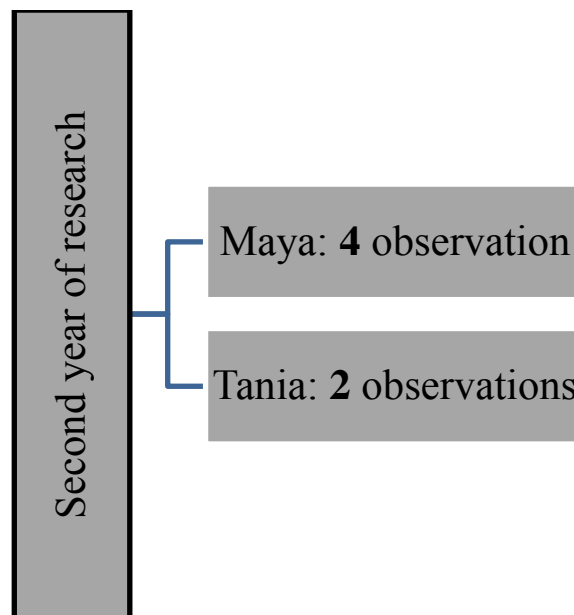


Figure 13. Schema for the number of classroom observations during the second year of research.

3.5. Data Analysis Procedures

This part presents the methods implemented for the analysis of the data collected from the different instruments (interviews, classroom observation, logbook and SRSR). Cross analysis and verification of all the data allowed the identification of *critical resources* and *critical situations* and the evolution of teachers' documentary work and conceptions related to genetic determinism. The method of analysis of interviews is presented first (§3.5.1) followed by the method for analysis of classroom observations (§3.5.2), logbooks (§3.5.3), SRSR (§ 3.5.4) and finally the resources (§ 3.5.5)

3.5.1. Method for analysis of interviews.

For analysis of the interviews, the data was divided into themes and then an analytical framework was constructed from these themes. This part presents the principles followed for the division of teachers' discourse during interviews and some examples from extracts of interviews.

Teacher discourse during the interviews was divided according to themes based on the theoretical framework of this study. Therefore, three themes were chosen: the system of resources (SR), documentary work (DW), and professional development (PD). Then, these themes were divided into categories which were in turn divided into sub-categories to construct a grid for the analysis of interviews. The grid related to the first theme (SR) was adapted from the study of Hammoud (2012) and the other grids were designed based on theoretical framework of the present study and in order to answer the research questions.

For the first theme, system of resources (SR), several categories to identify certain elements of this theme were defined. First, the resources mobilized by the teacher to organize her teaching practices were identified as well as the organization and structure of these resources. In addition to the verbal discourse of the teacher, the exploration of teachers' resources during the interviews reinforced what was said by the teacher and helped visualize how the resources were organized and structured.

The researcher also sought to identify, through interviews, evidence of the teachers' documentary genesis process believing that it is the driving force behind the documentary work. In the documentation genesis category there are, in fact, two distinguished subcategories, namely instrumentation and instrumentalization, which are at the heart of the documentary genesis process as illustrated in chapter two (§2.1.2). The categories and subcategories of the SR theme are illustrated in Figure 14.

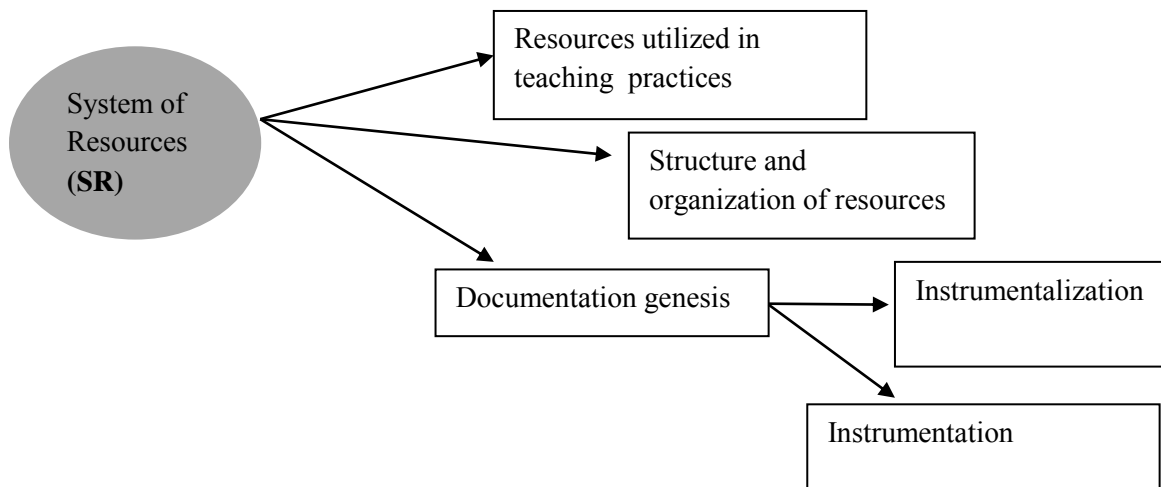


Figure 14. Categories and sub-categories for the first theme “System of Resources”.

Related to the second theme, documentary work (DW), several categories to identify certain elements of teachers' documentary work were defined. First, the researcher sought to identify whether or not teachers were integrating digital resources in their documentary work and exchanging their resources or doing any collaborative work. The researcher also wanted to identify how teachers interacted with resources in their preparation and teaching practices. Two subcategories are distinguished here: mobilization of resources to elaborate new resources to be implemented in class and implementation and in-situ adaptation of digital resources in class. The categories and sub-categories for the DW are illustrated in Figure 15.

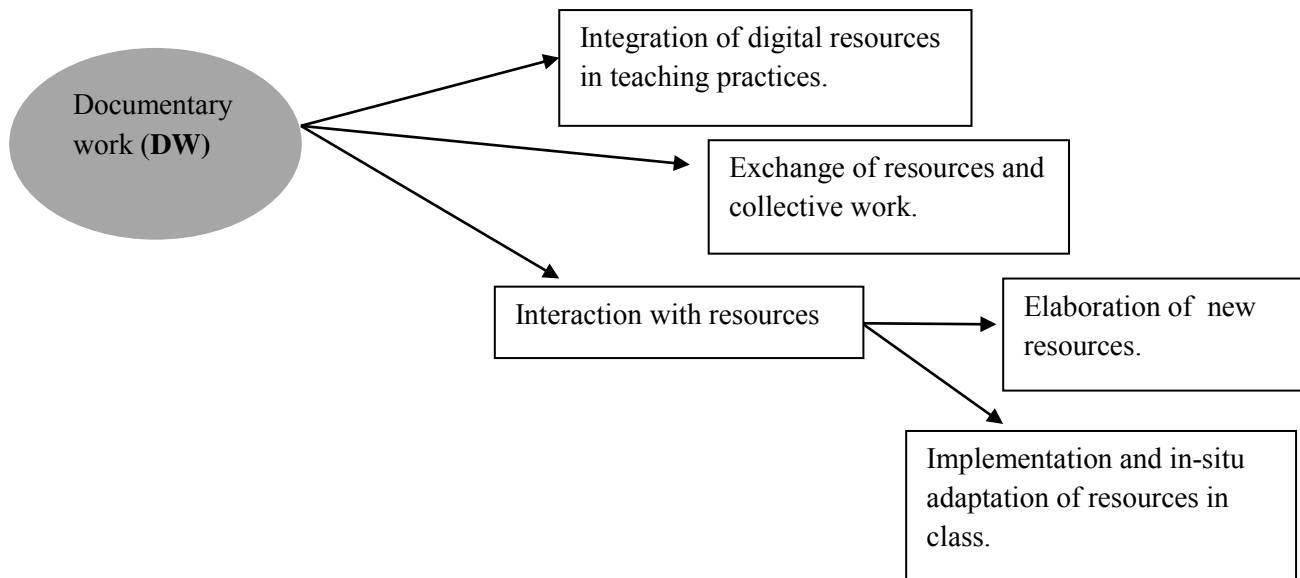


Figure 15. Categories and sub-categories for the second theme “Documentary Work”.

As for the third theme, professional development (PD), this study aimed to look at the professional development from the perspective of integration of new resources, particularly digital resources (Gueudet & Trouche, 2009) in teaching genetic concepts. Professional development can be defined as the interrelation among several processes: the opening to new resources, after the metamorphosis of digital resources; the development of teachers’ professional knowledge, both disciplinary (scientific knowledge related epigenetics) and pedagogical (teaching practices and strategies, introducing the environmental determinism of phenotype); the development of teachers’ relations with other stakeholders of the educational ladder (collective work with other teachers or coordinators); and evolution or change of teachers’ conceptions (from hereditarianism to epigenetics). In the context of this study, the researcher hypothesized that the integration of digital resources and elaboration of new resources might lead to the evolution of teachers’ documentary work and conceptions based on KVP interactions; i.e. updated scientific knowledge about environmental interactions with genotype and phenotype (K), evolution of values from innatism to more progressive values (V) and evolution in teaching practices related to relationship between genotype and phenotype (P).

Consequently, teacher interaction with available digital resources might lead to professional development. Figure 16 shows the categories related to professional development.

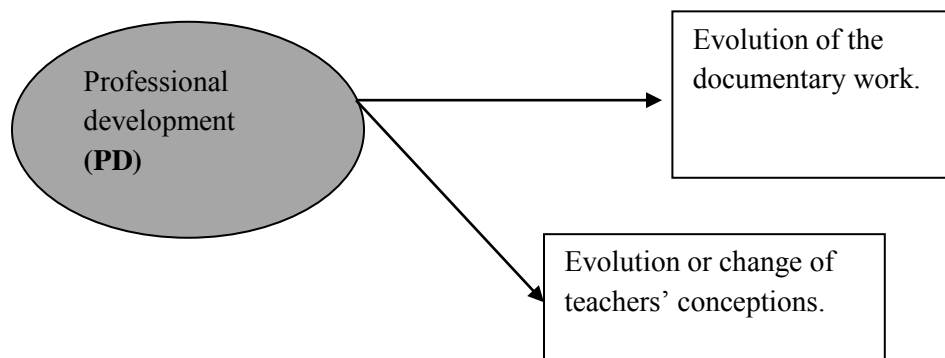


Figure 16. Categories for the third theme “Professional Development”.

After defining the categories and sub-categories for the three themes SR, DW and PD, specific examples from interviews will be shown to illustrate how teachers’ discourse was divided. The first step was to divide the teachers’ speech into sequences corresponding to the answers to the interview questions whereby each sequence corresponded to a complete answer to a specific question. Within the discourse of a teacher, one or more themes can be identified. Thus, a sequence can be monothematic, bi-thematic, tri-thematic, etc... Table 8 shows an extract from the first interview with Maya where the sequence of her answer is mono-thematic.

Table 8

Example of a Mono-Thematic Response from the First Interview with Maya during the First Year

Question	Response
From where did you get these resources?	Yes from Internet and I save them on my laptop and I take the laptop and connect it to the LCD For example transcription and translation every year I show it to them as videos.

In this example, the sequence included one theme which is the system of resources (SR). The teacher specified the resources used in her teaching practices

(Internet resources and videos) and how these resources are structured and organized (by saving them on her laptop to be utilized in class).

3.5.2. Method for analysis of classroom observations.

Analysis of classroom observations mainly focused on the two stages of the life cycle of the document (see § 2.1.2), implementation and in situ adaptation of *critical resources*. Teachers were observed during the explanation of the chapters related to genetics concepts and the relationship between genotype and phenotype as illustrated in section (§ 3.3.5)

The first step for analyzing the classroom observation was transcribing teachers' and students' verbal discourse during the observed sessions. The second step was developing "scripts" illustrating all the events occurring during the observed sessions by dividing them into "episodes". In this research, episodes were considered didactical situations occurring in class where interactions between students and teachers, students and students, teachers and resources, and students and resources are described. Many versions of the scripts were developed and discussed with the directors of the thesis until consensus was reached. The final version is shown in Table 9.

Table 9

Final Version of the Script for Classroom Observations

Time	Time of the episode
Episode	Title of the episode
Relevant verbal discourse	Extract of the verbal discourse of both teachers and students
Resources	Resources utilized in class including digital resources
Comments	Any interesting behavior of the teacher or students
Technological tools	Technological tools utilized

The third step was a preliminary analysis of the data collected from the scripts in order to identify the *critical situations* in the various episodes. Implementation of resources in the classroom leads to facts that might give rise to question by students and to answer these questions the teacher conceives new *critical resources* on the spot; this helped in identifying teachers' conceptions. When the teacher adds something to the resource, she is using both the current resource and what is fed from the students' questions to provide a new critical resource. So, it is a process of creating a new resource at this moment (*critical situation*) since these moments reflect the heart of conceptions. Finally, the output of *critical situations* and *critical resources* implemented in class were analyzed based on the grids elaborated in section (§ 3.2.2).

Therefore, the primary interest was the analysis of the observed sessions' *critical situations* and their output. In this sense, teacher actions related to classroom management were not considered *critical situations* and therefore were not included in the analysis. The interest in this study was the changes in teaching practices, if any, due to implementation of digital resources and any seeds of evolution of teachers' documentary work. This, in turn, may shed light on the consequences of integration of digital resources on teachers' professional activities, documentary work and conceptions, or in other words, their professional development.

3.5.3. Method for analysis of the logbook.

This section presents the method of analysis of the logbook filled out by the teacher during the follow-up period for two consecutive years whereby the teachers were preparing and explaining the chapters about genetics concepts and the relationship between genotype and phenotype. The analysis of the logbook focused on the resources mobilized by the teachers in their preparation and the origin of these resources, the resources elaborated and implemented in class; the collective work of the teachers; their documentary work and the documentary genesis process. Then, the time spent on each activity was analyzed assuming that more time will be spent on

more important activities. Thus, if the teachers are in the phase of evolution of resources and integration of new digital resources then more time will be spent for searching, combining, elaborating and adjusting these resources. A cross analysis of the data collected from the logbook with the data collected from the other tools was done to identify the *critical resources*. The grid for logbook analysis is illustrated in the Table 10.

Table 10
Grid for Analysis of the Logbook

Criteria for Analysis of the Logbook
<ul style="list-style-type: none"> • Identify the <i>critical resources mobilized</i> by the teacher to prepare his/her teaching sessions, after comparing with the resources mentioned in interviews and SRSR. • Identify the <i>critical resources elaborated</i> by the teacher and how they were designed. • Identify, after comparing with the data collected from the classroom, the <i>critical resources implemented</i> in class that can be used to infer teachers' conceptions. • Infer the documentary work of the teacher (search for resources, combining them). • Identify the collective work of the teacher (exchange of resources, collaborative work with colleagues or coordinator). • Infer the documentary genesis process: evolution of resources, evolution of usage of resources (by comparing the logbook filled during the two successive years of follow-up). • Specify the time spent for specific activity to infer its importance in the documentary work of teachers

Thus, the researcher sought to cross the teachers' notes in the logbook with teachers' interview responses, schematic representations, classroom discussions, resources collected, in addition to discussions made with the teachers about certain resources and activities mentioned in the logbook. All this was done in order to infer the *critical resources* mobilized, elaborated and implemented in class.

3.5.4. Method for analysis of the SRSR.

This part presents how teachers' SRSR drawings were analyzed. First, the general structure of the schematic representation was analyzed in relation to the terms used in the diagram, the presence or absence of centers and what was played around the centers, the forms of presentation of terms (square, rectangle, round...etc) and the colors used. Then, the location or position of the terms in the schematic representation was identified (center, at the margin, to the left or right, hierarchy of terms) in order to infer their relative importance. This was followed by the examination of the influenced terms and the influencing terms, the grouping of terms and loops. The researcher also aimed to identify, from the arrows, the nature of the relationship (strong or weak) and the links between the terms. To do this, the relationship between the terms that appeared in the schematic representations were described by relying on characteristics of links: causality (A causes B), similarity/likeness (A is similar to B), influence (A affects B), inclusion (A is included in B), implication (A implies B), equivalence (A is equivalent to B), and example (A is an example of B) (Gendre-Aegerter, 2008). In particular, the researcher sought to identify, from the arrows, reversible reactions between the terms of the schematic representations, that is to say when a term A affects B and in turn, the term B affects A. Analysis of the schematic representations also relied on teachers' discourse and discussions that accompanied the realization of the drawing in order to highlight the dynamic construction of the schematic representation. For instance, by identifying the order in which the drawing was made (what terms were the first to be shown in the diagram), the importance that the teacher gives to certain terms of the schematic representation can be indicated.

In addition, analysis of schematic representations designed by the teachers was analyzed based on the grid of analysis of interviews, in other words, on the categories/sub-categories of the themes. Indeed, the grid of analysis of interviews can be useful to interpret and analyze the schematic representations. Specifically, in the SRSR, the resources mobilized by teachers to organize their teaching were examined,

as well as the organization and structure of these resources. The criteria for the analysis of the schematic representation of the SRSR were adapted from the study of Hammoud (2012). Some additional criteria were elaborated for this research pertaining to the identification of *critical resources* mobilized by teachers during their preparation practices after crossing the data collected from the various tools. Table 11 shows the criteria for the analysis of the schematic SRSR drawn by the teachers.

Table 11
Criteria for Analysis of the SRSR

Criteria for Analysis of the SRSR
<ul style="list-style-type: none"> ● Identify the terms in the diagram, forms of presentation of terms (square, rectangle, round, etc...), colors used. ● Identify location or position of the terms in the diagram(center, at the margin, to the left or right, hierarchy of terms) ● Identify the order in which the drawing is performed (terms which were the first to be shown in the diagram) ● Infer the relative importance of each term: the influenced terms and the influencing terms ● Specify the grouping of terms/ Loops ● Infer the nature of relationship (strong or weak), links between terms(causality, similarity, implication...) ● Identify reversible reaction between the terms ● Utilize common analysis indicators to interviews related to the theme of system of resources.

3.5.5. Method for analysis of *critical resources*.

Critical resources were first identified by crossing the data collected from the structure and content of teachers' SRSR, logbook activities, verbal discourse in interviews and resources implemented in the classroom. The *critical resources* defined in (§ 2.3) are the resources mobilized, elaborated or implemented in preparation/teaching practices related to genetic determinism of phenotype. In the

SRSR, they are written at the top of resources like the textbook in the first SRSR of Maya or emphasized by +++ like the *archive* in the case of Tania. In the logbook, they are mentioned in many activities for preparation/teaching practices. In addition, these resources are emphasized by teachers in interviews like the exercise of Himalayan rabbits in the final exam and/or implemented in class like the slide show elaborated by Maya. The *critical resources* included textbooks, university books, digital resources and others. These were analyzed based on the grids developed in section § 3.2.2.

For the analysis of books, first the chapters related to genetics including phenotype-genotype or genetic determinism were identified, and then specific terms like “genetic program”, “genetic information”, “genetic predisposition”, “interaction with environment” and “environmental influence” were searched for in these chapters. The researcher also searched for diagrams that might show the relationship between genotype and phenotype with linear or reversible arrows. Also, photos that might reflect this relationship like photos of identical twins, Himalayan rabbits, and Siamese cats were searched for. Moreover, examples of genetic diseases and how they are presented in books were analyzed. For example, books that present genetic diseases like Duchene muscular dystrophy or cystic fibrosis in which the genotype is the only explanation to the pathological phenotype reflect a reductionist linear model. On the other hand, books that present genetic diseases like Xeroderma pigmentosum as an interaction between genotype and/or phenotype and the environment reflect an interactive model. In addition, exercises related to the nature of the relationship between genotype and phenotypes were identified.

For digital resources like animations or videos, the audio was analyzed searching for specific terms, illustrations or examples that might reflect the nature of the relationship between genotype and phenotype as either linear or interactive. Furthermore, the animated figures were analyzed to infer how this relationship is presented. In addition, the researcher referred back to the origin of these resources (i.e. the websites) to search for any information about genetic determinism in order to

infer if that particular resource applies the linear or interactive model. The sites were visited at different time intervals to see if there was any evolution in the information. Analysis of how these resources were implemented and adapted in class as well as teachers' discourse during their implementation was also done.

For the slide show elaborated by teachers after mobilizing, selecting and combining many resources, the terms, diagrams, pictures, videos and animations used in the slide show were analyzed. This was based on the grid shown in section (§ 3.3.2) to categorize teachers' conceptions based on the *critical resources* utilized. In the classroom, attention was focused on the teacher's verbal discourse while implementing this resource in addition to the illustrations used to explain the ideas or answer students' questions (in situ adaption of the resource, critical situation).

3.6. Validity and Reliability

This part presents the methods implemented to enhance the validity and reliability of the study in general (§ 3.6.1) and the questionnaire (§ 3.6.2), interviews (§ 3.6.3), classroom observations (§ 3.6.4) and elaborated grid (§ 3.6.5).

3.6.1. General validity and reliability of the study.

In this study, data were collected using many complementary instruments based on specific methodological principles for triangulation of sources. Cross data analysis and verification from many resources including questionnaires, interviews, classroom observations, logbooks and SRSR enhanced the validity of the research.

Interviewing the same teacher more than once (3-5 interviews) is a traditional approach for validity and reliability in qualitative research (Gay, 1996) which was applied in this study. Moreover, prolonged engagement of the researcher and persistent observations of the participants were applied for the credibility or internal validity of the study (Johnson & Christensen, 2008). Prolonged engagement provided scope as it required the researcher to be involved for a long enough time to detect any variation in teachers' documentary work and conceptions. Moreover, persisted

observation provided depth since the participants' classrooms were observed for two successive years during the explanation of the same topic for a period long enough to understand the context of the classroom. Also, peer review and member check was applied to enhance the credibility of the research whereby the data collected was checked by participants (Silverman, 2006).

Moreover, the data, *critical resources* and output of *critical situations* were analyzed separately based on the grid developed in this study (§3.3.2) by another biology teacher (Shaza) with 20 years of teaching experience (analyst triangulation).

3.6.2. Validity and reliability of the questionnaire.

The content validity of the first version of the questionnaire was determined by six expert researchers in didactics of biology (one), physics (two) and mathematics (three). For reliability purposes, a pilot test for the first version of the questionnaire was done with 16 secondary biology teachers that were not part of this study. For validity purposes, the “think-aloud technique” with four of those teachers was applied. The “think-aloud technique” is very helpful for determining whether the participants are interpreting the items as intended (Johnson & Christensen, 2008). Teachers were also asked to give their own feedback on the questionnaire. Based on the feedback and findings of the pilot test, a final modified version was constructed. For example, the question about the accessibility of technological tools in school was added to the final version of the questionnaire after teachers claimed that even if these tools are available, they are not always accessible for teachers since in most cases they have to be reserved ahead of time.

3.6.3. Validity and reliability of interviews.

All interviews were tape-recorded and transcribed. To establish credibility by member check, the transcripts of all the interviews were read by the participants themselves to ensure that their ideas were presented accurately. Then, the transcripts were divided into themes, categories and sub-categories as illustrated in section (§ 3.5.1) by the researcher and the biology teacher (Shaza) who separately analyzed

teachers' answers (analysis triangulation) (Hittleman & Simon, 2006). A discussion between the two analysts was done to reach inter-rater agreement. Therefore, content validity was insured by inter-rater analysis. According to Silverman (2006), inter-rater analysis involves giving the data to a number of analysts or raters and asking them to analyze the data according to a set of agreed on categories. Reports of each analyst are then examined and any differences are discussed until they are agreed upon.

Furthermore, for validity of coding of teachers' discourse in the interviews two rounds of coding were done. First, all the interviews done with the first case study, Maya, were coded one time and then after a while the coding was repeated for a second time. Based on this recoding, some categories were modified. This uncertainty in data coding is based on the principle that a single researcher may have different perspectives at two different times. Also, another researcher in the field of education was asked to analyze the same data using the same codes. The consensus of these researchers proved that the coding was not subjective which enhanced the validity of the study.

3.6.4. Validity and reliability of classroom observations.

During the first year of the research, all the observed sessions were recorded and transcribed and observation grids were filled. During the second year, the sessions were video-taped to capture the verbal and non-verbal behavior of the teacher. Although there is no way to record everything of interest, the use of recording devices assists in collecting accurate data since it can be replayed as many times as desired. Other researchers listened or watched them and gave their opinions and impressions thus enhancing the validity of the research. Furthermore, the researcher took extensive field notes during all the observed sessions by registering not only what was seen, heard or experienced, but also the researcher's reactions and reflections that might be useful for data analysis. Moreover, in order to support the data from the field notes and video-taped sessions, all the resources implemented in class were collected.

3.6.5. Validity of the grid to infer teachers' conceptions.

The models utilized in the elaborated grid to infer teachers' conceptions were implemented in many previous researches (e.g. Castéra & Clément 2009a, 2012; Forissier and Clément, 2003; Kochkar 2007). In addition, they were validated in the Biohead project (Castéra, 2010; Castéra et al., 2008). In this research, the grid was first implemented in the analysis of the national textbook for grade 11S, then it was refined before its implementation on other *critical resources* and data collection tools.

The next chapter, chapter IV, presents the quantitative analysis of the data collected from the questionnaire in order to study the current status of integration of digital resources by secondary biology Lebanese teachers. It also presents the characteristics of the participants of the research and some of the variables that might have influenced the documentary work and conceptions of the selected cases from the qualitative part of the research.

CHAPTER IV

THE CURRENT STATUS OF INTEGRATION OF DIGITAL RESOURCES BY SECONDARY LEBANESE BIOLOGY TEACHERS

In order to study the current status of integration of resources, particularly digital resources, by secondary Lebanese science teachers, a questionnaire (§ 3.2.1) was constructed and validated in the context of DOCENS (Documentation des Enseignants des Sciences) project. Three doctorate students in three disciplines (physics, mathematics and biology) participated in the project. This questionnaire contained a common part implemented in the three disciplines about teachers' working environment, their profiles, the types of resources integrated in their teaching practices and the purposes of their utilization. Also, for this research the questionnaire included a part related to the resources implemented in teaching genetics' concepts in biology.

The first part of this chapter presents the sample of biology teachers who filled the questionnaire, characterized according to their profiles and their working environment. Then, specific items of the questionnaire were cross-analyzed in order to choose the participants and to study the effect of some variables on teachers' documentary work and conceptions. In particular, participants were chosen based on their use of resources assuming that their documentary work and conceptions are influenced by digitalization (§ 4.1). Moreover, assuming that the teaching of genetics is one field of biology that is sensitive to the evolution of teachers' documentary work and conceptions based on their scientific knowledge (K), their values (V) and their evolved teaching practices (P), teachers' responses to the items of the questionnaire related to the teaching of genetics' concepts were analyzed in order to select the participants of the qualitative part of the research (§ 4.2). Finally, a comparison between teachers' responses in the three disciplines related to specific

items in the common part of the questionnaire are presented, in order to infer the peculiarities related to teaching biology (§ 4.3).

4.1. Profiles of the Secondary Biology Teachers that Filled the Questionnaire

In order to choose the participants of the qualitative part of this study, the results of specific items of the questionnaire are presented in this part. First, the demographic profiles of the sample of teachers that filled the questionnaire and a cross-analysis of the data are presented in § 4.1.1 and information about the working environment and a cross-analysis of the data are presented in § 4.1.2. Then, the extent of use of resources by teachers, types of resources used and purposes behind their use are presented in § 4.1.3, § 4.1.4 and § 4.1.5, respectively.

4.1.1. Demographic profiles of the biology teachers that filled the questionnaire.

The profiles of the sample of 116 secondary biology teachers taken in this study were characterized according to: gender, university degree, teaching experience, teaching language, type and location of school and grade levels taught. These refer to items 27-33 of the questionnaire (Appendix I). The results of the teacher profiles are presented in Table 12. Results of the table indicate that a majority of the participating teachers were female (70 %), have a BS degree (40 %), have more than ten years of experience (55 %), teach using the English language (58 %), teach in private schools (41 %), teach grade 12 (90 %) and teach in schools located in Mount Lebanon (46 %).

All the criteria mentioned in table 12 below were taken into consideration when the participants for the qualitative part of the research were selected. More specifically, participants were chosen to be females and males, to have various university degrees, to teach in English and French and to teach in different types of schools. In addition, the participants were chosen from Mount Lebanon and Beirut for reasons of convenience since the researcher lives in Mount Lebanon. All the selected participants teach grade 11S when genetic concepts are taught and had more than ten years teaching experience. The latter criteria was chosen in order for teachers to have

a developed system of resources related to genetic determinism of phenotype (see § 3.1).

Table 12

Demographic Profiles of the Secondary Lebanese Biology Teachers that Filled the Questionnaire (N = 116)

Teacher Profile		Percentage (%)
Gender	Female	70
	Male	30
University degree	BS	40
	MS	39
	BS & CAPES/TD/DEA	19
	Doctorate	2
Teaching experience	< 10 years	45
	> 10 years	55
Teaching language	English	58
	French	42
Type of school	Public	37
	Private	41
	Both	22
Grade levels taught	Grade 9	58
	Grade 10	72
	Grade 11S	84
	Grade 11H	54
	Grade 12	90
Location of school	Mount Lebanon	46
	Beirut	12
	South	15
	North	10
	Bekaa	10
	Nabatiyeh	7

Cross-tabulations using the SPSS program were done to identify the teachers that fulfill the criteria. Results showed that of all the grade 11S teachers, 37 of them were from Mount Lebanon (16 in public schools and 21 in private schools) and 11 of them were from Beirut (6 in public schools and 5 in private schools). Teachers working in both types of schools (private and public) were excluded for comparative purposes.

4.1.2. Availability of digital resources in teachers' working environment.

Assuming that the working environment of teachers might affect their documentary work as well as their conceptions, the characteristics of teachers' working environments in terms of availability and accessibility of technological tools were determined.

The first part presents the results related to presence of computers at schools, presence of Internet connection at schools, in addition to the results related to availability and accessibility of technological tools in schools. Table 13 presents the results related to the presence of computers (item 1) and Internet connection (item 6) at the school. Results show that a majority of the schools have a computer (81 %) and Internet connection (71 %).

Table 13

Presence of Computer Lab and Internet Connection at School (N = 116)

Item	Percentage (%)	
	Yes	No
Presence of computer	81	19
Presence of Internet connection	71	29

Tables 14 and 15 show the speed of Internet connection (item 7) and availability and accessibility of technological tools (items 14 and 15), respectively. Results show that most schools have average Internet connection and have overhead projectors and LCDs that are available and accessible to teachers. In addition, the main technological tools available in schools are traditional ones including overhead

projector, LCD, TV and videos and the least available are the IWB, laptop and DVD. Furthermore, the percentage of accessibility is lower than availability for all the tools. This indicates that despite their availability in schools, technological tools are not always accessible.

Table 14
Speed of Internet Connection at School (N=116)

Speed of Internet connection	Percentage (%)
Bad	4
Average	35
Good	22
Very good	10
Missing	29

Table 15
Technological Tools Available and Accessible at Schools (N=116)

Technological Tool	Available	Accessible
Overhead projector	83	73
LCD	81	67
Laptop	34	22
Interactive White Board (IWB)	36	22
DVD player	37	27
TV & video	71	46

A couple of studies in Lebanon have shown differences in teachers' conceptions in genetics due to the type of school (public versus private) (e.g., Khalil et al., 2007; Khalil, et al., 2007a, 2007b). Moreover, a study done by the ministry of education⁴ showed that only 43% of Lebanese public schools have computer labs. Therefore, based on this study and my personal experience as a teacher in public and private schools, cross-tabulations between for the presence of computer labs at school, Internet connection at school, and availability of technological tools were done by school type. Chi-square tests were also done to see if this difference was

⁴Ministry of Education and Higher Education (2012). Quality Education for Growth National Education Strategy Framework Education Sector Development Plan (General Education): 2010-2015.

significant or not. It should be noted that teachers that taught in both public and private schools were excluded from the analysis. Therefore, only 90 teacher responses were considered. The results of the cross-tabulations by school type are presented in Table 16.

Table 16

Availability of Technological Resources According to School Type (N = 90)

Item	Percentage		χ^2	P	
	Public	Private			
Presence of computer	45	56	1.03	.31	
Presence of Internet connection	44	56	1.44	.23	
Availability of technological tools	Overhead projector	45	55	1.81	.18
	LCD	47	53	.05	.83
	Laptop	34	66	3.58	.06
	IWB	56	44	1.44	.23
	DVD player	36	64	3.27	.07
	TV & video	39	61	5.40*	.02

* Chi-square is significant at $p < .05$.

Table 16 indicates that, compared to public schools, a larger percentage of private schools have a computer, Internet connection, overhead projector, LCD, laptop, DVD player and TV and video. However, this difference was not significant according to chi-square except for the availability of TV and videos in which a significantly higher percentage of private schools had TVs and videos than private schools, $\chi^2(1, 90) = 5.40$, $p = .02$. Nevertheless, if the risk of second order, Bonferroni correction⁵, is taken into consideration a p value of .01 and below is considered significant. Thus, according to the participants' answers, both types of schools have computers, Internet connection and technological tools without any significant differences between them. Therefore, in general the results show no

⁵ It is a statistical method used to counteract the problem of multiple comparison

significant difference between the studied public and private schools in relation to the availability of technological tools.

The same analysis was done for the characteristics of teachers' working environments outside school, particularly at home. Table 17 presents the results for the presence of computers (item 3) and Internet connection (item 8) at teachers' homes. Table 18 reveals the speed of Internet connection at home (item 9). The results show that almost all teachers (99%) have computers and Internet connection (85%) at home with average to good speed of Internet connection.

Table 17
Presence of Computer Lab and Internet Connection at Home (N=116)

Item	Percentage (%)	
	Yes	No
Presence of computer	99	1
Presence of Internet connection	85	15

Table 18
Speed of Internet Connection at Home (N=116)

Speed of Internet connection	Percentage (%)
Bad	4
Average	32
Good	36
Very good	13
Missing	15

Figure 17 synthesizes all the results related to the working environment of the participating teachers with regard to the percentages of possession of computers and Internet connection at home and at school. These four criteria were taken into consideration when the participants for the qualitative part of the research were selected.

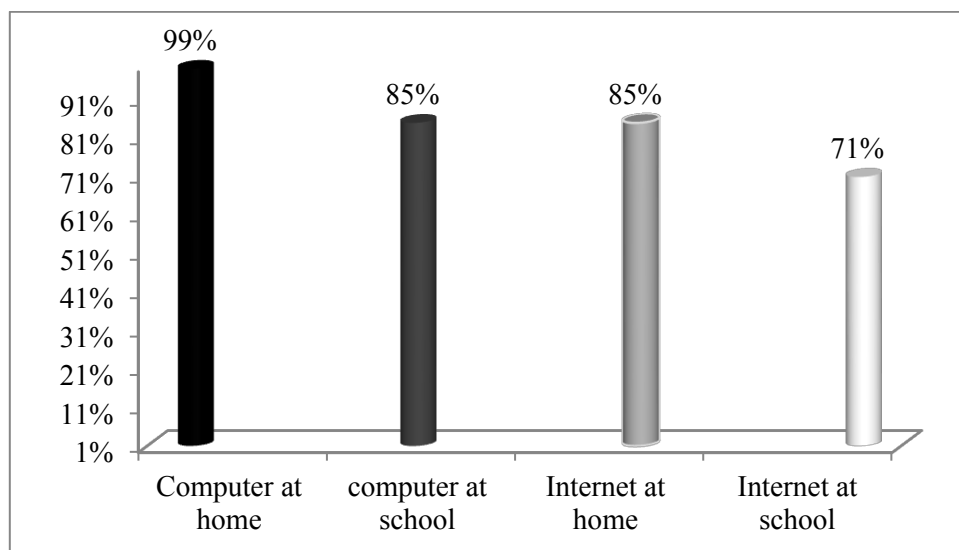


Figure 17. Percentages of presence of computer and Internet connection at home and at school.

The participants for the qualitative part of the research were selected from schools that were equipped with computer labs, with Internet connection and equipped with technological tools, specifically LCD or IWB in order to be able to implement digital resources in their teaching practices.

4.1.3. Extent of teachers' use of resources.

In order to answer the first research question related to the integration of digital resources in participants' preparation/teaching practices, the percentage of teachers' use of computers, software (e.g., Microsoft, real player, flash animation...) and technological tools, at school and at home, was calculated. These questions refer to items 2, 4, 12 and 17. The results for teachers' use of digital resources at school and at home are illustrated in Tables 19 and 20 respectively. Moreover, teachers' general use of software is illustrated in Table 21.

Table 19
Use of Computer and Technological Tools at School (N=116)

	Percentage (%)				
	Never	Sometimes	Often	Regularly	Missing
Computer	2	35	16	28	19
Technological tools	3	51	26	20	

Table 20
Use of Computer at Home (N=116)

	Percentage (%)				
	Never	Sometimes	Often	Regularly	Missing
Computer		24	31	44	1

Table 21
Use of Software (N=116)

	Percentage (%)				
	Rarely	Sometimes	Often	Regularly	Missing
Computer	2	39	35	24	

According to the results of Table 19, the largest percentage of teachers sometimes uses computers (35%) or technological resources (51%) at school. Moreover, the second largest percentage of teachers often use technological resources (26%) and regularly use computers (28%) at school. Also, Table 20 shows that 44% of the teachers regularly use computers at home while Table 21 indicates that 39% of the teachers sometimes use software. Thus, in general, teachers sometimes or often use digital resources at school whereas they regularly or often use computers at home. The participants for the qualitative study were selected from teachers that often or regularly use computer, software and technological tools.

Furthermore, a comparison by gender, school type, university degree and teaching experience was done to see if any of these factors influenced teachers' use of digital resources (computer, software and technological tools) at home or at school. The reason for comparing public and private schools was explained earlier. As for

comparing based on university degree and teaching experience, it is based on the fact that previous research has shown more technological competence and integration among teachers who have graduated from teacher preparation programs (Jones & Madden, 2002; O'Dwyer et al., 2004; Mims et al., 2006) and among teachers who have less years of teaching experience (Inan & Lowther, 2010). Moreover, with respect to gender, studies have indicated that males tend to be more technologically competent than females (Busch, 1995; Whitely, 1997).

For these comparison purposes, cross-tabulations and chi-square analyses were done. Table 22 shows the cross-tabulation for the use of computers at school for each factor. As revealed by the table, Chi-square analysis indicates that there is no significant difference for the use of computers at school by gender, type of school and number of years of teaching. However, there was a significant difference in computer use for teachers with different university degrees, $\chi^2(9, 116) = 26.14, p = .00 < .01$, taking the risk of second order into consideration.

Table 22
Use of Computers at School by Gender, University Degree, Teaching Experience and Type of School

Teacher Profile		Never (%)	Sometimes (%)	Often (%)	Regularly (%)	χ^2	<i>P</i>
Gender (<i>N</i> =116)	Female	2	40	14	22	1.03	.79
	Male		14	6	11		
University degree (<i>N</i> =116)	BS	1	19	5	16	26.14*	.00
	MS		15	4	18		
	BS & CAPES/TD/DEA	1	10	9			
	Doctorate			2			
Teaching experience (<i>N</i> =116)	< 10 years	1	15	11	17	2.69	.44
	> 10 years	1	29	10	17		
Type of school (<i>N</i> =90)	Public	1	23	11	11	3.27	.35
	Private	1	19	10	23		

*Chi-square is significant at $p < .05$.

Table 23 shows the cross-tabulation for the use of computers at home for each factor. Chi-square analysis indicates no significant difference for the use of computers at school by gender, university degree and type of school. However, there was a significant difference in computer use at home for teachers with different years of experience, $\chi^2(2, 116) = 6.61, p = .04$. In particular, teachers with less than ten years of experience use computers more regularly at home while teachers with more than ten years of experience sometimes use computers at home. Nevertheless, if $p < .01$ is considered to avoid the risk of second order, then these results are not significant.

Table 23
Use of Computers at Home by Gender, University Degree, Teaching Experience and Type of School

Teacher Profile		Never (%)	Sometimes (%)	Often (%)	Regularly (%)	χ^2	p
Gender (N=116)	Female		17	24.	29	1.75	.42
	Male		7	7	16		
University degree (N=116)	BS		12	13	15	10.0	.12
	MS		6	10	23		
	BS & CAPES/TD/DEA		6	6	7		
	Doctorate			2			
Teaching experience (N=116)	< 10 years		6	15	24	6.61	.04
	> 10 years		18	16	20		
Type of school (N=90)	Public	3	23	13	8	3.87	.28
	Private		30	12	10		

*Chi-square is significant at $p < .05$.

Table 24 shows the cross-tabulation for teachers' use of software for each factor. The table reveals no significant difference for the use of software by gender and type of school. However, there was a significant difference in the use of software by university degree, $\chi^2(9, 116) = 17.68, p = .04$, and by teaching experience, $\chi^2(3, 116) = 8.02, p = .04$. But again to avoid the risk of second order a p value $< .01$ is only considered significant and these differences are not significant.

Table 24
Use of Software by Gender, University Degree, Teaching Experience and Type of School

Teacher Profile		Rarely (%)	Sometimes (%)	Often (%)	Regularly (%)	χ^2	<i>P</i>
Gender (<i>N</i> =116)	Female		29	25	16	5.75	.12
	Male	1	10	10	9		
University degree (<i>N</i> =116)	BS	2	19	10	10	17.68*	.04
	MS		10	15	13		
	BS & CAPES/TD/DEA		10	9	1		
	Doctorate			2			
Teaching experience (<i>N</i> =116)	< 10 years		12	20	13	8.02*	.04
	> 10 years	2	27	15	11		
Type of school (<i>N</i> =90)	Public		22	22	3	7.91	.05
	Private	1	20	17	14		

*Chi-square is significant at $p < .05$.

Table 25
Use of Technological Tools at School by Gender, University Degree, Teaching Experience and Type of School

Teacher Profile		Never (%)	Sometimes (%)	Often (%)	Regularly (%)	χ^2	<i>P</i>
Gender (<i>N</i> =116)	Female	2	40	15	14	4.45	.22
	Male	1	11	11	7		
University degree (<i>N</i> =116)	BS	2	22	8	9	11.02	.27
	MS	1	17	10	10		
	BS & CAPES/TD/DEA		11	6	2		
	Doctorate			2			
Teaching experience (<i>N</i> =116)	< 10 years	3	21	13	9	4.53	.21
	> 10 years		30	13	12		
Type of school (<i>N</i> =90)	Public	3	23	8	4	3.87	.28
	Private		30	12	10		

As for Table 25, it shows the cross-tabulation for teachers' use of technological tools for each factor. Chi-square analysis shows no significant difference for the use of software by gender, university degree, teaching experience and type of school.

Therefore, the results taken together showed that, in general, teachers' use of computers, software and technological tools did not differ by gender, university degree, teaching experience or type of school. However, a significant difference was evident among teachers with different university degrees in terms of their use of computers at school and use of software. Also, there were significant differences in teachers' use of computers at home and use of software by number of years of teaching experience. In particular, teachers with more experience showed less use of software and computers at home. Moreover, teachers with a CAPES/TD/DEA degree used computers at school more often but used software less often than teachers with a BS, MS or doctorate degree.

According to Sabra (2009) the exchange of resources can affect the documentary work of the teachers and have an impact on their professional development. The influence of this variable on teachers' documentary work and conceptions is studied in the selected cases (see chapter V), thus teachers that exchange resources sometimes, regularly or often were selected. Table 26 presents teachers' exchange of resources by gender, university degree, teaching experience and school type. Results show no significant difference among teachers' exchange of resources according to gender, teaching experience and university degree. However, there was a significant difference between the exchange of resources of the studied private school teachers and public school teachers, considering p value less than .01 to avoid the risk of second order, $\chi^2(3, 90) = 12.77, p = .00$, with private school teachers exchanging resources more regularly.

Table 26
Exchange of Resources by Gender, University Degree, Teaching Experience and School Type

Teacher Profile		Never (%)	Sometimes (%)	Often (%)	Regularly (%)	χ^2	<i>P</i>
Gender (<i>N</i> =116)	Female	9	37	19	5	.62	.89
	Male	5	15	9	2		
University degree (<i>N</i> =116)	BS	4	22	10	3	6.86	.65
	MS	3	10	4	1		
	BS & CAPES/TD/DEA	6	11	3			
	Doctorate		2				
Teaching experience (<i>N</i> =116)	< 10 years	9	21	10	4	5.97	.11
	> 10 years	4	31	17	3		
Type of school (<i>N</i> =90)	Public	12	23	12		12.7	.00
	Private	3	28	12	9		

* Chi-square is significant at $p < .05$.

The impact of exchange of resources and collective work on teachers' documentary work and conceptions will be further investigated in the four case studies using data collected from interviews, logbooks and classroom observations (see chapter V). For this reason, the participants were chosen from both public and private schools. For validity purposes, two teachers from the same private school and two other teachers from public secondary schools with the same working environment related to technological tools and exchange of resources were chosen.

In sum, the results show that participants use computers at home more often and regularly than at school which might indicate that teachers are using computers for preparation purposes more than for teaching purposes. This part also shed light on the factors that might influence the integration of digital resources including type of school, university degree and teaching experience. These factors along with other factors will be further illustrated in the analysis of the data collected from the four selected cases in chapter V.

The participants for the qualitative part of the research were selected from schools that were technologically equipped with computers, Internet connection and technological tools in order for the teachers to be able to implement digital resources. Also, teachers that often or regularly use digital resources were chosen in order to infer the consequences of integration of digital resources on their documentary work and conceptions related to genetic determinism of phenotype.

Finally, the multifactorial analysis and factorial analysis of correspondence was not performed in this study since the main objective of the questionnaire was to select the participants of the research in addition to investigating the current status of integration of digital resources in preparation/ teaching practices.

4.1.4. Types of resources used by teachers.

This part presents the results related to the type of resources teachers use (item 20) and the types of software they use (item 13). Figure 18 shows the types of resources used in teachers' preparation/teaching practices and Figure 19 shows the types of software used by teachers. The results show that 85% of the participants use books (textbooks and other books) followed by specific websites (68%). In addition, software, online resources and scientific magazines are used to a certain extent. Also, Figure 19 shows that Microsoft Word (94%) and PowerPoint (80%) are the most commonly used software while animations and videos are used less often.

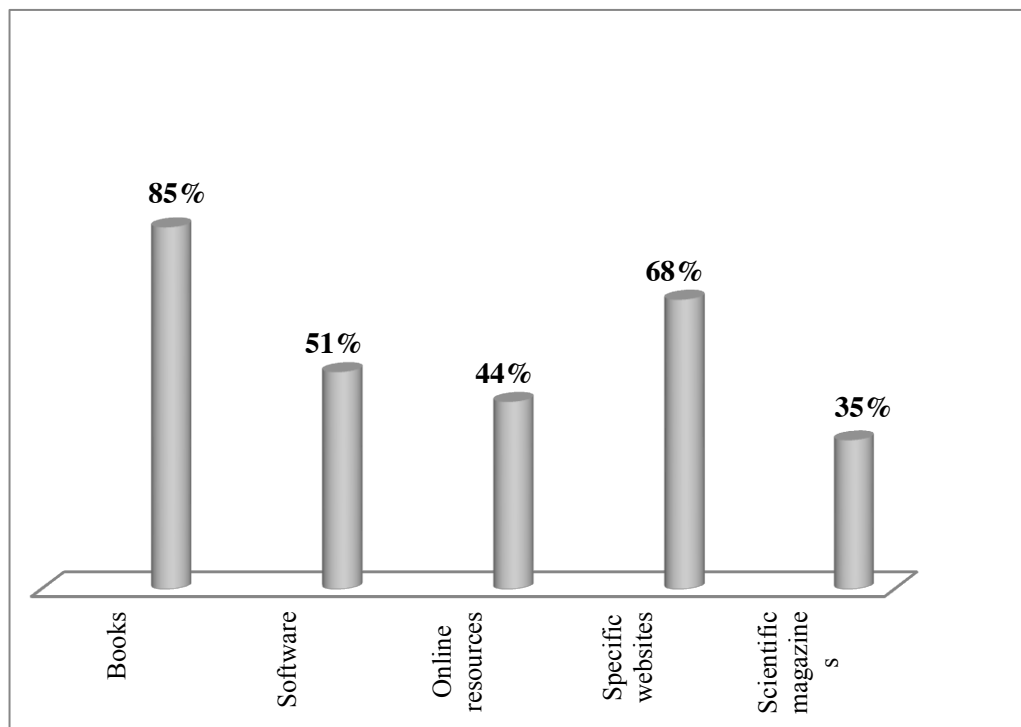


Figure 18. Resources integrated in the preparation/teaching practices of teachers.

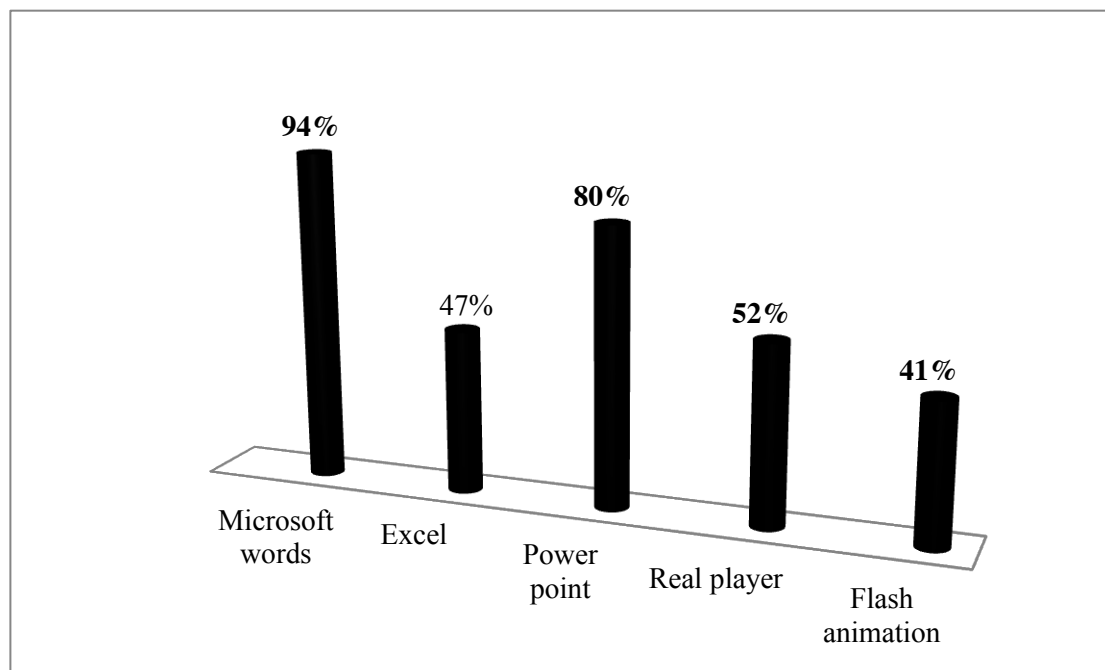


Figure 19. Types of software utilized in teaching practices.

4.1.5. Teachers' purpose behind their use of technology and resources.

This section deals with teachers' purposes behind using technology such as computers, technological tools and software as well as their reasons for using specific types of resources (items 5, 10, 18 and 21). Tables 27, 28 and 29 respectively show why teachers use computers, Internet and technological tools. The results of Table 27 show that a majority of the teachers use computers to type their exams (89%) or search for resources on the net for teaching purposes (72%). As for teachers' use of the Internet (Table 28), they use it mainly for checking their e-mails (72%) or searching for new resources (68%). Table 29 shows that teacher use technological tools mainly for illustration purposes (>70 %) followed by student motivation (66%) and simulation (61%).

Table 27

Purposes for Using Computers at Home or at School (N = 116)

Purpose	Percentage (%)
To use Internet	66
To use Internet for teaching purposes	71
To install and use software	35
To install and use software for teaching purpose	56
To type your exams	89
To search for resources on the net	72
To play games	9

Table 28

Purposes for Using the Internet (N = 116)

Purpose	Percentage (%)
e-mail	72
Facebook	47
Professional purpose	59
Searching for new resources	68
Searching for new websites	44

Table 29

Purposes for Using Technological Tools (N = 116)

Purpose	Percentage (%)
Illustration	73
Simulation	61
Awaken students' curiosity	66

Table 30 shows the reasons why teachers use resources such as books, scientific magazines...etc. The results show that the majority of the participants use resources to update (78%) and enrich their scientific knowledge (76%).

Table 30

Purpose for Using Resources (N = 116)

Purpose	Percentages (%)
Update your scientific knowledge	78
Enrich your scientific knowledge	76
Prepare students' activities	51
Prepare application exercises	53
Prepare exams	68
Illustration	46

To determine specifically which types of resources teachers most often use to update and enrich their scientific knowledge, a cross-tabulation was done between type of resources and purpose of utilizing these resources (Table 31). The results show that the participating teachers, to a large extent, are using specific websites, online resources and scientific magazines, in addition to books, to update and enrich their scientific knowledge.

Table 31

Resources Used to Update and Enrich Scientific Knowledge

Resource	Update scientific knowledge	Enrich scientific Knowledge
Books	82 %	78%
Specific websites	84%	80%
Scientific magazines	88%	83%
Online resources	82%	82%

Table 32 reveals the reasons behind teachers' use of certain software such as Microsoft Word, PowerPoint, Real Player...etc. The table indicates that teachers mainly use software to prepare exams (88%) or student worksheets (72%) and to show students videos and animations (69%).

Table 32

Purposes for Using Software (N = 116)

Purpose	Percentage (%)
Writing your exams	88
Preparing student work sheets	72
Writing students Grades	29
Calculating averages and ranks	21
Preparing & presenting your lecture	59
Showing your students videos & animation	69

Figure 20 shows the crossing of the type of software used and the purpose of its use. The graph shows that biology teachers particularly use Microsoft Word for preparing students' activities, they use Microsoft PowerPoint for preparation and presentation of their lectures and they use Real Player and animations to show their students videos and animations.

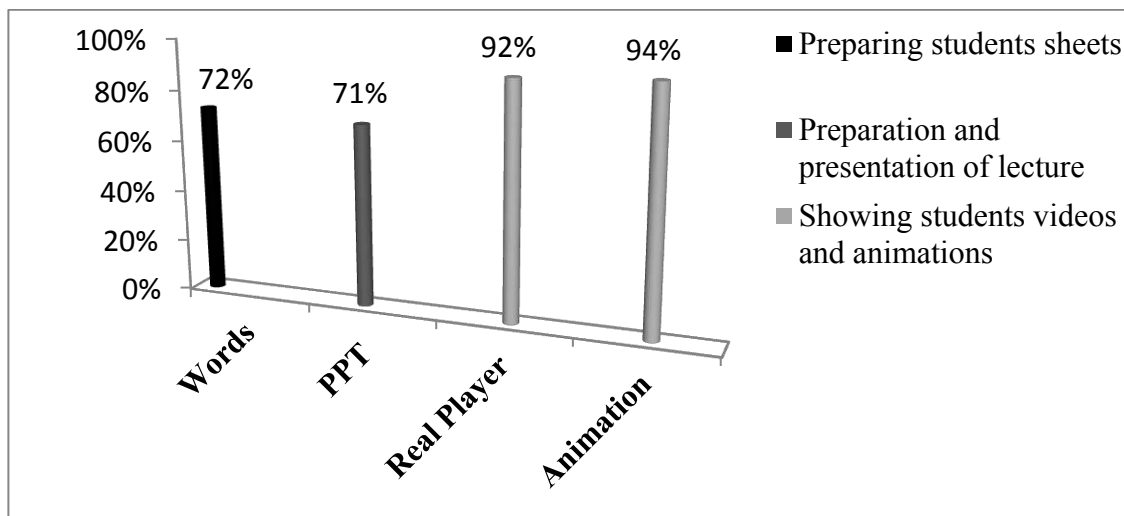


Figure 20. Different types of software used by teachers and the purpose of their use.

In sum, secondary biology teachers mainly use books, then specific websites on the Internet, software, and online resources for their teaching practices. To update and enrich their scientific knowledge they utilize digital resources - specific websites and online resources - in addition to paper resources - books and scientific magazines. Teachers also search for new resources and specific websites on the net and they use Microsoft Word and PowerPoint primarily for preparing students' exams and worksheets in addition to preparing and presenting their lectures; they also use Real Player and animations in their teaching practices. Teachers reported that their reasons behind using resources - particularly digital resources, software and technological tools - is to update and enrich their scientific knowledge, present illustrations and simulations to their students, to motivate students and to initiate their curiosity. The participants selected for the qualitative part of the research generally integrated digital resources (computer, software and technological tools in addition to specific websites and online resources) in their teaching practices.

4.2. Teachers' Use of Resources for Teaching Genetics Concepts

Previous studies have indicated that genetic concepts are difficult and constantly evolving like for instance, the paradigm of epigenetics (see § 2.4.1). The use of illustrative digital resources, like animations and videos, might enhance the

teaching process and the proliferation of Internet resources might help biology teachers cope with the evolution of genetics concepts which in turn might influence the evolution of their conceptions from hereditarianism towards epigenetics. This chapter presents teachers' use of resources, particularly digital resources, for the teaching of genetics concepts in specific. The effects of integration of digital resources in teaching genetics concepts, particularly genetic determinism, on teachers' documentary work and conceptions are studied in chapter V.

Items 23 to 26 of the questionnaire addressed teachers' use of various resources, including digital resources, when teaching genetics concepts as well as the reasons behind their choice of particular resources. Table 33 presents the various sources that teachers use when teaching genetics concepts (item 23). Since this was an open-ended item, teachers' common responses were categorized and then the frequencies were determined.

Table 33
Resources Utilized in Teaching Genetics Concept (N = 116)

Resources	Percentage (%)
Books	48
Specific websites	38
Specific software	35
Others	9

The results of Table 33 show that the most frequently used resources are books followed by specific websites and software. With regard to the books, the common responses were classified into six categories: the national textbook, French textbooks for secondary classes, university books, guides, online books, encyclopedias and others. The percentages of these categories are illustrated in Table 34.

Table 34
Different Categories of Books Utilized in Teaching Genetics Concepts

Categories of books	Percentage (%)
National text book	32
French books	33
University books	24
Guides	8
Online books	1
Encyclopedia	1
Others	6

According to the table, the majority of the secondary teachers are using French textbooks (33%) and/or national textbooks (32%). Thus, teachers mainly rely on students' textbooks for teaching genetics concepts. Since curriculum textbooks are not frequently updated, this may indicate that teachers are not keeping up-to-date with latest advances in genetics concepts.

In relation to websites, the participants mentioned 40 different sites, the names and percentages of which are found in Appendix XVI. The most frequently used search engine is Google (13%) followed by www.Intelligo.com (5%), YouTube (4%) and Pubmed (4%). Based on my personal experience, this might be due to the fact that there are no specific Lebanese educational websites that are publicly available for biology teachers to use to extract scientific information related to the teaching of genetics. This will be further investigated in chapter V based on the deep analysis of the digital resources utilized by the studied cases in this research.

Teachers' common responses related to software utilized were also classified into categories (Table 35). The results show that the participants mainly use PowerPoint, Real Player and Flash Animation software. These results are consistent with the results obtained in part § 4.1.4 emphasizing that the biology teachers use these software in their teaching practices.

Table 35
Different Categories of Software Utilized in Teaching Genetics Concepts (N = 116)

Categories of software	Percentage (%)
Power Point	13
Real Player	10
Flash animation	7
CDs	5
Videos	3
Anagene	1
Active inspire	1
Others	5

In addition, 4% mentioned the use of scientific magazines and 1% mentioned DNA models as other types of resources used in teaching genetics. For the qualitative part of the research, participants were selected from the sample that utilizes digital resources (specific websites and/or software) in their preparation/teaching practices for genetic concepts.

Table 36 presents the purposes for utilizing digital resources in teaching genetics according to the participants' answers. This refers to item 24 of the questionnaire.

Table 36
Purpose for Utilizing Digital Resources in Teaching Genetics Concepts (N = 116)

Purpose	Percentage (%)
To deepen and update the knowledge of the gene concept	69
To look for videos and/or animations that facilitate and enhance teaching of the gene concept	58
To look for activities, pictures and exercises that can facilitate and enhance teaching of the gene concept	66
To motivate and encourage students to search for new resources	58
No answer	14

The percentages of teachers' answers show that digital resources are primarily used to update and deepen scientific knowledge related to genetic concepts (69%) and to look for activities and exercises that enhance the teaching of such concepts (66%). In order to determine which resources teachers mainly resort to for the latter purposes, a cross-tabulation between these two purposes and the types of resources mentioned earlier were done (Table 37). Results show that participants use digital resources - specific websites and software - in addition to books in their preparation/teaching practices for genetic concepts. These results are consistent with the results obtained related to utilization of digital resources in teaching practices in general.

Table 37

Types of Resources Used to Deepen and Update Scientific Knowledge and Look for Activities to Enhance the Teaching of Genetics

Type of resource	Deepen and update scientific knowledge	Look for activities, pictures and exercises that can facilitate and enhance teaching of genetics
Books	80%	84%
Specific websites	80%	84%
Specific software	76%	84%

When teachers were asked to specify criteria they use when searching for new resources (item 25), teachers provided various responses including:

updated knowledge; clear documents; correct and clear information; concepts related to the objectives of the book; can be used in class; does not lead to misconceptions; meets the requirements of the Lebanese curriculum; explains the concepts in an easy way; attractive; valid sites; include educational games...etc.

The complete list is presented in Appendix XVII. These results emphasize what is inferred before about the absence of specific websites utilized by Lebanese biology teachers and shows the need to build such websites dedicated to updating scientific information and teaching methods and to share resources. This was the ultimate objective of DOCENS project that we hope to fulfill one day.

Finally, regarding the open-ended item about the effectiveness of using digital resources in teaching genetics concepts (item 26), 64% of the teachers answered: “yes digital resources enhance and facilitate teaching”. Examples of responses that teachers gave to support their answers included: “the use of animations to facilitate this concept; to facilitate comprehension of students; hard to explain this concept depending on the book only; facilitate communication and exchange of knowledge; fix the ideas and decrease ambiguity; can change the abstract idea into vivid, provide new teaching methods; can enhance the imagination of students...” The complete list is provided in Appendix XVIII. These results show that the teachers believe in the importance of digital resources to enhance the teaching of genetics concepts.

In conclusion, the results of the questionnaire show that a certain number of teachers integrate digital resources in their documentary work emphasizing their importance in teaching difficult and abstract concepts at the cellular level like genetics concepts. These results addressed the question of research related to the integration of digital resources in the teaching practices related to genetic concepts of secondary Lebanese biology teachers. Despite the fact that this sample was not quite representative and cannot be generalized, the quantitative results of the questionnaire shed light on the current status of integration of digital resources by biology teachers in Lebanon. The results showed that biology teachers are specifically utilizing Internet resources to update and enrich their scientific information. In addition, they are utilizing specific software like slide shows, Real Player and Flash animation for illustration, simulation and student motivation.

The four teachers selected for deep case study analysis in the qualitative part of the research integrated digital resources in their teaching practices in general and specifically in teaching genetics concepts. This choice allowed the researcher to investigate the consequences of interactions with available digital resources on teachers' documentary work and conceptions related to genetic determinism of phenotype. This will be the subject of the following chapter, chapter V.

4.3. Comparison of Teachers' Responses among the three Disciplines

This part presents a comparison of the results of specific items of the common part of the questionnaire implemented in the three disciplines, namely, biology, physics and mathematics, in the context of DOCENS project. A total of 317 teachers filled the common part of the questionnaire, 101 were physics teachers, 116 were biology teachers and 100 were mathematics teachers. Based on statistics obtained from CERD, biology teachers constitute 8% of the total number of secondary Lebanese biology teachers, physics teachers constitute 6% of the total number of secondary Lebanese physics teachers and mathematic teachers constitute 4.5% of the total number of Lebanese mathematic teachers of grade nine. The answers of the teachers on specific items of the questionnaire - resources utilized, software used, purpose for using resources, software and technological tools - were crossed in order to infer differences and similarities among the three disciplines. Figure 21 below shows a comparison among the teachers in the three disciplines related to the type of resources integrated in their preparation/teaching practices.

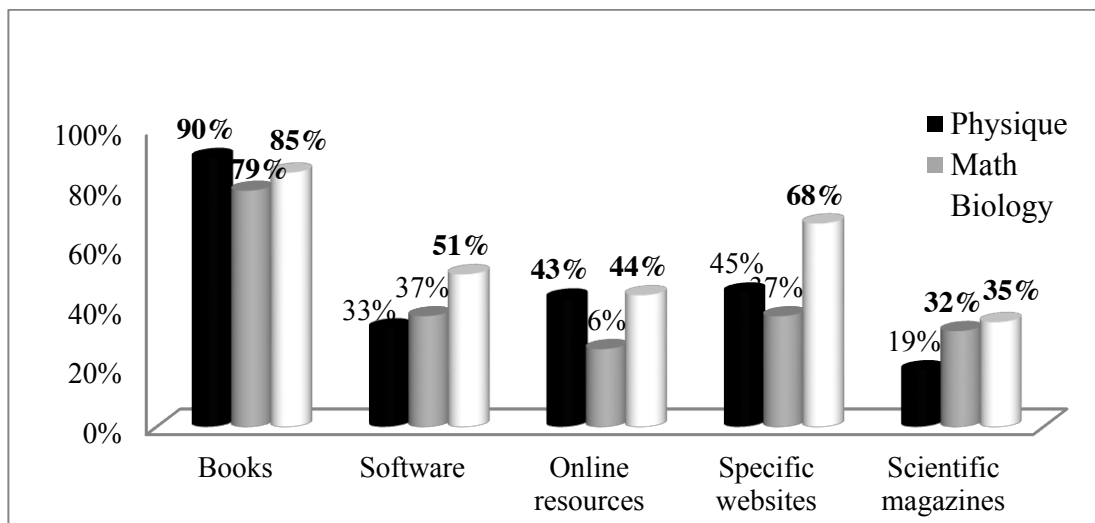


Figure 21. Types of resources integrated in the preparation/teaching practices of physics, math and biology teachers.

The results show that books are still used as major resources in the three disciplines. In addition, the graph indicates that biology teachers use digital resources such as specific websites and software more than math and physics teachers. Moreover, an almost equal percentage of biology (44%) and physics (43%) teachers utilize online resources compared to mathematics teachers. This might be due to the scientific evolving nature of biology which necessitates the updating of scientific knowledge and teaching practices utilizing all *available resources* including digital resources.

Figure 22 compares the types of software utilized in the three disciplines.

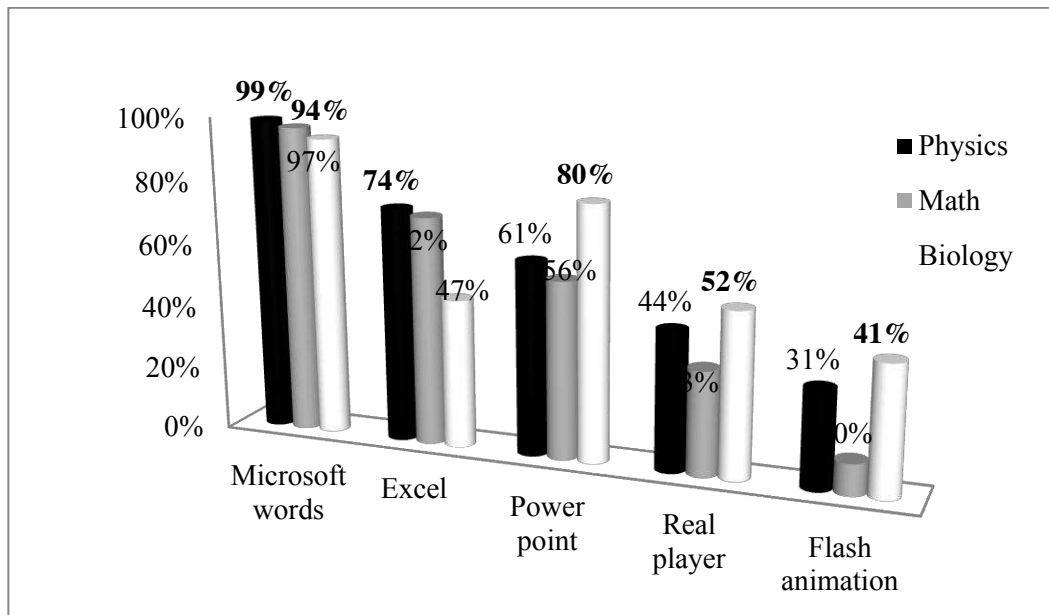


Figure 22. Types of software used in the preparation/teaching practices of physics, math and biology teachers.

Figure 22 reveals that teachers in the three disciplines use Microsoft Word the most often while physics and math teachers use Microsoft Excel more and biology teachers use Microsoft PowerPoint, Real Player and Flash Animation more. This might indicate that biology teachers implement slide shows to present their lecture and use more videos and animations in their teaching practices. This can be explained by the fact that in biology there are lots of abstract concepts that cannot be visualized by students, so these tools may be used for illustration and simulation purposes.

Figure 23 compares teachers' answers related to the purposes for utilizing resources in their teaching practices and Figure 24 compares teachers' answers related to the purposes for utilizing software in their teaching practices.

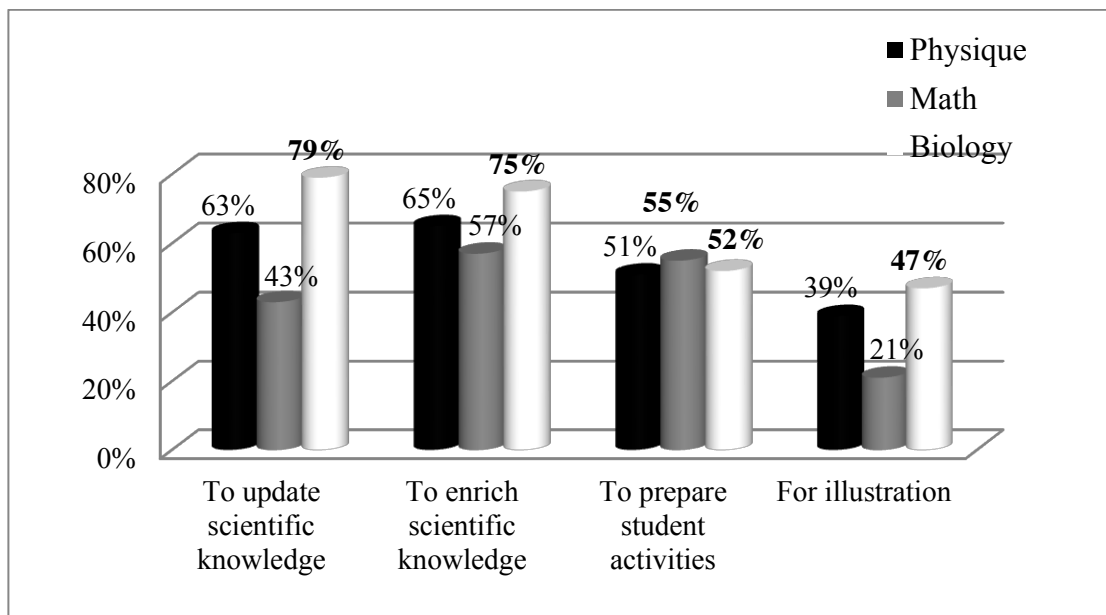


Figure 23. Purposes for integrating resources by math, physics and biology teachers.

After comparing the reasons for integration of resources in teaching practices among the three disciplines, the results obtained confirm the inferences emphasizing the use of digital resources by secondary biology teachers to update and enrich scientific knowledge and illustrate concepts more than math and physics teachers. Also, the percentages of teachers' responses in the three disciplines were approximately similar related to their utilization in preparation of student activities.

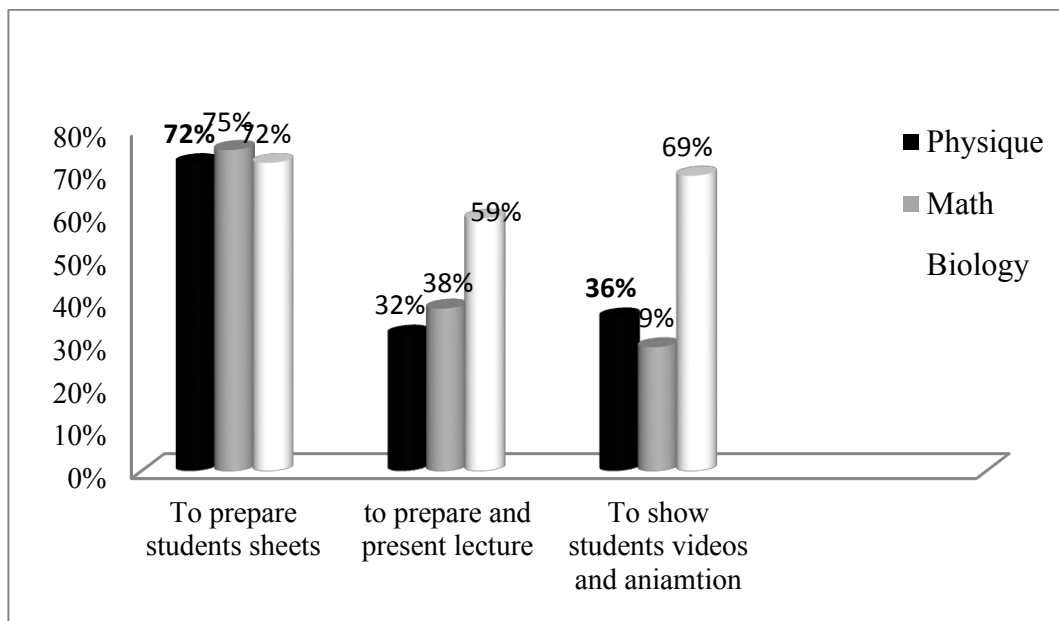


Figure 24. Purposes for utilizing software by math, physics and biology teachers.

Regarding the purpose of using software, results show that teachers in the three disciplines equally use software to prepare students' sheets. However, biology teachers also use them to prepare and present their lectures which may be why they use Microsoft PowerPoint to a large extent as illustrated in Figure 22. Biology teachers also utilize Real Player and Flash Animation software to show their students videos and animations.

Figure 25 compares the purposes for using of technological tools among the three disciplines.

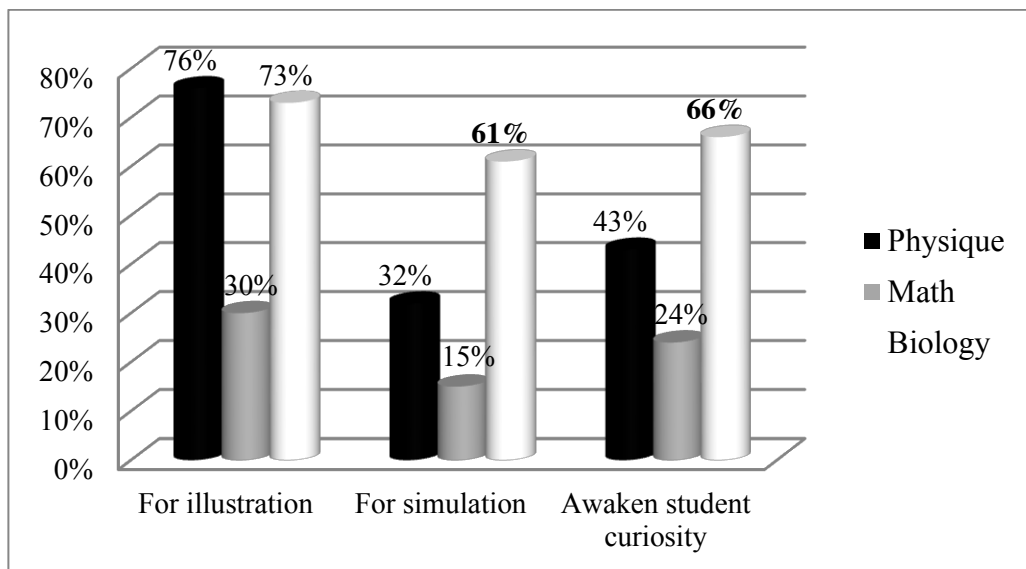


Figure 25. Purpose for utilizing technological tools by math, physics and biology teachers.

Results of Figure 25 show similarities between physics and biology teachers related to the use of technology for illustration. In addition, biology teachers utilize them for simulation more than physics and mathematics teachers which, again, may be due to the fact that there are lots of biological concepts at the cellular level that cannot be visualized or imagined by students. Moreover, they are used by biology teachers to initiate student curiosity and motivation more than physics and mathematics teachers.

In sum, biology teachers similar to mathematics and physics teachers mainly use books as their primary resources for teaching, particularly students' textbooks required by their schools (national textbooks and/or French textbooks). In addition, biology teachers integrate digital resources more than physics and mathematics in order to update, enrich and apply their scientific knowledge. They also use Microsoft PowerPoint for illustration, Real Player and Flash Animation for simulation of cellular phenomena like genetic concepts and Microsoft Word for preparing students' sheets. These inferences will be further investigated utilizing the data collected from the selected cases for the qualitative part of the research (chapter V).

The next chapter presents the analysis of data collected from various tools related to the four selected cases in order to infer any evolution in teachers' documentary work and their conceptions related to genetic determinism as a result of their interactions with digital resources.

CHAPTER V

ANALYSIS OF TEACHERS' CONCEPTIONS ABOUT GENETIC DETERMINISM THROUGH THEIR DOCUMENTARY WORK

This chapter presents the analysis of the documentary work and conceptions of the four selected cases of this study: Maya, Tania, Fadi and Marwa. The documentary works of the teachers were analyzed utilizing the data collected from different tools based on the *documentational approach* (Gueudet & Trouche, 2009). Also, teachers' conceptions were analyzed as interactions between scientific knowledge (K), values (V) and practices (P) according to the *KVP model* (Clément, 2004, 2006). As an articulation between the two frameworks, the *critical resources* mobilized, elaborated or implemented by the teachers and the output of *critical situations* during their documentary work were identified and analyzed based on the *KVP model* to infer teachers' conceptions.

The participants of this research were purposefully selected based on pre-determined criteria (§ 3.1). In particular, they were selected to implement digital resources in their teaching practices in general and in teaching genetics' concepts in specific as indicated by their questionnaire responses (§ 4.1 and § 4.2). During the first year of the study, all four participants were followed while in the second year only Maya and Tania were followed. Similar data collection tools were used for the four cases: interviews, logbooks, and classroom observations. In addition, the two cases that were followed for two successive years were asked to draw a schematic representation of the system of resources (SRSR). *Critical resources* like textbooks, university books, students' sheets and exams, and digital resources mobilized, elaborated and implemented during the observed sessions were collected and analyzed, along with the output of *critical situations* in order to infer teachers' conceptions related to genetic determinism of phenotype. The duration of the follow-up period varied among the four teachers and the data collection tools were implemented at different time intervals (see § 5.1).

This chapter is divided into two major parts. The first part presents a comparison of the documentary works of the four selected teachers in public and private schools during the first year of the study as well as the evolution of the documentary works of Maya and Tania during two successive years (§ 5.1). The second part presents teachers' conceptions related to genetic determinism of phenotype through their documentary work; this was done for each case separately and then a comparison was done across cases (§ 5.2).

5.1. Analysis of the Documentary Work of the Participant Teachers in the Public and the Private Schools

This part presents the analysis of the documentary work of the four selected teachers. Documentary work refers to all professional activities of the teacher outside as well as inside class during the transformation and appropriation of resources for preparation/teaching practices. To analyze the documentary work of teachers, data was collected from various sources including resources: interviews, logbooks, SRSR and classroom observations, in addition to *critical resources*. This section first presents a comparison between the documentary works of Tania and Fadi who teach in the same private school (§ 5.1.1) and of Maya and Marwa who both teach in public schools (§ 5.1.2). Then, the documentary works of the participant teachers in private schools are compared with that of the participant teachers in public schools (§ 5.1.3). Finally, the evolution of Maya's and Tania's documentary work during the two successive years of this study and a comparison between their documentary works is presented (§ 5.1.4)

5.1.1. Comparison of the documentary work of the two teachers in the same private school.

Tania and Fadi have been teaching in the same private school since 2002 under the supervision of the general biology coordinator, Samia. Regular meetings between the teachers and the coordinator are held mainly at the beginning and end of the year as well as during the year. Samia supplies teachers with updated resources including books, mainly updated French textbooks, and digital resources including animations, videos and new software like anagene and phylogene. Collaborative work among teachers in the biology department is efficient in which they exchange and discuss their resources. In the French section, the French program is applied in biology and thus French textbooks are used in all classes except for grades 9 and 12 where the Lebanese curriculum is applied. In those classes, national textbooks are used because students have national exams at the end of the year. The Hachette series is used in grades 3, 4 and 5 and the Bordas series is used for the remaining classes. As for the English section, teachers use booklets translated from the French textbooks except for grades 3 to 5 where American textbooks (the Harcourt series) are used in addition to booklets prepared by teachers from French textbooks.

Tania is the French biology teacher for grades 9, 11 Scientific and 12 Economics. She was followed for two successive years from September 2011 till September 2013. On the other hand, Fadi is the English biology teacher for grades 9 and 11 Scientific. He was followed during the first year from June 2011 till May 2012. Figures 26 and 27 illustrate the time course for the implementation of data collection for Tania and Fadi, respectively. In addition to following these two teachers Samia, the coordinator, was interviewed two times, in June 2012 and December 2012.

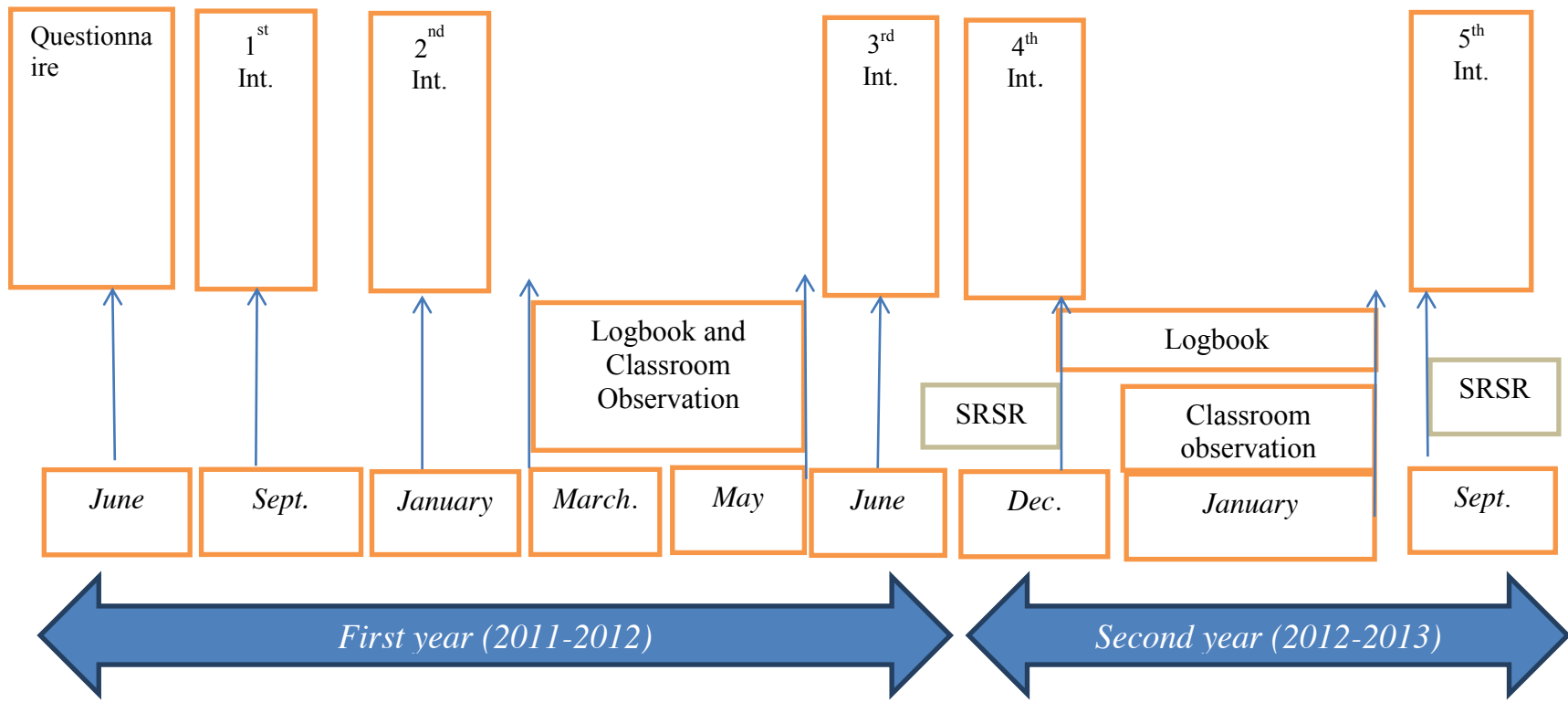


Figure 26. Schema showing the time course of data collection with Tania.

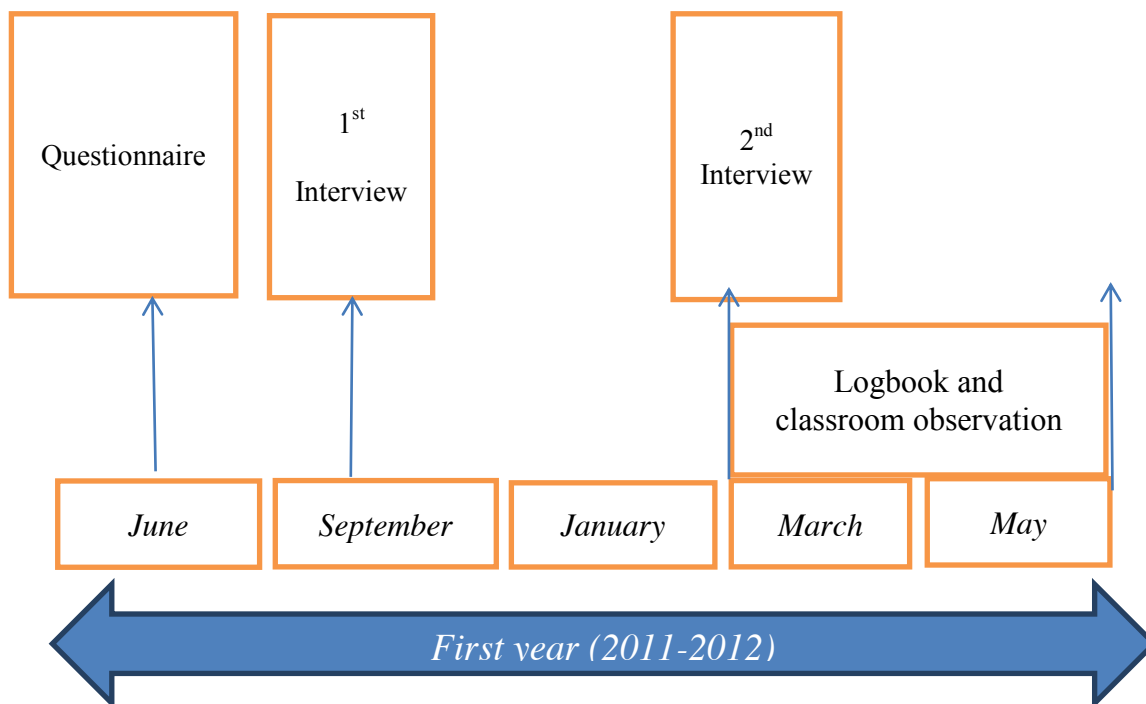


Figure 27. Schema showing the time course of data collection with Fadi.

Comparison of the resource system of the two teachers

First the system of resources (see § 2.1.2) of the two teachers was compared. A resource system includes books, student worksheets, videos, animations...etc., in addition to other resources that can be inferred from interviews, SRSRs and logbooks but cannot be collected like conversations with a colleague or reading an article on the net.

Data collected from the interviews, logbook and SRSR during the first year of research show that Tania relies on her *archive* and textbooks as essential resources in her teaching practices. She uses the students' textbook (Bordas, 2007) and other parallel French textbooks (Hachette, Belin and Nathan) from which she develops documents for extra sheets or exams. She utilizes scientific magazines like "Science et Vie" and "Scientific America" to update her scientific knowledge. In addition, she utilizes a lot digital resources including animations (her favorable digital resource), slide shows and videos from the Internet. Tania considers digital resources crucial

teaching aids that allow students to actively construct information and enhance teaching and understanding of difficult and abstract concepts at the cellular level like genetic concepts.

Throughout her professional career, Tania has built a big *archive* of digital resources through several years of extensive search on the Internet. She saves all digital resources in her *archive* according to topic. Tania spends many hours downloading animations, specifically from the McGraw Hill site (<http://www.mheducation.com>) which is a digital learning company that provides educational content, software and services for pre-K through postgraduate education for educators, students and administrators. In addition to animations, Tania claims that this site is a “*dynamic online resource that contains incisively written, high-quality reference material that covers all major scientific disciplines...it offers links to primary research material*”. This site presents the modern ideas of epigenetics. In the first interview, during the exploration of her resources Tania said:

I have lot of data. I am not obliged to do a research. I have a very big library...when I have time in the summer; I do research and save them in a folder called 'logicial' and classified activities.

This is consistent with what she mentioned in her logbook filled during the first year (Appendix XIX). Analysis of the logbook shows that Tania is constantly manipulating her resources and searching for and elaborating new resources to be implemented in class. Moreover, she adapts her resources according to her students' needs. She implemented, for example, new resources about DNA to review and explain the ideas that students had not previously taken in school. All the resources are implemented to achieve a particular learning objective which Tania mentioned in her logbook. An extract of the logbook is illustrated in Table 38.

Table 38
Extract of Tania's Logbook during the First Year

Activity type	Time	Place	Other persons involved	Resources used	Materials produced	Archiving: What? Where?
Searching for resources on the Internet related to teaching of the gene concept	Many hours for more than one year	Home & school	No	Many sites: McGraw-Hill, youtube and many other sites that I reached by Google search	PowerPoint related to genetic information & DNA. Students work sheets prepared using specific animations on: DNA replication, transcription and translation	Many animation videos and application related to the concept of the gene, Organized in specific folder on my laptop under the title of genetics
Discussion with coordinator	Many periods	Coordinati on room-school	Coordinator and the biology teacher of the English section of Bac I	Exchange of resources With the coordinator and the other teacher	Many digital resources from my archive	Construction of specific sequence to be followed in the genetic part this year: skipping certain ideas we used to give before like enzymes and following the sequence of the French books (as specified in our second interview)

Analysis of the logbook and interviews also shows that collective and collaborative work play an essential role in Tania's teaching practices and documentary work. She exchanges resources with the coordinator and supplies the English biology teacher, Fadi, with digital resources. Tania also discusses with her colleagues the resources, strategies and knowledge to be taught. In addition, she practices collaborative work with the coordinator to search and select resources and strategies to be implemented in class. Tania's collective and cooperative work also extends outside her school.

In order to collect more data related to Tania's system of resources and how she perceives their organization, she was asked at the end of the first year to draw a schema of all resources utilized in her teaching practices and the relationship between them (this refers to the SRSR). Tania's SRSR is illustrated in Figure 28 below. The analysis of her SRSR is based on a specific grid (§ 3.4.4) and is presented in Table 39.

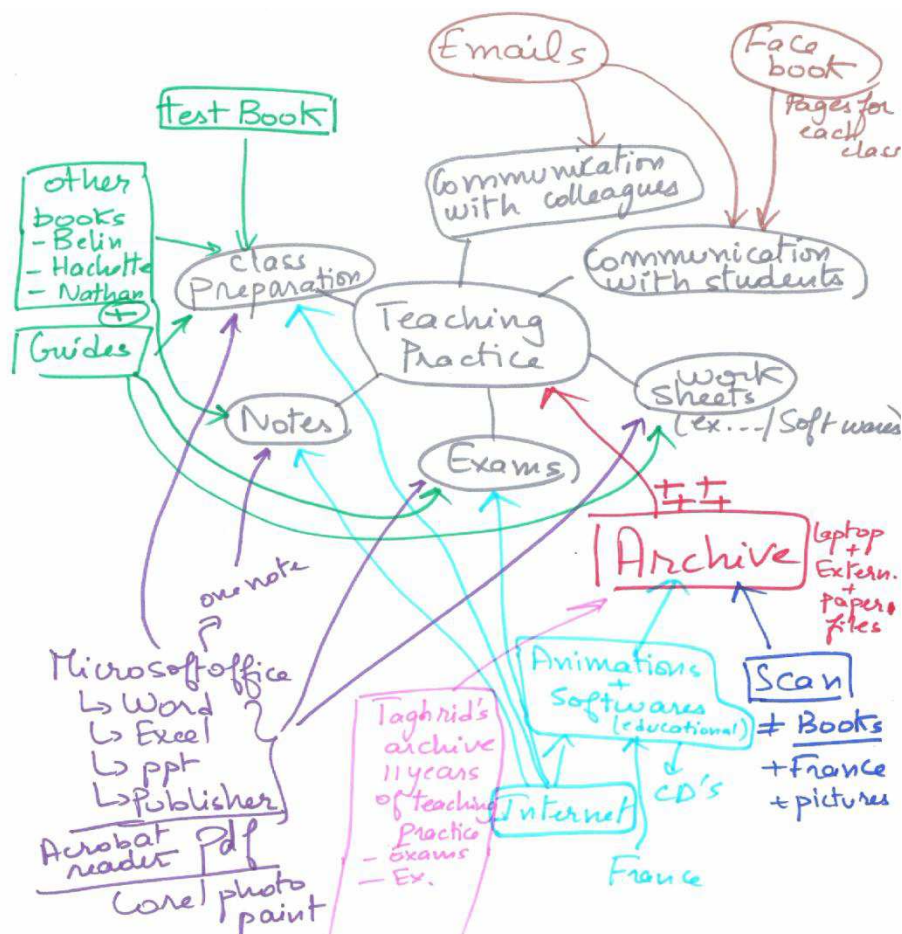


Figure 28. Scan of the SRSR drawn by Tania during the first year.

Table 39

Analysis of Tania's SRSR Drawn during the First Year

Analysis criteria	Tania's SRSR
Order in which the drawing is performed	<p>The teaching practices are drawn in the middle with all resources and activities feeding on it directly or indirectly.</p> <p>There is no hierarchy of resources all are placed around the center, but three +++ are placed on her archive feeding directly on the center, indicating its essential part of her system of resources</p>
The relative importance of each term/ The influenced terms and the influencing terms	<p>According to the drawing of Tania the influenced terms are the teaching practices, class preparation and her archive. The influencing terms of her class preparation are: textbooks (on top), French books, guides, various software and Internet. The influencing terms of her teaching practices are: her archive, her class preparation, her communication with colleagues and students, her notes, her exams and work sheets. The influencing terms of her archive are: her teaching archive for 11 years, animation, CDs and software, scans of books and pictures from France. In addition Internet is drawn as an influencing term on her exams, notes, animation and software; the software are influencing terms on her notes, exams and worksheets; and guides are an influencing term on her notes exams and work sheets.</p>
Grouping of terms/Loops/Reversible reaction between the terms	<p>There is grouping of terms; all terms can be classified into three groups: teaching practices, class preparation and her archive. There are interrelationships between the three groups: class preparation and archive feeding on teaching practices. But there are no loops and no reversible arrows in the whole drawing.</p>
Nature of relationship (strong or weak) and links between terms	<p>The only relation that appears is a causal one between the influencing terms and the influenced terms, as illustrated before.</p>
Resources utilized and their organization	<p>Data of SRSR shows the resources available for the teacher during her preparation practices. In her SRSR she mentioned the textbook, other French textbooks, Guides, archive, notes, exams, students' work sheets, communication with colleagues and students, Internet, animations, CDs.</p>

Analysis of the SRSR shows that her teaching practices represent the center of activities of her documentary work. In addition, the *archive* constitutes a basic resource in Tania's system of resources and it feeds directly on her teaching practices. Crossing the data with the interviews and her logbook confirms these results showing that Tania relies mainly on her *archive* as major *available/mobilized resource*. She stated "*my archive is very big and I rely a lot a lot on it*". According to her, she now has her own library that she can rely on during her preparation/teaching of all the classes and topics she teaches. The SRSR further shows that the Internet is an influencing term in which she built her *archive* from digital resources such as animations and software, CDs, educational software and scans of books from the Institut Universitaire de Formation des Maitres in France (IUFM; University Institute for Teachers' Training/education)., Tania uses these as resources for preparing lessons, exams and notes.

Moreover, Tania uses the web to communicate with colleagues and students via e-mail and Facebook. In fact, she explained during the interview that she has a page on Facebook for each class where she communicates with students and supplies them with resources and links for projects and extra exercises. Considering class preparation as an activity during her documentary work, the resources utilized can be considered as *mobilized resources* in her teaching practices. Students' textbook was located at the top of Tania's *mobilized resources* in the SRSR and was also mentioned in her logbook and used during classroom explanation; thus, the student textbook is considered a critical resource. The sequence of genetics content and the key ideas and sub-ideas related to the topic of research including the relationship among genotype, phenotype and environment (epigenetics) are presented in Appendix XXX. Content analysis of the genetics part of the student textbook is illustrated in the second section (§ 5.2.2) while analyzing Tania's conceptions through *critical resources*.

Thus, the resource system of Tania is very rich containing a big *archive* of *available* digital resources - her library - including all the resources implemented during her 11 years of teaching practices (digital resources, notes, students' worksheets and exams) and French textbooks including students' textbook. These resources can be directly mobilized to elaborate new resources or to implement in class.

Related to the organization of her resources, Tania is highly organized. She saves all her digital resources on her laptop and external hard disc. In addition, all students' worksheets and exercises are printed and saved in paper files. The exploration of Tania's digital resources on her laptop in the first interview showed that she saves all the resources implemented in her teaching practices since 2002 in files classified by academic years (Figure 29) and in each file, they are classified by class (Figure 30). In addition, in each academic year, she has separate files for resources used for coordination and exams (Figure 30). Then, within the files for each class the resources are arranged by topic and chapter title (Figure 31). The file of each chapter contains all the resources implemented, animations, worksheets, sequence, and tests. This highly organized *archive* constitutes the basic part of her system of resources including her *critical resources* for all topics, and this *archive* is constantly revised and renewed.

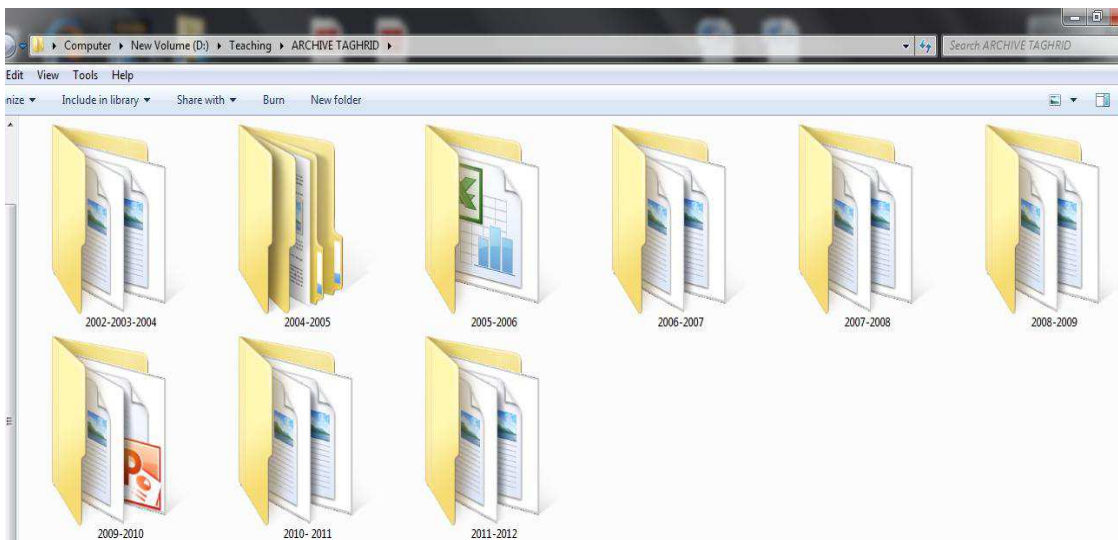


Figure 29. Organization of Tania's archive by academic year.

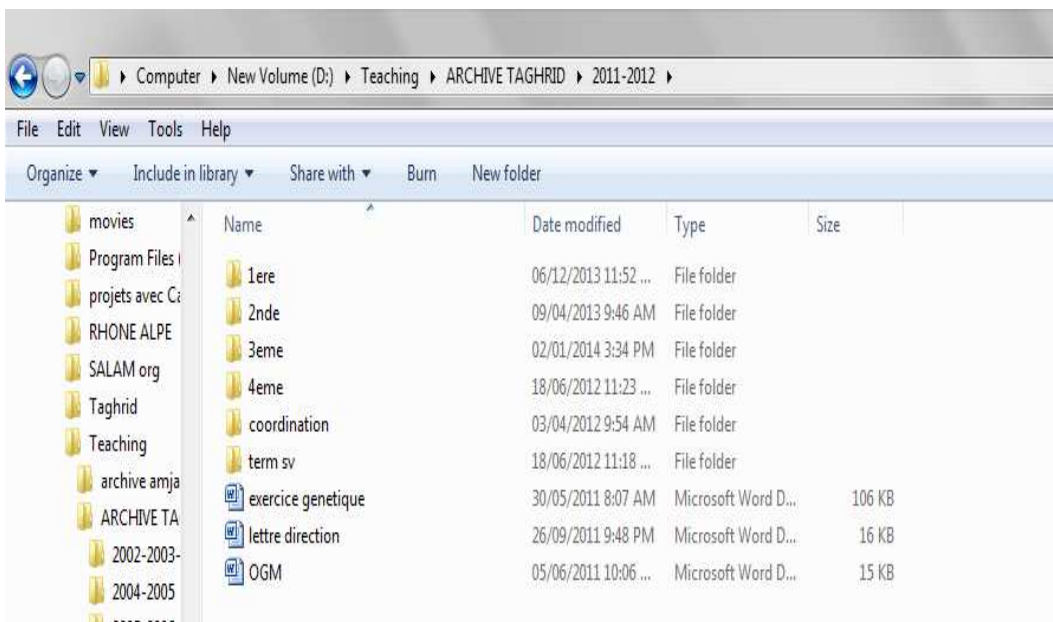


Figure 30. Organization of Tania's archive by class.

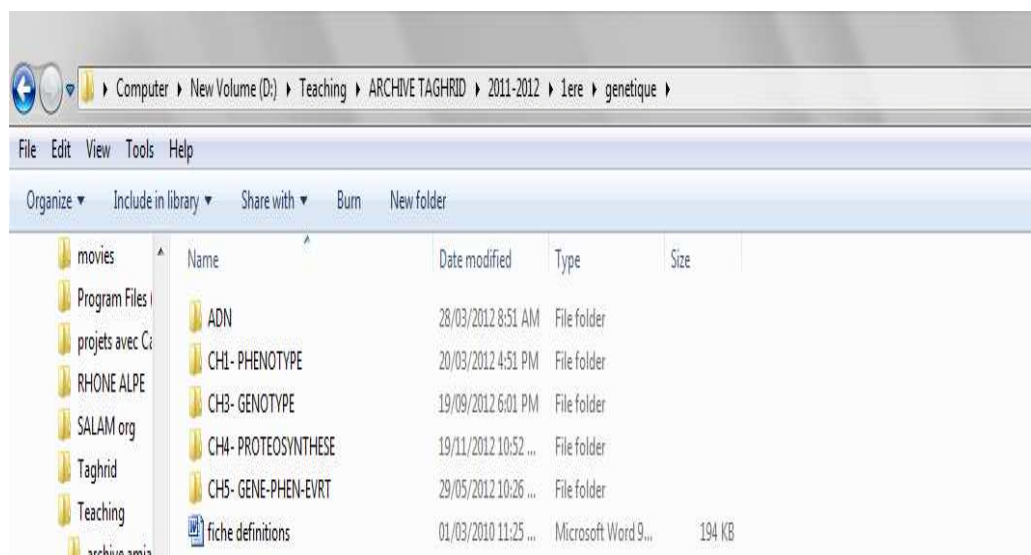


Figure 31. Organization of Tania's *archive* by chapter and topic.

On the other hand, Fadi relies mainly on his professional knowledge and experience, media (National Geographic), scientific magazines (Scientific Americana) and collective work with the coordinator in his preparation/teaching practices. In contrast to Tania, he does not utilize Internet resources to update his scientific knowledge and does not rely on digital resources in his teaching practices. When he is confronted with a confusing idea, he prefers to ask a colleague, particularly the coordinator, instead of searching on the net. This indicates the importance of his collective work with the coordinator to enrich and update his scientific information.

Fadi mainly utilizes textbooks in his teaching practices and prefers hands-on activities. He also has no *archive* of digital resources and he rarely searches for resources on the Internet. Fadi is a very creative teacher whereby he simulates biological phenomena through student activities. He invented a patented game called “*Flip and Guess*” using special playing cards to teach the major ideas in genetics. He also uses dice to simulate gamete recombination during fertilization and he designed card papers with chromosomes carrying alleles drawn on them to show the process of

genetic recombination during fertilization leading to genetic diversity; students can hold these cards and simulate the processes of mitosis and meiosis. According to him, he is able to concretize genetics in class by using these activities in grade 9.

In addition, based on his suggestion, Fadi has been working on projects with students since 2009 for the science fair at the American University of Beirut (AUB). He helps students choose the topics and guides them throughout the whole process. He seemed proud of his work and his students' work. Fadi searches for new ideas to use in his projects from watching TV channels, like National Geographic (media), and from his daily life experiences. However, he does not search the Internet because he claimed that he never finds what he wants and he is not as skilled in searching the Internet. Some of the projects done include models that simulate certain processes while others are researches done by students to test specific hypotheses; they collect data and analyze them. In Fadi's logbook (Appendix XX), he describes a project done with grade 11S students to build a model using the textbook and very simple material to simulate the process of protein synthesis. He argued that this model was a "*simple demonstration for a complex combination*" which will help students understand the process of protein synthesis. This indicates the importance of hands-on activities in his teaching practices. In addition, Fadi rarely searches for new resources to prepare his sessions because the curriculum is the same and he is pressed with time; he only changes the way he delivers the material in class. This is illustrated in the quote below:

Honestly 80% of my session is from my mind...in my preparation very rarely I go back to resources since the ideas are the same but what I try to change in class is the way I deliver the material.

Furthermore, according to him, digital resources on their own have no potential and they are not his priority. During the first interview, Fadi stressed the fact that he is not with technology, as presented below:

For me personally and with my respect to technology, as much as it is facilitating life, it is becoming a load, an overload, that is pushing the teacher's work downward. So hard-working teachers should not be evaluated by how much they are expert in technology, in my opinion. If technology will change the direction of my work and move me away from my objectives, I will refuse it, and I will not take it to class.

Furthermore, cross-analysis of the data collected from interviews and the logbook (Fadi did not draw an SRSR) showed that the most important resource elaborated by him is a booklet for grade 11S. This booklet constitutes his *critical resource* in teaching genetics in grade 11S as illustrated in Table 40 below. It is a combination of documents from the national biology textbook for this grade 11 (Dagher, Hajjar, Safi & Sabeh, 1999), the French textbook, SVT 1^{re} S, Bordas (2007) edition (Lizeaux & Baude, 2007), figures taken from American books and questions and exercises based on his professional experience. The sequence of the genetics content and the key ideas and sub-ideas related to epigenetics are presented in Appendix XXXIII. Content analysis of the genetics part of this book is illustrated in the second section (§ 5.2.4) while analyzing Fadi's conceptions related to genetic determinism of phenotype. In addition to Fadi's use of the above mentioned resources, Samia and Tania supply him with animations from their *archive* of resources related to mitosis, meiosis, DNA replication, chromosomal abnormality, transcription and translation to be implemented in class. Based on these resources, Fadi elaborated questions in his booklet to be answered by students. According to Gueudet and Trouche (2009), development and elaboration of new resources is part of development of teachers' documentary work. So, the elaboration of this resource by Fadi may be considered an evolution in his documentary work.

Table 40
Extract of Fadi's Logbook during the First Year

Activity Type	Time	Place	Other persons involved	Resources Utilized	Materials produced	Archiving: What? Where?	Comments
Discussion of DNA replication	2 periods	Classroom	Students	Documents of my book Animation about DNA replication	Schematic drawing of the process of DNA replication	Animation is kept on my laptop	When I prepared my book I used this animation and I formulated questions about it and place them in the book. So when I explain this part the students will see the animation answer the questions and then we will discuss
Explanation of transcription & genetic code	3 periods	Classroom	Students	Documents of my book & animation about transcription	Schematic drawing of transcription step	Animation saved on my laptop	My book contain questions related to this animation to Be answered by students and then discussed in class

Related to the organization of resources, scrutiny over Fadi's resources on his laptop in the first interview showed that he has a file saved on the desktop titled "Genetics". This file contains the animations taken from the coordinator (mentioned before), a slide show called "Genetics all in one" explaining the game he invented for teaching genetics and a slide show in Arabic about genetics he used when he was training teachers in Kurdistan and the same slide show in English. There is also an animation about gel electrophoresis that Fadi recently downloaded from the Internet. In addition, he mentioned that he uploads videos from You Tube but he does not save them. Related to paper resources, he has prepared student assignments to be solved at home in order to test their skills and competencies.

Therefore, despite the fact that they work in the same school under the same environmental conditions, the major difference between Tania and Fadi is the type of resources implemented during their documentary work. Tania has built a big *archive* of resources, specifically digital resources, while Fadi has an *archive* of paper resources (student activities and assignments and a booklet for grade 11S), very few animations and slide shows prepared for his work outside school. On the other hand, both Tania and Fadi practice collective work with the coordinator.

Comparison of data collected from classroom observations

Analysis of the data collected from Tania's classrooms shows that she implements digital resources in order for students to extract information, make problem situations, allow students to ask questions and formulate hypotheses and synthesize discussed ideas. Thus, Tania utilizes digital resources to implement the investigative or experimental method which requires observation, statement of a problem, formulation of hypotheses...etc. In addition, Tania elaborates student worksheets to be answered after observing animations. In the second session observed, for example, she first showed students videos about a particular concept and asked them to infer information; then she used a slide show she downloaded and edited from the Internet to further explain the scientific information that students

extracted. Moreover, in the third, fifth and seventh observed sessions which deal with DNA replication, transcription and translation respectively, she used two identical animations. After showing them the first animation which contained no audio, she asked students to answer questions on a worksheet and then to ask their own questions or problems. Then, she showed the second animation which contained comments in order for students to find answers to their questions. In Tania's classroom, students are active learners, working in groups or individually, asking questions, formulating hypothesis and extracting information from the textbook and digital resources.

Compared to Tania, Fadi does not implement group work in class; he asks students to answer the questions on a particular document individually. He does not present students with problems or ask them to formulate hypotheses, as Tania does. Instead, Fadi applies the IRE (Initiate, Respond and Evaluate) method in which he asks a question, students answer and then he evaluates students' answer.

As a conclusion, cross-analysis of the data collected during the first year indicate evolution of the documentary work of Tania due to her interaction with resources, specifically French textbooks, Internet resources and her *archive* of resources. In addition, she practices collective work with both teachers and students and collaborative work with the coordinator and associations outside school. Collective and collaborative work plays a central role in Tania's documentary work and has helped her build a system of resources. During her teaching practices, she elaborates new resources to be implemented in class including slide shows, student worksheets and exercises and she has built her own *archive* of resources which constitutes her critical *mobilized resources*. In class she applies student-centered learning utilizing digital resources and students' textbook. Compared to Tania, Fadi does not integrate digital resources in his teaching practices except for animations taken from the coordinator and from Tania. He also applies the IRE method in class rather than the investigative method. Similar to Tania, Fadi practices collective work with Samia and Tania who supply him with resources, animations and French

textbooks. Fadi's documentary work evolved due to interactions with these new resources whereby he elaborated a booklet for grade 11S (critical resource). In addition, the evolution of the documentary work of Fadi was evident from his invention of games and student activities for teaching genetics. He also prepared a slide show about genetics for teacher training sessions. So, Fadi's collective work and integration of new resources caused the evolution of his documentary work.

5.1.2. Comparison of the documentary works of the two teachers in public schools.

Maya and Marwa teach in two public secondary schools in Mount Lebanon and Beirut, respectively. In the Lebanese educational system, the Ministry of Education and its National Center for Educational Research and Development (CERD) oversee the country's national curriculum and textbooks. A CAPES degree offered by the Faculty of Education of the Lebanese University is required for employment in public secondary schools. To be admitted to the CAPES program, students are required to hold a 4-year degree in a subject area taught at the secondary school level such as biology, chemistry, or physics and to pass an entrance examination administered by the Council of Civil Service, a department of the Lebanese Government in charge of employment in the civil service. Public schools in Lebanon follow the Lebanese curriculum and the teachers are obliged to use national textbooks. Moreover, public school teachers can follow sessions prepared by CERD for professional development, but this is not obligatory.

In the two public schools considered in this study, there is no proper coordination or exchange of resources among teachers and there is no collective work. Also, in both schools, teachers have to take students to the IT room or computer room in order to use digital resources. Assuming that the conditions of the working environment are similar in the two public schools, the documentary work of the two teachers, Maya and Marwa, was compared. Marwa was followed for one year from September 2011 till June 2012. Figure 32 shows the time course for collecting data from Marwa.

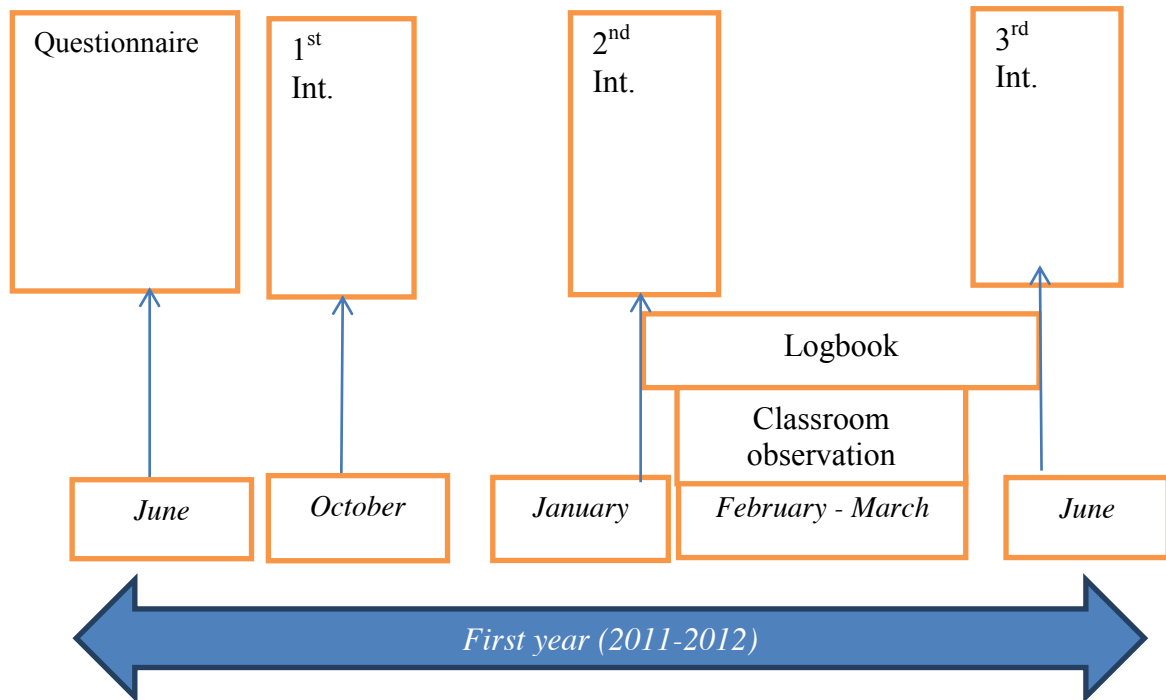


Figure 32. Schema showing the time course of data collection with Marwa.

Maya was followed for two consecutive years, from September 2011 till October 2013. Figure 33 illustrates the time course for the implementation of data collection with Maya.

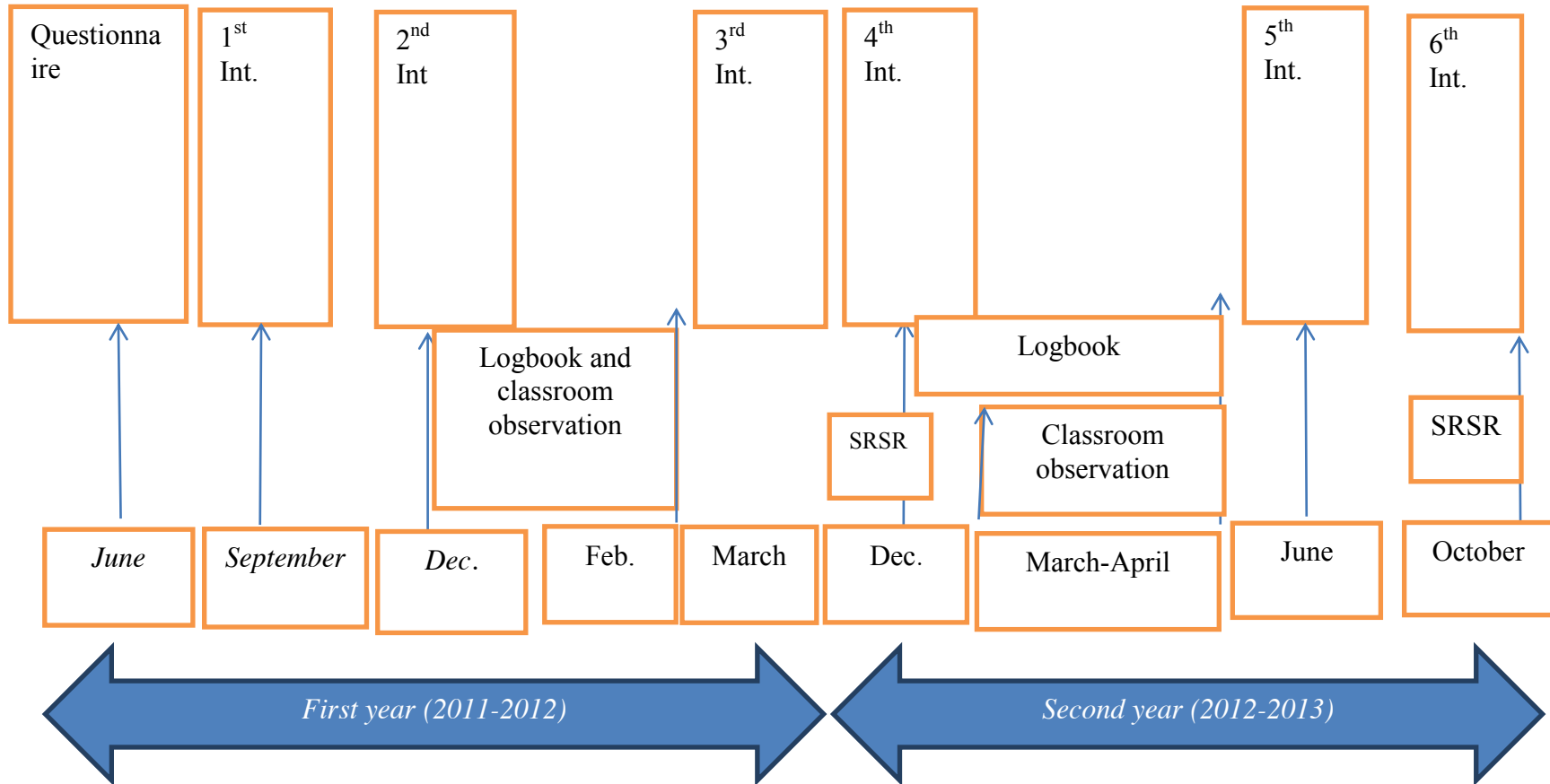


Figure 33. Schema showing the time course of data collection with Maya.

Comparison of the resource system of the two teachers

To analyze the system of resources, the data collected from interviews, SRSRs, and logbooks during the first year were exploited.

Data collected from Maya's interviews, logbook and SRSR show that she uses a combination of digital and paper resources for her preparation/teaching practices. She mainly uses textbooks, national textbooks and university textbooks, in addition to her notebook and digital resources. Analysis of the SRSR drawn by Maya during the first year shows the resources utilized in her teaching practices, the relationship among these resources and the organization of these resources. Figure 34 shows a scan of the first SRSR drawn by Maya.

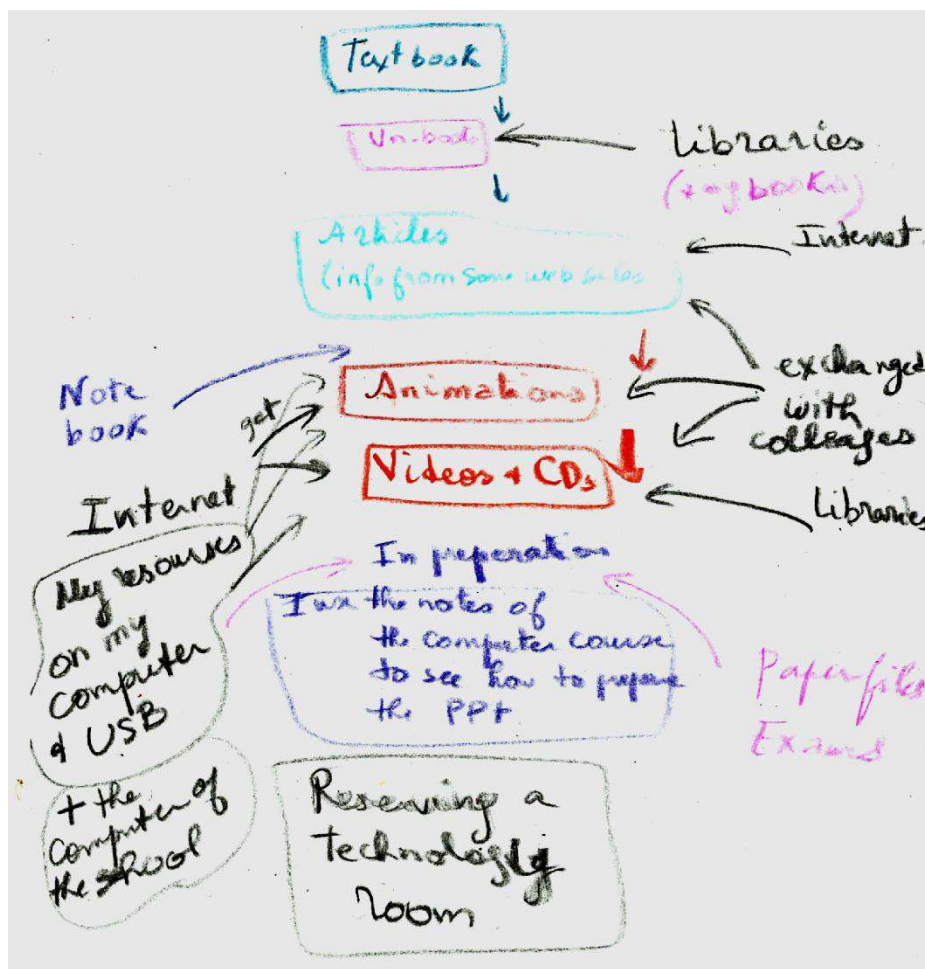


Figure 34. Scan of the SRSR of Maya drawn at the end of first year.

The analysis of Maya's SRSR was done based on a previously developed grid (§ 3.4.4). The analysis is illustrated in Table 41 below.

Table 41

Analysis of Maya's SRSR Drawn during the First Year

Criteria for analysis	Maya's SRSR
Order in which the drawing is performed	The resources are listed in somehow hierarchy, along a temporal dimension. The order shows the textbook on top, then university books, followed by articles taken from Internet or from colleagues and at the end animations, videos and CDS.
The relative importance of each term/The influenced terms and the influencing terms	According to the drawing of Maya the influenced terms are the resources utilized in her preparation (Textbook, university books, animations...) and the influencing terms are the origin of these resources.
Grouping of terms/Loops/Reversible reaction between the terms	There is no grouping of terms, no loops, no interactive arrows and no reversible arrows in the whole drawing. Only linear arrows are drawn showing the origin of the resources she utilized in her teaching practices and hierarchal arrows showing the resources utilized in her preparation.
Nature of relationship (strong or weak) and links between terms	The only relation that appears is a causal one showing the origin of the resources mentioned, for example, exchange of resources with colleagues are the origin of some articles, animations, videos and CDS.
Resources utilized and their organization	Data of SRSR shows the resources available for the teacher during her preparation practices. In her SRSR she mentioned textbook, university books, notebook, animations, videos and CDs that she get from Internet, exchange with colleagues, libraries and the archived resources on her computer, USB and computer at school.

Analysis of Maya's SRSR shows a hierarchy of the list of resources she uses in her teaching practices. Consistent with the results of the interviews and the logbook, the SRSR shows that the national textbook (CERD, 1999) is one of her essential resources as it is mentioned at the top of her list of resources. Thus, it is a *critical resource* for Maya. The textbook contains a section on genetics entitled

“Functional Characteristics of Living Things at the Cellular Level”; the first sub-part “Biological Identity and Genetic Information” is composed of four chapters related to the topic of this research. The sequence of the genetic contents and the key ideas and sub-ideas related to the topic of research are presented in Appendix XXXII. Content analysis of the genetics part of this textbook is illustrated in the next section (§ 5.2.1.1) where Maya’s conceptions related to genetic determinism are analyzed through her *critical resources*.

Another *critical* resource she uses, according to the SRSR, is university books, specifically one by Solomon, Berg, Martin and Villee (1996), which she uses to complement her paper resources by getting extra scientific information. She also uses new books from libraries, her notebook and articles from websites. In addition, she uses digital and online resources such as animations, CDs and videos from the Internet. In fact, Maya recently (since 2009) started using animations and videos from the Internet to illustrate the scientific ideas of the textbook in order to enhance and facilitate the teaching of difficult concepts like the gene concept. According to Maya, the Internet is the main resource she currently uses to search for animations as she said in the first interview: “*I mainly use the Internet and educational websites, they have animations*”. For this purpose, she installed a special program called webzib that allows her to download and save animations to be implemented in class since they do not have Internet access in classrooms. During and after her CAPES studies in 2010, she started elaborating PowerPoint slide shows with hyperlinked videos and animations about translation (2010) and the genetic program and its expression (2011).

Moreover, before 2010, Maya did not practice any collective or collaborative work outside or inside school. However, during CAPES, she collaborated with her colleagues at the university to develop projects such as Active Inspire projects about photosynthesis and stem cells and she exchanged digital resources, like videos and animations, with them. In 2011, she also started to exchange resources with her colleagues at school, particularly with the French biology teacher. This indicates that

collective and collaborative work with her student colleagues enhanced her documentary work. This is coherent with Hammoud (2012) and Sabra (2009) who highlighted the potential of collective work for teachers' documentary work and their professional development.

Her use of various resources is also evident in the professional activities mentioned in her logbook (see Appendix XXII) when she prepared a PowerPoint presentation related to genetics. To prepare this presentation she searched for resources on the net, used university textbooks and exchanged resources with her colleagues. The extract of the logbook presented in Table 42 below shows that she utilizes the national textbook, Solomon book in addition to Internet resources in her preparation/teaching practices. Further analysis of the logbook also shows that Maya spent long hours searching for resources on the net and selecting resources taken from her colleagues and from her *archive* in order to elaborate a new resource to be implemented in class. This instrumentalization process provides evidence of the evolution of Maya's documentary work through collective work and through integration of various sources.

Table 42
Extract from Maya's Logbook during the First Year

Activity Type	Time	Resources Utilized	Materials Produced	Archiving: What? Where?	Comments
Preparation of lesson plan	About 2 hours	The book of life science Bac I and the book 4 th edition " Solomon ", chapter 4	A lesson plan and a work plan made to achieve the objectives	In the teacher's copybook for preparation	The lesson plan includes general and specific objectives
Preparation of a PowerPoint for transcription and translation	About 15 hrs	Biology book Solomon , 4 th edition. Internet resources	A PowerPoint for the explanation of transcription and translation	PowerPoint on computer and flash memory	The PowerPoint succeeds in presenting information with videos to students but it is not sufficient to over-rely on PPT to explain this hard concept.

Based on a careful analysis of Maya's paper and digital resources, I realized that she elaborated personal resources to be implemented in class utilizing books and digital resources. Maya has built an *archive* of resources, particularly paper resources, related to many topics in different secondary classes. Lately, after her CAPES degree (2010), she elaborated new digital resources related to specific topics that are considered difficult for both teachers and students, like genetics and neurophysiology. For other topics that need more illustration of scientific information, she prepared courses mainly using books and sometimes pictures from the net.

With regard to Maya's organization of resources, the first exploration of her laptop in September 2011 showed that her digital resources are saved on her desktop in three files: 1) File containing her *archive* of digital resources (exams, projects done in CAPES and university, courses, downloaded resources for various topics). These files are organized by topic; 2) File for videos and animations of different topics downloaded from the net or taken from colleagues; and 3) File for PPT presentations created by Maya about plant organs, translation and the brain. All these resources are saved on her USB and the digital resources to be implemented in class are saved on the school computer. Figure 35 illustrates the organization of Maya's digital resources on her desktop.



Figure 35. Organization of Maya's digital resources on her desktop

Therefore, Maya's *archive* of digital resources is not well organized since everything is placed in one file (Maya file). Moreover, the documents in this file are not organized and they are mainly titled by topic. However, her newly elaborated PPT slide shows for specific lessons are saved in one file and can be easily reached. This indicates that Maya has started to build her own *archive* of digital resources, utilizing mainly Internet resources, resources exchanged with her university colleagues and resources from her *archive*. In addition, she started editing her paper resources by adding figures downloaded from the Internet. All these new resources are saved in specific files inside Maya's file on the desktop on her laptop. This indicates evolution in Maya's documentary work.

On the other hand, analysis of the data collected from the first interview with Marwa shows that she utilizes national textbooks, university books, and digital resources in her preparation/teaching practices. In addition, she has an *archive* of digital resources, mainly slide shows with animations and videos downloaded from the net for many topics and for different classes. For instance, Marwa prepared a CD for students of grade 11S and a slide show related to immunology and neurophysiology for grade 12 Life Science. According to what she said in the first interview, she renews and edits her slide show when she finds something new:

Every year I renew the same PPT. The first time I did for immunology, I did it in a way then I saw something that I like I put, then you see that you should organize, I remove this and that, and add others. I continuously update and add new things...if I found things better than the old ones I change.

Marwa claimed that digital resources are important for updating her teaching practices in addition to communicating with students. In fact, she made a group on Facebook for her students in order to share with them important resources, videos, documents, exercises, solutions for exams and grades. Compared to Maya, she seemed more technologically competent in which she was capable of manipulating digital resources and implementing them in various aspects of her teaching. For

example, the CD prepared for grade 11S students contain slide shows, animations and videos for basic genetic topics such as cell cycle, DNA, cell cytology, plant and animal mitosis and protein synthesis. The slide show contains animated diagrams, figures and videos prepared by her in addition to scientific information from the net to further illustrate the ideas of the textbook, like Meselson and Stahl's experiment of DNA replication, mitosis, transcription and translation. Her use of digital resources for enriching scientific information is an indication of the evolution of Marwa's documentary work.

Marwa practiced collaborative work with her grade 11S students where they built a model for DNA and used it to simulate the processes of DNA condensation and DNA replication. They presented this model in the science fair at AUB and in the science exhibition at the Lebanese University. She searches on the net for activities that can be implemented in class and emphasized on one important site from which she downloaded lesson plans and hands-on-activities: www.lessonplansinc.com. She mentioned that this site "*offers life and physical science teachers' curriculums that are aligned to State and National standards. It is a high school science education resource*". This site also offers biology lesson plans, free formative assessments and classroom management strategies. The biology lesson plans offer experiments and labs, activities, worksheets, tests and quizzes, web quests, multimedia and research. The genetics part of these lessons also includes modern ideas like gene regulation and epigenetics. Content analysis of these resources is presented in part (§ 5.2.4).

In her logbook (Appendix XXI), Marwa mentioned that she searched on the Internet and found an interactive blog about DNA and epigenetics on the following site: www.eyendna.com. She downloaded from this site a post illustrating 100 facts about DNA. She then copied the information on a word document and distributed it to her students who were asked to check the facts they already know and cross the facts they did not know. By doing so, Marwa claims that students will learn more about DNA. In addition, she downloaded from You Tube a rap song about DNA structure and asked the students to memorize it. According to what she mentioned in

the logbook: “*By memorizing the song the students will learn the DNA structure and have fun at the same time*”. In addition, she mentioned in the logbook that using hands-on-activities or digital resources will allow students to understand. This indicates that Marwa is applying new teaching strategies based on student-centered learning using Internet resources and other elaborated digital resources. Table 43 shows an extract of Marwa’s logbook.

Compared to Maya, Marwa also implements digital resources for emphasis and illustration after explaining a lesson using the documents of the national textbook which is also considered as an essential *critical* resource for her as indicated by her logbook and interviews. According to Marwa, digital resources can facilitate teachers’ work a lot and they can be used for simulation to facilitate students’ understanding. She stated that “*digital resources prevent the waste of time and allow the acquisition of ideas in a nice way and faster; it is interesting and active for students*”.

Similar to Maya, Marwa said that there is no proper coordination and no exchange of resources in her school. However, she sometimes exchanges resources with university professors. This indicates that collective and collaborative work with her colleagues is not essential in her documentary work. Marwa practices collective work only with her students inside and outside school to elaborate models and projects.

Related to organization of resources, results showed that Marwa’s *archive* of digital resources are organized and saved in files on her desktop titled by class. For each class she prepared slideshows and animations mainly for illustration and simulation purposes. In addition, she prepared copies of CDs for students containing the slideshow, animations and videos to be implemented in class. Marwa has an *archive* of digital resources saved on her laptop and hard disk that is also considered essential in her teaching practices.

Table 43

Extract from Marwa's Logbook during the First Year

Activity Type	Time	Resources Utilized	Materials Produced	Archiving: What? Where?	Comments
Constructing DNA model, simulation of condensation of DNA	1 period	Activity downloaded from Internet Site: www.lessonplansinc.com	DNA model constructed by students	The model was kept in class	On the model directly the students simulated the process of DNA condensation by coiling the DNA molecule on their friend representing the histones
Explanation of DNA replication	2 periods	Documents of the textbook PowerPoint about replication And video about replication	Schematic drawing of the process of replication	PowerPoint and video are saved on my laptop and on CD	Simulating the experiments of DNA replication using digital resources allows the students to understand the semi-conservative process of DNA replication

In conclusion, both teachers still rely on the national textbook to teach genetics; however, they use other resources, particularly digital resources, to complement and further illustrate the concepts covered in the textbooks. Maya is now in the phase of building her *archive* of digital resources utilizing Internet resources and resources exchanged with her colleagues. On the other hand, Marwa has already built an *archive* of digital resources that she constantly revises and renews. She also uses Internet resources to renew her teaching practices.

Comparison of data collected from classroom observations

Data collected from classroom observations emphasized that Maya implemented digital resources to further elaborate and illustrate the scientific information found in the national textbook. For instance, she used a simulation to show the process of protein synthesis that occurs at the cellular level and therefore cannot be easily visualized or imagined by students. Thus, Maya's objective for implementing digital resources in class is to illustrate textbook ideas, which are usually not comprehensive, in order to enhance and facilitate the teaching/learning process of difficult concepts including genetics. In the classroom, students are not asked to extract information from the digital resources. In fact, the classroom rarely involved student-student discussions in which Maya applied the IRE type of discourse in order to check whether or not students acquired the required knowledge. Therefore, Maya did not apply student-centered teaching/learning strategies while implementing digital resources.

Similarly, during the first observed session, Marwa applied the IRE method in which she asked students to answer specific questions related to protein synthesis and the importance of proteins in our body. After explaining the lesson using students' national textbook, she implemented digital resources for illustration and to enhance students' understanding. She tried to infer from students' answers if they understood the process. The teaching style in this session was not student-centered. However, in the second observed session, Marwa allowed students to work in groups on an

activity she downloaded from the net. Students worked in groups of four to simulate the process of protein synthesis. She glued on the board a paper representing the nucleus with genes of varying DNA sequences. On students' tables, she glued a paper representing the cytoplasm with amino acids (t-RNA) and she provided students with a table of the genetic code. Each group was supposed to turn in a polypeptide chain to the teacher and then the teacher corrected them and gave students bonus points for their work. Applying student activities can be considered an evolution in Marwa's teaching practices towards student-centered learning and this might lead to an evolution in her documentary work.

In sum, cross-analysis of all the data collected from the various methodological tools during the first year of research indicated several important findings. First, it was evident that Maya's documentary work was in an evolutionary state in which she changed from resource user to resource producer. She elaborated courses and extra notes for students to illustrate and complement the genetics concepts tackled in the national textbook. In addition, her documentary work was progressing due to her interaction with resources, particularly Internet resources, her collective work with university colleagues and her development of technology skills that she acquired during CAPES in 2010.

As for Marwa, her interaction with resources, particularly Internet resources, allowed her to apply new teaching strategies in class by applying student activities. These resources also helped her elaborate her own digital resources such as slide shows to be implemented in class for the same objective as Maya, simulation of biological processes and phenomena and to facilitate and enhance teaching and learning practices. What distinguishes Marwa from Maya is her collective work with students outside school via Facebook and projects. Thus, the interactions with digital resources in both cases led to evolution in their system of resources and documentary work.

5.1.3. Comparison of the documentary work of the participant teachers in public schools versus the participant teachers in private schools.

Teachers in secondary public schools in Lebanon share the same institutional environment. They have the same accessibility of technological tools, coordination, and availability of resources and they use the same curriculum and students' textbooks. As for many private schools, technological tools are usually more available and accessible, there is efficient coordination, availability of resources, freedom to use any textbooks, and more exchange of resources and collective work between teachers. Due to these differences between some public and private schools, a comparison between the documentary works of teachers from both types of schools was done.

Availability, accessibility and integration of digital resources

Policies and teaching strategies in many private schools nowadays focus on the integration of digital resources in the teaching-learning process while teachers in public schools abide by the Lebanese curriculum which does not emphasize the integration of technology (Mounsef, 2005). In the two public secondary schools where Maya and Marwa were observed, technological tools are available but they are not easily accessible for teachers. In Maya's SRSR, reserving the technology room was mentioned as a condition to implement the use of digital resources. While in the private schools of Tania and Fadi, all classes are equipped by white boards and LCDs and are accessible for teachers.

Analysis of the results of the study shows that despite the availability and accessibility of technological tools, the extent of integration of digital resources varied between the two teachers in the same private school. The English biology teacher, Fadi, rarely integrates digital resources in his teaching practices and does not search for resources on the net because of his weak ICT skills. Fadi did not take ICT courses in university and did not attend any ICT training sessions. He believes that, on their own, digital resources do not have potential and thus are not his preferable

teaching tools. In class, he implemented few animations related to genetics given to him by the biology coordinator of his school. On the other hand, the biology French teacher, Tania, is more technologically competent due to her university studies as well training sessions and therefore implemented digital resources in almost every session. At the same time, the institutional practices of the private school and the efficient collective work allowed both Tania and Fadi to elaborate their own resources which might be considered an evidence of evolution of their documentary work.

For the case of Maya, the teacher in the public school, the integration of digital resources in her teaching practices started mainly after CAPES (2010) where she took a technology course on how to integrate ICT in teaching and acquired the required technological skills. Maya did not take ICT courses in university nor attended any ICT sessions in CERD during her in-service professional development. This explains the turning point in the documentary work of Maya towards the integration of digital resources in teaching genetics as well other topics. This is consistent with the results of the study of Abed-El-Khalick (2005) which emphasized that teachers should be trained to master technology and should develop positive attitude towards technology in order to be able to use it efficiently with their students. Marwa's interaction with Internet resources allowed her to update her scientific knowledge and to integrate new resources such as animations and videos into her teaching practices. Similarly in the case of Marwa, her interactions with Internet resources allowed her to update her teaching strategies and to renew her resources.

In sum, results show that technology is more accessible and available in the private school than in the two studied public schools. Nonetheless, it is evident that the integration of technology in teaching does not only rely on the availability and accessibility of technology, but rather on teachers' attitudes toward and skills in technology integration.

Types of resources used

In Fadi and Tania's private school, teachers share their resources under the supervision of the coordinator and they benefit from these resources to update their scientific knowledge. Tania uses updated French textbooks and Fadi elaborated a booklet for grade 11S which includes updated scientific information taken from the French textbook. This booklet constitutes his *critical resource* in teaching grade 11S in which he tried to make an adaptation between the sequence followed in the Lebanese program and the French program. Tania, on the other hand, also uses digital resources taken from her *archive* or the Internet as well as scientific magazines to update her scientific information. So, although these two teachers teach in the same private school, they utilize different resources. However, the institutional practices of the school obliged Fadi to update his scientific knowledge following the French program, but this does not necessarily lead to evolution in his conceptions that were affected by his beliefs (*KVP model*), as illustrated in part (§ 5.2.4). Fadi thinks that he knows everything related to the subject matter to be taught. He is also convinced with the sequence of his booklet and in the classroom he does not follow the exact sequence proposed by the coordinator and followed by the French teacher, Tania. He does not have time to update his knowledge and he will only update his knowledge when the curriculum changes. In fact, he said: "*When the curriculum changes and its borders are widening then of course I will widen my information before entering the class*". This might have a negative effect on his documentary work and conceptions. On the other hand, Tania seemed more confident about her scientific information that is based on updated French textbooks compared to the Lebanese national textbooks with DTD, scientific magazines and Internet resources.

In the public schools of Maya and Marwa, there is no exchange of resources and no coordination. In addition, both teachers rely heavily on the outdated national textbook in addition to Solomon book (1996) to illustrate scientific information. In this case, the P pole of the school according to the *KVP model* is not a positive influencing factor on teachers' documentary work and conceptions. Nevertheless, the

proliferation of Internet resources provides teachers with a wide range of *available resources* that can be mobilized in their teaching practices. Both Maya and Marwa are integrating digital resources in their teaching practices and they rely on Internet resources to update their scientific information. Maya is convinced that she needs to read more and search for more resources on the net to update her scientific information. Similarly, Marwa is mainly relying on Internet resources to update her scientific knowledge and improve her teaching practices.

In sum, the analysis shows that many teachers in public schools may be inclined to use digital and more updated resources if they believe that this will update their scientific knowledge and improve their teaching. On the other hand, as was the case with Fadi, digital resources will not be used if they are perceived to be futile. Thus, the results again show that despite the culture and practices of the school environment, technology integration at the classroom level depends on teachers' attitudes and beliefs.

Collective work and exchange of resources

In the private school, Tania and Fadi practice collective work with the coordinator and sometimes with each other to agree on the sequence to be followed or to discuss exams. In addition, Fadi practices collective work with students outside school assisting them to prepare projects for science fairs. Tania communicates with both students and teachers via Facebook and e-mail and she practices collective work with students outside school. For instance, she took her grade 11S students to a Thalassemia lab in Beirut and asked them to do a project about the genetic causes of the disease. This collective work has a positive effect on teachers' documentary work which was evident in the case of Tania and Fadi. This coincides with the results of the studies of Hammoud (2009, 2012) about the pivotal role that collaborative work plays in enriching the system of resources of teachers and the study of Sabra (2009) which showed that collective work between teachers lead to the evolution of their system of resources.

Regarding Maya and Marwa who are teachers in public schools, they do not practice collective work with their colleagues in school. This is coherent with what was found earlier that there is more collective work and teamwork among the participant teachers in private schools compared to those in public schools. This was emphasized by the results of the questionnaire which showed that teachers of the studied private schools exchange their resources more than teachers in public schools (§ 4.1.2).

Teaching practices

Another aspect of distinction between public and private school participant teachers is related to teaching practices. Fadi and Maya seemed to follow strategies that do not promote critical thinking but rather focus on students' skills and competencies by applying the teacher-centered IRE method (initiating, response and evaluate). Conversely, Tania implements the student-centered investigative method of teaching by posing problems and asking students to formulate hypotheses. Similarly, Marwa started to implement students' activities in class which concur with student-centered learning. This indicates that despite the institutional practices of some private schools as well as the Lebanese national curriculum that emphasizes student-centered learning, some teachers in both public and private schools are still implementing old teacher-centered strategies.

In conclusion, the comparison between the participant teachers in public versus private schools shows some similarities as well as some differences. Integration of digital resources and teaching strategies seemed independent of school type while exchange of resources and collective work between teachers depended on school type. Moreover, the environmental conditions of the studied private school in relation to availability of resources and technological tools, collective work and interaction with digital resources caused evolution in Tania's documentary work. On the contrary, for some teachers in the public schools where there is an absence of obligatory continuous in-service training sessions, it is mainly the interaction with digital resources on the Internet which allowed the evolution of teachers'

documentary work. These results provide some elements to answer the question of research related to the factors that might influence the integration of digital resources in teaching practices like availability and accessibility of technological tools, teachers' technological skills and beliefs, collective work, interactions with digital resources and institutional practices.

5.1.4. Evolution of the documentary work of Maya and Tania during two successive years.

This part presents elements of evolution in the documentary work of the two teachers that were monitored for two successive years, Tania in a private school and Maya in a public school. The system of resources will be compared to infer new resources implemented in teaching genetics concepts and genetic determinism of phenotype. Moreover, the teaching strategies and adaptation of resources will be compared during the two successive years. First the evolution of the documentary work of Maya is presented (§5.2.4.1) and then the evolution of the documentary work of Tania is presented (§5.2.4.2). Then, a comparison between the documentary work of the two cases is presented in (§ 5.2.4.3).

5.1.4.1. Evolution of the documentary work of Maya.

In order to infer any evolution in Maya's documentary work, data collected from interviews, exploration of her resources, the two SRSRs, and the two logbooks and the observed sessions during the two successive years are compared.

Evolution of the system of resources

Comparison between the data collected during the first exploration of her resources in September 2011 and the second exploration in October 2013 shows that Maya has elaborated new resources, after searching, selecting, revising and editing her *available resources*. Maya's *available resources* include: digital resources (from the net and others), resources exchanged with her university colleagues and the French biology teacher at her school, national textbooks and university books, and her *archive* of resources and notebook. She edited her previously prepared courses by

adding illustrating figures from the Internet and she elaborated a new slide show about neurophysiology consisting of pictures, animated figures, videos and animations from the Internet, scientific information from the net illustrating the ideas of the national textbook and application exercises. In addition, she edited the previously prepared slide show about gene expression by adding new animations. This indicates evolution in Maya's system of resources and consequently her documentary work. This evolution was also evident when comparing the digital resources implemented for three successive years in teaching genetic concepts (one year before the study and two years of the study) as illustrated in Table 44. Analysis of the data shows that Maya has edited her previously prepared digital resources, elaborated new ones and selected new resources to be implemented in class.

Table 44

Comparative Table for the Digital Resources Utilized by Maya during the First and Second Year and the Year before the Research Study

Type of digital resource	Year before the study (2010-2011)	1 st year of the study (2011-2012)	2 nd year of the study (2012-2013)
PPT: “Genetic program and its expression”	-	√	Edited
Animation of translation	-	√	√
Quick time movie about protein synthesis	-	√	√
MP4 video: m RNA translation	√	√	√
Animation about transcription	√	√	√
Movie clip: DNA basics	√	√	-
Quick time movie about mitosis	-	√	-
Quick time movie about transcription	-	√	√
Quick time movie about translation	-	√	√
Quick time movie about translation	-	-	√
MP4 Ribosome in action about translation	√	-	√
Animation about DNA, RNA, protein, endoplasmic reticulum and Golgi bodies	√	-	-
PowerPoint about translation	√	-	-

Cross-analysis of the data collected from Maya’s interviews, logbook and SRSR during the first year showed that she searched for new resources on the Internet, selected resources from her *archive* and resources taken from colleagues

(university and school), and then she combined all these resources to elaborate and design a new digital resource for teaching genetic concepts in grade 11S - a slide show entitled “Genetic Program and Its Expression”. Her elaborated slide show is now considered her *critical* resource for explaining genetics concepts in class; it is written in her second SRSR at the top of her resources prepared at home and circled in red. It was also mentioned in two logbooks and in the interview Maya said: “*My PowerPoint that I have finished this year I will for sure use it next year, it is my best resource*”. In addition, she implemented it for two successive years and is willing to continue using it in proceeding years for explaining genetics. Thus, this new *elaborated resource* is integrated in her system of resources. She elaborated this *critical* resource to explain how genetic information in the form of DNA nucleotide sequences can be translated into proteins (transcription and translation steps) that determine our hereditary characteristics thus applying a linear causal model. The slide show elaborated by Maya during the first year and edited during the second year after its implementation in class shows evolution in her documentary work related to teaching genetics.

A comparison between the two SRSRs, redrawn by the researcher from the initial drawing of the teacher (Figures 36 and 37) was performed (Table 45)

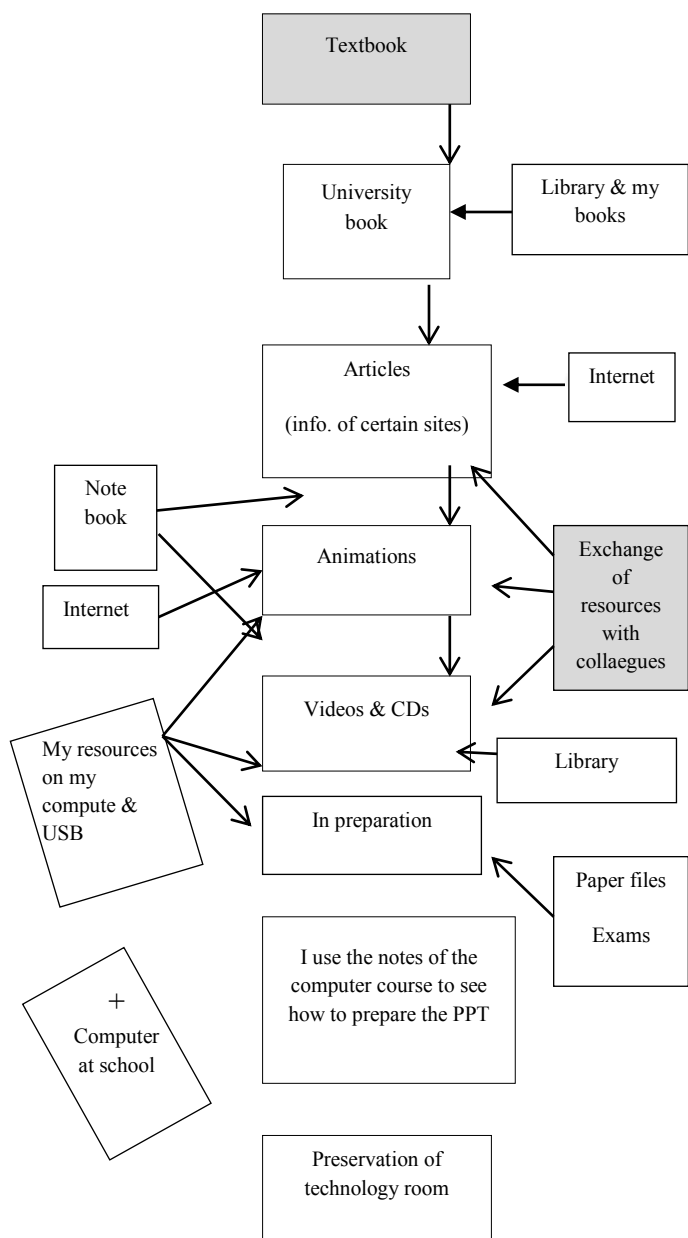


Figure 36. SRSR of Maya first year

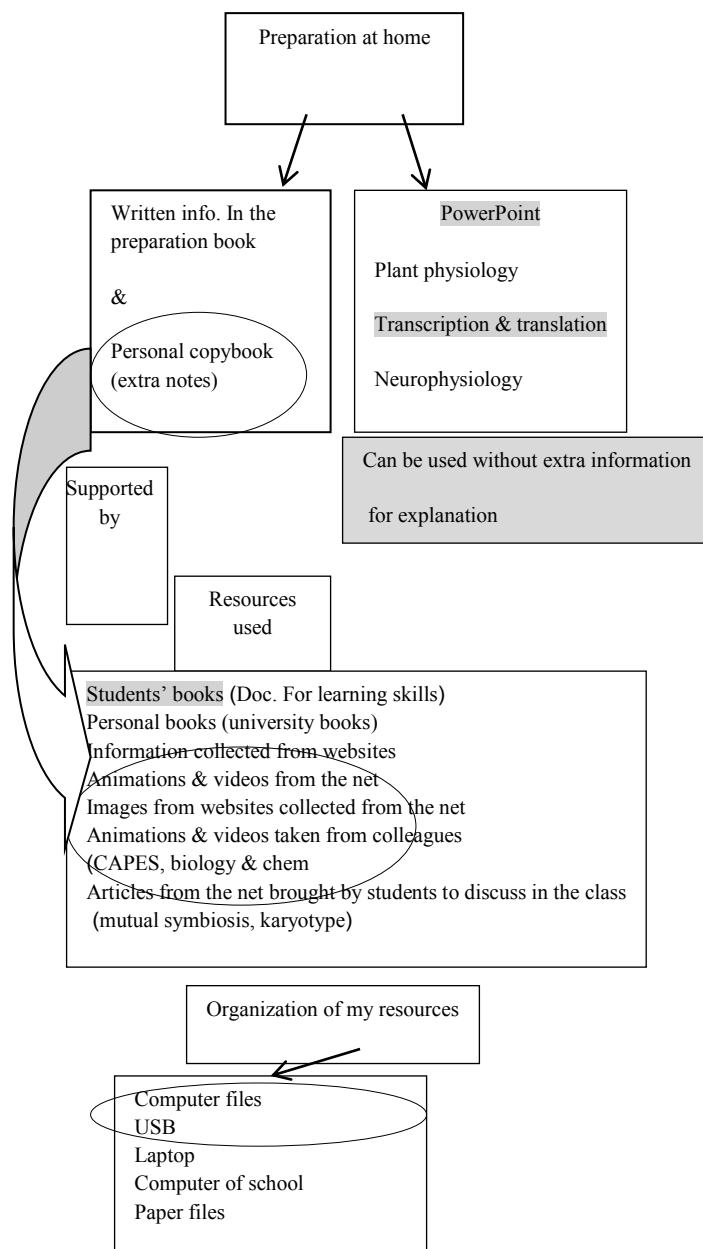


Figure 37. SRSR of Maya second year

Table 45
Comparison between the First and Second SRSR Drawn by Maya

SRSR Elements	Differences		Similarities between the two SRSR
	1 st SRSR	2 nd SRSR	
<i>Available resources</i>	CDs	Slide show elaborated by the teacher	Internet resources; digital resources from her colleagues; digital resources from her <i>archive</i> ; personal notes; textbook and university books.
Linking arrows between resources	Links between resources and arrows showing the origin of resources	Link between personal copybook and animations videos and images from net and colleagues	
Loops and reversible arrows			Not found in the two SRSR
Organization of resources	Not mentioned	Mentioned	Saving of resources on USB, laptop, the school computer, and in paper files.
Resources elaborated by Maya	Not mentioned	Mentioned: PPT	
Collective work	Exchange with colleagues	Exchange with CAPES teacher, biology and chemistry teacher and students	

This comparison shows that Maya has elaborated new slide shows for specific topics such as plant physiology, transcription, translation and neurophysiology that contain all the required information for explanation indicating the integration of digital resources in her teaching practices related to the gene concept as well as for other topics. Moreover, her *critical resources* (circled red in the second SRSR) include her personal notes, personal PPTs (slide shows elaborated by her) and the videos and animations from the Internet and from her colleagues.

The link drawn between the preparation at home, which is an activity done by Maya, and her resources, show that the influenced terms are the animations and videos and the influencing terms are the personal notes. This emphasizes what was inferred before, that Maya uses animations and videos for illustration of the textbook's scientific information. Consistent with the previous SRSR, the analysis shows that she is extracting new scientific information from the Internet. Moreover, the textbook is mentioned as the first *mobilized resource* in the two SRSR as well as in the logbooks and interviews and it is implemented in class, so it is considered a *critical* resource. In addition, the university book Solomon et al. (1996) was also mentioned in the two SRSRs and Maya said in the interviews that she relies on it to illustrate the ideas of the textbook and it is mentioned in the two logbooks. So, this book can be also considered as a *critical* resource for Maya. Thus, the comparison between the two SRSRs emphasizes the collective work between Maya and her colleagues during and after CAPES. In addition, it shows evolution of Maya's system of resources due to her integration of the new elaborated slide show in her system of resources.

Moreover, analysis of the logbook filled during the second year (Appendix XXIII) shows that Maya practiced collaborative work with the French biology teacher and the chemistry teacher in her school. This collaborative work with her school colleagues caused her to edit the previously prepared slide show. This also indicates evolution in the documentary work of Maya. Further analysis of this logbook emphasizes what is inferred from the comparison of the SRSR with the interviews related to the integration of digital resources in Maya's teaching practices in addition to textbooks, her notebook and the university book (Solomon et al., 1996) as illustrated in Table 46. In addition, changing the slide show into Active inspire might lead to changes in her teaching practices to integrate the interactive white board (IWB) and this might consequently lead to evolution in her documentary work. This might lead to changes in her teaching practices causing an evolution in her documentary work.

Table 46

Extract from Maya's Logbook during the Second Year

Activity	Time	Place	Persons involved	Resources utilized
Reading a book	2 hrs	At home	None	A book "Biology 4 th edition" Solomon (1996)
Preparation to show animation videos about transcription		At school	Biology & chemistry teachers	www.johnkyrk.com www.class.uni.com www.transcription.mov www.traduction.mov www.proteosynthese.mov
Preparation of Active Inspire project	10 hrs	At home	None	- Previous PPTs - Previous Active Inspire project prepared by a biology colleague "Sarah" - Websites

It is important to mention that four of the websites mentioned in the second logbook of Maya are not valid since the addresses are incorrect. She wrote them depending on her memory as she said in the 6th interview while discussing the *implemented resources*. The only valid site is: www.johnkyrk.com which is a website that provides animations about animal cell biology. In terms of the relationship between genotype and phenotype, it has animations about transcription and translation showing the direct process of protein synthesis and the fate of the synthesized proteins without mentioning the interaction with environment or the idea of epigenetics. However, on the videos about transcription and translation collected from Maya the following website is mentioned: www.dnalc.org (DNA Learning Center) which is a science center devoted entirely for genetics education; it is an important center for molecular genetics research. Its mission is: "*to prepare students and families to thrive in the gene age*". It provides a library of 3D animations about

cellular and molecular processes such as DNA replication, transcription and translation. Maya utilized the basic animations from this site about transcription and translation having the following addresses respectively: www.dnalc.org/resources/3d/12-transcription-basic.html and www.dnalc.org/resources/3d/15-translation-basic.html. Moreover, surfing the website shows that it contains a blog providing information about epigenetics. In addition, the last resource mentioned in the logbook is a film that is integrated by the following hyperlinks: <http://www.genome.gov/25520211>, http://www.youtube.com/watch?v=_EK3g6px7Ik) on a slide of the PPT elaborated by Maya and implemented in class during the 4th observation in the first year. This movie presents the environmental influence of the genetic determinism reflecting the epigenetic model.

Evolution in teaching strategies

A comparison of the implementation of the elaborated slide show in the classroom during two successive years shows that Maya has adapted her resource based on students' reactions and her teaching strategies. In the second year, she hyperlinked all the other digital resources to be implemented in class on the slides while in the first year they were not organized and they were scattered on her desktop. Moreover, she implemented the videos and animations directly after explaining the ideas and not at the end of the presentation. Finally, she implemented the simple animations about translation before the complex ones based on students' reaction during the first year. This new adaptation of the slide show after its first implementation in class reveals a change in Maya's teaching practices which are part of her documentary work. According to Trouche and Guin (2005) a resource is a living entity that evolves according to use. Figure 38 illustrates the evolution of the slide show elaborated by Maya "Genetic Program and Its Expression" in two consecutive years. This is also consistent with the idea of the life cycle of the document produced from a set of resources as a continuous process as proposed by Hammoud (2012).

Therefore, cross-analysis of the data and comparison between the documentary work of Maya for two successive years shows that she is preparing her personal repertoire of digital resources not only for genetic concepts but also for important topics that she teaches in other classes. She is renewing her resources, *mobilizing* and combining *available resources* to elaborate new resources to implement in class and all these resources are integrated in her system of resources. This can be considered a turning point in the documentary work of Maya towards the integration of digital resources, emphasizing what is inferred before that her documentary work is dynamic and evolving.

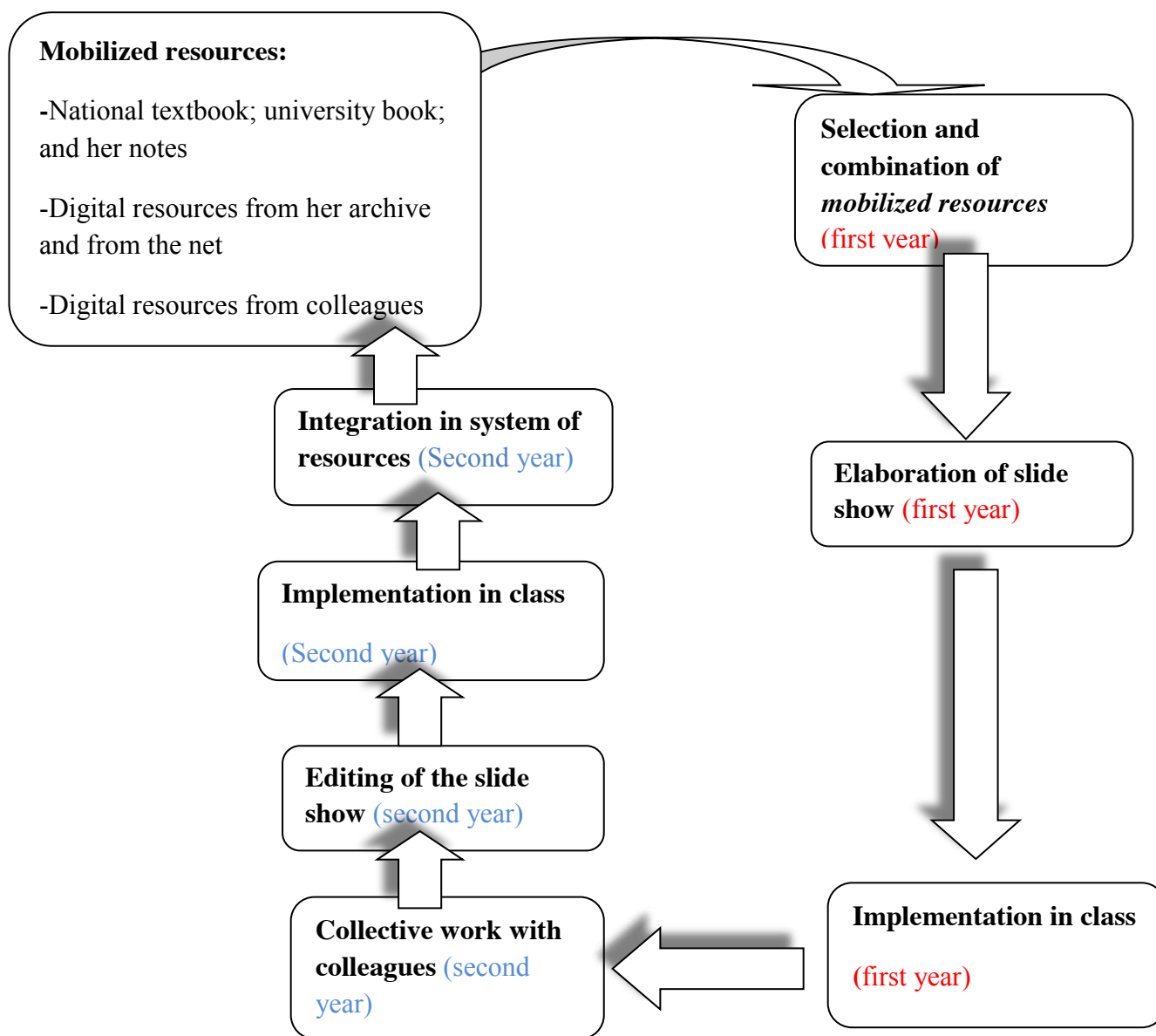


Figure 38. Example of the evolution of a resource elaborated by Maya in two successive years.

5.1.4.2. Evolution of the documentary work of Tania.

This part presents the comparison of the documentary work of Tania during the two successive years to infer any evolution. The analysis utilizes the data collected from interviews, the two logbooks, comparison of the edited SRSR to the original one and a comparison of the system of resources during the two years.

Evolution of the system of resources

During the second year of research, Tania implemented a new updated French textbook, Bordas SVT 1^{re} S, 2011 edition (Lizeaux & Baude, 2011). The fourth interview with Tania during the second year focused on the modifications related to teaching genetics in accordance with the new textbook. Cross-analysis of the data of this interview with the data collected from the second interview with the coordinator shows that the textbook contains new genetics topics that emphasize the interaction between genotype, phenotype and environment. The sequence of genetics content and the key ideas and sub-ideas related to epigenetics are presented in Appendix XXXI. Content analysis of the textbook will be analyzed in part (§ 5.2.2). This textbook was mentioned in Tania's logbook during the second year. Its importance as an updated resource was also emphasized in the interviews and it was used during preparation and in class. Thus, it is considered a *critical* resource for Tania during the second year of research. Tania also used other French textbooks in parallel like Hatier, Belin and Nathan and annals. Referring to what she said, she utilizes these additional textbooks for elaboration of exercises, extra sheets and exams:

I extract -especially exercises- from the parallel books to make extra sheets or exams; sometimes I take some activities to apply in class or to conceive extra working sheets. They help me during preparations to have more examples or just to have more information.

Moreover, she searched in her digital *archive* of animations from McGraw Hill about the new topics, like exons, introns and cancer. In addition, she searched for

and downloaded videos about biodiversity, mutations and ozone hole from You Tube and daily motion. Daily motion is a French video sharing website on which users can watch, share and upload videos. It allows users to browse and upload videos by searching tags, channels, or user-created groups.

During the fifth interview, the previously drawn SRSR was edited by the teacher, as illustrated in Figure 39 drawn by the researcher. According to the edited SRSR, it is evident that Tania added two new resources, scientific magazines and Active Inspire software, circled red in the figure. She uses scientific magazines like “Science et Vie” and “Scientific America” to update her scientific knowledge by reading new articles. These are added under textbooks and guides to be used as “*personal culture*” in her teaching practices to prepare lessons. Scientific magazines were also mentioned as resources in the first interview but they were not drawn in the first SRSR. This might indicate that Tania did not mention all her *mobilized resources* in the first SRSR, particularly the resources that are not used directly for class preparation. The second resource Tania uses is the Active Inspire software newly introduced in her school. Teachers are trained on the software in order to use the Interactive White Board (IWB) in classrooms. This renewal of resources at Tania’s school might lead to change in teaching strategies and documentary work and consequently can lead to professional development.

Another modification done on the SRSR is the reversible arrow, circled red in the figure, drawn from her teaching practices back to her *archive*. This indicates that the resources utilized in her teaching practices are integrated in her *archive* and consequently enriching her system of resources year after year. With regard to Tania's organization of resources, exploration of the resource files on her laptop in September 2013 showed the same organization as before. However, all the new digital resources about exons and introns, biodiversity, ozone hole, mutations and cancer were integrated in her system of resources in the files related to the corresponding chapters. All the resources implemented in class were saved in specific files in her yearly *archive* according to class. So, cross-analysis of the edited SRSR with to the first SRSR and the interviews shows that there is an interaction between Tania's *archive* of resources and her teaching practices. All the resources elaborated and implemented in her teaching practices are integrated in her *archive* which constitutes the essential part of her system of resources, a *critical* resource. Moreover, her *archive* is revisited to select, combine and elaborate resources to be implemented in class.

Evolution of collective work and teaching strategies

During the second year, Tania discussed with the coordinator the new strategies to be followed in teaching genetics and the resources to be implemented. Also, she searched in collaboration with the coordinator for resources related to genetic printing in order to prepare a problem situation for students (Tache complexe). This indicates the use of more student-centered teaching strategies. This was also evident in the comparison of the second logbook (Appendix XXIV) with the first logbook which shows that Tania implemented new activities including: student projects; "Tache complex" (putting students in problematic situations) prepared with the coordinator in school using Internet resources; lab work such as extraction of DNA; and concept maps prepared by students. This emphasizes what was inferred before during the first year about the importance of collective work in Tania's teaching practices and documentary work.

In conclusion, comparison of the data collected from interviews, SRSRs and logbooks from the first and second years of the study shows evolution in Tania's documentary work. In particular, she reviewed the resources implemented in the first year, selected the resources that allowed her to overcome difficulties in teaching the genetics concepts and then re-sequenced them according to the activities of the new textbook. Moreover, she searched for new resources in her *archive*, specifically animations, and for new resources on the net such as videos. Furthermore, she implemented new teaching strategies based on student-centered activities after practicing collaborative work with the coordinator. This indicates evolution of her *archive* and system of resources, teaching practices, and the dynamicity of her documentary work which is constantly evolving.

5.1.4.3. Comparison between the documentary work of Maya and Tania during two successive years.

This section presents the comparison between the evolution of the documentary works of Tania and Maya. The two selected cases teach in different working environments in Lebanon, public and private schools. As discussed earlier, these two types of schools differ in terms of availability and accessibility of technology and extent of collaboration among colleagues.

Evolution of the system of resources

Tania has built a big *archive* of digital resources for almost every topic she teaches through the eleven years of her professional experience. At the same time, she is always revising, re-sequencing and adding new resources, mainly digital resources, depending on students' needs in order to renew her teaching practices and to introduce new, updated scientific knowledge. This led to evolution in her system of resources and documentary work. In Maya's case, cross-analysis of the data collected during two years showed that she is now in the phase of renewing and updating her resources, searching the net, selecting, combining and elaborating resources to be implemented in class, like the slide show elaborated during the first year of research and edited during the second year. Thus, compared to Tania, Maya is now in the phase of building her *archive* of digital resources to replace her *archive* of paper resources relying mainly on Internet

resources and resources exchanged with her colleagues. Her system of resources has evolved due to her interaction with Internet resources in addition to collective work with her colleagues and this led to evolution in her documentary work.

Collective work

Tania practices collective work in school, particularly with the general biology coordinator and the other biology teachers, with whom she exchanges resources, discusses sequences, teaching strategies and resources to be implemented in class. She also did collaborative work with the English biology teacher and the sociology teacher while explaining the theme of biodiversity in grade 10 (in 2011-2012). In addition she practices collective work outside school; Tania is a member in many associations (MADA⁶, Alumni committee of the Faculty of Education at USJ...). Therefore, Tania's extensive involvement in collective work may have played an essential role in building and enriching her system of resources which in turn lead to evolution in her documentary work as illustrated in (§ 5.1.4.2).

On the other hand, for Maya, collective and collaborative work was not important during her professional development since there is no collective and collaborative work in her school; she only sometimes exchanges resources with the French biology teacher and the chemistry teacher. A turning point in the documentary work of Maya was during her CAPES studies (2010-2011) during the first year of research in which she practiced collaborative work with her university colleagues and elaborated with them many projects. Moreover, during the second year of research, she started practicing collective work with her the

⁶Mada is a non- partisan, non-sectarian Lebanese NGO (Non-governmental organization) which aims to reinforce the relationship between local communities and their natural environment for the satisfaction of their substantial needs. Members of these communities would be committed, accountable, and creative citizens, able to realize their initiatives and unite their energies within effective partnerships.

biology and chemistry teacher to edit a previously prepared slide show titled “Genetic Program and Its Expression”.

Therefore, based on this comparison, it can be inferred that many factors influence the evolution of the system of resources and documentary work of the participating Lebanese biology secondary teachers. Among the most important factors are the conditions of the working environment, collective work and interaction with proliferating digital resources, particularly Internet resources.

The next section explores teachers’ conceptions related to genetic determinism through their evolving documentary work.

5.2. Analyzing Teachers’ Conceptions through their Documentary Work

After the analysis and comparison of the structure and organization of the system of resources of the selected cases, this part presents their conceptions about genetic determinism of phenotype inferred from their documentary work. Teachers’ conceptions will be inferred from analysis of their *critical resources* and output of *critical situations* based on the *KVP model* (Clément, 2006). In order to do so, cross-analysis of the data collected during two successive years was performed, in addition to content analysis of the *critical resources* mobilized, elaborated and implemented in class and analysis of the output of *critical situations* in interviews and classroom. First, Maya’s conceptions (§ 5.2.1) and Tania’s conceptions (§ 5.2.3) are presented. Then, Maya and Tania’s conceptions are compared (§ 5.2.3).

5.2.1. Maya’s conceptions related to genetic determinism.

Cross-analysis of the data collected from the two SRSRs, the two logbooks, interviews and classroom observations (§ 5.1.4.1) enabled the inference of three *critical resources* utilized by Maya to prepare and explain the expression of genotype and genetic determinism: the grade 11S national textbook, the university book Solomon et al. (1996) and the slide show “Genetic Program and Its Expression” elaborated during the first year. In addition, specific *critical situations* in interviews and the classroom were identified. First, Maya’s conceptions will be analyzed through *critical resources*, mobilized and elaborated

(§ 5.2.1.1). Then, Maya's conceptions are analyzed through *critical situations* during interviews and while implementing *critical resources* in class (§ 5.2.1.2). Then, Marwa's conceptions will be compared to that of Maya.

5.2.1.1. Maya's conceptions inferred from analysis of mobilized and elaborated critical resources.

This part illustrates Maya's conceptions based on: content analysis of the Lebanese biology curriculum syllabus for grade 11S; content analysis of the national biology textbook for grade 11S as a mobilized *critical resource*; content analysis of the university book Solomon et al. (1996) another mobilized *critical resource*; and analysis of the elaborated digital resource for teaching genetics and the genetic determinism of phenotype, the slide show "Genetic Program and Its Expression".

Maya's conceptions inferred from analysis of the mobilized critical resources

To recall, Maya teaches at a public school where Lebanese teachers are required to abide by the national Lebanese curriculum and use the national textbooks of the CERD. Content analysis of the curriculum syllabus for biology of grade 11S presented in Appendix XXV shows that the modern topics of genetics like "gene regulation", "gene expression" "polygenic inheritance" and "epigenetics" are not tackled. The objective of the genetics part is stated as follows:

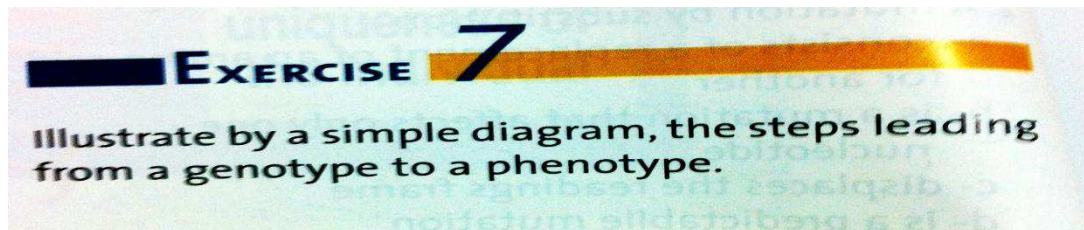
This part of the program includes the genetic make-up of living things, molecular turn over, and energy metabolism. Emphasis is placed upon the effect of the "predetermined genetic" programming of organisms and their need for nutrients. (CERD, 1997, p. 487)

This might implicitly indicate hereditarianism conceptions of the curriculum designers. The genetics content of the national biology textbook for grade 11S (CERD, 1999), one of Maya's mobilized *critical resources*, was analyzed in the Biohead Citizen Project (biology health and environmental education for better citizenship) (Castéra, 2010; Castéra et al., 2008) based on specific grids in Appendix XXVI. According to Castéra (2010), although there is

a frequent use of the term “genetic information”, the term “genetic program” is also used which suggests that everything in our life is determined by our DNA program. In addition, images of monozygotic twins having the same hair style and the same behaviour also have an implicit ideological message since they strongly suggest that features other than morphological ones can be genetically determined.

In this study, the textbook’s content was also analysed based on the grid shown in section § 3.2.2. Results of this analysis are consistent with the results of Castéra (2010). More specifically, the term “genetic program” is frequently used and the image of identical twins shows the same hair style and exactly the same features indicating that everything is programmed by genes. Further analysis shows that the gene is presented as a Mendelian factor, portion of chromosome or DNA, but the modern concept of the gene is not mentioned including DNA methylation, transposon (jumping genes), mutation after radiation, DNA damage and repair. This gives a wrong impression about the DNA, as independent of its environment thus indicating the linear causal model aligned with hereditarianism conceptions of the authors of the textbook. Similarly, further content analysis of the teacher’s guide reveals that the relationship between genotype and phenotype is presented and drawn in a linear manner: genotype → phenotype, in response to an exercise in the textbook asking students to draw a diagram to illustrate the relationship between genotype and phenotype. The exercise and its answer are illustrated in Figure 40. This explicitly reflects hereditarianism conceptions of the authors of the textbook and the guide.

Textbook exercise:



Teacher's guide answer:

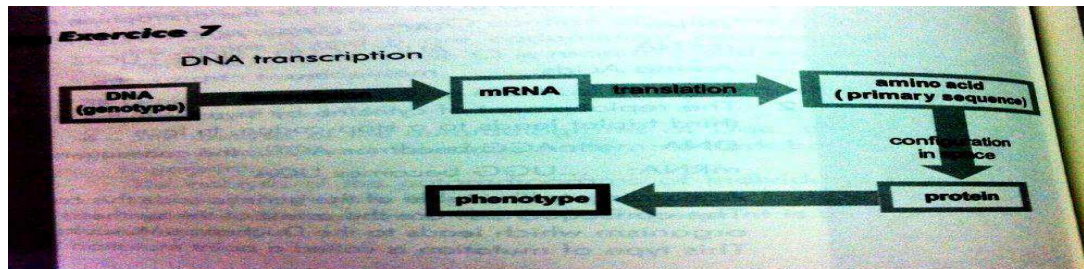


Figure 40. Genetics' exercise taken from the national textbook (CERD, 1999) and teachers' guide.

In addition, in the introduction of the fourth chapter titled “Biological Identity and Genotype” there is an indication that a direct relationship between genes and characters exists, as illustrated in the following statement “*Proteins, which are the products of gene expression, determine the phenotype of an individual*” (see Figure 41).

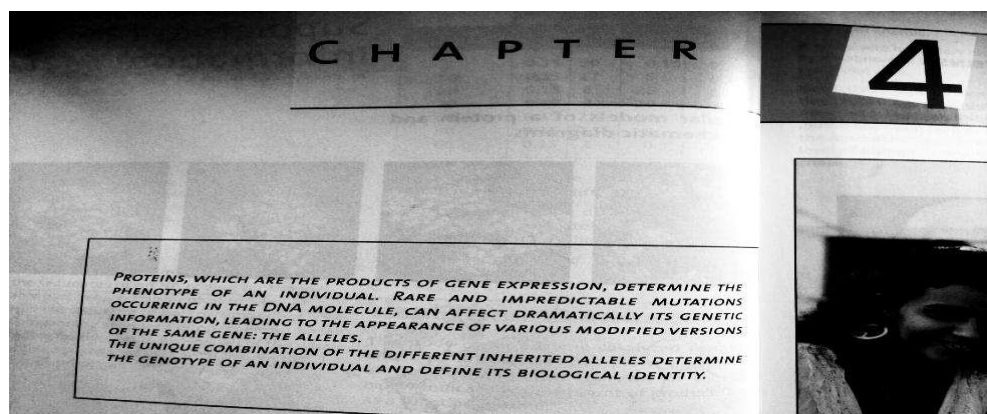


Figure 41. Introduction of chapter four of the national textbook (CERD, 1999, p. 74).

Furthermore, content analysis shows that for all genetic anomalies presented in the textbook: B Thalassemia, sickle cell anemia, albinism, diabetes, Duchene muscular dystrophy (DMD), and Chinese B Thalassemia, the influence of the environment is not mentioned. Albinism and sickle cell anemia are examples of polygenic disease where interaction with the environment is evident. However, in the textbook they are presented as monogenic diseases without any external influence. This is illustrated in the case of albinism which is explained without mentioning any influence of the environment (see Figure 42).

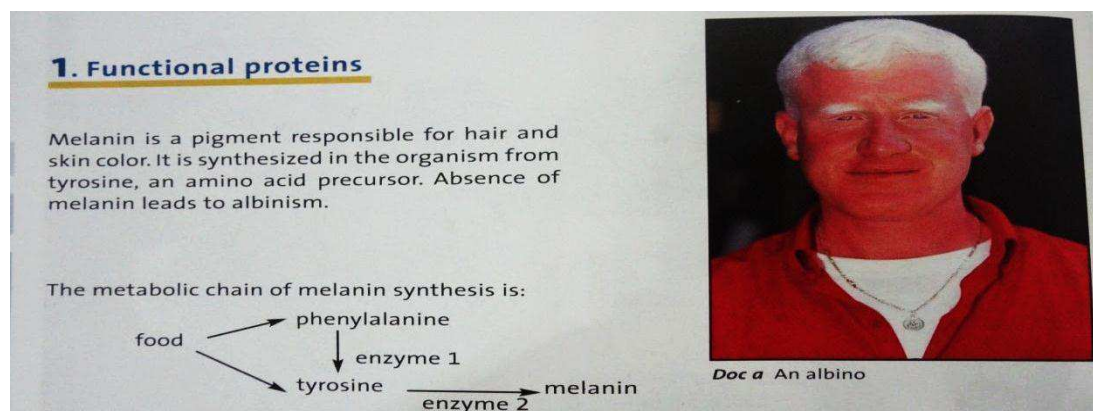


Figure 42. Albinism as presented in the national textbook (CERD, 1999, about p. 76).

Also, Duchene muscular dystrophy (DMD), a strictly monogenetic disease, is presented as an example of a hereditary disease; Diabetes and cancer are two important examples of genetic diseases that can illustrate the interaction between genotype and environment. However, in the national textbook, cancer is not tackled at all and diabetes is presented as a result of abnormal insulin without any influence of environmental factors. These results are consistent with the study of Castéra et al. (2008) which showed that the national textbooks present only the genetic factors of hereditary diseases without mentioning any environmental influence.

Moreover, biological identity was simply defined as “the unique combinations of the different inherited alleles determine the genotype of an individual and defines its biological identity” (CERD, 1999, p. 74). This definition does not consider the idea of environmental determinism of phenotype and how behavioral and psychological characteristics can interact with genotype

to influence certain phenotypes. These results are in line with the studies of Abou Tayeh (2003) and Clément (2007). In addition, questions such as: Are there genes for obesity, violence or intelligence? Are not tackled in the textbook. Similar results were obtained in the study of Abrougui (1997) that analyzed Tunisian biology textbooks, Forissier and Clément (2003) that analyzed the old French biology textbooks implemented in 2000, and Castéra, Bruguière and Clément (2008) that analyzed genetic diseases in French textbooks.

Taken together, the results of the content analysis of the national biology textbook for grade 11S indicates that the genetic model taught corresponds almost completely to a linear, causal model with the unique influence of a single gene; the idea of environmental determinism of phenotype is not tackled in the textbook. These interactions between outdated scientific knowledge (K), linear values (V) and practices of the authors (P) in choosing the figures, diagrams, expressions and examples of genetic diseases applying a simple linear causal model indicate hereditarianism conceptions of the textbook's authors. This indicates a DTD in introducing new scientific knowledge about the interaction between genotype and the environment and the paradigm of epigenetics in the Lebanese curriculum and the Lebanese national textbooks. The length of this DTD might be influenced by the socio-cultural practices in the Lebanese context. The major social practices of the curriculum and textbook (P) in addition to the outdated scientific knowledge presented in the textbook (K) may have influenced Maya's conceptions (instrumentation).

Another mobilized *critical* sources used by Maya is the university book by Solomon et al. (1996) which she uses to further illustrate and elaborate on the scientific information of the textbook. This book is constituted of eight parts, one of them dedicated for genetics and comprises of eight chapters. Content analysis of the chapters relevant to genetics shows that this book addresses modern topics related to the gene and its expression. The topics tackled include: polygenic determinism of one character; morphological, physiological and biochemical phenotypes; the environmental influence on phenotypic expression (control of gene expression); epistasis; and recombinant DNA technology and genetic

engineering. In addition, the book presents the idea of introns, exons, split genes, jumping genes and the splicing of introns. The genetics content of the book illustrate how the environment can influence gene expression by controlling the amount of mRNA available, the rate of translation and the activity of protein and how proteins can be affected by the environment. The textbook also presents the notion of gene regulation by explaining that certain sets of genes turn on and off when they respond to changes in their environment and that a given gene may be transcribed in many ways resulting in different forms of proteins. In addition, the chapters present quantitative traits such as height and intelligence that are controlled by poly-genes and significantly influenced by the environment. All this indicates the epigenetic conception of the authors of the textbook. Excerpts from the textbook showing the environmental determinism of phenotype are illustrated in Figures 43 and 44.

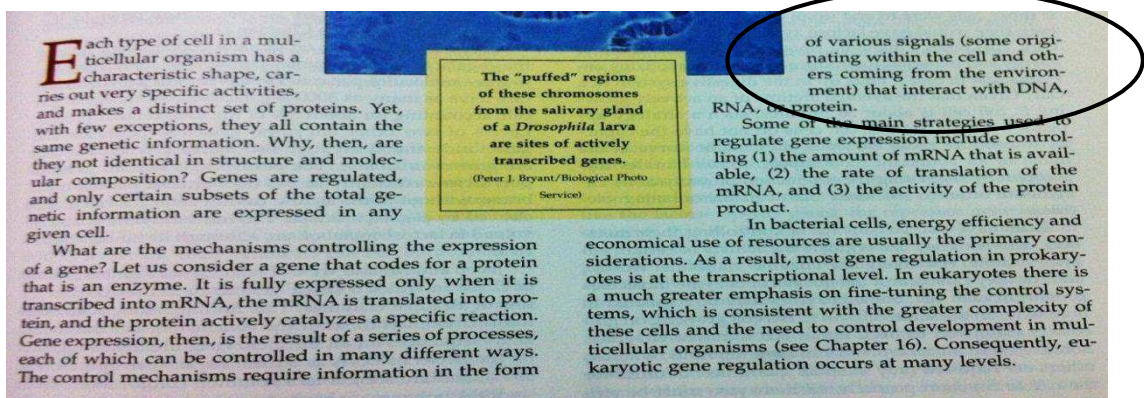


Figure 43. Excerpt from Solomon et al. (1996) from chapter 13 "Gene Regulation: The Control of Gene Expression" (p. 311).

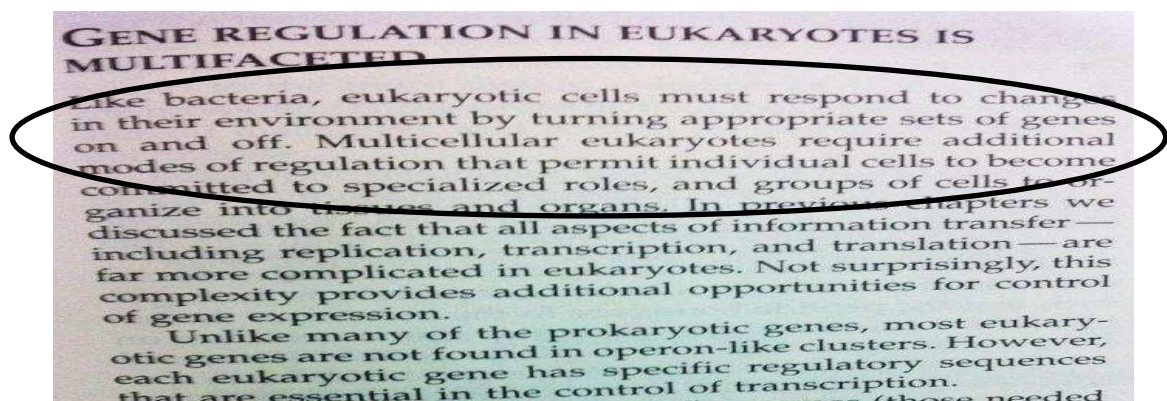


Figure 44. Excerpts from Solomon et al. (1996) from chapter 13 "Gene Regulation: The Control of Gene Expression" (p. 319).

The above two excerpts from the university book (Solomon et al., 1996) show the influence of the environment on genotype and phenotype, as illustrated below:

*Gene expression, then, is the result of a series of processes, each of which can be controlled in many different ways. The control mechanism require information in the form of various signals (some originating within the cell and others coming from the **environment**) that **interact** with DNA, RNA, or protein. (p. 311)*

*Like bacteria, eukaryotic cells must respond to changes in their **environment by turning appropriate sets of genes on and off.** (p. 319)*

Despite Maya's interaction with this updated *critical* resource, these modern topics were not addressed in her learning objectives (Appendix XXVII) that are aligned with the curriculum objectives as presented in section § 5.2.5 Table 48 nor illustrated in her notebook to be presented for students in class. This shows that Maya has utilized this book just to illustrate the scientific information of the national textbook and not to update or introduce new scientific ideas. Maya, like many other secondary Lebanese biology teachers, limit their teaching to concepts associated with learning objectives proposed by the Ministry of Education and Higher Education. This is a clear example illustrating the *KVP model* where updated scientific information of the book (K) interacted with Maya's strong hereditarianism, innate values (V) and the practices (P) of the public schools that abide by the national curriculum and its learning objectives, and caused a DTD in introducing new scientific information about epigenetics, in addition it prevented Maya's conceptions from evolving towards epigenetic conceptions, thus DTD in the conceptions of Maya.

Maya's conceptions inferred from analysis of elaborated critical resources

The slide show "Genetic Program and Its Expression" elaborated by Maya and implemented during the first year of the study is considered a *critical* resource based on the analysis of Maya's documentary work (§ 5.1.4.1). Content analysis of this elaborated *critical* resource shows that, similar to the national textbook for

grade 11S, both terms “genetic program” and “genetic information” are utilized by the teacher. In fact, the term “genetic program” is present in the title indicating that everything is programmed by our genes, this reflect the innate values of Maya. The gene is defined in the slide show as a coded sequence of DNA and the modern notion is not mentioned. The gene concept is simplified to a mere recipe used to synthesize a protein that determines our characteristics. The animated figures, animations and videos used in the slide show illustrate the scientific ideas related to the two steps of protein synthesis: transcription and translation, without mentioning any environmental influence, thus implicitly indicating the linear causal model. Moreover, Maya drew in the slide show two linear diagrams illustrating the relationship between genotype (DNA) and protein (phenotype) as illustrated in Figure 45.

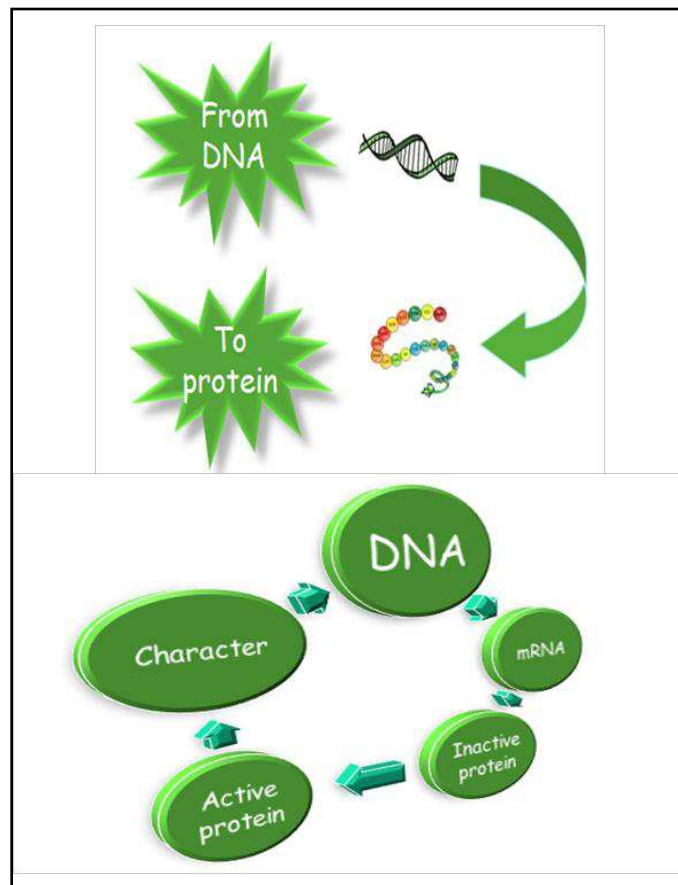


Figure 45. Two linear diagrams drawn by Maya in the elaborated slide show “Genetic Program and Its Expression”.

During the second year, the scientific content of the slide show was not updated or changed; Maya only hyperlinked to it new animations related to the two steps of transcription and translation (instrumentalization) without mentioning any influence or interaction with the environment. Therefore, the genetic model explained in this *critical* resource elaborated by Maya is a direct linear one. Maya's choice of language and diagrams reflects her conceptions of what should be taught related to gene expression emphasizing her hereditarianism conceptions. On the other hand, the innate values underlying Maya's hereditarianism conception might justify the delay of introducing the new scientific knowledge of epigenetics in this elaborated critical resource, DTD.

5.2.1.2. Maya's conceptions inferred from analysis of the output of critical situations.

In this part, Maya's conceptions are inferred based on the analysis of the output of *critical situations*. The output of *critical situations* of the interviews will be first analyzed followed by *critical situations* during implementation of *critical resources* in the classroom. Finally, the evolution of Maya's conceptions of genetic determinism is discussed.

Maya's conceptions inferred from analysis of the output of critical situations during interviews

During the fifth interview at the end of the second year of research, Maya was exposed to *critical situations* when asked specific questions related to preparation and teaching of the gene concept, genetic determinism of phenotype and genetic diseases. In addition, she was asked to draw diagrams representing the gene and the relationship between genotype and phenotype. This methodology was adapted from previous research for determining teachers' conceptions related to genetic determinism (Castéra & Clément, 2009a, 2000b; Castéra, Munoz & Clément, 2007; Forissier & Clément, 2003; Kochkar, 2007). According to Maya's responses in this interview, she perceived the gene as a fragment of DNA that may express itself. She further stated that some alleles are active and give a functional product while others are recessive and may not produce proteins or

produce inactive proteins. She claimed that the produced proteins determine character without mentioning any interaction with the environment. This is illustrated in the excerpts below from Maya's interview:

...the gene is responsible for the characters...the characters appear due to the work of gene that produces protein as in the case of pigments...phenotype depends mostly on the activity of the alleles of a gene in the case if the character was monogenic in this case we may have inside the body hidden in the cell genetic information different or identical types of genetic information inherited from both...Monogenic multi allelic human character is the B globin that may cause in the case that it is defected it may produce different type of human diseases such as sickle cell anemia, B Thalassemia etc...

*The main idea of giving them these examples of genetic disease- Diabetes, Sickle cell anemia, Duchene muscular dystrophy and B-Thalassemia- to feel that the alleles are the ones that are responsible for our characters. So small change in these genes may lead to chronic disease that has no treatment for example....adult onset diabetes where also lot of people are affected by this disease also in Lebanon which is **not due to defect** of the gene it is due only to environment influence , the way the obese people they excite the B cells all the time to produce insulin this big amount of insulin lead to degradation of receptors for insulin so the cells will not respond to take excess glucose from the blood this causes diabetes.*

These quotes show that Maya emphasizes the importance of genotype in determining our characters and that the objective behind explaining genetic diseases is to infer that alleles determine our characters and any variation at the level of these alleles might lead to chronic diseases. She also mentioned the effect of the environment; however, she mentioned this in isolation to its influence on genotype in the onset of adult diabetes. Furthermore, when Maya was asked to draw a diagram showing the relationship between genotype and phenotype, she drew the linear model shown in Figure 46.

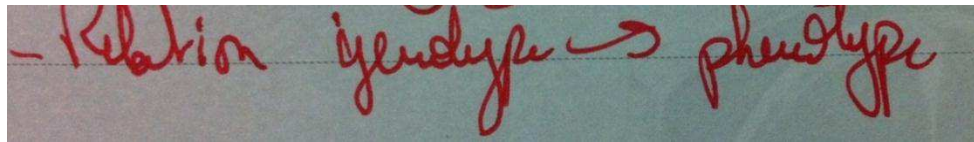


Figure 46. Linear diagram drawn by Maya during a *critical situation* in the fifth interview.

In sum, analysis of the output of the *critical situations* in interviews emphasizes the predominant hereditarianism conception of Maya reflecting her innate values and maybe her fatalist values.

Maya's conceptions inferred from analysis of the output of critical situations in the classroom

During the explanation of the gene expression in the classroom for two years, Maya utilized the elaborated slide show which reflects her hereditarianism conception. Analysis of the teachers' verbal discourse in the session transcripts shows that she explained to learners that only genes are responsible for our characters (*critical situation*). She simplified the process of gene expression to a simple translation between genetic language and protein language that determines our phenotypes and characters, without mentioning anything about the influence of neither the environment nor the interaction between genes and environment or between phenotype and environment. Reducing complex processes to simple molecular determinism reflects innatism, and might reflect fatalist values (Clément, Quessada and Castéra, 2012). This is illustrated in the excerpt below taken from the session transcripts:

*From DNA **genetic information** we get messenger RNA, inactive protein, protein is activated to get a **character**...Gene is transcribed into m RNA, translated into **inactive linear protein**; Protein leads to having a **character or phenotype**, color function anything in our body.*

Maya talked about genes determining visible characters like hair colour which reflects a hereditarianism view rather than an epigenetic view. According to Clément and Castéra (2013), to reduce all the phenotypes to a genetic influence is more ideological than scientific, expressing innate values.

In addition, all the animations and videos implemented in Maya's class do not show any interactions with environmental factors. The animations hyperlinked on the slide show and mentioned in the logbook as [www.transcription.mov](#) and [www.translation.mov](#) present the two steps of transcription and translation: copying genetic information carried by DNA onto mRNA and translating the genetic language into amino acid language to synthesize proteins that determine hereditary characters. This reflects the causal linear model of genetic determinism. However, the website from which these animations were downloaded, [www.dnalc.org](#), presents the idea of epigenetics, but Maya did not introduce these ideas in class. This might indicate that Maya's hereditarianism conceptions affected her choice of digital resources and their implementation in class (instrumentalization). This emphasizes what is inferred before that DTD also affected the resources selected by Maya to be implemented in class.

Maya showed students a video that mentioned the interaction between our genes and the environment: "*different sets of genes interacting with complex environmental factors influence our looks, personality and risk for diseases like cancer and heart diseases*" which indicates the interactive model. This film was integrated by a hyperlink (<http://www.genome.gov/25520211>, http://www.youtube.com/watch?v=_EK3g6px7Ik) on the slide show and mentioned in the logbook of Maya as: [www.proteosynthese.mov](#). However, while implementing this resource (*critical situation*) in the classroom Maya neither emphasized this information nor explained it to students. According to her, she only implemented this resource in order to show students how trace our phenotype back to our genes (innate values). Together the results show a strong interaction among updated scientific knowledge (K) and the innate values of Maya (V) that influenced her teaching practices in class (P).

Evolution of Maya's conceptions

Based on the *critical situations* identified from analysis of the data in the fifth and sixth interviews during the second year of research, it was evident that Maya followed a model similar to that of the additive one. In fact, she mentioned

relative percentages of the influence of the environment (20%) and genes (80%) in determining phenotype. Maya's change in conceptions was also evident during the fourth session observed in the second year of research while she was explaining genetic diseases using the grade 11S national textbook. Here Maya illustrated some examples that mention the influence of the environment on the activity of the gene and its expression (*critical situation*). She mentioned the influence of the environment in addition to the influence of genes indicating the additive model. Nonetheless, this additive model is scientifically not correct and reflects a conception closer to hereditarianism because it does not evoke any interaction between genotype and the environment. Percentages of contributions from both genotype and environment were proposed by Cyril Burt to explain intelligence from research on twins but based on the study of Lewontin, Rose and Kamin (1984) these results turned out to be fraud. Nonetheless, this addition representation (genes + environment) is still very popular in students' conceptions (e.g., Lewis, Leach, & Wood-Robinson, 2000 a & b; Lewis, 2004) and even in school textbooks and teachers' conceptions (Clément & Forissier, 2001; Forissier & Clément, 2003).

Maya read about these percentages from an article on the net, but she did not save it in her system of resources. After surfing the net, I found that these percentages are still present in certain sites, but without any scientific reference or date as illustrated in the examples below:

Estimates of the heritability of intelligence vary, depending on the methods used. Most researchers believe that heritability of intelligence is between 60 percent and 80 percent. (Retrieved February, 2014 from: www.sparknotes.com/psychology/psych101/intelligence/section3.rhtml)

A study of 256 monozygotic and 326 dizygotic twins confirms the high heritability of intelligence in adolescents and young adults (15-22 years): 0.76 (meaning that 76% of individual differences can be explained by genes, the remaining 24% by the shared or non-shared environment).

(Retrieved February, 2014 from: <http://socialiste.forumactif.com/t980-intelligence-heredite-80-milieu-20>).

According to Recker, 2004, while surfing the Internet biology teachers found outdated digital resources and information that was too “simple” or too “advanced”. This indicates that outdated scientific knowledge is still found in present resources, including digital resources. This DTD of Internet resource might be explained by socio-cultural practices in addition to the values of the authors and publishers. Thus there is KVP interactions at the level of digital resources, including Internet resources that should be subjected to epistemological vigilance like all other resources. Excerpts from interviews with Maya that indicate the outdated additive model are illustrated below:

*The environment influences **also** the activity of these genes... but the **big effect** is for the genetic information”. “...the intelligence of the individual depends first on the genes that influence **80%** of our intelligence but **20%** is due to the environment)”“...some scientists that even say that the influence of the environment may exceed 50% I don't know if they are right or not. I don't agree with them that the environment has the biggest influence but it has 20%.*

This reveals that Maya's interaction with digital resources, particularly Internet resources and media, allowed her to learn more about the influence of the environment and caused an evolution in her scientific knowledge (K). However, this did not lead to an evolution of her conceptions due to the interaction of this updated scientific knowledge with her hereditarianism, innate values (V). This applies the *KVP model* showing the strong influence of values (V) on updated scientific knowledge (K). This caused DTD in the conceptions of Maya.

Evidence of the interactive model was also shown in some *critical situations* during the interviews with Maya and during the observed sessions. Maya mentioned the influence of some environmental factors on gene expression that she learned about from the net or from media (TV, Animal Planet and

National Geographic). From these sources, she read about identical twins, the effect of temperature in determining the sex of turtles, Himalayan rabbits and epigenetics. This is illustrated in the interview quotes below:

We can't ignore the environmental factor, even ,for example, in the identical twins that are copies of each other after their birth directly, scientists discovered that they have some differences in their fingerprints ,and they said or they hypothesized that the environment ,even in the umbilical sac where they grow inside their maternal womb, the way the nutrition or the amount of nutrition of embryo- more or less than the other- influences their bodies, their weight, even their fingerprints.

...difference in fingerprint, even when they are embryos, identical twins are affected by uterine environment...I watched on National Geography a documentary about the influence of educational environment on the intelligence of identical twins, and I read an article on the net...I was reading once, and I was surprised by this term (epigenetics), and it was the first time I heard about it, I was reading about Himalayan rabbits (on the net), I read epigenetics...effect of temperature on turtles I observed this issue on National Geographic or Animal Planet which I watch a lot.

In the classroom, Maya illustrated many examples of the influence of the environment on gene expression while explaining genetic diseases, particularly Albinism. This indicates an epigenetic conception. Maya explained that overexposure to solar energy (UV rays) activates the gene to produce more melanin thus causing the skin to become darker. She also talked about genes that turn off due to aging, like those responsible for white hair. When students asked what causes the gene to turn off, Maya answered that it may be the environment such as the food we eat or due to genotype. Here the teacher added a percentage and said it is 80% due to genotype. She stated “*On the food or the environment or on the genes...It most probably/ mainly 80% depends on genes inherited from the parents*”. Mentioning percentages indicates again an additive model. Below are some excerpts from Maya’s verbal discourse in the classroom during the last observed session of the second year. These excerpts indicate an interactive model:

*These individuals might suffer from skin cancer if they are exposed to UV rays for a long time... UV rays pass through your cells they can hit your gene and change them....if you expose your body to excess sunlight what happens to the color of your skin... **becomes darker**... “If skin cells receive excessive amount of solar energy, your cells will react... They will activate gene for melanin for this reaction present in the skin cells so they more mRNA they make more.... More melanin will be produced in your skin it becomes darker.*

Maya also elaborated a critical resource, an exercise in the final exam, about Himalayan rabbits where the colour of their nose, ears and paws were darker than the colour of their body under the action of low temperatures that affects the activity of the enzyme tyrosine which is responsible for the synthesis of melanin. She asked the students a question: “Based on this study, explain briefly the relation between the genotype, the phenotype, and the environment”. The fact that she introduced this updated knowledge not mentioned in the Lebanese curriculum or in the national textbook, DTD, clearly indicates an evolution in Maya’s scientific knowledge (K) about the environmental influence on phenotype and an evolution in her teaching practices (P). This, in turn, might lead to an evolution of her conceptions from hereditarianism towards epigenetics.

In conclusion, Maya’s hereditarianism conceptions due to her KV interactions seem to have affected her choice of *critical resources* (P), the *mobilized resource* (the national textbook) and the *elaborated resource* (the slide show) all of which express the linear model (instrumentalization). However, the documentary practices (P) of Maya evolved towards the integration of digital resources (taken from colleagues or personally mobilized or elaborated) which in turn interacted with her innate values (V) and modulated her knowledge (K) about genetic determinism towards the additive and the interactive model (instrumentation). Therefore, Maya started by addressing the linear model in the first year reflecting innatism and probable fatalist values but addressed the additive and interactive models during the second year which are not found in the Lebanese curriculum, reflecting progressive values. This may be the result of her

interaction with all the elements in her evolving documentary work, particularly with digital resources and media, in addition to collective work with her colleagues. Although Maya used the university book Solomon et al. (1996) for several years which refer to the influence of the environment on gene expression, she did not introduce this new scientific knowledge (K) in her teaching practices (P) right away. This DTD in introducing this new scientific knowledge might be due to the influence of the social practices of her public school in addition to her innate values. It was her interactions with digital resources which seemed to cause destabilizations of Maya's conceptions and led to her inclusion of more modern models. The evolution of Maya's documentary work due to her interaction with digital resources and media enabled her to identify the limitations of the curriculum and to introduce the environmental influence in class and in one critical resource she elaborated (the exercise about the Himalayan rabbit).

Marwa's conceptions related to genetic determinism compared to Maya's conceptions

Marwa, the second biology teacher in the public school, shares the same environmental and institutional condition as Maya. Marwa also elaborated a slide show with animated figures about protein synthesis and implemented it as a *critical* resource in teaching the relationship between genotype and phenotype. Content analysis of this elaborated slide show indicates that it illustrates the two steps of protein synthesis, transcription and translation, with a detailed explanation starting from the gene which was defined as "*the part of the DNA molecule that the cell wants the information from to make a protein*", to synthesis of mRNA a complimentary copy of the gene, to the steps of translation to synthesize a protein. The slide show does not present any environmental influence to determine the phenotype; rather it implicitly reflects a direct relation between genotype and phenotype. This also indicates the hereditarianism conceptions and the innate values of Marwa similar to Maya.

Marwa was monitored during two sessions: while implementing the elaborated slide show and the animations and videos about transcription and translation, and during the implementation of the students' hands-on activity

about protein synthesis. During the two sessions she did not mention the environmental influence on gene expression. Similar to Maya, the slide show and the two animations implemented in class were just used to clarify and illustrate the scientific information of the national textbook and not to introduce new scientific ideas. Also, the objective of the hands-on activity implemented in class was to let students model the two steps of protein synthesis, transcription and translation, in order to allow them to understand the process of protein synthesis.

The website from which this students' activity was downloaded, www.lessonplansinc.com, provides biology lesson plans for various topics including genetics. Teachers can download these plans in addition to students' handouts and teachers' notes. The topics of genetics include meiosis, DNA, RNA, protein synthesis, and gene regulation. Gene regulation lesson plans include activities about gene expression (ghost in your genes), understanding cancer, and issues in genomics. Analyzing the contents of the gene expression activity showed that it illustrates the new ideas about epigenetics, how the epigenome - *the body's complex chemical network that controls gene expression* - plays a role in human biological identity and that there is something other than genes that determines gene expression. Also, the environmental influence on gene expression is presented. A classroom activity was provided that allowed students to model how scientists use DNA microarrays⁷ to determine levels of gene expression in breast cancer patients, and then choose treatments based on what they learn. In the same activity there was a video illustrating how epigenetics can affect gene expression. Thus, this site explicitly applies the interactive model indicating the epigenetic conceptions of its authors. However, in the classroom, Marwa did not mention anything about the environmental influence of genotype and about epigenetics; she only extracted activities that directly address the information in the textbook regarding the relationship between genotype and phenotype, as was the case with Maya. This might indicate that Marwa's hereditarianism conceptions affected her choice of resources (instrumentalization).

⁷Microarrays: a collection of microscopic DNA spots attached to a solid surface, such as glass, plastic, or silicon chip, forming an array. Scientists use DNA microarrays to measure gene expression levels.

Therefore, from the analysis of the cases of Maya and Marwa it can be inferred that some public school teachers that apply the Lebanese curriculum and utilize national biology textbooks which do not illustrate environmental influence of the genotype might have hereditarianism conceptions and might reflect fatalist values. This clearly shows the need for continuous condensed training programs for in-service biology teachers in order to insure the evolution of their conceptions. The Introduction of the analysis of KVP interactions when training biology teachers might allow them to face their conceptions and to be aware of the danger of reductionism. There is also an urgent need to update the Lebanese biology curriculum to include the modern topics in genetics, like the environmental influence of the genotype and the new paradigm of epigenetics.

5.2.2. Tania's conceptions related to genetic determinism.

As in the case of Maya, in order to infer Tania's conceptions, cross-analysis of the data collected during two successive years was performed, in addition to content analysis of the *critical resources* mobilized, elaborated and implemented in class and analysis of the output of *critical situations* in interviews and the classroom. First, Tania's conceptions are analyzed through mobilized *critical resources* (§ 5.2.2.1). Then, Tania's conceptions through *critical situations* during interviews and during implementation of *critical resources* in class are analyzed (§ 5.2.2.2). Then Fadi's conceptions will be compared to that of Tania.

5.2.2.1. Tania's conceptions inferred from analysis of mobilized critical resources.

This part illustrates Tania's conceptions based on content analysis of both the French curriculum syllabus of biology for grade 11S (1ère S) and the French textbooks, Bordas (2007, 2011) as mobilized *critical resources*.

In Tania's private school the French program is implemented in grade 11S where the relationship between genotype and phenotype is tackled. During the first year of the study, the syllabus of the curriculum (Appendix XXVIII) was analyzed and was found to state clearly the action of the environment on genes and proteins as illustrated below:

Le phénotype moléculaire des êtres vivants dépend en général de plusieurs gènes et de l'action de l'environnement pouvant agir sur l'expression des gènes comme sur l'activité des protéines codées par ces gènes.

The molecular phenotype of living beings depends in general on several genes and the environmental action that can affect gene expression as well as the activity of proteins encoded by these genes (researcher's translation).

This indicates that the French curriculum implemented in 2007 applies the interactive model. Furthermore, as illustrated in part § 5.1.4.2 Tania's critical resource for teaching genetics during the first year was Bordas, SVT 1ère S (2007). Tania, as stated in her logbook, uses this textbook to explain the chapter about the relationship among genotype, phenotype and environment. This textbook contains a genetics part entitled: "Du Genotype au Phénotype" (From Genotype to Phenotype) which is made up of four chapters (Appendix XXX). Content analysis was performed for the genetics chapters related genetic determinism illustrated in section § 5.2.5 in Table 48 based on the grids elaborated for this study (§ 3.2.2). The analysis shows that the term "genetic information" is the only term used throughout the textbook. Interaction with the environment is discussed in one chapter "Les Relations Entre Genes, Phenotypes et Environnement" (The Relation between Genes, Phenotype and Environment). This chapter contains many illustrating examples showing the influence of the environment on gene expression as well as on phenotype (Figure 47). Below are some excerpts from the textbook, translated by the researcher:

*Genes play a fundamental role directing the synthesis of proteins and establishing the phenotype; however, **the phenotype depends also on environmental factors.** (p 59)*

The effect of alleles depends also on external factors. (p. 64)

*Most human traits result from **complex genetic and environmental interactions.** (p. 70)*

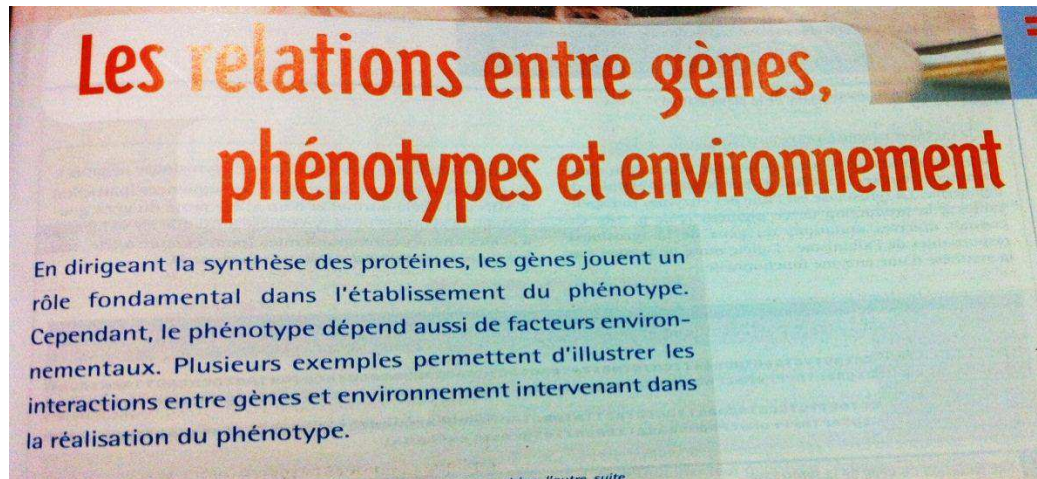


Figure 47. Excerpt from Bordas SVT, 1ère S (2007) from chapter four “Les Relations Entre Genes, Phenotype et Environnement” (p. 59).

In addition, environmental determinism of phenotype is presented in the case of genetic diseases. UV rays are mentioned as an environmental factor that might cause cancer for individuals with Xeroderma pigmentosum. Also, in the case of sickle-cell anemia there is mention of the intervention of a protein in the realization of the phenotype (sickle cell) which is dependent on environmental factors (concentration of oxygen, PH and temperature) which can modulate the effect of the gene. Diseases with genetic predispositions in which many genes interfere interacting with environmental factors, like cancer and cardiovascular diseases, are also presented in the genetics chapters. Albinism is discussed as an example of a polygenic disease where environmental factors influence genetic expression: “*If the skin is exposed to sun rays it becomes bronze, it influences the mechanisms for the synthesis of melanin*” (Lizeaux & Baude, 2007, p. 69). These results are aligned with the study of Castéra, Bruguière and Clément (2008) which showed that in the newly published French biology textbooks after changing the French curriculum in 2007, environmental influences on genetic diseases are addressed and are associated to polygenic models. According to this study the environmental influence was mentioned in one third of genetic diseases and the highest percent, 34%, for the environmental influences as percentages of number of genetic diseases was in the textbooks of grade 11 scientific class, “Premier S”. However, the term epigenetics was not mentioned in all the studied French textbooks. Moreover, the example of Siamese cats is illustrated in the form of

experiments, indicating the influence of temperature on tyrosinase enzyme causing variation in the color of fur, dark brown at the level of the tail, legs, nose and ears.

Therefore, content analysis of this critical resource shows that all characters, simple or complex, depend on genes, but the realization of the phenotype depends on other factors like interaction between different genes and influence of external environmental factors. This might reflect an epigenetic conception of the authors of the French Bordas textbook.

During the second year of research, Tania used another *critical* resource, the new French textbook - Bordas SVT 1ère (2011) - that is based on the new French syllabus implemented in 2010 (Appendix XXIX). The syllabus of this new curriculum emphasizes the environmental determinism of phenotype in many themes: Theme one A, “Expression, Variation and Stability of Genetic Patrimony” composed of four chapters and theme three B, “Genetic Variation and Health” composed of three chapters. Analysis of this new textbook (Bordas, 2011) shows that it contains a chapter about the relationship among genotype, phenotype and the environment. The contents of the genetics part related of this textbook are presented in § 5.2.5 in Table 48. Content analysis of this chapter shows that sickle cell anemia and Xeroderma pigmentosum are presented as examples to show the different levels of phenotype (the level of the organism, cellular and molecular level). UV light is mentioned as an environmental factor that causes skin cancer in case of Xeroderma pigmentosum. The textbook illustrates an example where the interaction with environmental factors affect the expression of the genes, like in the case of the bacteria *Escherichia coli*, where the transcription of specific genes depends on the medium (presence or absence of glucose). In addition, environmental factors might affect the properties of the proteins produced by these genes, like in the case of sickle cell anemia where HbS hemoglobin becomes insoluble under the conditions of dehydration or decrease in the concentration of oxygen. In addition, content analysis of the chapter related to genetic variation and health shows that it presents the interaction between genetic factors and environment to cause the initiation of certain diseases. For example, smoking,

diet-rich in cholesterol, mode of life (sedentary or physical activity) interact with genetic factors in case of cardiovascular disease. Smoking and air pollution can initiate lung cancer in case of genetic predisposition. Mutagenic factors like UV rays and some chemical substances and certain viral infections might lead to cancer. Therefore, the content analysis shows that the genetics' chapters in the new textbook (Bordas, 2011) presents the environmental determinism of phenotype, indicating that the functions of the gene and its protein product can interact with environmental factors at one or many steps involved in producing a character. This indicates the epigenetic conception of the authors of the textbook. However, according to the study of Clément (2013) the new Bordas books published in 2008 and 2012 the importance of epigenetics in explaining our phenotype is not explicitly introduced. In addition, the implicit message of identical twins with same clothes and same hair style suggesting that these socio-cultural features are genetically determined, is not taken into consideration.

During the two successive years of research, Tania utilized only the documents of the textbooks (Bordas, 2007, 2011) that illustrate the environmental determinism of phenotype in teaching the chapter of the relation between genotype, phenotype and environment. The epigenetic conceptions of the French curriculum designers and French textbook authors might have influenced Tania's conceptions after interacting with and implementing these *critical resources*.

5.2.2.2. Tania's conceptions inferred from analysis of the output of critical situations.

In this part Tania's conceptions will be inferred based on the analysis of the output of *critical situations*. First, the output of *critical situations* of interviews and then *critical situations* while implementing *critical resources* in the classroom are analyzed.

Tania's conceptions inferred from analysis of the output of critical situations during interviews

During the fifth interview, Tania was asked about the relationship between genotype and phenotype. She drew a diagram that explicitly indicates the interactive model as illustrated in Figure 48.

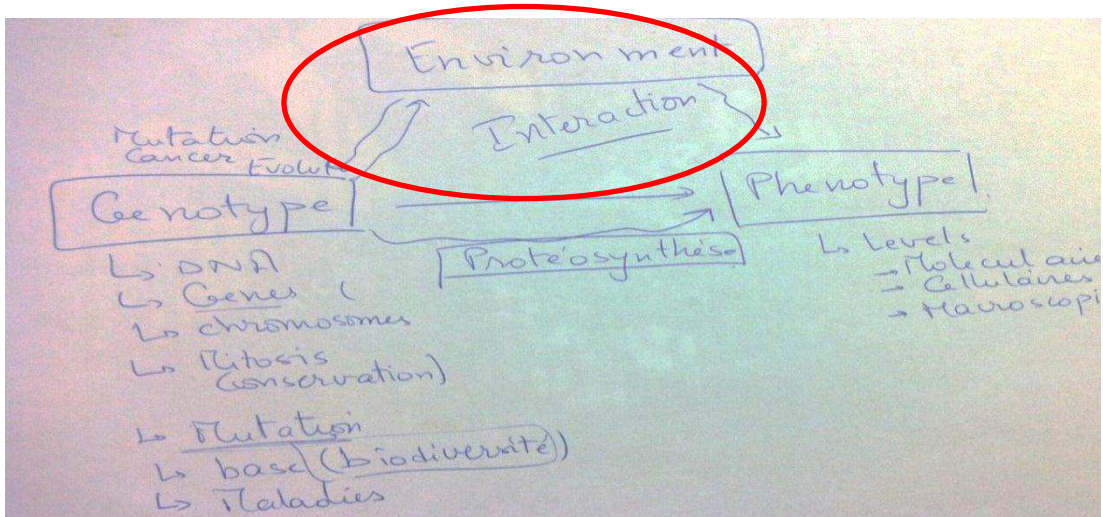


Figure 48. Schema drawn by Tania representing the relationship between genotype and phenotype.

This diagram clearly shows the interaction between genotype and the environment in determining phenotype. In addition, it illustrates the influence of the environment on phenotype at the molecular and cellular levels and at the level of the organism. This was also evident when Tania was asked during the same interview to define a gene, she drew a diagram showing it as part of a chromosome, a sequence of DNA that codes for one protein and not character. The diagram shows that many proteins might interfere to determine phenotype; phenotype has different levels and at each level there is interaction with the environment as illustrated in Figure 49. In addition, when asked about the presentation of genetic diseases she mentioned breast cancer and heart diseases as examples of the interaction between genetic predisposition and environmental factors.

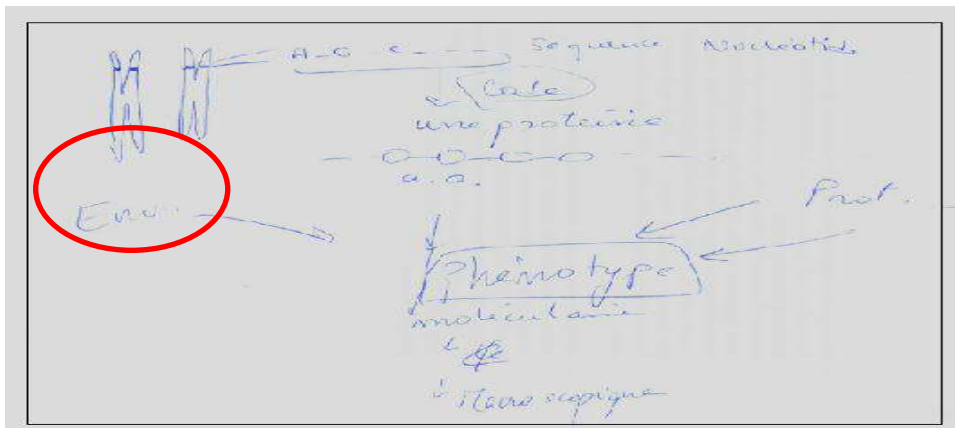


Figure 49. Schematic representation of a gene as drawn by Tania.

Tania's conceptions inferred from analysis of the output of critical situations in the classroom

In the classroom, *critical situations* during explanation of the relation between genotype, phenotype and environment were identified. During the ninth observation at the end of the first year, Tania discussed the whole chapter of interaction between genotype phenotype and environment in one period due to lack of time. Throughout her explanation, she illustrated many examples about the influence of the environment on gene expression. For instance, she explained albinism as a phenotype coded by more than one gene (multi-genic) interacting with environmental factors, as illustrated below:

There is influence of environment on the expression of the gene and protein synthesis; the example that we explained shows that the gene of tyrosinase is more active under the effect of UV light. So the expression of gene in the same individual is affected.

Tania gave the example of Siamese cats to emphasize the influence of temperature on the activity of a gene:

For Siamese cats the mutation at the level of the gene that codes for tyrosinase enzyme, it is influenced by temperature; the activity of this mutated enzyme varies in function of temperature.

She also discussed with students how environmental factors can be controlled. For instance, following a healthy life can decrease the risk of having

diseases like cancer and cardiovascular diseases. All the above examples apply the interactive model showing epigenetic conceptions of Tania.

During the second year of the study, Tania was observed during her implementation of a new strategy to explain the Cancerization process. The topic was chosen because it can illustrate the environmental influence on gene expression. Tania asked students to work in groups and prepare a project about the Cancerization process by searching for information from different resources including their own elaborated digital resources, slide shows, figures from the net and videos and animations about cancer. Two consecutive sessions were observed. In the first session, two groups of students presented their projects about cancer; the first group explained genetic predisposition (mutation at the level of corrector gene) and carcinogenic agents, illustrating the interaction with environment, as stated by one student in the group:

All physical, chemical and biological factors of the environment are susceptible to provoke cancer if the individual is exposed to them for a certain duration, for example certain elements of food, soil and radiation; there are several agents in the environment, like biological, chemical and in some food; Smoking provokes mutation in a specific oncogene P53, which opposes normally the proliferation of cells.

The second group of students explained the mechanism of DNA repair and also emphasized environmental factors, as stated by one student in the group:

The factors are smoking, food rich in chemical product, fast food, air pollution, ultra violet rays; there are genetic factors that make the person predisposed, and there are also environmental factors.

In the second session, Tania asked students to work on the documents of the textbook (Bordas, 2011) to synthesize ideas about cancer. Content analysis of these documents show that they present the steps of the Cancerization process and address certain environmental factors that might increase the risk for genetically predisposed individuals to develop cancer, like smoking in the case of lung cancer. This also indicates epigenetic conceptions of the textbook authors and

curriculum designers. Similarly, Tania's verbal discourse during this session focused on environmental factors for initiation of cancer, as presented below:

*There is genetic predisposition; there are genetic factors and environmental factors; like smoking and pollution, but it is not caused by these two factors only, as there are many other factors...So if an individual is exposed to mutagenic factors, there is a probability of developing cancer more than other individuals that are not exposed to these mutagenic factors. So there are genetic factors that make the person predisposed, and there are also environmental factors; it is multifactorial..."If we resume cancer is a very serious consequence of cellular mutation, mainly at the level of somatic cells; it is at the level of certain genes. Cancer might be caused by many factors mutagenic or carcinogenic; **there are environmental factors and genetic factors in the family.***

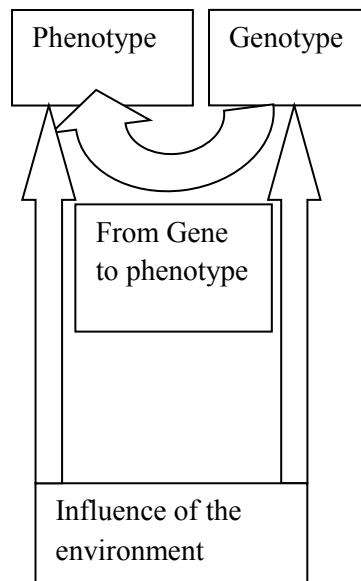
Cross-analysis of the data to emphasize Tania's Epigenetic conception

Cross-analysis of the data collected from the output of *critical situations* in the classroom and in interviews, and from the logbook emphasizes the epigenetic conceptions of Tania as illustrated in Table 47. In the logbook, Tania wrote that the objective for the study of the relationship among genotype, phenotype and environment is for students to infer the influence of the environment on gene expression. In addition, during *critical situations* in the classroom and in interviews she illustrated many examples about the interaction between environmental factors and genotype.

Table 47

*Categorization of Tania's conceptions based on a sample of extracts of the data
Collected from interviews, classroom and logbook*

Tania's Conception	Diagrams	Critical Situation
Epigenetics (E)	Diagram synthesized by the researcher based on what the teacher drew in classroom, 3 rd and 9 th observations. (our construction)	<ul style="list-style-type: none"> - <i>For the students to infer the influence of the environment on gene expression</i> (logbook objective) - <i>The environment affects the expression of the gene, the gene for heart problem; if I eat a specific type of food the gene will be expressed.</i> (second interview) - <i>There is genetic predisposition in case of cancer and obesity; if I regulated the environmental factor, I can make a control on the expression of the gene.</i> (second interview) - <i>Environment might affect protein synthesis.</i> (classroom, 1st year). - <i>Gene can be very active or less active or inactive...in summer we are more tanned because tyrosinase is more active in UV light.</i> (classroom) - <i>For the expression of the phenotype there are different levels of complexity; the phenotype is not expressed simply.</i> (classroom) - <i>The activity of the gene is regulated by environmental factors the simplest example I told you is the sun that affects the color of the skin</i>". (classroom) - <i>the gene of tyrosinase is more active under the effect of UV light.</i>(classroom) - <i>...under the influence of the environment there is mutation, cancer or evolution ...genes are active or inactive</i> (5th interview)



Tania's epigenetic conceptions may be the result of interactions of several factors during her documentary work including social practices of her school (P), her updated scientific knowledge (K) and her values (V). With regard to the social practices of her working environment (P), the private school where Tania has been teaching for 10 years follows the French program and utilizes updated

French textbooks that illustrate the interactive model. In addition, collective work among biology teachers who constantly exchange resources and her collaborative work with the coordinator to elaborate new resources and implement new teaching strategies helps her keep her knowledge and resources up-to-date.

As for Tania's updated scientific knowledge (K), her interaction with updated French textbooks illustrating the environmental determinism of phenotype, with online resources related to the influence of the environment, and with scientific magazines addressing the recent knowledge about epigenetics. Finally, regarding her beliefs and values (V), Tania's higher studies in the field of environmental education, her collective work in many environmental institutions outside school, in addition to her responsibility for the environmental club in school built her beliefs about the influence of the environment on gene expression.

In conclusion, KVP interactions had a positive influence on Tania's conceptions that are in alignment with modern conceptions in genetics related to interactions between genotype, phenotype and environment. Her epigenetic conceptions affected her choice of *critical resources* implemented in teaching the genetic determinism of phenotype (instrumentalization) including the French textbooks Bordas (2007, 2011) which deal with an interactive model. Her documentary practice (P) using French textbooks with updated scientific information (K), the ongoing interaction with her huge digital *archive* that is updated regularly, and finally her collaboration with colleagues and especially with the coordinator, has strengthened her epigenetic conceptions (instrumentation). Thus, the dynamicity of Tania's documentary work lead to her professional development.

Fadi's conceptions related to genetic determinism compared to Tania's conceptions

Fadi, the English biology teacher in the same private school as Tania, tried to make an adaptation between the Lebanese program and the French program under the supervision of the coordinator. He elaborated a booklet for grade 11S which is a combination of documents from the national textbook for this grade

level and the French textbook, SVT 1ère S, Bordas (2007). He utilized it as a *critical* resource for teaching genetics in this grade (§ 5.1.1). The chapters and activities of the unit of genetics in the booklet are illustrated in Appendix XXXIII. Content analysis of the genetics unit: “Biological Identity and Genetic Information” shows that it presents the same documents of the national textbook of grade 11S and the French textbook (Bordas, 2007) with elaborated questions based on students’ skills and competencies. Content analysis of chapter five related the relation among genotype, phenotype and the environment shows that Fadi mixed documents of the national textbook about biological identity and phenotype and documents from the French textbook about influence of the environment. It presents alleles as different versions of the gene resulting from mutation, where chromosomal mutations are presented as well; genotype as a whole set of genes or the combination of different alleles carried by an individual; and identification of genetic polymorphism using restriction enzymes and gel electrophoresis (similar to the sequence of the national textbook). On the other hand, this chapter presents the same documents as the chapter on the relation between genotype, phenotype and environment in the French textbook, Bordas (2007): a character coded by more than one gene in the case of albinism and obesity, external factors that impact gene expression in the case of sickle cell anemia and Siamese cats, multiple factors to determine a phenotype, and genetic predisposition in case of breast cancer and cardiovascular diseases. The chapter ends by the following statement:

The complexity of relations between genotypes and phenotypes makes it very difficult to predict with precision a given phenotype based uniquely on the knowledge of genotype. (p. 192)

Based on the analysis done in section (§ 5.2.2) this chapter clearly indicates the interactive model showing the epigenetic conceptions of the authors of the textbook by Bordas (2007). However, in Fadi’s case, he translated and presented this chapter under the influence of the coordinator and the practices of the school (P). This illustrates the interaction between the institutional practices of private school applying the French program and introducing the influence of the

environment on gene expression as well as on phenotype (P) pole and the scientific knowledge (K) of Fadi that were updated due to interaction with French textbooks in addition to his collective work with the coordinator. Fadi's values cannot be inferred easily based on this data.

Moreover, Fadi implements another elaborated *critical* resource, a slide show about genetics to train biology teachers outside Lebanon. Content analysis of this *critical* resource shows that it illustrates the following topics: the principles of heredity before and after Mendel's experiments; the extension of Mendel's models of inheritance to include pleiotropy, which refers to an allele that has more than one effect on the phenotype; polygenic inheritance, when multiple genes are involved in controlling the phenotype of a trait. In addition, environmental influences are also presented in specific examples as illustrated below:

Coat color in Himalayan rabbits and Siamese cats. The allele produces an enzyme that allows pigment production only at temperatures below 30°.

Based on the grids elaborated to categorize teachers' conceptions (§ 3.2.2), mentioning the effect of temperature on allele expression in case of tyrosinase enzyme might be considered as an indication of an interactive model rather than a linear model. Mentioning the environmental influence in teachers' training might reflect the epigenetic conceptions of Fadi.

As for Fadi, he did not answer the direct questions related to the relationship between genotype and phenotype. The only *critical situation* that might indicate the beliefs of Fadi was during the second interview when he was illustrating the sequence to be followed for the explanation of genetics concepts. According to Fadi, he introduces the notion that many genes can be responsible for phenotype in order to overcome students' misconceptions, as illustrated below:

To overcome the misconception of one gene one trait, because students usually think that; we explain how external factors or environment affects the expression of the allele.

Similarly in another *critical situation* in the classroom Fadi mentioned the influence of the environment as illustrated below:

There are genetic predispositions or risk and environmental factors that may trigger the initiation of cancer...Some have it due to eating green fava beans, but if during their lifetime they did not eat them, they do not show favism, so there is a genetic problem and environmental factors that boost it.

This might indicate that because of the interaction between his updated scientific knowledge (K) and the institutional practices of the school (P) where the French program is implemented and collective work is part of the culture; Fadi's scientific knowledge about the influence of the environment has developed toward epigenetics conceptions. This explains the short DTD in introducing the new scientific knowledge about the interaction between genotype and environment.

Finally, the analysis of the cases of Tania and Fadi allowed me to hypothesize that some private school's teachers utilizing updated textbooks illustrating the environmental influence of phenotype might have epigenetic conceptions.

5.2.3. Comparison between Maya's and Tania's conceptions related to genetic determinism.

The comparison between the two cases focuses on their working environment, the content and learning objectives of students' textbooks and their interactions with digital resources.

Working environment

The social practices (P) of the school interacted with teachers' conceptions related to genetic determinism. In the private school where Tania teaches, there is efficient collective work and coordination and updated resources – French textbooks, software and animations - that are available for teachers. Training sessions are done regularly at the school to update scientific knowledge and teaching strategies. Technological tools are also available and easily accessible at

school. In the case of Maya, there is no proper coordination in her public school, limited exchange of resources with her colleagues and no collective or collaborative work. For continuous professional development, teachers of public schools in Lebanon sometimes go to training sessions in CERD, but Maya did not attend any session related to updating scientific knowledge in genetics. To implement digital resources, students have to leave their classes and go to IT class or the computer room that have to be reserved beforehand.

Content and learning objectives of students' textbooks

The textbook required by school is the basic *critical* resource utilized by the two teachers in addition to digital resources mobilized and elaborated. For teaching genetic concepts in grade 11S, Tania has been referring to the French textbook, Bordas SVT 1ère S (2007) since 2009, and during the second year of research she used the updated 2011 version. However, Maya utilizes the national textbook published by CERD (1999) for grade 11S. The content and the learning objectives of the textbooks utilized in relation to the chapters on genetic determinism are compared in Tables 48 and 49, respectively.

Table 48

Comparison between the Genetics Content of the National Lebanese Textbook and the French Textbooks (Bordas, 2007, 2011)

National Biology Textbook for Grade 11 S	SVT, 1ère S Bordas (2007)	SVT, 1ère S Bordas (2011)
Part I: Functional characteristics of living things at the cellular level	Part II : From genotype to phenotype	Part I: Expression, stability and variation of genetic patrimony
A-Biological identity and genetic information	Chapter 3: Protein synthesis.	Chapter 3 : Expression of genetic patrimony
Chapter 1: The diversity of organisms and the uniqueness of the individual (Suspended)	3.1.From gene to protein, an indispensable intermediate	3.1. The discovery of the relation between proteins and DNA
1.3: Biological identity of organisms	3.2. Transcription, making copies of expressed genes.	3.2. The transfer of genetic information
Chapter3: Protein synthesis and enzymatic activity	3.3. The genetic code a system of correspondence.	3.3. The genetic language
3.1: Proteins, an association of amino acids	3.4. Translation of messenger RNA to protein).	3.4. The translation of m RNA into protein
3.2:the gene structure and information unit	Chapter 4:The relation between genes, phenotype and environment	3.5. From genome to « protome »
3.3: transcription :First step of protein synthesis	4.1. Two alleles for the same gene	Chapter 4: Genotype, phenotype and environment
3.4: Translation: second step of protein synthesis	4.2. Many genes for one character	4.1. The phenotype is defined at different levels 4.2.Molecular phenotype and genetic expression 4.3. The influence of the environment on the phenotype
Chapter4: Biological identity and genotype	4.3. The effect of alleles depend also on environmental factors.	Part IV-Human body and health
4.1. Phenotypes and proteins.	4.4. The phenotype depends on multiple factors.	Chapter 3: Genetic variation and health
4.2. Genes and alleles.		3.3. Genetic diseases and environmental factors
4.3. The genotype		

Table 49

Comparison between the Learning Objectives of the Genetics Chapters in the National Lebanese Textbook and the French Textbooks (Bordas, 2007, 2011)

National Biology Textbook for Grade 11 S	SVT, 1ère S Bordas (2007)	SVT, 1ère S Bordas (2011)
<p>Chapter 1: activity 3</p> <ul style="list-style-type: none"> - Know that the building of an organism and the maintenance of its characteristics constitute its biological identity. <p>Chapter 4: Activity 1:</p> <ul style="list-style-type: none"> - Note that the majority of the phenotypic characters are hereditary and are often determined by genetic program. - Relate the phenotype of an individual to the expression of its genes <p>Activity 3:</p> <ul style="list-style-type: none"> - Recognize that the genotype is an assortment of alleles conserved in an individual. - Relate the phenotype to the expression of the genotype. - Note that each individual is genetically unique (except identical twins) because its biological identity results from the recombination of the alleles of his species. 	<p>Chapter 4</p> <ul style="list-style-type: none"> - Identify the different levels of complexity of the genotype (poly-allelism – polygenic traits ...) - Determine the influence of the environment on the expression of the genotype. - Deduce the complexity of the phenotypic expression. 	<p>Chapter 4:</p> <ul style="list-style-type: none"> - Identify, extract and exploit information (such as from a sickle cell disease or Xeroderma pigmentosum) to characterize different levels of phenotype. - Identify, extract and exploit information (such as from sickle cell) to differentiate the roles of environment and genotype in the expression of a phenotype. - Identify, and extract information that proteins found in a cell (molecular phenotype) are dependent on the nature of genes expressed as a result of the influence of various external and internal factors.

Content analysis done in the previous parts (§ 5.2.1 and § 5.2.2) shows that the genetic topics vary between the textbooks utilized by the two teachers. Compared to the French textbooks, the national textbook is not updated in which *Didactic Transposition Delay* (DTD) is evident because it does not present the following modern topics presented in the French textbooks: different levels of phenotype (macroscopic, molecular and microscopic) and the molecular origin of the phenotype; many genes for the same character; the relationship among genes, phenotype and environment; and the complexity of the relation between phenotype and genotype (the phenotype depends on many factors). All these topics emphasize that the relation between genotype and phenotype is not a linear simple relation but instead many factors are involved and they affect gene expression, protein production and phenotype. The examples given in the French textbooks about sickle cell anemia, albinism and Siamese cats clearly illustrate the environmental interactions at these different levels (refer to § 5.2.2). Nevertheless, the term epigenetics is still not introduced explicitly in these modern French textbooks. Similarly according Clément 2013 the importance of epigenetics in explaining our phenotype is not explicitly introduced in the French curriculum and textbooks published in 2008 and 2012 for the class of “3ème”, grade 9 class. Conversely, analysis of the content of the genetics chapters in the national textbook (§ 5.2.1) shows that it does not present the environmental determinism of phenotype; instead there are many indicators showing that the relation between the phenotype and the genotype is direct and simple not affected by any external factors.

Moreover, Bordas (2011) contains more updated topics of genetics compared to Bordas (2007) like the influence of UV rays, DNA repair, mutation and biodiversity. It illustrates the interaction between genotype phenotype and environment; environmental factors can modulate gene expression and influence the properties of proteins, like the case of sickle cell anemia. In addition, the process of Cancerization is illustrated in details emphasizing the interaction with environmental

factors. Thus content analysis of this textbook shows the implicit epigenetic conception of the authors as illustrated in section (§ 5.2.2).

Furthermore, the two French textbooks present practical activities in the genetics chapters utilizing the software anagene that allows the comparison of two different alleles for the same gene and the software for molecular visualization that shows the cellular organelles in three dimensions. In addition, there is a site for the textbooks: www.bordas-svtlycee.fr/1èreS. It provides registered teachers with free additional resources: corrected teachers' book; additional exercises; audio and/or videos to listen online or download; online animations; software to download, interactive quizzes; and some contributing sites where teachers can comment on the proposed documents. Moreover, the collection Lizeaux-Baude SVT High School (Bordas textbooks) provides many practical activities to conduct an investigative approach, additional resources (animations, videos ...), available in digital form with an enriched manual on CD-ROM and website resources. This indicates that the French textbooks provide teachers with additional resources in order to enrich and update their scientific information. On the other hand, in the national textbook there are no additional resources suggested.

As presented in Table 49, a comparison of the basic learning objectives between the national textbook and the French textbooks show that the biological identity of the organism in the national textbook is presented as a result of genotype while phenotype is the result of gene expression without mentioning any other factors. On the contrary, in the French textbooks, the complexity of both phenotype and genotype is addressed and the influence of the environmental factors are emphasized through examples of genetic diseases like Xeroderma pigmentosum and sickle cell anemia and diseases where there is an interaction between genetic predisposition and environment such as cancer. In addition, the learning objectives of the new French textbook, Bordas (2011) focuses on the ability of students to interpret, analyze, and use software and data base to understand, extract and relate

information. This reflects new student-centered strategies that promote critical thinking.

Unlike the national Lebanese biology textbooks and the Lebanese biology curriculum, the French curriculum and textbooks are constantly updated. This is one influencing factor that may have led to the epigenetic conceptions of Tania. Thus, the *Didactic Transposition Delay* (DTD) of the national textbook could have an influence on some public school teachers' conceptions who are obliged to apply the outdated national Lebanese curriculum, leading to hereditarianism conceptions, like the case of Maya and Marwa.

Interaction with digital resources

The metamorphosis of digital resources and the availability of online resources are enabling teachers to update their scientific knowledge. In Maya's case, her interaction with digital resources updated her scientific knowledge and this was evident from cross-analysis of the data collected. Nevertheless, her predominant conception was still hereditarianism although she indicated some signs of an additive and interactive conception. In Tania's case, the epigenetic conception was predominant and is probably a result of many factors including her interaction with digital resources, her collective and collaborative work and her advanced scientific knowledge about the environment.

Therefore, based on this comparison between the two studied cases, Maya and Tania, it can be inferred that many factors might influence the evolution of the documentary work and conceptions of teachers. Among the most important factors were conditions of the working environment, collective work and interaction with proliferating digital resources, particularly Internet resources. The interaction and utilization of digital resources in the case of Maya allowed her to introduce the additive (A) and interactive model (epigenetics) in her teaching practices in addition to the linear model (hereditarianism) related to genetic determinism of phenotype. However, during her teaching practices, her hereditarianism conceptions and innate

values guided her choice of linear resources that are outdated (instrumentalization) even when she worked on the updated resource (Solomon et al., 1996) that illustrate the interactive model. This is the result of strong interactions between her innate values (V), her new updated knowledge about the influence of the environment on the genotype and phenotype (K) and the practices of public school (P), causing DTD in her conceptions.

Contrary to public school teachers, teachers of some private schools have the freedom to utilize updated French textbooks that introduce the influence of the environment on gene expression and on phenotype, indicating the epigenetic conceptions of the authors and program designers compared to the hereditarianism conceptions of the authors of the Lebanese textbooks. This could explain the epigenetic conceptions of Tania influenced by the use of such updated resources (instrumentation). In addition, coordination and collaborative work among teachers played an important role in their selection of resources. Furthermore, the updated scientific knowledge of Tania and her research in the field of environmental education (K) strengthened her epigenetic conceptions. Thus, in the case of Tania, KVP interactions facilitated the acquisition of her epigenetic conceptions while in the case of Maya KVP interactions during her documentary work did not allow the steady evolution of her conceptions.

CHAPTER VI

DISCUSSION

This chapter presents a discussion of the main findings of this study. The major issues tackled in this discussion include: discussions related to the research questions (§ 6.1); the theoretical and methodological development of the study (§ 6.2), the limitations of the study (§ 6.3), perspectives, implications and recommendation for further research (§ 6.4), and the conclusion (§ 6.5).

6.1. Back to the Research Questions

The aim of the study was to investigate teachers' interactions with resources, particularly digital resources, and the evolution of teachers' documentary work and conceptions of genetic determinism of phenotype as a result of those interactions. For this purpose, a *documentational approach* was used to analyze teachers' documentary work which was in turn analyzed in terms of KVP interactions. Thus, in this study, teachers' professional development was viewed as a combination of various interrelated processes: the opening up to new resources and evolution of teachers' documentary work; evolution of their relation with other actors in education; and evolution of their genetics conceptions. For the purpose of this study, a methodology was constructed such that a comprehensive view of teachers' professional activities inside and outside the classroom could be observed and analyzed. Data analysis suggests a number of findings related to teachers' interactions with their system of resources, their documentary work, and their conceptions related to genetic determinism.

This section presents a discussion of the results corresponding to the four research questions presented in section (§ 2.5). The first part presents an answer to the first research question related to the current status of integration of digital resources by secondary Lebanese biology teachers in their preparation/teaching practices in general and in teaching the genetic determinism of phenotype in specific

(§ 6.1.1). The second part presents an answer to the second research question pertaining to the factors that might influence the integration of digital resources (§ 6.1.2). The third part presents a discussion of the third and fourth research questions related to teachers' interactions with resources, specifically digital resources, and teachers' conceptions related to genetic determinism of phenotype (§ 6.1.3).

6.1.1. Status of secondary Lebanese biology teachers' integration of digital resources.

This section presents a discussion of the major findings of the first research question: Are secondary Lebanese biology teachers utilizing digital resources in their preparation/teaching practices in general? Is there a use of particular digital resources related to the teaching of genetics concepts? To answer the first part of the question, data was analyzed from the common part of the questionnaire in addition to data collected from the first interview which focused on the resources utilized by teachers during their preparation/teaching practices (§ 6.1.1.1). For the second part of the research question, data collected from the part of the questionnaire related to preparation/teaching practices of genetics concepts and from the interviews, logbooks and classroom observations were used to infer if teachers were implementing digital resources in teaching genetic concepts and for what purpose (§ 6.1.1.2).

6.1.1.1. Integration of digital resources in preparation/teaching practices in general.

Analysis of the results of the questionnaire filled by a sample of secondary Lebanese biology teachers shed light on the current status of integration of digital resources in preparation/teaching practices in general. Moreover, a comparison of the results among the three disciplines - biology, mathematics and physics - related to the common part of the questionnaire, in the context of DOCENS project, allowed the inference of the peculiarity of biology teachers' implementation of digital resources (§ 4.3).

Findings of the questionnaire (§ 4.1.2 and § 4.1.3) and the first interviews (§ 5.1.1 and § 5.1.2) generally showed that a majority of the participating secondary biology teachers integrate digital resources in their teaching practices. In particular, teachers use computers and technological resources such as the Internet and educational websites at school and at home. According to Perrault (2007) 70 out of 72 biology teachers in New York State reported the use of Internet and online resources in their instructional planning. Similarly, an online survey for 11,132 K-12 teachers in all 50 United States of America, the District of Columbia, Virgin Islands and on American military bases worldwide show that 85% of the teachers considered effective use of technology a top or middle priority for their own school (NetDay, 2004).

However, the results of our study showed that teachers tend to use computers more regularly at home than at school indicating that they mainly use it for preparation purposes. Also, despite their use of digital resources, teachers still significantly rely on textbooks. Teachers also sometimes use software such as Microsoft Word and PowerPoint while animations and videos are used less often according to the results of the questionnaire.

Teachers' use of digital resources in their teaching practices may be explained by the fact that we currently live in an era of technology where access to knowledge has become easy and knowledge is constantly evolving. In fact, the last ten years have witnessed a great evolution of technology in Lebanon where computers, Internet access and other technologies have become more available. Some Private as well as some public schools are more technologically equipped since "informatics" was introduced as a separate subject in the reformed Lebanese curriculum (1997). In fact, results of the questionnaire (§ 4.1.2) emphasize that the majority of both public and private schools are equipped with computer labs and have Internet connection with average to good speed according to the participants' answers. Technology has also become important for keeping updated on recent knowledge and in order to keep students motivated. In fact, this was confirmed by the results of this study in which

the participating biology teachers claimed that they use the Internet, for example, to search for new resources and specific websites in order to enrich and update their scientific information and to motivate their students.

Furthermore, in biology there are lots of abstract concepts at the cellular level that cannot be visualized or imagined by students which requires the use of simulations and illustrations through videos and animations. This was also confirmed by the teachers that participated in this study who argued that they use illustrations and simulations to help students visualize biological phenomena at the cellular level and to enhance their understanding. In addition, the comparison among the three disciplines showed that biology teachers are more likely to integrate digital resources like animations and videos, slide shows and Internet resources. The teachers that participated in this study claimed that they use these resources to update and enrich and illustrate scientific knowledge that is usually difficult to grasp by students.

6.1.1.2. Integration of digital resources in preparation/teaching practices related to genetic concepts.

Results of the questionnaire (§ 4.2) and the logbooks and classroom observations (§ 5.2) showed that the majority of the participating teachers agreed that the utilization of digital resources, specifically animations and videos, can facilitate and enhance the teaching and learning of difficult genetics concepts. In fact, most teachers agreed that genetics concepts are difficult and/or abstract. This is in line with previous studies which have shown that students encounter many difficulties in modern genetics concepts (Duncan & Resier, 2007; Kindfield, 1992; Lewis, Leach & Wood-Robinson, 2000 a, 2000b; Marbach-Ad, 2001; Marbach-Ad & Stavy, 2000; Stewart & Van Kirk, 1990; Tsui & Treagust, 2003). Thus, in addition to books, the teachers of this study utilize software and specific educational websites in teaching genetics. In particular, they use the Internet to search for resources related to teaching the genetic concepts and DNA on specific websites such as McGraw-Hill or YouTube to find videos, pictures, animations and simulations from daily life about

transcription and translation and other genetics concepts. To overcome students' conceptions and difficulties in learning genetics and to understand abstract, difficult-to-grasp concepts, several researches have suggested that animation-based activities, interactive computerized learning environments, and inquiry-based learning are highly successful in promoting conceptual understanding (Buckley et al., 2004; Cartier & Stewart, 2000; Gelbart & Yarden, 2006; Rotbain, Marbach-Ad & Stavy, 2006).

Teachers also claimed that they use digital resources to deepen and update their own scientific knowledge related to genetics' concepts and to motivate their students since they do not like to use books. Also, the evolving nature of genetics (Atlan, 1999; Morange, 2005) requires teachers to regularly update their knowledge which can most readily be achieved by using the Internet or up-to-date resources. However, when dealing with Internet resources teachers should be critic, they have to know the origin of the information, the references and the dates; they should search for trusted educational sites.

6.1.2. Factors influencing the integration of digital resources.

This section presents an answer to the second research question: What are the factors that influence the integration of digital resources in teaching practices in general and in teaching genetics concepts in specific? To answer this question, a discussion of the results of the questionnaire, interviews, SRSRs, and classroom observations is presented.

Developing countries have many obstacles for effective ICT integration in teaching (Osta, 2005). This is consistent with the results of this study which showed that several factors hinder or support teachers' use of digital resources in their preparation/teaching practices. These factors include: type of school (public or private), accessibility and availability of ICT resources (both software and hardware), time availability, professional development for ICT integration in education, attitudes towards technology integration and teaching experience.

The results of this study showed that the participant teachers in private schools use technological tools and resources more often compared to the participant teachers in public schools (see § 4.1.2 and § 5.1.3). This might be due to the fact that teachers of some private schools are usually more technologically competent due to the training sessions that their schools organize, while in many public schools there are no obligatory ICT training sessions for teachers. In addition, policies and teaching strategies in many private schools nowadays focus on the integration of ICT in teaching/learning practices; while teachers in most public schools abide by the Lebanese science curriculum objectives where ICT integration is not emphasized (Mounsef, 2005).

Private and public schools also might differ in their availability and accessibility of technological resources which, in turn, may be a limiting factor itself. In the two public secondary schools where the study was conducted, technological tools were available but not easily accessible for teachers. In those schools, teachers have to take their students to a separate room to use technological tools and resources and that room has to be reserved ahead of time. On the other hand, in the private school of this study, all classes are equipped with a white board and LCDs are available on every floor and readily accessible for all teachers. In fact, previous studies have indicated that availability and accessibility of computers and technological resources is a common concern among teachers (Hohlfeld et al., 2008; Inan & Lowther, 2010, NCES, 2000; Norris et al., 2003).

Despite the importance of availability and accessibility of technology in classrooms, this is not enough to insure integration of technology. Another important factor is teachers' skills in integrating technology which they acquire from professional development experiences or teacher preparation programs. The results of this study showed that teachers who underwent a teacher preparation program (through a CAPES/TD/DEA degree) used computers at school more often than those that did not (§ 4.1.3). This is consistent with the findings of the case study which indicated that Fadi, who had not taken ICT courses in university, did not extensively

integrate the use of digital resources in his teaching due to his weak ICT skills. On the other hand, Tania used digital resources due to her university background and Maya implemented technology more often after her CAPES degree where she took a course on how to integrate ICT in teaching (§ 5.1.4.1). According to many studies, teachers who feel ready and confident to integrate technology use it more frequently in their classroom instruction (Kanaya, Light & Culp, 2005; NCES, 2000; Scheffler & Logan, 1999). In fact, Webb (2008) claims that teachers need to be supported to explore, use and evaluate new uses of IT so that they can contribute to curriculum and resource development.

Teacher training may also influence attitudes toward technology integration, since, as Fadi claimed, he does not believe in the potential of digital resources. Teachers' computer and software knowledge helps them figure out the affordance of technology and how particular software might be beneficial to student learning (Angeli & Valanides, 2009; Newhouse & Rennie, 2001; Snoeyink & Ertmer, 2002).

Teaching experience was also found to be an important factor in technology integration. Teachers with more than ten years of experience showed less use of software and computers at home than those with less than ten years of experience (§ 4.1.2). In fact, Tania who had ten years of teaching experience used digital resources more often than Fadi who had 25 years of experience. This might be explained by the fact that teachers who have been teaching for a shorter period of time tend to be younger and have recently graduated from universities during a time when the use of technology in education is encouraged. Thus, these teachers are more technologically competent and more appreciative of the value of technology in teaching. This was evident in the case of Maya whose documentary work witnessed a turning point after acquiring technology skills during her CAPES where she took a course on how to implement technology in teaching.

Another factor that can influence integration of digital resources is time (§ 2.4.2.2). The process of transformation and appropriation of resources is time

consuming and teachers are already pressed with time. In addition, searching the Internet for appropriate resources that apply to a curriculum takes a long period of time (Hedtke, Kahlert & Schwier, 2001; Karchmer, 2001; Recker et al., 2004). In fact, time constraints were a factor that influenced one of the studied cases, Fadi (§ 5.1.1), which did not allow him to search for new digital resources related to teaching of genetic concepts; instead, he took animations from the coordinator to be implemented in class. Time constraint is an influencing factor outside as well as inside school. Secondary school teachers in Lebanon usually work in more than one school and sometimes they give extra private lessons after school for financial reasons. Thus, they do not have enough time to search for and elaborate digital resources. Moreover, in most public schools and according to the Lebanese curriculum, usually only two periods of biology per week are given for grade 11S and three periods in many private schools. This may explain why teachers do not often implement digital resources in their teaching practices since they are pressured to finish the curriculum on time.

6.1.3. The influence of digital resources on teachers' evolution of documentary work and conceptions of genetic determinism of phenotype.

This part presents a discussion of the third and fourth research questions: Do teachers' conceptions of genetic determinism of phenotype affect their choice and integration of resources and consequently their system of resources and documentary work? Can teachers' interactions with resources, particularly digital resources, lead to the evolution of their documentary work and conceptions related to genetic determinism of phenotype, consequently leading to their professional development? To answer these questions, cross-analysis of the data collected from interviews, logbooks, SRSRs and classroom observations related to the cases studied, Tania, Marwa, Fadi and Maya, were performed (§ 5.2). A comparison across the cases studied showed the dialectical relationship existing between resources and conceptions during the documentary work of teachers leading to their professional development.

In the case of Maya, analysis of the outputs of her *critical situations* and *critical resources* indicated that she began with hereditarianism conceptions, innatism and probable fatalist values, everything is programmed by our genes, during the first year of this study (§ 5.2.1). This can be explained by the fact that she did not learn about epigenetics in her university studies or in the training sessions of CERD. In addition, in teaching genetics she relied mainly on the national biology textbook (*critical resource*) with outdated scientific information (DTD) and abided by the learning objectives of the Lebanese curriculum that do not introduce the environmental determinism of genotype and phenotype. Therefore, when searching for resources on the net she was influenced by her hereditarianism conceptions, her innate and probable fatalist values (V) and the conceptions of the curriculum designers and the authors of the national textbook (P) (instrumentalization). Thus, the resistance to introduce the new scientific knowledge about epigenetics in the conceptions of Maya might be due to the influence of her innate and probable fatalist values and the social practices of the public school that abides by the outdated Lebanese curriculum. These KVP interactions caused DTD in the conceptions of Maya. Similar results were obtained by Castéra et al. (2007) whose study showed that teachers' scientific knowledge, beliefs and values - or in other words their conceptions - might influence their choice of resources used in teaching genetics' concepts.

Maya's interaction with resources available on the net, specifically during her CAPES studies, in addition to her collaborative work with university colleagues caused an evolution in her system of resources and her documentary work. This is consistent with the studies of Hammoud (2012) and Sabra (2009) which showed that collective work leads to evolution of teachers' documentary work. Findings of this study indicated that over the last three years Maya elaborated new digital resources after mobilizing her previous resources and searching for new resources on the net (§ 5.1.4.1). This can be explained by the fact that during CAPES, Maya took a course on how to integrate technology into teaching practices, prepare PowerPoint and use Flip

Chart. Therefore, Maya can be considered to be in an evolutionary state with regard to her documentary work due to her integration of digital resources in her system of resources. Results further indicated that this evolution in Maya's documentary work updated her scientific knowledge (K) related to genetic determinism of phenotype is due to her interaction with resources on the net and media (such as National Geographic). This instigated her curiosity about the “*mysterious*” relation, as she called it, between genotype and phenotype which in turn led her to introduce the relationship among genotype, phenotype and environment in her classroom instruction (§ 5.2.1). However, the strong interactions between her updated scientific knowledge (K) and reductionist, innate values (V) prevented the stable evolution of her conceptions related to environmental determinism of phenotype (DTD in her conceptions).

Therefore, Maya's interaction with resources in general and specifically digital resources, in addition to her elaboration and integration of digital resources, and collective work with colleagues (at university or school) led to evolution of her teaching practices (integration of digital resources), enrichment of her system of resources, evolution in her documentary work and some evolution in her conceptions. According to Gueudet and Trouche's (2009) definition of professional development and our contribution to this definition (refer to section §6.1), the combination of all these interrelated processes give evidence of Maya's professional development after her CAPES studies in 2010.

Findings from the second case, Tania, also confirm the above discussion. Compared to Maya, Tania was monitored in a static state. During her 11 years of teaching and documentary work, she has built her system of resources and conceptions which align with epigenetic conceptions regarding genetic determinism of phenotype (§ 5.2.2). Her epigenetic conceptions can be explained by several factors including the institutional practices of her school (P), her collective and collaborative work inside and outside school (P), her interactions with updated resources (French textbooks and Internet resources) (K) while building her system of

resources, and the progressive values (V) she acquired during her higher education. In the private school of Tania, French textbooks are used for all classes except for grades 9 and 12 where they utilize the national textbooks due to the Lebanese official exams. These textbooks present the environmental determinism of phenotype (§ 5.2.2). Moreover, the general biology coordinator of the school supplies the biology teachers with new updated resources and discusses with them the new teaching strategies. In addition, Tania practices collective work in many environmental associations. Thus, social and institutional practices (P pole) are positive factors influencing Tania's conceptions since they caused her to update her scientific knowledge (K pole) related to the environmental determinism of phenotype. Moreover, Tania's field of research in her masters' studies is about environmental education and she is involved in collective work in many associations concerned with the environment. This can explain her beliefs, ideologies and values about environmental interactions with genotype as well as with phenotype, progressive values (V pole).

Tania's acquired epigenetic conceptions and progressive values (V) also affected her choice of resources to be implemented in teaching genetics. For instance, she used online resources and French textbooks that apply the interactive model. She also edited, re-sequenced and combined the resources in her *archive*, and she searched for new updated resources on the net, then she integrated them in her system of resources. In contrast to Maya, the DTD in the case of Tania is short influenced by her more progressive values and the social practices of her school implementing updated scientific resources. Similarly, she updated her teaching strategies in order to cope with the new objectives of involving students in collecting, and designing resources as well as in extracting information using a constructive approach (§ 5.1.4.2). Therefore, Tania's system of resources as well as her teaching practices evolved leading to the evolution of her documentary work which strengthened her epigenetic conceptions. All this led to her professional development.

In the two cases of Fadi and Marwa, similar results were evident. On the one hand, Fadi's interactions with the updated French textbooks because of the social practices of his private school and the collective work with the coordinator (P), allowed him to elaborate his own resources based on his teaching practices (§ 5.2.4). This caused an evolution in his system of resources as well as his documentary work and some signs of epigenetic conceptions, thus leading to his professional development. On the other hand, despite the limitations of the national curriculum and the environmental conditions of her public school, Marwa's interactions with digital resources allowed her to update her teaching practices and to elaborate new resources to be implemented in class (§ 5.2.4). These changes lead to an evolution in her system of resources and documentary work resulting in her professional development.

6.2. Theoretical and Methodological Development and Contribution of the Study

This research attempted to maintain consistency between the topic of research and each of the theoretical framework and the methodology used. This section presents this consistency and this study's contribution to these two levels. The first section presents discussions related to the theoretical framework (§ 6.2.1) and the second part presents discussions related to the methodology (§ 6.2.2)

6.2.1. Back to the theoretical framework.

In order to answer the research questions, two theoretical frameworks were used, namely, *the documentational approach of didactics* in order to study teachers' appropriation and transformation of resources and the *KVP model* to study teachers' conceptions related to genetic determinism of phenotype. These two theoretical frameworks were combined in order to investigate teachers' conceptions through their documentary work and to infer any signs of evolution of conceptions accompanying evolution of documentary work.

Previous studies based on the *KVP model* highlighted a strong persistence of the ideology of hereditarianism (one gene \rightarrow one phenotype) for practicing teachers and prospective teachers in Lebanon (Abu Tayeh, 2003; Abu Tayeh & Clément, 1999; Castéra, et al., 2007). In this study, data analysis based on *KVP model* allowed the inference of the hereditarianism conceptions of Maya and the epigenetic conceptions of Tania. However, conceptions inferred in this study focused more on teachers' scientific knowledge (K) and practices (P) than their values (V). Thus, in future studies another theoretical framework might be applied to infer teachers' values. Nevertheless, when a hereditarianism conception is inferred then it reflects innatism and probable fatalist values, a reductionist ideology in life science is equivalent to a fatalist ideology in society and when epigenetics conception is inferred then it reflects progressive values leading to a socially active and more responsible individual having the value of equality between human beings. Progressive values are important in building scientifically literate students.

Based on the *documentational approach*, teachers' documentary work was studied; it comprises collecting, selecting, transforming, recombining, sharing, revising and implementing resources. Based on this approach, the consequences of the generalized availability of digital resources on teachers' professional activities inside as well as outside the classroom were analysed. However, in order to study the consequences of interactions between digital resources and teachers' conceptions, the two theoretical frameworks, the *documentational approach* and *KVP model*, were combined. As an articulation between the two frameworks, a document was defined as an interaction between reworked resources and teachers' conceptions based on the *KVP model* (§ 2.3). In the case of Maya, for example, she elaborated during the first year of the study, a new a slide show about "Genetic Program and Its Expression" and after its implementation in class she edited this resource in collaboration with her colleagues. Thus, it can be considered a document reflecting teachers' conceptions. The study of KVP interaction of this elaborated *critical* resource indicated the hereditarianism conception of Maya.

Several new terms were also elaborated and used in this study in the context of the *documentational approach* including *available resources*, *mobilized resources*, *implemented resources*, *critical resources* and *critical situations*. This study emphasized the importance of *critical resources* to infer teachers' conceptions on the one hand and on the interactions between *critical resources* and teachers' conceptions on the other. In the case of Maya, as illustrated in section (§ 5.2.1), the new elaborated slide show and the national textbook are considered *critical resources* mobilized and implemented in her teaching practices and reflecting her hereditarianism conception. However, analysis of the output of specific *critical situations* in class and during interviews reveals both the additive and interactive model in addition to the linear model. On the other hand, the new exercise elaborated by Maya about Himalayan rabbits is considered a *critical resource* that reflects a change in her conceptions towards epigenetics.

Thus, through the theoretical construction of this study, new theoretical concepts were built to deepen the study of teachers' interactions with resources and the consequences of these interactions on teachers' documentary work and conceptions, and consequently on their professional development. The data analysis in this study based on these constructions seemed relevant and allowed the researcher to answer the research questions. This paves the way for researchers to build on these theoretical contributions in studies related to teachers' professional development in biology as well as in other disciplines. However, the definition of *critical resources* is still open to discussion: Can it include any resource mobilized for the preparation of the lesson? Can it be any resource integrated in the teachers' system of resources that might reflect their conceptions? Moreover, to clarify the notion of *critical situations* specific criteria should be used in future researches to induce *critical situations* in class as well as during interviews.

6.2.2. Methodological development and contribution.

This section presents a discussion related to the methodology elaborated for this study and its contribution to the field of research. This study used a mixed-methods design in which both quantitative and qualitative data collection and analysis methods were used.

The quantitative part relied on data collected from a questionnaire filled by 116 teachers in order to study the current status of integration of digital resources in the teaching practices of secondary Lebanese biology teachers. However, the sample that filled the questionnaire is not a representative sample. In future research, it would be better to randomly select teachers from various public and private secondary schools from all Lebanese regions. Moreover, the questionnaire was elaborated and implemented in the context of “DOCENS” project (refer to section § 3.3.1). It contained a common part filled by biology, physics and mathematics teachers, related to the type of resources utilized in teaching and the purpose of their utilization. In this study, a comparison of the results among the three disciplines was done (refer to section § 4.3). This allowed the researcher to infer similarities and differences related to preparation/teaching practices in the three disciplines. According to the objective of “DOCENS” project, this study investigated teachers’ professional development based on the evolution of their documentary work and conceptions related to genetic determinism of phenotype.

In addition, quantitative analysis using the SPSS program (cross-tabulations) allowed the researcher to select the cases to be included in the qualitative part of the research. In the qualitative part, the documentary works of four selected teachers inside as well as outside school was followed. To collect data about teachers’ system of resources, a tool was adapted from the *documentational approach*, namely, the schematic representation of the system of resources, SRSR (Gueudet & Trouche, 2010). In addition, unstructured and semi-structured interviews were designed to collect data about teachers’ mobilized, elaborated and *implemented resources*.

Related to SRSR, several modalities were implemented in this study. In the first year, teachers were asked to draw a schema representing all the resources utilized in their teaching practices in general and the organization of these resources. They were provided with colored pencils and an A4 paper and the following question was asked: *“I want you to draw like a schematic drawing for all the resources you use in your teaching practices, everything you use...try to make like a relationship between these resources and if you can use for each type of resource a different color it would be better that’s why we need colors...anything used can be considered as a resource”*. The objective behind this was to infer the resources integrated in teachers’ system of resources after crossing it with data collected from other tools. Then, teachers were asked to specify the resources utilized in teaching genetics after putting a calc paper over the first drawn SRSR in order to highlight the *mobilized resources* related to genetics. In order to infer any evolution in teachers’ system of resources in general and specifically the resources related to genetics, at the end of research the two selected teachers were asked to make any modifications to the first version of both the SRSR and the calc paper. During implementation, Tania edited the first version by adding more resources and arrows while Maya did not add or change anything and just said that she utilized the same resources. As a methodological intervention, Maya was asked in the sixth interview to draw a new SRSR without looking at the first version. She was asked the following question: *“I want you to draw another SRSR, what have changed, you added you removed on what you are emphasizing more now not only in genetic in all your teaching practices in general in preparation and in class and what you reserve”* and she was provided again with A4 paper and colored pencils. Analysis showed that this new method not only provided additional information and allowed the comparison of resources but it also validated previous inferences made about the teachers’ resources. Consequently, in future research this methodological tool should be better refined, perhaps by keeping the first version with the teacher and asking her/him to edit it on regular basis during the whole period of follow-up. Then, at the end of the research, all the modifications can be discussed with the researcher. By doing so, the SRSR will provide more accurate and important

information about teachers' system of resources and its evolution during their professional activities.

Another tool adapted from the *reflective investigation* methodology elaborated for the *documentational approach* (Gueudet & Trouche, 2008b) is the logbook. It was implemented in this study to collect data about teachers' professional activities outside as well as inside the class, the resources *mobilized*, *elaborated* and *implemented* in class, and any collective work performed by teachers. In addition, other traditional tools like interviews and classroom observations were also implemented to collect data related to the system of resources, professional activities and collective work. After analysis of the data collected from the first year, the logbook was edited to include a separate part related to resources. Through this methodological development, the researcher aimed to focus more on the *mobilized* and *implemented resources* used in teachers' preparation/teaching practices related to genetic determinism, emphasizing their origin, the purpose of their utilization and their organization. Despite the relevance of this developed methodological tool to the theoretical framework and purpose of the study, the data collected was not satisfactory since the teachers did not include all the details related to their professional activities and resources. This tool should be better refined in future research, utilizing a methodology that allows the researcher to discuss the professional activities and resources on a regular basis after observing the sessions directly which might enrich the data collected from this tool.

These two tools, the logbook and SRSR, show the reflectivity of the teachers on their activity as well as on their resources. Cross-analysis of the data collected from these two tools allowed the researcher to infer the *available*, *mobilized*, *elaborated*, and *implemented resources*. Moreover, cross-analysis of the data collected from all the tools (SRSRs, logbooks, interviews and classroom observations) was performed in order to infer *critical resources* implemented in preparation/teaching practices related to genetics concepts.

The methodological contributions of this study affect both data collection tools and data analysis methods. Analysis methods for all tools utilized were elaborated based on the theoretical frameworks to answer the research questions. Grids were also developed based on common analysis indicators that allowed the crossing of data collected from various tools. The grid elaborated to infer teachers' conceptions based on different models (linear, additive and interactive) was utilized to analyze teachers' *critical resources* in addition to analysis of the output of *critical situations* during interviews and in class. This can be considered an important methodological development since this grid might be utilized to analyze the genetic contents in other national biology textbooks for other grade levels, specifically grades 9 and 12 where genetics is taught, in order to infer the conceptions of the authors of the books and provide data for curriculum reformation.

In sum, the methodological development of this study to a large extent allowed the collection of relevant and valid data for this research. It allowed the collection of data based on two theoretical frameworks in order to study teachers' professional development from a new perspective, namely, the evolution of their documentary work and conceptions. However, this methodology should be better refined to infer the conceptions of resources and institutions, since using the current methodology difficulties were encountered when inferring the values (V) pole of the *KVP model*. The tools did not allow the accurate examination of the conceptions as a result of interactions between their KVP either because the tools were not sufficient (few questions to identify knowledge (K) or because they were not relevant (to identify the values (V) or practices (P) of such resources). Nevertheless, the data collected enabled us to infer the values of Maya and Tania based on the deduced conceptions in the two cases. In addition, certain points remain to be clarified. Combining these two approaches allowed the analysis of the KVP of a resource, but what about the KVP of the system of resources? And what other theoretical developments are needed to better understand the simultaneous evolution of resources

and conceptions? Thus, this research paved the way for further research to refine the methodology and apply it in the same field.

6.3. Limitations of the Study

This part presents certain methodological limitations including: limitations related to the participants selected for the study; limitations related to implementation of the questionnaire and time limitations.

The first limitation is related to the number of cases studied. At the beginning of the research, eight teachers were selected satisfying the conditions of the study after analysis of the results of the questionnaire. Then, after analysis of the data of the first interview only four cases seemed relevant to the purpose of the study and agreed to participate in the research. Two teachers were selected from the same private school in Mount Lebanon and were monitored in the first year of research during the preparation and explanation of genetics chapters. However, Fadi was not completely cooperative and did not participate in the second year of research due to his time constraints. Data collected from this case was analyzed in comparison to the selected case, Tania. Moreover, one teacher was selected from a public school in Beirut and another teacher from a public school in Mount Lebanon. For practical and personal reasons, the researcher was unable to efficiently monitor the teacher in Beirut. Thus, data analysis related to the documentary work and conceptions for this case was limited because of the truncated follow-up (§ 3.1).

The second limitation of the study is that the two selected cases, based on the purpose of the research, were considered advanced teachers, both continuing their higher studies with evolved documentary work. This does not apply to all secondary Lebanese biology teachers specifically those with long teaching experience who are not following training sessions to update their scientific knowledge and practices or are not interacting with new resources. These specific conditions threatened the generalizability of the study.

The third limitation is related to the questionnaire implementation which was administered during the day where the answer key for the national exams for grade 12 Life Science section, was discussed. The teachers were preoccupied and did not spend enough time to completely fill out the questionnaire, specifically the open-ended questions. A more proper methodology would have been to select public and private schools in the same region and follow a specific sampling technique for selecting the teachers, then implementing the questionnaire in their schools under the supervision of the researcher.

The fourth limitation is related to time constraints. The researcher was not able to attend all the sessions during the explanation of the genetics chapter. Moreover, the sessions chosen for observation were only those in which the teacher implemented a new resource, a *critical* resource, a new strategy or a lesson that introduced important scientific knowledge related to the topic of this study. In addition, time was an important factor that prevented the researcher from following the teachers over a longer period of time (i.e. more than two years). Prolonged periods of time are crucial to capture elements of stability and developments in teachers' system of resources, documentary work as well as their conceptions.

Despite the limitations of this study, its results shed light on important aspects of teachers' use of digital resources and its influence on their documentary work and conceptions of genetic determinism of phenotype. In addition, it paved the way for future research in this field.

6.4. Perspectives, Implications and Future Research

This part presents the perspectives and future implications based on the discussion of the results obtained in this study, the new methodology implemented and the elaborated theoretical concepts.

This study opens several research directions as an extension of this thesis. At the theoretical level, two new theoretical frameworks in didactics the *KVP model*

(Clément, 2006) and the *documentational approach* (Gueudet & Trouche, 2009) were articulated. This resulted in new concepts and models used to infer teachers' interactions with resources, particularly digital resources, and to study the consequences of these interactions on teachers' documentary work and conceptions. Teachers' professional development was considered from the perspective of evolution of documentary work and conceptions. Future researches can utilize these concepts in studying teachers' professional development in different disciplines.

The methodology used enabled the study of teachers' activities inside as well as outside class in addition to teachers' conceptions related to a particular biological concept. In future studies, teachers with hereditarianism conceptions can be exposed to specific *critical resources* with updated scientific knowledge that reflects the epigenetic conceptions, then asked to implement these resources in class using an experimental method to infer any conceptual change from the analysis of the output of these *critical situations*.

It would also certainly be interesting to extend this study by monitoring teachers in the same school implementing the same *critical resources* provided to them related to evolving biological concepts. In this respect, the following questions could be raised: What might cause two teachers in the same working environment and utilizing the same resources to have different conceptions? Can collaborative work between teachers cause evolution in their conceptions? Can the interaction and implementation of the correct *critical resources* with updated scientific knowledge about epigenetics lead to teachers' conceptual change? Is the documentary work of teachers sufficient to cause conceptual change? How can teachers' training programs contribute to the evolution of teachers' system of resources and conceptions? Thus, this study paves the way for many future studies that can implement the same methodological tools and theoretical framework to answer these questions.

This study also has important implications on teachers' preparation and training programs for professional development, and on curriculum development. Despite the

fact that this study was limited to four cases, it shed light on important factors and constraints that might influence the evolution of teachers' system of resources, documentary work and conceptions. Teachers should be trained to master technology and develop positive attitude towards technology in order to be able to use it efficiently with their students (Abed-El-Khalick, 2005). For this purpose, teachers' preparation programs and professional development programs should be modified to highlight the integration of digital resources in teaching practices in a constructive way and to enhance teachers' technological skills. These programs should focus on teachers' documentary work and conceptions, teachers' should be trained to search for resources specifically Internet resources (web search engines), and to know how to select and appropriate these resources in order to be implemented in class. In addition they should introduce KVP interactions of resources in order for teachers to have epistemological vigilance when handling new resources, including Internet resources. Introducing KVP interactions in training programs might free teachers from the constraints of their conceptions. Teachers should be supplied with *critical resources* in order to update their scientific knowledge. During this study we investigated specific educational websites that provide teachers with educational critical digital resources, below is a list and brief description of some of these specific educational websites:

- McGraw Hill site (<http://www.mheducation.com>) which is a digital learning company that provides educational content, software and services for pre-K through postgraduate education for educators, students and administrators.
- The National Science Digital Library (NSDL) ([http:// www.nsdlib.org/about/](http://www.nsdlib.org/about/)) which is an example of an educational digital repository that contains collections of high- quality learning resources. The U.S. National Science Foundation sponsored NSDL which provides access to a comprehensive collection of science, technology, engineering, and mathematics (STEM) education content and services to learners, educators, and academic policy-

makers (Recker et al, 2004) . NSDL advances STEM teaching and learning by providing:

- High quality, interactive resources that help our nation's educators bring cutting-edge, real-world science into their classrooms and stimulate excitement for science in today's digital learners.
 - Web-based applications that help teachers and learners to optimize their experiences with digital content.
 - Professional learning opportunities for college faculty, K12 teachers, and other science educators.
 - Software tools and services to help school districts, museums, educational non-profits and other digital learning enterprises to organize, manage, and disseminate digital educational content.
 - Research-based findings and best practices on teaching and learning with digital content.
 - Partnerships with STEM stakeholder groups, organizations, and coalitions that promote the dissemination of STEM educational technology use and digital content expertise.
- The Instructional Architect (IA) (<http://ia.usu.edu/>) is a simple digital library service designed to support the instructional use of online resources in the National Science Digital Library (NSDL). It is used to support teachers in collecting, sharing, and designing with online resources. The IA enables users (particularly teachers) to discover, select, sequence, annotate, and reuse online learning resources stored in digital libraries to create instruction (e.g., lesson plans, study aids, homework...). In this way, the IA is intended to increase the utility of online learning resources for classroom educators (Recker et al., 2006).

For teaching genetics specifically there are important educational websites like:

- BIOPS Interactive (<http://biops.cs.nmsu.edu:8800>) is a web-based learning environment that enables students to practice with concepts in molecular biology.
- DNA from the Beginning is another important website ([http:// dnaftb.org/](http://dnaftb.org/)) which is an animated primer on the basics of DNA, genes, and heredity.
- Learn.Genetics (<http://learn.genetics.utah.edu/>) is a website which delivers educational materials on genetics, bioscience and health topics. It is designed to be used by students, teachers and members of the public.
- Teach.Genetics (<http://teach.genetics.utah.edu/>) is a website which provides resources for K-12 teachers, higher education faculty, and public educators.
- Another important website (<http://www.johnkyrk.com/>) which provides important animations about the cell, the chromosomes, DNA structure, DNA replication, transcription and translation.

On the other hand, teachers should also be trained and encouraged to do collective and collaborative work in order to elaborate their own resources that can be shared, discussed and implemented in classes. The results of this research indicate the importance of interaction with resources for teachers' professional development. Therefore, in-service teachers should be supplied with *critical resources* that might cause the evolution of their conceptions; in addition, they should be trained to elaborate new resources. Continuous development programs should also cater the needs of teachers depending on their extent of ICT skills. One way to do this is by constructing a website specifically for secondary Lebanese biology teachers for updating their scientific knowledge and teaching methods, and where they can share and discuss resources with colleagues from various public and private schools across Lebanon. Researcher and the participant teachers of this study will collaborate to build this site and will post *critical resources* and modern teaching methods to implement them, like:

- Digital resources, animations and videos, that allow the teachers to overcome the obstacles of teaching the difficult and evolving concepts like genetic concepts
- Scientific articles presenting the latest scientific discoveries to avoid DTD of resources and of teachers' conceptions
- Elaborated resources like PowerPoint that can be implemented directly in class, following a constructive teaching methodology.

Moreover, curriculum designers and textbook authors can benefit from the comparison done in this study among the genetics chapters in the Lebanese national textbook for grade 11S and the updated French textbooks that are utilized in the French program. This can shed light on the new concepts that should be integrated into the Lebanese biology curriculum; some of these concepts related to genetics and genetic determinism of phenotype are listed below:

- The phenotype depend on proteins: The phenotype is defined at different levels; molecular origin of the phenotype; molecular phenotype and nucleotide sequence.
- The relation between genes, phenotype and environment: Two alleles for the same gene; many genes for one character; the effect of the alleles depend on external factors; the phenotype depends on multiple factors.
- Epigenetics: DNA methylation; Histone modification; the influence of the environment on the phenotype; the influence of the environment on gene expression.
- Genetic variation and health: Genetic diseases and environmental factors; interaction between genetic predisposition and environmental factors in diseases like cancer

In addition, the same grid developed for data analysis of resources could be applied to all national biology textbooks for different grades and compared to French

textbooks and English textbooks in order to highlight curriculum reformations related to genetics concepts in both public and private schools.

6.5. Conclusion

This study had major findings with regard to secondary Lebanese biology teachers' use of digital resources in their teaching. Teachers were generally found to integrate digital resources in their preparation/teaching practices to facilitate and enhance the teaching and learning process of the difficult and evolving genetics concepts. Teachers' integration of technology and evolution of documentary work and conceptions were found to be influenced by availability and accessibility of technological tools, teachers' technological proficiency, time constraints, collaborative work and environmental conditions.

Teachers' conceptions were studied through their documentary work and the results provided evidence that the relation between resources and conceptions is dialectical. KVP interactions of teachers influence the choice and implementation of resources on the one hand (instrumentalization) and the KVP of resources interacting with teachers' documentary work influences teachers' conceptions on the other (instrumentation). This leads to integration of new resources, elaboration of new documents, evolution in professional knowledge, teaching practices and system of resources. This, in turn, leads to evolution of teachers' documentary work and conceptions. All these combined processes can lead to teachers' professional development. In particular, the cases considered in this study began using resources that were in line with more epigenetic conceptions.

The combined methodology used in this study was appropriate. It allowed the identification of *critical resources* and *critical situations* from the data. The combination of the two theoretical frameworks the *documentational approach* and the *KVP model* also allowed the inference of teachers' conceptions about genetic determinism reflecting their values as either innate or as progressive. The inferred

teachers' conceptions allowed the identification of the probable values of the teachers.

Finally, in this digital era where resources are more available for teachers, they can easily communicate, share and exchange their resources. To integrate ICT into teaching necessitates re-examining curricular goals and pedagogical approaches (Abd-EL-Khalick, 2005). This also involves supporting science teachers throughout the implementation process. Thus, in-service professional development is necessary and aids teachers in efficiently implementing technology. In this respect, the results of this study can be considered a reference for curriculum designers and educators that should realize that ICT in itself is not a teaching approach. They have to elaborate effective strategies for the integration of digital resources and technology in the new biology curriculum and to develop programs that can aid pre-service and in-service teachers to integrate technology efficiently in their teaching practices, in order to enhance the evolution of their documentary work and conceptions. This might enable the Lebanese biology curriculum to cope with the global reformation of science curriculum towards a pedagogical approach based on constructivist learning.

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APPENDICES

Appendix I: The questionnaire



Questionnaire

Ste@d Project: “Science Teachers’ Documentation”

DOCENS (Documentation des enseignants de sciences)

This **anonymous** questionnaire will be used in a research project (Ste@d in English and DOCENS in French) involving several doctoral theses (physics, biology and mathematics teaching) and several researchers from the Lebanese University of Doctoral School of Literature and Humanities and Social Sciences in Lebanon and from IFE (Institut Français de l’Education) in France. This project aims to better understand the complexity of the science teachers’ work in finding, preparing and using all *available resources* including digital resources (resources means anything that can be used by the teacher as a support for teaching and learning, during the preparation of sessions and teaching sessions. Like: books, students’ sheet, discussion with a colleague, software, online exercises, specific websites, digital libraries...). It aims to produce a methodological guide to assist teachers in their documentary work (collecting, selecting, transforming, recombining, sharing and revising resources; implementing them in class) and to give proposals for renewing teachers’ training. Hence your participation in this project is of crucial importance.

Thank you for answering all questions.

Questions related to your current working environment: *In responding to the questions, mark the appropriate box(es).*

1- Is there a computer lab at your school? Yes No

2- Do you use the computer at your school?

Never Sometimes Often Regularly.

3- Do you have a computer at home? Yes No

4-Do you use the computer at home?

Never Sometimes Often Regularly.

5- For what purpose do you use computer? (At home or at school)

To use the Internet

To use the Internet for teaching purposes To install and use software

To install and use software dedicated to your teaching

To type your exams

To search for resources on the Internet

To play games Other, specify: _____

6- Is there an Internet connection at your school(s)? (Answers a, b & c refer to different schools, in case you teach at more than one school). Same answering order for question 7.

a- Yes No b- Yes No c- Yes No

7- The speed of Internet connection at your school(s) is:

a- Bad Average Good Very good

b- Bad Average Good Very good

c- Bad Average Good Very good

8- Is there an Internet connection at your home? Yes No

9-The speed of Internet connection at your home is:

Bad Average Good Very good

24- For what reason(s) do you utilize these resources? (Please check all answers that apply to you)

- To deepen and update the knowledge of the gene concept
- To look for videos and / or animations that can facilitate and enhance the teaching and learning of the gene concept
- To look for activities, pictures and exercises that can facilitate and enhance the teaching and learning of the gene concept
- To motivate students and encourage them to search for new resources.
- Other (specify): _____

25- Specify the criteria that you use while searching for a new resource related to the gene concept.

26- Do you think that the use of digital and online resources can facilitate and enhance the teaching of the gene concept? Explain your opinion.

Questions related to your educational background and your teaching experience. In responding to the questions, mark the appropriate box (es).

27- How long have you been working as a teacher?

- 1-5 years
- 6-10 years
- 11-15 years
- Above 15 years

28- Specify the Grades that you have been teaching:

- Grade 9
- Grade 10
- Grade 11(Scientific)
- Grade 11(Humanity)
- Grade 12 Specify the section(s)

29- In which sector have you been teaching?

- Public Private Both

30- Which educational system have you been teaching?

- Lebanese French American

31- What is your teaching language?

- English French Both

32- Information about your school(s) (please mention all the secondary schools where you have been teaching):

Name of your school(s)	Region/Specific location	Telephone number

33- Personal information:

Gender	<input type="checkbox"/> M <input type="checkbox"/> F
Phone number	
e-mail address	
Degrees /Certificates	
ICT (information and communication technology) training sessions	

Questions and/ or remarks

Appendix II: Questions related to personal and professional information and the working environment of the teachers during the first interview:

1- What is your name?

2- _____
What are your University degrees?

3- Do you have a “CAPES”/ Teaching Diploma degree? Any other, specify?

4- What are the training sessions that you have attended? Specify anything else you were involved in related to your professional development (projects, researches, team work)?

5- Did you receive any training sessions related to ICT? Specify.

6- How many years of teaching experience do you have?

7- Name the schools you have taught at? Are they official or private schools? Where do you teach now? Is it a private school or an official school?

8- What are the classes you taught during your profession as a teacher?

9- What is your teaching language?

10- What are the classes you are teaching this year? What are the classes that you taught last year?

11- How many Bac I scientific sections are there in your school?

12- How many biology teachers teach these sections?

13- Are computers available and easily accessible at your school?

14- Do you have an Internet connection at your school? Is it good?

15- What are the technological tools available at your school? Are they easily accessible?

16- Do you use technology in your own teaching practice? If yes specify.

17- How long have you been using technology?

18- What are the obstacles prevent you sometimes utilizing digital resources and implementing them in class?

19- Do you consider your skills in using the computer weak, average, good or excellent?

20- Are your skills in using the Internet weak, average, good or excellent?

21- Do you regularly use the Internet for professional purposes: searching for new resources and specific websites?

Appendix III: First interview guidelines and objectives

First part: Related to the resources utilized in general & questions related to the potentialities and actual use of digital resources

- 1- What are the resources that you utilize in preparing and/ or teaching practices? Specify all: books including the textbook you utilize: digital resources (software, CDs, interactive white board, digital books etc...Online resources: online exercises, specific websites, digital libraries, online periodical database, and any other resources.
- 2- **According to you what are the most critical or the most important resources that you have used (and you are using) in your teaching practices and in preparing your documents?**
- 3- Do you discuss your resources and/or documents with your colleagues? Do you exchange them with your colleagues in school or outside school? If yes what do exchange and why?
- 4- How did your documents evolve after the proliferation of digital resources?
- 5- What are the potentialities of digital resources in your opinion?

Second part: Related to teaching the gene concept and the resources utilized.

- 6- What are the obstacles that face you when you teach the gene concept? How do you overcome these obstacles?
- 7- How do you approach and teach the gene concept in your class? What documents do you implement for teaching this concept? (more probing questions related to teaching specific ideas in the chapter of the gene, like how do you relate gene to phenotype, do you mention the influence of the environment on the expression of the gene...)
- 8- What are the resources that you utilize for preparing your documents for teaching the gene concept? Specify all: books including the textbook you utilize: digital resources (software, CDs, interactive white board, digital books etc...Online resources: online exercises, specific websites digital libraries, online periodical database, and any other resources.
- 9- Can you present two or three of the most important documents that you have implemented or you implementing in teaching the gene concept?

Questions related to the documents presented

- 10- Are these documents produced personally by you alone or with colleagues? What are the specific resources that you have utilized in preparing these documents? Did you modify them after use? Do you put the references utilized in preparing your document?
- 11- If they are not of personal production: how they were encountered, chosen, modified, used...

Objectives of the first interview in general:

- To investigate the resources utilized by teachers and the changes induced by utilization of digital resources on the teachers' documentary work.
- To infer if the teachers are utilizing digital resources in general and specifically in teaching the gene concept.
- Elaboration for the data of the questionnaire related to the gene concept. Since their answers were not complete and accurate in the questionnaire due to the lack of time.
- Select the four participants of the research after the analysis of the first interview.

The first interview is a typical qualitative interview where the interviewer will ask open-ended, probing questions, the interviewer can also ask follow-up questions that may naturally emerge during the qualitative interview. It follows the interview guide approach, where the interviewer asks specific open-ended questions with a plan to explore specific topic. These topics and questions are provided on an interview protocol written by the researcher before the interview session, but the interviewer can change the wording of any question listed in the interview protocol. The interview session is still a relatively unstructured interaction between the interviewer and the interviewee. At the same time, because of the interview protocol, the interviewer will cover the same general topics and questions with all of the interviewees (Johnson & Christensen, 2008).

Objectives of the questions of the first interview and their relation with the theoretical background, literature review and questions of research.

- **Question 1:** To know the types of resources utilized by the teachers and to infer if the interviewed teacher utilizes digital resources in general. This is related to the theoretical back ground “the *documentational approach* of didactics” where a particular attention is paid for digital resources.
- **Question 2:** To infer if the teachers are utilizing digital resources in preparing their documents and in their teaching practices. Related to the questions of research, to investigate the effects of digital resources on the documentary work of teachers.
- **Question 3:** To know if teachers share and exchange their documents and discuss them with their colleagues, in order to infer if there is collaborative work. This is related to the theoretical background collaborative work is important in teachers' documentary work.
- **Question 4:** To know how the documents of the teachers evolved after the proliferation of digital resources. To answer the question of research related to the effects of digital resources on teachers' documentary work.
- **Question 5:** To answer the questions of research about the effect of digital resources on teachers' documentary work.

- **Question 6:** To know the obstacles related to the teaching of the gene concept in order to see if they are similar to the obstacles described in my literature review. And to infer if the teachers are aware of students' conceptions related to the gene concept, in order to be able to relate it after to our literature review about students' conceptions in genetics. And to see what do they utilize to overcome these obstacles and if they are going to mention the use of digital resources
- **Question 7:** This question might allow us to infer the conceptions of teachers related to the gene concept and then relate it to our literature review (if they teach the genetic determinism: one gene = one phenotype or if they introduce the ideas of Epigenetics). This can be emphasized after the analysis of the contents of the documents developed by the teachers related to the gene concept. And to see if teachers are utilizing digital resources to overcome the obstacles mentioned in the previous question. Moreover, related to the theoretical background it might allow us to infer the schema of utilization of resources.
- **Question 8:** To know if teachers are utilizing digital resources in preparing their documents related to the gene concept (an important condition to select the teacher, since I cannot study the effects of digital resources on teachers' documentary work if they are not utilizing these resources).
- **Questions related to the resources presented:** the documents presented will allow us to investigate the changes induced by digital resources on teachers' documentary work. Moreover, the documents will be used as criteria to select the participating teachers. And analysis of these documents may allow us to infer the conceptions of teachers related to the gene concept.

Appendix IV: Guidelines of the second interview

Resources to be implemented in class

- What is the title of the lesson/activity that you are going to explain today (or during this period)?
- What are the objectives of the lesson?
- What are the documents that you have prepared and you are going to use in class?
- What are the resources that you have utilized to prepare these documents?
- Why you are planning to use these documents?
- How you are planning to implement them in class (procedure planned to be followed in class)?
- Are these the same documents that you have implemented last year?
- Are there any modifications done after implementing these documents for the first time?

Logbook to be filled during the period of the follow-up:

The logbook will be discussed with the teacher: The items of the logbook will be discussed with the teacher, he will be asked about the activities he has in his mind, and the researcher will intervene in order to deepen the look of the teacher on his activities by mentioning some types of activities:

- Search for resources related to the gene concept on the Internet.
- Search for any resource related to the gene concept.
- The review of previous documents (related to this chapter) and any modification done on these documents.
- Preparation for the lesson plan.
- Documents prepared and the resources utilized to prepare these documents.
- Discussion with a colleague related to the chapter to be discussed.
- Preparation of students' worksheets or exercises.
- Preparation of students' exams.
- Activities done in class.
- Anything considered important by the teacher and related to preparing and teaching of the chapter related to the gene.

Appendix V: Sample of the guidelines of the third interview with Tania

- What are the new modifications that you have added for your resources this year related to the gene concept? For what purpose you did these modifications?
- What are the new digital and online resources that you utilized this year related to the gene concept? Can you precise the reason behind utilizing these new resources?
- Are you satisfied with the resources that you have utilized this year?
- Are there any modifications you are willing to do to these resources before implementing them next year? Can you precise these modifications and the reason behind them.
- How can the ministry of education or the CRDP support and help the teachers in utilizing digital resources?
- Why you did not utilize all the resources you gave in the second interview related to the gene concept (in translation, transcription and tour of genetics)
- How do you cooperate with teachers with other disciplines related to the exchange of resources? Do you discuss with them your resources?
- Do you ask them about new resources?
- Discuss the logbook with her.

Appendix VI: Guidelines for the fourth interview with Tania

- 1- According to you what are the modifications in the biology content for Bac I scientific class this year related to the gene concept?
- 2- What are the difficulties encountered in teaching the gene concept in general in your opinion?
- 3- Do you think that the new modifications related to the gene concept can solve these difficulties?
- 4- What were the interactions with the coordinator about these modifications?
- 5- What were the interactions with the teacher of the other class about the modifications related to the gene concept?
- 6- What are the *available resources* that can be used for teaching the gene concept this year?
- 7- Is there a necessity to introduce new resources about the gene concept related to the new modifications?
 - a- What are the kinds of these resources?
 - b- What is the source of these new resources?
- 8- Did you do any collective work with the coordinator to search for new resources about the gene concept related to the new modifications?
- 9- Did you do any collective work with the other teacher to search for new resources about the gene concept related to the new modifications?
- 10- Did you share any of your resources related to the gene concept with the other teacher of the class?
- 11- How are you going to implement in class the new modifications related to the gene concept?
- 12- Can you show me how do you organize the resources related to the gene concept on your computer?
- 13- **Can you draw a schematic representation that describes all the resources utilized in your teaching practices and how they are organized and the relation between these resources?**

Appendix VII: Guidelines of the fourth interview with Maya

- 1- How many CERD sessions did you attend during your professional life?**
 - a- Are there any sessions related to the gene concept?
 - b- Did any of these sessions affect you? In which way?
 - c- Did you use any material from these sessions as resources for your preparation and/ or teaching practices? What specifically and for what objective?
 - d- Did you attend any ICT session(s)? What precisely?
 - e- What did you incorporate in your system of resources from these sessions?
- 2- How do you interact with the other biology teachers in your school and outside school?**
 - a- Do you exchange resources with them?
 - b- Did you exchange with them any resources related to the gene concept? What did you exchange precisely?
 - c- What is the consequence on your system of resources and your teaching practices?
- 3- How do you interact with other teachers in the school? With the chemistry teacher of your school?**
 - a- What do you exchange with them precisely?
 - b- Do you ask them about any resources related to the gene concept?
- 4- How do you interact with your university colleagues?**
 - a- Did you exchange with them any resources related to the gene concept?
 - b- What did you exchange precisely?

Note: the question about the chemistry teacher and the university colleagues because she mentioned them in her interview.

- 5- How does the program webzib works?**
 - a- For what purpose you use it? What is the consequence on your resources and your teaching practices?
- 6- How did you search on the Internet for the digital resources that you utilized to prepare the PowerPoint about the gene concept?**
 - a- What specific key terms did you use to reach these resources?
 - b- What are the other resources utilized in designing this PPT?
 - c- Out of your repertoire of resources why did you choose these resources only?
 - d- For what reason you did not use the other resources?

- e- What are the resources that you utilized to achieve the objectives that you wrote in your lesson plan for this chapter?
- f- What were your criteria for choosing the resources related to the gene concept?
- g- If you want to classify these resources, what are the criteria that you will follow?
- h- Can you make a hierarchy for these resources according to these criteria?
- i- In the logbook filled last year you mentioned two teachers as other persons involved in the preparation of the PPT about the gene concept, can you explain for me your interaction with the two teachers precisely?
- j- Did the resources that you utilized last year in the preparation and teaching the gene concept met your expectations? In what way? If not why?

7- How are you going to implement the PPT about the gene and genetic information in class this year?

- a- What is the precise scenario that you are going to follow in implementing this PPT this year?
- b- Are there any modifications related to this PPT?
- c- If yes can you specify precisely these modifications?
- d- What is the purpose of these modifications?
- e- Are there new resources prepared this year related to the gene concept?
- f- What are the resources that you have eliminated this year and why?

8- Can you show me how do you organize the resources related to the gene concept on your computer?

9- Can you show me how do you organize other resources on your computer?

- a- How many similar PPTs related to other subjects did you prepare?

10- Can you draw a schematic representation that describes all the resources utilized in your teaching practices and how they are organized and the relation between these resources (schematic representation of the system of resources)?

Can you show me on this drawing what are the resources that you utilized this year for preparation and teaching of the gene concept?(The teacher will be provided with a paper and colored pencils)

Appendix VIII: Objectives and guidelines of the fifth interview

- 1- Define what is a gene for you? Draw a diagram to show what is a gene? What are the resources that allowed you to build your scientific information about the gene? How did your resources evolve during your teaching practices?

Objective: The definition and the drawing of the teachers will allow me to know the model in order to categorize teachers' conceptions as either H or E.

- 2- How do you define the gene concept for your students? Do you utilize the same resources that you used for building your scientific knowledge? If yes why and if not why? Among the resources that you have utilized to explain this concept, which one is considered as the best resource for you, for what reason? How did you evolve it?

Objective: The data collected from this question might allow me to understand the effects of conceptions on the choice of resources in general and specifically digital resources for teaching the gene concept in order to validate my hypothesis about the interaction between resources utilized, scientific knowledge, teaching practices and conceptions of teachers.

- 3- Draw a diagram to show what does the phenotype depend on?

Objective: The drawings of the teachers will allow me to know the model (Linear, interactive or intermediate) in order to categorize their conceptions about genetic determinism of phenotype as either **H or E**.

- 4- How do you explain the relation between genotype and phenotype for your students?

Among the resources that you have utilized to explain this relationship, which one is considered as the best resource for you, for what reason? How did you evolve it? Is it the same resource that you used 5 years ago?

Objective: The data collected from this question might allow me to better understand the effects of conceptions on the choice of resources in general and specifically digital resources for explaining the genetic determinism of phenotype in order to validate my hypothesis about the interaction between resources utilized scientific knowledge, teaching practices and conceptions of teachers. The answers of the teachers about resources might indicate evolution of resources that might lead to evolution of conceptions.

- 5- How do you define and present genetic diseases for your students? What are the resources that you utilize to explain genetic diseases for your students? How did your resources evolve during your teaching practices?

Objective: the answers of the teachers will allow me to infer their conceptions about the genetic determinism of phenotype; to know if teachers are utilizing resources other than the textbook (Internet for example) to present examples of genetic diseases illustrating the interactive process (Epigenetics) in determining the pathological phenotype like cancer (since these are not mentioned in the official textbook); validate the hypothesis about interaction between resources, scientific knowledge, teaching practices and conceptions of teachers

- 6- Give the name of the first genetic disease that comes to your mind other than those mentioned in the official textbook (Albinism, DMD and Sickle cell anaemia)? Explain the development of this disease and what might effect this development?

Objective: the example chosen by the teachers will allow me to know if the teacher is aware about the diseases that can show the interaction between genotype and environment, since some genetic diseases illustrate a simple linear genetic determinism, while others clearly demonstrate interactive processes (Epigenetics) in the development of the pathological phenotype.

Appendix IX: Objectives and guidelines for the sixth interview with Maya
Objectives:

- To infer the knowledge of Maya related about the influence of the environment on gene expression and the resources for this knowledge.
- To know when and how she introduces this influence for students.
- To know the objective of Maya for introducing the influence of environment.
- To know if she has any information about Epigenetics
- To know the resources used by Maya to prepare her personal PPTs, and the extra notes and courses she prepared for certain topics.
- To know the organization of her paper and digital resources (bags, her laptop, USB, computer at school...)
- To ask the teacher to draw a new SRSR to compare to the previous one
- To know the *critical resources* used by Maya
- To infer if there is any evolution of her resources after the two consecutive years of follow
- To clarify certain data of the logbook related to the documentary work of the teacher and the consequences of this work.

Guidelines for the 6th interview with Maya:

Part I: related to her scientific knowledge about the influence of the environment on gene expression and the resources for this information

- 1- When did you hear about the influence of the environment for the first time? (University, online, CAPES, colleagues...)
- 2- What are the resources?
- 3- When did you introduce the influence of the environment for students for the first time? For what purpose? How do you introduce it to students? What are the specific resources used?
- 4- You mentioned many times 80% influence of the gene and 20 % influence of the environment. What is the source of this information or it is an intervention from you? If yes what are the resources on which you build this information?
- 5- You mentioned certain examples about influence of environment can you specify for me the resources for your information:
 - About twins
 - About Himalayan rabbit
 - About intelligence
 - About the turtle

Can you show me these resources?

- 6- What was your objective of introducing example of Himalayan rabbit in your final exam?
- 7- You told me in the last interview that you changed the way of thinking about characters, why? And because of what?
- 8- What are the biological discoveries that you are reading about as you told in the last interview? What are the resources?
- 9- Have you heard about epigenetics before? When, how, what are the resources?

Part II: related to the resources used for her teaching practices personal

- 10- What are the resources used for the preparation of the PPTs that you prepared previously about: plants, brain and translation?
- 11- What is the purpose for preparing these PPTs?
- 12- Are you always implementing them in class?
- 13- Can you specify some educational websites that you use as resources in your teaching practices? What are their characteristics?
- 14- For what purpose you use these sites (new information, search animation, complements the book, illustration for the book?
- 15- Can you specify for me for which topics you prepared personal notes?
- 16- What are the resources you used for their preparation? For what purpose do you prepare them?
- 17- Can I see the bag for your resources and how they are organized
- 18- The papers in your bags are for what specifically?
- 19- What are the resources of these papers?
- 20- Do you always use them? For what purpose?
- 21- Do you renew them? How and using what resources?
- 22- Show me the knowledge extracted from the book Solomon and in which way they are stored?
- 23- Show me your preparation book?

Part III: related to SRSR:

- 24- Can you draw a new SRSR, showing all the resources mobilized for your teaching practices, how they are organized and what is the relation between them?
- 25- Can you explain for me your drawing?
- 26- Can you specify for me your *critical resources*?

Appendix X: Guidelines of the second interview with the coordinator

- 1- According to you what are the major modifications in the biology content for Bac I scientific class this year?
 - a- Are there any new scientific knowledge introduced?
 - b- Are there any new topics introduced?
- 2- For you what is the objective of these modifications?
- 3- According to you what are the modifications related to the gene concept?
- 4- For what purpose you introduced these modifications related to the gene concept?
- 5- Did you do any collective work with the two teachers of the class to discuss the modifications related to the gene concept?
- 6- What are the difficulties encountered in teaching the gene concept in general in your opinion?
- 7- Do you think that the new modifications related to the gene concept can solve these difficulties?
 - a- What are the consequences of these modifications on the teaching practices of the two teachers related to the gene concept in your opinion?
 - b- Can you anticipate the reaction of the two teachers of the class about these modifications related to the gene concept?
- 8- What are the *available resources* that can be used for teaching the gene concept by the teachers?
- 9- Is there a necessity to introduce new resources?
 - a- What are the kinds of these resources?
 - b- What is the source of these resources?
- 10- Did you do any collective work with the two teachers to search for new resources related to the gene concept?
 - a- Did you ask the two teachers to collaborate in searching for resources related to the gene concept?
Did you ask the two teachers to share their resources related to the gene concept.

- 11- What kind of common material resources will be given to the French and English students?
- 12- How did you follow the implementation of the new content this year?

Common questions to be asked to the two teachers of the same class for validity and reliability purposes:

- 14- What are the modifications done in the content of biology of BAC I scientific class related to the gene concept?
- 15- What are the difficulties encountered in teaching the gene concept in general in your opinion?
- 16- Do you think that the new modifications related to the gene concept can solve these difficulties?
- 17- What were the interactions with the coordinator about these modifications?
- 18- What were the interactions with the teacher of the other class about the modifications related to the gene concept?
- 19- What are the *available resources* that can be used for teaching the gene concept?
- 20- Is there a necessity to introduce new resources about the gene concept related to the new modifications?
- c- What are the kinds of these resources?
 - d- What is the source of these new resources?
- 21- Did you do any collective work with the coordinator to search for new resources about the gene concept related to the new modifications?
- 22- Did you do any collective work with the other teacher to search for new resources about the gene concept related to the new modifications?
- 23- Did you share any of your resources related to the gene concept with the other teacher of the class?
- 24- How are you going to implement in class the new program related to the gene concept?

Appendix XII: Logbook filled during the second year of follow-up
Related to resources the teacher can fill the format below:

Resources used (paper doc, digital resource, meeting, discussion with a colleague...)	Source of the resource (Personal repertoire, website, colleagues, other)	Purpose of using the resource, if applicable	The resource gives rise to production. Of What?	Production individual / collective (with whom?)	Archiving (where?)

Related to activities the teacher can fill the format below:

Type of activity carried out with the resource	What theme/sub-theme	Time of the activity	Location of Activity	Other persons involved	Resources utilized	Comments

Appendix XIII: Observation Grid**Name of the teacher:** _____**Name of the school:** _____**Private or
public:** _____**Location of the
school:** _____**Date:** _____**Place:** _____

- Classroom
- Technology room
- Other

Class observed: _____**Textbook utilized:** _____**Lesson explained:**

- Title of the
chapter _____
- Title of the
activity _____
- **Objectives of the lesson:**

Resources utilized by the teacher:

- 1- Use of the board for:
 - Drawing figures
 - Writing notes
 - Explaining ideas
- 2- Use of pictures about:

- From a book
 - From Internet
- 3- Use of transparencies about:

Digital resources

- 4- Utilization of animation
about: _____
 - Teacher explaining the animation
 - Students answering questions related to the animation
 - Students' work sheet prepared by the teacher related to the animation
- 5- Utilization of video or real player
about: _____
 - Teacher explaining the video
 - Students answering questions related to the video
 - Students' work sheet prepared by the teacher related to the video
- 6- Utilization of PowerPoint
about: _____
 - Teacher reading the slides
 - Teacher explaining all the slides
 - Asking students about the slides
 - Others: _____

Documents utilized

7- Utilization of the documents of the book

Type of document(s): _____

- Teacher explaining the documents
- Students working on the documents
- Discussion in class related to the documents

8- Utilization of documents prepared by the teacher

9- Type of document(s): _____

- Teacher explaining the document
- Students working on the document
- Discussions related to the document

10- Documents given for the students.

Type of documents(s): _____

Technological tools utilized:

- 1- LCD
- 2- Laptop
- 3- Overhead projector
- 4- Other:

Teacher's activities in the class (movement, asking questions and type of questions asked, his interaction with the students, how he is handling the class), extensive field notes about the development of the lesson along the time moment by moment from the beginning till the end of the period:

1- _____

2- _____

3- _____

Students' activities in class (group work, students working on the board....):

1- _____

2- _____

3- _____

Students' assignments:

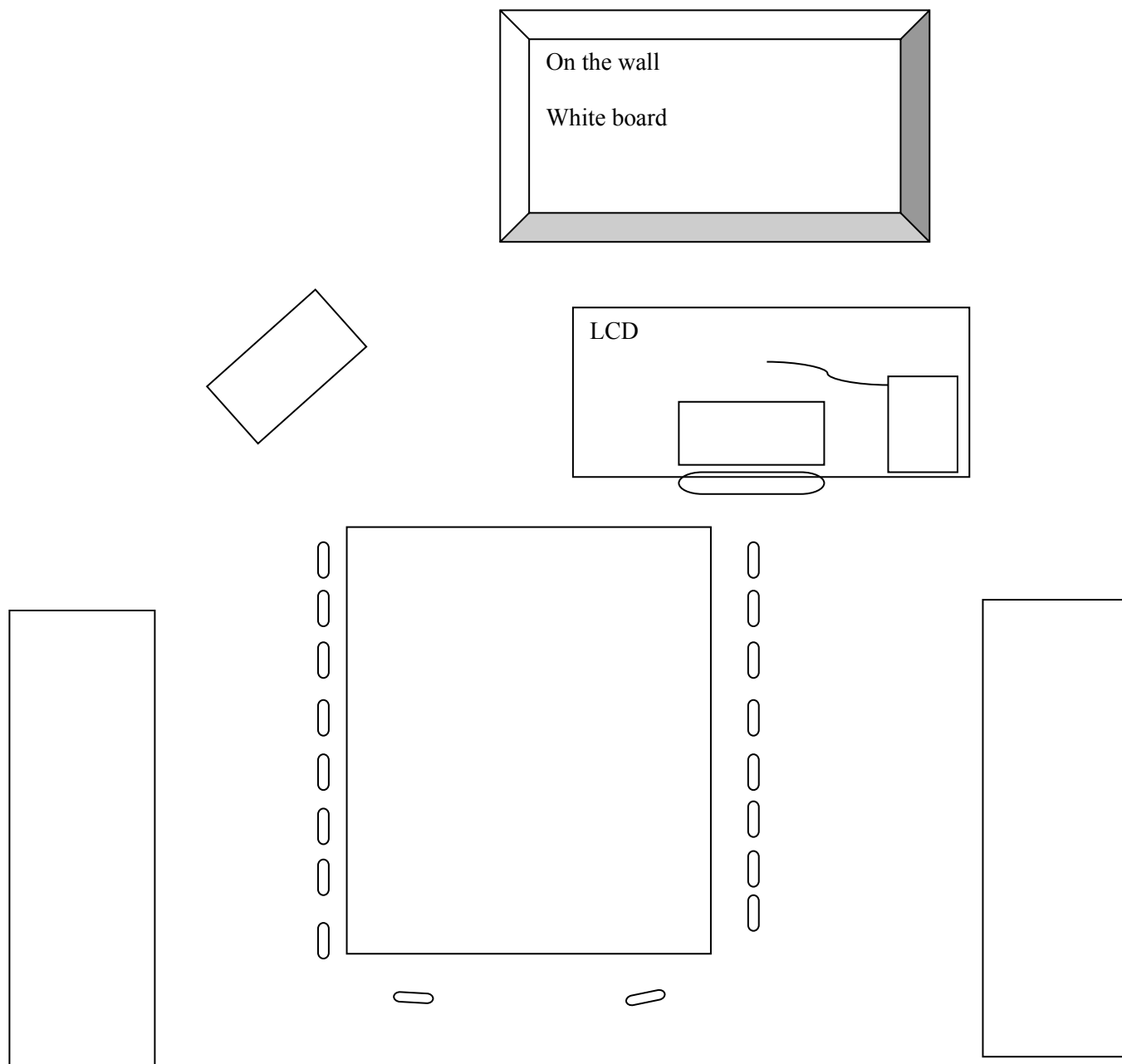
1- _____

2- _____

3- _____

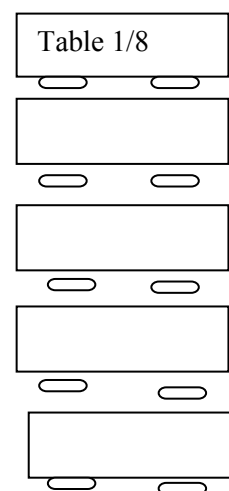
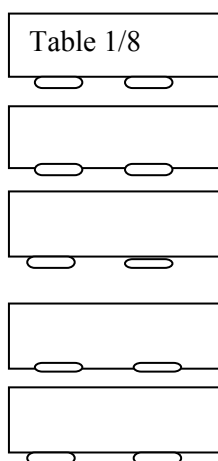
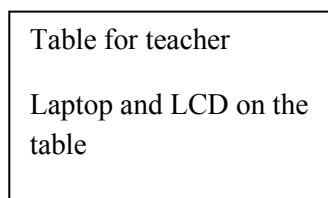
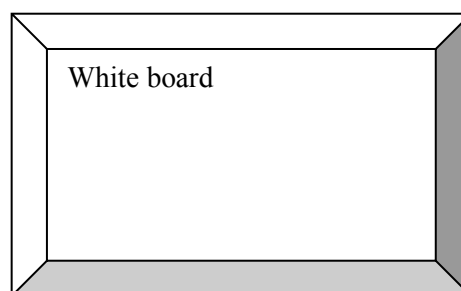
Comments:

Appendix XIV: Plan of the computer room in the public school of Maya



Appendix XV: Plan of the classroom of Tania

It contains white board, table and chair for teacher; two rows of students each row on a wall, with a space in the middle between the two rows. Two students sat on each table. The laptop, LCD and speakers were placed on the table of the teacher and the projection was on the white board.



Appendix XVI: Websites utilized in teaching genetic concepts

Websites	Percentage
Google	13%
www.Intelligo.com	5%
U tube	4%
Pubmed (NCBI)	4%
Wikipedia	3%
Many sites	3%
Different websites	3%
Not remembered	2%
Learn genetics	1%
McGrave virtual laboratory links	1%
www.4shared.com	1%
www.wiley.com/college	1%
www.learner.org/courses/biology	1%
Biol.alive.com/animation/genetics	1%
www.biology-books.com	1%
www.prometheanworld.com	1%
Le café pedagogique	1%
www.victoriaschool	1%
www.scilinks.orggoogle.com	1%
www.cnnfyi.com	1%
NSTA	1%
www.si-edu/hrwg.hrw.com	1%
Bio.com	1%

Officalexam.fr	1%
Any	1%
Medical sites	1%
Mc-grave hill	1%
www.dnalc.org	1%
Learn.genetics.utah.edu	1%
www.ravenbiology.com	1%
www.sylviamaderbiology.com	1%
Web quests	1%
Encyclopedia	1%
Education.com	1%
www.virtuallab.co.uk	1%
www.teacherswithoutborders.org	1%
www.studytemple.com	1%
www.wikipedia.org.gene	1%
www.theconceptgene.com	1%
www.genebase.com	1%

Appendix XVII: Criteria for using digital resources

Criteria	Percentage
No response	48%
Clear document	4%
Searching for updated information	4 %
Scientific knowledge	3%
It gives precise and correct information	3%
New ideas and information	3%
Obvious videos and animation	3%
Satisfies the objectives	3%
Simple and clear	3%
Utilize animation	2%
Search for concepts related to the objectives of the books	2%
Updated	2%
If the resource is referenced	1%
Everything new	1%
Can be handled easily	1%
Well informed	1%
Deepen knowledge	1%
Encyclopedia	1%
French books and software	1%
Remove information from many sites	1%
Can be used in class	1%
Does not lead to misconception	1%
Include just the needed information	1%
Meet the requirements of the Lebanese curriculum	1%

Explains in an easy way the concept	1%
Validity of the site	1%
To make exams	1%
No criteria at random	1%
Simplicity	1%
Challenging	1%
Relevant to teaching	1%
Depending on the grade	1%
Provide supplementary exercises	1%
Not specific	1%
Just from books	1%
Insists on the study of chromosomes, DNA & genetic information	1%
Books Internet	1%
Google and enter links	1%
Attractive and original	1%
Variety of supports	1%
Includes educational games	1%
Includes examples from daily life	1%
Includes figures and animation	1%
Educational websites	1%
Visual learning is a quick method for learning and understanding	1%
Students activities	1%
Accessible by students	1%

Appendix XVIII: Reason for integrating digital resources in teaching genetic concepts

Reason for integrating digital resources	Percentage
To see animation that facilitate the concept	11%
Facilitate and enhance teaching of gene concept	11%
No explanation	10%
To facilitate the comprehension of students	7%
Videos	6%
Simulation	6%
Make it easier to understand gene concept	6%
Because explanation of gene concept is difficult	5%
Updating knowledge	4%
To motivate students	4%
Since gene concept is abstract	3%
Deepen knowledge	2%
To see pictures	2%
Clarifies the relation between DNA sequence and genes	2%
Illustration	2%
Refresh the concept	1%
Demonstration	1%
They are continuously updated	1%
Oriented and controlled	1%
Clarity and diversity of documents	1%
New ideas	1%
In order to obtain many information	1%

To satisfy my own curiosity	1%
Active learning	1%
Make the concept much near to reality	1%
Since it is hard to explain this concept depending on the book only	1%
Open for more discussion in class	1%
Enrich scientific knowledge	1%
It facilitates communication and exchange of knowledge	1%
Fix the idea and decrease ambiguity	1%
New & additional information	1%
Provide new teaching methods	1%
Can change the abstract concept into vivid	1%
It is a matter of how to present the material	1%
Provide a live reference for teachers	1%
New ideas	1%
Saves time	1%
Can enhance long term memory	1%
Can enhance imagination of students	1%
Can make the ideas more clear and simplified	1%

Appendix XIX: Logbook filled by Tania, first year of follow up

Activities related to the preparation and teaching of the gene concept in grade 11 SC

Activity number & date	Activity Type	Time	Place	Other persons involved	Resources Utilized	Materials produced	Archiving: What? Where?	Comments
1 During the summer & vacations	Searching for resources on the Internet related to teaching of the gene concept	Many hours for more than one year	Home & School	No	Many sites: McGraw-Hill, you-tube and many other sites that I reached by Google search	PowerPoint related to genetic information & DNA. Students work sheets prepared using specific animations on: DNA replication, transcription and translation	Many animation videos and application related to the concept of the gene, Organized in specific folder on my laptop under the title of genetics	This work has been done continuously over several years so now I have a big archive with great number of resources related to genetics that I can use when I need.
2- At the beginning of the year 2011-2012	Discussion with coordinator	Many periods	Coordination room-school	Coordinator and the biology teacher of the English section of Bac I	Exchange of resources With the coordinator and the other teacher	Many digital resources from my archive	Construction of specific sequence to be followed in the genetic part this year: skipping certain ideas we used to give before like enzymes and following the sequence of the French books (as specified in	Specific folder on my laptop containing all the digital resources and work sheets to be utilized this year during the discussion of the topic of genetics. Paper folder containing

							our second interview)	all the hard copies of resources to be utilized in class: students work sheets, Exercises, and extra sheets to be given to students arranged in order according to the sequence to be followed
3 5-3-2012	Searching for a specific resources about protein structure	1 hour	Home	-	Quick time movie about the structure of protein	-	This new resource was added to the folder of the resources utilized in explaining the first chapter of the unit of genetics: phenotype depend on protein	My objective was to made students understand the relation between the three-dimensional structure of protein and its function and relate it to diseases studied in this chapter
4 18-3-2012	Searching for new resources to review basic ideas about DNA	2 Hours	Home	-	Videos downloaded from the Internet Reviewing the ideas that the students are supposed to know from grades 9 & 10			These new resources are added this year to do revision for the prerequisites for the chapters of DNA replication and mitosis and protein synthesis.
5	Revision about DNA & genetic	2 period	Classro	Students	3 videos downloaded	Schematic drawing	Videos saved on my	To review basic ideas taken before about DNA

<p>19-3-2012 & 21-3-2012</p>	<p>information</p>		<p>om</p>		<p>from Internet & animation about DNA from my archive</p>	<p>on the DNA structure</p>	<p>laptop.</p>	<p>& genetic information specifically because we have five new students this year from another school & to infer how DNA can determine the genetic information</p>
<p>6 26- 3-201</p>	<p>Discussion about Genetic printing</p>	<p>1 period</p>	<p>Classroom</p>	<p>Students</p>	<p>Animation and application Work sheet for student with extra -exercises</p>	<p>-</p>	<p>Specific folder on my laptop And papers saved in paper folder</p>	<p>Objective in order to make students understand the southern blot technique and apply it in paternity testing</p>
<p>7 27-3-2012</p>	<p>Discussion about electropherogram</p>	<p>1 period</p>	<p>Classroom</p>	<p>Students</p>	<p>Animation & Application sheet</p>	<p>-</p>	<p>Specific folder on my laptop and paper folder</p>	<p>Objective for students to be able to read an electropherogram</p>

<p>8 3-4-2012</p>	<p>Discussion of the conservation of genetic information</p>	<p>1 Period</p>	<p>Classroom</p>	<p>Students</p>	<p>Animation and application about cell cycle and DNA replication. & Student work sheet about DNA replication</p>	<p>Schema drawn about DNA replication</p>	<p>Specific folder on my laptop and paper folder to save the hard copies</p>	<p>Objective for students to understand how can DNA replication conserve the genetic information</p>
<p>9 22-4-2012</p>	<p>Preparing exercise about DNA replication</p>	<p>1 hour</p>	<p>Home</p>	<p>-</p>	<p>Exercises downloaded from Internet before and kept in my archive And documents of the book</p>	<p>Exercices application on Taylor experiment</p>	<p>Specific folder on my laptop and paper folder</p>	<p>For students to understand that DNA replication is semi-conservative depending on Complementarily between bases</p>
<p>10 24-4-2012</p>	<p>Application experiment on DNA replication</p>	<p>1 period</p>	<p>Classroom</p>	<p>students</p>	<p>Video about Meselson and Stahl Experiment</p>		<p>Video saved on my laptop</p>	<p>For students to understand that DNA replication is semi-conservative depending on Complementarily between bases</p>

11 2-5- 2012	Discussion about transcription	1 period	Classroom	Students	Animation and application about transcription And student worksheet	Schema for the transcription step	-	Objective for the students to recognize that transcription is a mechanism by which the gene is the template for the synthesis of m RNA
12 2-5- 2012	Correction of students work sheets about transcription	1 hour	Home	-	-	-	-	To infer the parts that they did not understand in order to choose the resource on which I will make my synthesis to emphasize the idea of transcription

13 7-5-2012	Searching for resources from my archive	Half an hour	Home	-	Video about early genetic engineering experiment and video about creating a transgenic animal			Objective to review for the students the idea of transgenesis
14 8-5-2012	Discussion of genetic code	1 period	Classroom	Students	Resources mentioned in activity 13 and PowerPoint about genetic code downloaded from Internet and modified by me			Objective to infer that genetic code is universal and to learn how to translate nucleotide language to amino acid language using the table of genetic code
15 14-5-2012	Organizing my resources about translation	Half an hour	Home	-	Resources utilized before about translation: animations about translation and students work sheet about translation	New folder containing the resources to be utilized in translation	Folder saved on my laptop	

16 15-5-2012	Discussion of translation	1 period	Classroom	Students	Resources mentioned in activity 15	Schema related to the step of translation		Objective to learn the steps of translation and precise the tools of translation
17 16-5-2012	Discussion of mutation	1 period	Classroom	Students	Documents of the book and student work sheet about mutation	Exercises about mutation		Objective to treat mutation at the level of the gene and apply it directly in translation
18 21-2-2012	Discussion of the fate of synthesized protein	1 period	Classroom	Students	Animation: application about fate of synthesized proteins	Graph drawn showing the variation of radioactivity In different cellular organelles with respect to time after placing cells in medium containing radioactive amino acid	Animation saved in specific folder on my laptop and graph saved in my paper folder	Objective to infer the fate of protein after they are synthesized in ribosome
19 29-5-2012	Discussion of the relation between gene, phenotype and environment	1 period	Classroom	Students	Documents of the book			For the students to infer the influence of the environment on gene expression

Appendix XX: Logbook filled by Fadi, first year of follow up

Activities related to the preparation and teaching of the gene concept in grade 11 scientific Class:

Activity number	Activity Type	Time	Place	Other persons involved	Resources Utilized	Materials produced	Archiving: What? Where?	Comments
1 Form beginning of February till the end of April 2012	Working on a project with students related to the gene concept	1 hour after school twice per week from February - April/2012	School	Group of students form Grade 11 Scientific	Documents of the book. House hold material: pins, attach, wires, cardboard papers, wooden stand, colored pencils, colored beads.	A model was constructed that simulate the process of protein synthesis	It will be used in the science fair and then it will be kept in school	I am responsible about science club in the school and this year I thought in constructing this model because it will help the students in understanding protein synthesis
2 20 & 23 /4 2012	Discussion of DNA replication	2 periods	Classroom	Students	Documents of my book Animation about DNA	Schematic drawing of the process of DNA replication	Animation is kept on my laptop	When I prepared my book I used this animation and I formulated questions

					replication			about it and place them in the book. So when I explain this part the students will see the animation answer the questions and then we will discuss
3 27-4-2012	Application exercise on DNA replication	1 period	Classroom	Students	Exercise on DNA replication prepared by me before		Schematic drawings of colored chromosomes representing the semi-conservative replication	This is done as practice for students
4 15-18-5-2012	Explanation of transcription & genetic code	3 periods	Classroom	Students	Documents of my book & animation about transcription	Schematic drawing of transcription step	Animation saved on my laptop	My book contain questions related to this animation to Be answered by students and then discussed in class

5 21-25-5-2012	Explanation of translation	3 periods	Classroom	Students	Documents of my book & animation about translation	Schematic drawing of translation on step	Animation saved on my laptop	My book contain questions related to this animation to Be answered by students and then discussed in class
6 28 & 29-5-2012	Explanation of mutation as application on translation	2 period	Classroom	Students	Documents of my book			In order for the students to make the link between Gene mutation and appearance of hereditary diseases

Note: I spent a long period of time several months preparing my book utilizing many resources: mainly the official textbook, the French book “Bordas” (2007) American books that I use to get pictures from, my archive of students work sheets, exams and exercises. And of course using my experience in teaching I organized all these resources. I have been utilizing this book in this school since the academic year 2009-2010.

**Appendix XXI: Logbook filled by Marwa, first year of follow up
Activities related to the preparation and teaching of the gene concept in grade 11 scientific class.**

Date: January- April- 2012

Activity number	Activity Type	Time	Place	Other persons involved	Resources Utilized	Materials produced	Archiving: What? Where?	Comments
1	Explanation of the DNA	1 Period	Classroom	Students	Documents of the textbook	Drawing the DNA structure		
2	Searching for information about DNA on The Internet	2 hours	Home	No	Specific site on the Internet containing 100 facts about DNA Site: www.eyendna.com A video with a rap song about DNA structure	Copy printed out for the students about 100 facts about DNA CD for the students containing the Song about DNA	I saved the information in a folder about DNA and I made hard copies for the students CD with the	Students were supposed to put check marks beside the information they know and by reading all they will learn new information about DNA. By memorizing the song the students will learn the

					downloaded from u-tube	for the students	Video about the rab song for the students to learn it	DNA structure and have fun at the same time
3	Recall information about DNA	1 period	Classroom	Students	PowerPoint prepared about DNA structure	I made the animation in the PowerPoint after drawing the structure of DNA	Folder on my laptop	To reemphasize the structure of DNA
4	Constructing DNA model, simulation of condensation of DNA	1 period	Classroom	Students	Activity downloaded from Internet Site: www.lessonplansinc.com	DNA model constructed by students	The model was kept in class	On the model directly the students simulated the process of DNA condensation by coiling the DNA molecule on their friend representing the histones

5	Explanation of DNA replication	2 periods	Classroom	Students	Documents of the textbook PowerPoint about replication And video about replication	Schematic drawing of the process of replication	PowerPoint and video are saved on my laptop and on CD	Simulating the experiments of DNA replication using digital resources allows the students to understand the semi-conservative process of DNA replication
6	Extraction of DNA	Half period	Laboratory	Students	Document from book (Solomon)			To learn how to extract DNA
7	Simulation for the process of DNA replication	1 period	Classroom	Students	The DNA model produces in previous activity	Model for DNA condensation	The model was kept in class	The students simulated the process of DNA replication on the DNA model and they were able to understand the semi-conservative process.
8	Explanation of the first step of protein synthesis, transcription	2 periods	Classroom	Students	Documents of the textbook and from book Solomon			Objective: Proving the presence of RNA Differences between RNA and DNA Path of RNA observed by radiography.

8	Explanation of translation the second step of protein synthesis	2 periods	Classroom	Students	Documents of the textbook and from book Solomon			For students to learn: -the elements of translation and the role of each Steps of translation and results.
9	Revision and emphasis on the process of protein synthesis	1 period	Audio room	Students	PowerPoint prepared, Animation about translation and videos about transcription and translation			To simulate transcription & steps of translation. The students liked the presentation
10	Searching for application on protein synthesis	One hour	Home	No	Specific Internet site: www.lessonplansinc.com	Students worksheets related to the activity	Saved in a folder on my laptop. Hard papers saved in my paper folder	To check if the students can apply the steps of protein synthesis
11	Explanation of the fate of synthesized proteins	1 period	Classroom	Students	Document of textbook			To relate the function of different cellular organelles to the steps of secretion of synthesized protein
12	Simulation of transcription and	1 period	Classroom	students	Activity downloaded from Internet	Polypeptide chain of amino acids	-Folder on my laptop	Each group will simulate protein synthesis and synthesize a polypeptide

	translation				Site: www.lessonplansinc.com Teach to inspire		Polypeptide chain produced with the corresponding gene were kept in class	chain starting from a gene
13	Simulation for mutation	1 periods	Classroom	Students	Activity downloaded from Internet Site: www.lessonplansinc.com		Activity saved on my folder on my laptop and hard copies saved in my paper folder	Identification of different types of mutation and their effect on produced protein
14	Explanation of DNA finger printing or profiling and gel electrophoresis	3 periods	Classroom	Students	Documents of the book PowerPoint about DNA finger prints and gel electrophoresis, animation about southern blot technique and video about southern blot technique		The PowerPoint, animation and videos are saved in a folder on my laptop	When observing the video that shows the steps of DNA profiling and the equipment used the students can understand how this process done in reality because it can not be done in school laboratory
15	Simulation for the DNA profiling and Gel electrophoresis	1 period	Classroom	Students	Activity from Internet I downloaded from long time I don't remember the site	Report by students about analysis of the results	Paper documents	Applying the activity of DNA profiling in class was very effective and the students were able to understand all the steps and they liked it a lot

**Appendix XXII: Logbook filled by Maya, first year of follow up
Activities related to the preparation and teaching of the gene concept in grade 11 scientific class.**

Date: December 6 → February 20- 2012.

Activity number	Activity Type	Time	Place	Other persons involved	Resources Utilized	Materials produced	Archiving: What? Where?	Comments
1	Hands on activity: Playing with clay to relate the protein structure to its function.	Half an hour	At the classroom	The students of Bac I sections A & B	Colored clay and wires	Models of proteins	I kept the model at home	The model was successful; the students were motivated and understood the concept.

2	Preparation of lesson plan	About 2 hours	At home	–	The book of life science Bac I and the book 4 th edition “Salomon”, chapter 4	A lesson plan and a work plan made to achieve the objectives	In the teacher’s copybook for preparation	The lesson plan includes general and specific objectives
3	Preparation of a PowerPoint for transcription and translation	About 15 hrs	At home	Biology teacher (2)	Biology book Salomon, 4 th edition. Internet resources (given as a list)	A PowerPoint for the explanation of transcription and translation	PowerPoint on computer and flash memory.	The PowerPoint succeeds in presenting information with videos to students but it is not sufficient to over rely on ppt to explain this hard concept.
4	Making search on the Internet to find videos or animation	About 10 hrs	At home		The Internet: specific education websites(14 websites)	Videos and animations and pictures about transcription and translation	Videos and animated pictures down loaded from the net and saved in specific files on computer	This work took huge time to be done

5	Show the PowerPoint with videos and animated pictures	About 3 periods	At the classroom	The students of Bac I sections A & B	-LCD -Computer		The PowerPoint in the school's computer	Te presentation was successful. The students were motivated and understood this concept.
6	Searching for an example from students' life to imitate the gene conception.	About 2 hrs	At home		The Internet educational websites (4 websites for transcription and translation.	Simulation or imitation idea that the gene resembles a recipe that codes for one food type.	This idea was used in the PowerPoint in the form of animated pictures.	This concept was better understood by the students since it is related to their daily life.

Appendix XXIII: Logbook filled by Maya, second year of follow up
Related to resources the teacher can fill the format below:

Resources used(paper doc, digital resource, meeting, discussion with a colleague...)	Source of the resource (Personal repertoire, website, colleagues, other	Purpose of using the resource, if applicable	The resource gives rise to production. Of What?	Production individual / collective(with whom?)	Archiving (where?)
A book "Biology Solomon"	Personal repertoire	Revision of knowledge and preparation	-Preparation of lessons for Bac I	-Individual	-In the preparation Notebook
Discussion with a biology teacher "French"	Websites	To determine the type of videos that will be shown in class	Use some animation videos for the explanation of transcription	-Collective with another biology & chemistry teachers	-In a software at school
the teacher's (my) notebook "preparation"	Personal repertoire (my preparation)	revision of the preparation	-A lesson plan	-Individual	-In the preparation copybook

Previous PowerPoint prepared in 2011 & 2012	-Personal repertoire & websites	-Revision of PPTS to improve them	-New improved PPTs	-Individual	-My laptop -USB
Previous Active Inspire projects	-Personal repertoire -Active Inspire Project taken from a colleague	-Preparation of new project "Active Inspire"	-A new Active Inspire project	-Individual -Collective "by taking a project prepared by a colleague"	My laptop -USB
For animation videos the websites used are:	www.johnkyrk.com www.class.uni.com www.transcription.mov www.traduction.mov DNAbasics.mpg proteosynthese.mov				

Related to activities the teacher can fill the format below:

Type of activity carried out with the resource (activity preparation, implementation in class, review of the resource after its implementation)	What theme/sub-theme	Time of the activity	Location of activity	Other persons involved	Resources utilized	Comments
Reading a book	Gene regulation: the control of gene expression Chap:13	2 hours	At home	_____	A book "Biology 4 th edition Solomon	
Preparation	-To show animation videos about transcription	50 min	At school	-Biology teacher -Chemistry teachers -Students	-websites www.johnkyrk.com www.class.uni.com www.transcription.mov www.traduction.mov	

					DNAbasics.mpg proteosynthese.mov	
Reading the lesson plan for transcription (previous year)	- Transcription	10 min	At home	_____	-My preparation copybook Lesson plan	
Review of the Power Points	- Transcription & translation	1 hour	At home	_____	PPTs prepared before in 2011 & 2012	
Review of the	- Transcription	10 min	At home	_____	Websites mentioned above	

Animations videos	& translation					
Preparation of a new PPT by improving the previous ones	- Transcription & translation	5 hours	At home	_____	-previous PPTs prepared by me in 2011&2012	
Preparation of Active Inspire project	- Transcription & translation	Around 10 hours	At home	_____	-previous PPTs -Previous Active Inspire project prepared by a biology colleague "Sarah" -websites	

Implementation in class	Transcription & DNA structure	50 min	At school in technology room	-Students of grade 11 -Lab assistant	Animation videos mentioned before	Students were motivate & understood the DNA structure
Implementation in class	Translation	50 min	At school in technology room	-Students of grade 11 -Lab assistant	PPT prepared by me +Animation videos	Students were motivated

Implementation in class	Translation	50 min	At school in technology room	-Students of grade 11 -Lab assistant	PPT prepared by me +Animation videos	Students were motivated
Implementation in class	Translation	50 min	At school in technology room	-Students of grade 11 -Lab assistant	PPT prepared by me +Animation videos	Students were motivated

Appendix XXIV: Logbook Filled by Tania, second year of follow up
Related to resources the teacher can fill the format below:

Resources used (paper doc, digital resource ,meeting, discussion with a colleague...)	Source of the resource (Personal repertoire, website, colleagues, other	Purpose of using the resource, if applicable	The resource gives rise to production. Of What?	Production individual / collective(with whom?)	Archiving (where?)
Digital resources (animation and videos)	Personal archive	Visual	Group work and students' sheets; synthesis; problem situation	Individual	Laptop
Lab (extraction of DNA)					
Books					
Annals					

Related to activities the teacher can fill the format below:

Type of activity carried out with the resource)	What theme/sub-theme	Time of the activity	Location of Activity	Other persons involved	Resources utilized	Comments
Lab (extract DNA	DNA		School	Students	Archive books	
two researches	Cancer Myeloma Mucoviscidose. Maladies genetique et environnement Resistance bact.		Home School	Students	Internet	
Animation sheets			School			
Tache complexe	Emprint genetique		School	Coordinator/ Internet		

Appendix XXV: Syllabus of the Lebanese curriculum for grade 11 Sciences

Section:

1- Functional characteristics of living system at the cellular level

Studying the functional characteristics of living systems at the cellular level allows the explanation of some fundamental aspects of biology.

This part of the program includes the genetic make-up of living things, molecular turn over, and energy metabolism.

Emphasis is placed upon the effect of the “predetermined genetic” programing of organisms on their need for nutrients

1.1 Genetic information

1.1.1 Diversity of organisms: prokaryotes and eukaryotes

1.1.2 DNA, genetic information and, and the cell cycle

1.1.3 From gene to protein

1.1.4 Enzymes as biological catalysts

1.1.5 Genetic make-up of living things

1.2 Molecular turnover and metabolic energy

1.2.1 Molecular turnover

1.2.2 Use of energy by organism

1.2.3 Cellular energy

1.2.4 Energy metabolism in man

2- Interdependence between living things and their relations with the environment

2.1 Converting light energy into chemical energy

2.2 Energy flow and the carbon cycle in ecosystems

2.3 The human impact on carbon cycle

3- Nutrition and health

The purpose of this section is to explain the need for a diversity of feeding habits and the requirements of a balanced diet. Both favor maintaining normal body functions and in preventing diseases caused by malnutrition.

3.1 Dietary habits

3.2 Basic principles of balanced diet

3.3 Diet related diseases: characteristics, causes and prevention

Cat.a: Image of a chromosome

Cat.b: Image of DNA (part of) molecule or other molecule

Cat.c: Image of a phenotype

Cat.d: Symbolic/logical models of crosses

Cat.e: Other images (specify)

C-3. Grid-Linear (causal, simple) determinism *versus* retroaction(s), cyclic or systemic approach for Human Genetics

C-3.2. Images of human twins:

Human Twins		Same clothes, hair style...	specific differences
p.20(1)		Yes	
Total	1	Total of "yes"	1

C-3.3. Analysis of images of genetic mechanisms containing at least one arrow

	Linear determinism (or additive model)			Cycles, feedback (interactive models)			
	Images categ.A	Images categ.B	Images categ.C	Images categ.D	Images categ.E	Images categ.F	Images categ.G
Pages et number of images	p.22 (1) p.28 (1) p.30 (1) p.47 (2) p.52 (1) p.53 (1)	p.24(1)					
Total	7	1	0	0	0	0	0

Without feedback

categ. A: one arrow

categ. B: single chain of arrow

categ. C: ramifications of arrows (without any feedback)

categ. D: other linear causal or additive determinism

• One or several feedback arrows

categ. E: one cycle with 2 arrows

categ. F: one cycle but with a chain of arrows

categ. G: systemic approach, if more than 1 cycle

Any specific comments?

Most of the images of genetic mechanism contain one arrow and they indicate the single linear causal determinism: Genotype → Phenotype.

C-7. Grid-Epistemological approach for Human Genetics**C-7.0. Interactions between DNA and its surroundings**

Example	If yes, specify the page(s)
DNA methylation	
Interaction with histones	p.38 p.32* P.42
DNA damage and repair	
Mutation after radiation (X-ray, radiation UV, etc.)	
Transposon (jumping genes)	
Other, specify	

* In this page I find out that the DNA is interacting with a protein without specifying its name, which is “histone”

C-7.1. Conceptions of the gene.

Chapter by chapter	Mendelian factor	Population Genetics	Mutation Evolution	Chromosome(s) or portion of it	Portion of DNA	Other (specify)
1	+	+	0	0	0	0
2	+	0	0	0	0	0
3	0	0	+	0	++	0
4	+	+	++	++	+	0

C-9.Grid- Conformity between syllabus and textbook for Human Genetics.

The main concepts and ideas of the National Program for human genetics are all illustrated in this textbook.

Appendix XXVII: The objectives of the activities of the chapter of the gene concept as written by Maya:

Title of the chapter: Protein synthesis and enzymatic activity		
Title of activity	General objectives	Specific objectives
Activity 1: proteins an association of amino acids	The relationship between DNA, the carrier of genetic information and the synthesized protein.	<p>1-To identify the constituents of proteins by studying the results of chromatography (Doc. a, from the textbook).</p> <p>2-the function of a protein depends on its structure which is made up of a specific sequence of amino acids.</p> <p>3-Deduce the cause of the diversity of proteins by solving exercise 1 (p: 51, in the textbook).</p> <p>4-What changes should an inactive protein undergo in order to become active (answer by comparing documents c & d, p: 51, in the textbook).</p>
Activity 2: The gene, structure and information unit	<p>1-Note that the genetic material is made up of a group of units called genes aligned in a linear form along the DNA molecule.</p> <p>2-To know that a specificity of a gene depends on the sequence of the nucleotides.</p> <p>3-To note that the gene is a <u>structural unit</u> (a coded segment of DNA molecule) & an <u>informative unit</u> that directs the synthesis of predetermined polypeptide chain.</p>	<p>1-Deduce the relation that exists between the gene of interest & the protein by interpreting doc-a (p: 52, in the textbook).</p> <p>2-To define the transgenic individual.</p> <p>3-to compare between the material constituting a gene to those constituting a protein (doc-b)</p> <p>4-To relate the sequence of amino acids of proteins to the sequence of nucleotides of a gene that directs its synthesis.</p> <p>Work: explanation of the genetic code</p>

<p>Activity 3: Transcription: 1st step of protein synthesis</p>	<p>-Understand that m RNA is a copy of a gene made by transcription</p>	<p>1-Determine the chemical structure of RNA molecule by referring to doc-b (p:54, in the textbook)</p> <p>2-Extract from doc. a location of DNA & RNA molecules after reading the text 1.</p> <p>3-Determine the fate of synthesized m RNA by referring to doc –c.</p> <p>4-Compare between DNA & RNA in a table by referring to doc-b (p: 54) and doc-d (p: 39).</p> <p>5- explain the steps of transcription:</p> <p>Detailed explanation written in the lesson plan</p>
<p>Activity 4: Translation: second step of protein synthesis</p>	<p>1-m RNA is the carrier of genetic information from the nucleus to the cytoplasm.</p> <p>2-During protein synthesis the amino acids are connected together in order under genetic control.</p> <p>3-Determine the tools of translation. (Details of explanation of the tools of translation is written in the lesson plan).</p> <p>4-Explain the steps of translation.</p>	<p>1-Compare b/w m RNA & t RNA using docs- b & d.</p> <p>2-Resume the main steps of translation. (detailed explanation of the steps written in the lesson plan)</p> <p>3-Analyze doc- c to link between m RNA and the synthesized protein.</p>

Appendix XXVIII: Syllabus of the French program, 2007, applied during the first year

DIVERSITE DES PHENOTYPES

Les différentes échelles

Problématique : Comment définir un phénotype ?

EXEMPLES DE PHENOTYPES :

□ **La drépanocytose :**

- à l'échelle de l'organisme = **anémie**
- à l'échelle cellulaire = hématies (= globules rouges) déformées (en forme faucilles)
- à l'échelle moléculaire = solubilité de l'hémoglobine modifiée.

L'anémie est due au changement d'un acide aminé dans la séquence polypeptidique de l'hémoglobine.

- ==> modifie la solubilité des HbS prenant un aspect fibreux
- ==> déforme les hématies
- ==> difficultés respiratoires
- ==> anémie

□ **La phénylcétonurie :**

- à l'échelle de l'organisme = retard mental irréversible
- à l'échelle cellulaire = dysfonctionnement des cellules hépatiques (du foie) qui entraîne une accumulation de phénylalanine
- à l'échelle moléculaire = enzyme PAH (phénylalanine hydroxylase) chargée de transformer la phénylalanine en tyrosine a une séquence modifiée.
- ==>enzyme partiellement voire entièrement inactive.

CONCLUSION

Il y a donc trois niveaux de définition du phénotype :

- Phénotype **MACROSCOPIQUE**
- Phénotype **CELLULAIRE**
- Phénotype **MOLECULAIRE**

Dans les différents cas, **transformations de protéines** au niveau moléculaire.

Leur réalisation dépend des protéines

Problématique : Comment les protéines sont-elles à l'origine des phénotypes ?

Les variants protéiques sont à l'origine des phénotypes alternatifs.

EXEMPLES DE VARIANTS :

Protéines d'hémoglobine :

Phénotypes malades (drépanocytose, -thalassémie).

-> changement sur chaîne de l'HbA -> Maladie

Variants protéiques :

Apparition du phénotype « couleur des yeux » chez les drosophiles.

Pour un caractère donné, il existe plusieurs variants : « alternatifs » dus à des différences dans les protéines qui les conditionnent.

- **Différences qualitatives** -> la protéine ne présente pas la même structure primaire, donc tridimensionnelle, donc elle présente des propriétés fonctionnelles différentes.

- **Différences quantitatives** -> la protéine fabriquée est identique, mais la quantité n'est pas la même d'un individu à l'autre donnant ainsi plusieurs phénotypes.

CONCLUSION :

Dans tous les cas, il y a plusieurs phénotypes d'un même caractère qui apparaissent conditionnés par les caractéristiques d'un type moléculaire: **les protéines**.

Synthèse des protéines

Problématique: Comment sont synthétisées les protéines ?

RELATIONS ADN-PROTEINES

• Les gènes permettent la formation des protéines :

-Mise en évidence

Dans les expériences de **transgénèse** :

L'insertion d'un gène chez un individu qui ne le possède pas conduit à la synthèse d'une protéine qu'il ne fabriquait pas auparavant d'où la relation entre le gène et la protéine.

-Interprétation Les protéines doivent leur spécificité à leur séquence, liée à l'ADN (porteur de l'information génétique).

La portion d'ADN portant l'information pour une protéine est appelée « gène » (portion d'ADN occupant un locus précis sur un chromosome donné et qui gouverne la synthèse d'une protéine).

Les gènes sont responsables de la synthèse des protéines.

• Les gènes sont des fragments d'ADN, supports de l'information génétique.

ADN = Acide désoxyribonucléique. C'est la plus grosse macromolécule du monde vivant.

Formé de nucléotides, eux-mêmes formés par :

- un acide phosphorique,
- un sucre : désoxyribose,
- une base azotée (Adénine, Thymine, Guanine ou Cytosine).

Formé de deux chaînes complémentaires de nucléotides, reliées par leurs bases azotées complémentaires deux à deux (A - T et G - C) et formant une double hélice (3'-5' et 5'-3').

Problématique : Par quels mécanismes l'ADN permet-il la synthèse des protéines ?

DE L'ADN A LA SYNTHÈSE DES PROTEINES :

• Transcription : 1ère étape de la synthèse des protéines

La transcription se fait **dans le noyau de la cellule**.

□ *Mécanisme :*

- Copie d'une séquence nucléotidique d'un brin d'ADN sur la portion d'un gène en une séquence nucléotidique complémentaire constituant le brin d'**ARNm** (m comme messenger).
 - L'ADN se « déenroule » au niveau d'un gène codant pour une protéine donnée grâce à un complexe enzymatique : l'ARN polymérase.
 - Un des deux brins de l'ADN, à savoir le brin informatif (ou transcrit ou 3'-5') sert de modèle à la fabrication de l'ARNm.
 - Chaque nucléotide de l'ADN « attire » un nucléotide complémentaire à l'exception de l'Uracile qui remplace la Thymine sur l'ARNm.
 - L'ordre de nucléotides de l'ARNm est imposé par l'ordre de ceux de l'ADN.
 - L'ARNm se détache et migre hors du noyau cellulaire dans le cytoplasme en sortant par les pores nucléaires.
 - Réassociation des brins d'ADN lorsque l'ARN polymérase se détache.
- Le brin d'ARNm est identique à celui de l'ADN non transcrit sauf que l'Uracile remplace la Thymine dans la séquence.

□ *Molécules impliquées :*

A part l'ADN et l'ARNm, d'autres types d'ARN sont formés, notamment l'ARN de transfert (ARNt) qui est une molécule formée de peu de nucléotides (environ 70) et présente un aspect globulaire. L'ARNt est « bilingue » car cet anti-codon (= complémentaire au codon) fixe un acide aminé complémentaire du codon de l'ARNm qu'il est capable de reconnaître.

De l'ARNr (ribosomal), constitutif des ribosomes, est aussi produit.

Tous ces ARN vont intervenir dans l'étape suivante : la Traduction.

• **Traduction : 2ème étape de la synthèse des protéines**

La traduction se fait **dans le cytoplasme**.

□ **Mécanisme :**

- C'est le **code génétique** qui permet le passage du gène à la protéine
- Dans celui-ci, un acide aminé correspond à une succession de 3 nucléotides : **TRIPLET ou CODON**.
- Le code génétique est redondant (= dégénéré) car plusieurs triplets peuvent avoir la même signification, c'est-à-dire coder pour le même acide aminé.
- **Le code génétique est universel** car un même triplet correspond à un même acide aminé, que ce soit chez l'homme, l'animal, le végétal ou la bactérie.
- Certains codons ne correspondent à aucun acide aminé, ce sont les codons « Stop » ou « Non Sens ».

La traduction est la transformation d'un message contenu dans un acide nucléique, l'ARNm, en une chaîne polypeptidique. Elle se réalise au niveau des **ribosomes** avec l'intervention des **ARNt** (t comme transfert) en **3 étapes** :

- l'initiation :

L'ARNt initiateur se fixe sur un codon de l'ARNm. Cet ARNt est relié à la Méthionine car le premier codon est toujours AUG (Adénine, Uracile, Guanine). Pendant ce temps, les 2 sous-unités du ribosome viennent se fixer à l'ARNm.

- l'élongation :

Fixation d'un nouvel ARNt en face du 2ème codon de l'ARNm => formation d'une liaison peptidique entre deux acides aminés.

Translocation du ribosome d'un codon => mise en place d'un 3ème acide aminé.

L'ARNt du second retourne dans le cytoplasme et ainsi de suite.

- la terminaison :

Le ribosome arrive à un codon STOP ou NON SENS (UAA, UAG, UGA) auquel ne correspond aucun acide aminé, donc aucun ARNt.

La chaîne protéique se détache alors du ribosome.

□ **Structures impliquées :**

Ces structures cellulaires peuvent être mises en évidence par l'autoradiographie.

L'autoradiographie permet de suivre l'ADN par marquage de la Thymine (présente seulement sur l'ADN et non sur l'ARN) et l'ARN par marquage de l'Uracile (présente seulement sur l'ARN) ou encore le devenir des protéines par marquage des acides aminés.

Dans la cellule : différents ensembles (=organites) interviennent dans la Traduction :

- **le Réticulum Endoplasmique** : ensemble de « sacs plats » sillonnant les cellules.

- peut être granuleux (REG - Réticulum Endoplasmique Granuleux), c'est-à-dire tapissé de ribosomes

- peut être lisse (RE - Réticulum Endoplasmique)

- **l'appareil de Golgi** : ensemble de sacs plats, proche du noyau, qui émet des vésicules dites Golgiennes.

- **les Ribosomes** : particules plus ou moins sphériques riches en ARN et protéines et formées de 2 sous-unités : 1 grande et 1 petite. Les ribosomes peuvent être groupés (polysomes) sur l'ARN ou être fixés au REG.

La synthèse des protéines nécessite donc la présence de diverses molécules (ARNm, ARNt, ARNr, ADN) ainsi que de structures cellulaires telles que les ribosomes, l'appareil de Golgi ou le REG.

Complexité des relations entre génotype, phénotype et environnement UN PHENOTYPE POUR PLUSIEURS GENOTYPES

• Le génotype conditionne le phénotype

Génotype : ensemble des allèles des gènes.

* La plupart des êtres vivants sont constitués de cellules majoritairement **diploïdes** (2n) sauf les gamètes qui sont **haploïdes** (n).

* 1 cellule = x paires de chromosomes. Pour l'homme $x = 23$.

Gènes sur les 22 paires d'autosomes (homologues), chaque chromosome a les mêmes gènes que son homologue (l'autre chromosome de la même paire), mais ceux-ci peuvent ou non contenir des informations, appelées **allèles**.

Exemple : le gène codant pour la chaîne β de la globine se trouve sur la paire de chromosome 11.

Nous possédons donc deux allèles de ce gène sur chaque chromosome 11 au même locus.

* Ces allèles peuvent être :

- **identiques** => on dit alors que les individus sont **homozygotes** pour le gène

- **différents** => les individus sont **hétérozygotes** pour le gène.

Individus hétérozygotes : si 1 seul des 2 allèles s'exprime, on dit qu'il est **dominant** par rapport à l'autre, dit **récessif**. Si les 2 allèles s'expriment en même temps : **codominants**.

Notations internationales :

[] phénotype (-)génotype

Problématique : Quel mécanisme est à l'origine de l'apparition d'allèles différents ?

* **L'apparition d'allèles est due aux mutations.**

Une mutation : modification aléatoire (rare et imprévisible) pouvant affecter la molécule d'ADN et risquant d'altérer la signification du message génétique.

Remarque : La mutation est d'emblée héréditaire si elle affecte les cellules germinales (gamètes).

* Il existe 3 grands types de mutations au niveau des séquences nucléotidiques :

- Les mutations par **substitution** d'un ou plusieurs nucléotides.

- Les mutations par **addition** ou **délétion** d'un ou plusieurs nucléotides. Celle-ci décale très souvent le cadre de lecture.

Les répercussions sont variables au niveau du phénotype. Ces mutations peuvent être silencieuses ou avoir des répercussions plus ou moins importantes : mutations non sens (codons STOP), inactivations ou mutations « faux sens » avec des activités des protéines produites plus ou moins réduites.

Les mutations sont à l'origine de la formation de nouveaux allèles qui, en s'exprimant ou non, conditionnent le phénotype.

• La plupart des phénotypes sont multigéniques

- Un caractère est dit **monogénique** s'il ne dépend que d'un seul gène, ce qui est rare (mucoviscidose ou myopathie de Duchenne).

La relation génotype-phénotype est alors linéaire, c'est-à-dire le phénotype observé est le résultat de l'expression d'un gène.

- Un caractère est dit **polygénique ou multigénique** s'il dépend de plusieurs gènes à la fois, cas dans la plupart des caractères visibles (couleur de peau).

La mutation d'un gène, celui qui code pour la tyrosinase, se traduit par l'absence de pigmentation de la peau (albinisme). Mais la mutation d'un gène très différente, codant pour la myosine Va, ne permet plus l'exportation des vésicules de mélanine vers les cellules épidermiques ? Anomalie traduite par une absence de la pigmentation de la peau.

Des génotypes différents peuvent conduire à un même caractère phénotypique. Il en résulte que dans le cas des caractères polygéniques, **la simple observation du phénotype ne permet pas de déduire le génotype.**

PHENOTYPES ET ENVIRONNEMENT

• Action de l'environnement au niveau du phénotype

Exemples :

- Alimentation : dans l'exemple du cancer colorectal, on observe que le phénotype est le résultat de l'action conjointe du génome et de l'environnement.

- Rayonnement solaire : Dans cet exemple, le soleil accélère l'effet du phénotype moléculaire sur la peau par multiplication des dimères de Thymine.

CONCLUSION

Phénotype = plusieurs échelles selon le niveau d'observation.

Le phénotype de l'organisme est dit macroscopique mais il s'exprime à l'échelle cellulaire et est repérable au niveau moléculaire.

L'activité des protéines enzymatiques contribue à la réalisation de ces phénotypes. Des changements de structure dans une protéine modifient son activité. Or, la séquence induit la structure des protéines et celle-ci est imposée par la séquence contenue dans les gènes.

Le phénotype moléculaire des êtres vivants dépend en général de plusieurs gènes et de l'action de l'environnement pouvant agir sur l'expression des gènes comme sur l'activité des protéines codées par ces gènes.

Appendix XXIX: Syllabus of the new French program of 1ère S applied during the second year in the private school

Programme de SVT de 1ère S 2012-2013 : *Source: Bulletin officiel spécial n°9 du 30 septembre 2010 (2011-2013)*

1. La Terre dans l'Univers, la vie et l'évolution du vivant
 - 1. Expression, stabilité et variation du patrimoine génétique**
 1. Reproduction conforme de la cellule et réplication de l'ADN
 2. Variabilité génétique et mutation de l'ADN
 3. L'expression du patrimoine génétique
 - 2. La tectonique des plaques: l'histoire d'un modèle**
 1. La naissance de l'idée
 2. L'interprétation actuelle des différences d'altitude moyennes entre les continents et les océans
 3. L'hypothèse d'une expansion océanique et sa confrontation à des constats nouveaux
 4. Le concept de lithosphère et d'asthénosphère
 5. Un premier modèle global: une lithosphère découpée en plaques rigides
 6. Le renforcement du modèle par son efficacité prédictive
 7. L'évolution du modèle: le renouvellement de la lithosphère océanique
2. Enjeux planétaires contemporains
 1. Tectonique des plaques et géologie appliquée
 1. Première possibilité: tectonique des plaques et recherche d'hydrocarbures
 2. Deuxième possibilité: tectonique des plaques et ressource locale
 2. Nourrir l'humanité
 1. La production végétale: utilisation de la productivité primaire
 2. La production animale: une rentabilité énergétique réduite
 3. Pratiques alimentaires collectives et perspectives globales
- 3. Corps humain et santé**
 1. Féminin, masculin
 1. Devenir femme ou homme
 2. Sexualité et procréation
 3. Sexualité et bases biologiques du plaisir
 - 2. Variation génétique et santé**
 1. Patrimoine génétique et maladie :
Le plus souvent, l'impact du génome sur la santé n'est pas un déterminisme absolu. Il existe des gènes dont certains allèles rendent plus probable le développement d'une maladie sans pour autant le rendre certain. En général les modes de vie et le milieu interviennent

également, et le développement d'une maladie dépend alors de l'interaction complexe entre facteurs du milieu et génome. Un exemple de maladie (maladie cardiovasculaire, diabète de type II) permet d'illustrer le type d'études envisageables

2. Perturbation du génome et cancérisation
 3. Variation génétique bactérienne et résistance aux antibiotiques
3. De l'oeil au cerveau: quelques aspects de la vision
1. Le cristallin: une lentille vivante
 2. Les photorécepteurs: un produit de l'évolution
 3. Cerveau et vision: aires cérébrales et plasticité

Appendix XXX: Sequence of the contents of the genetic concepts presented in SVT, 1ère S, Bordas, 2007 edition

Part II : Du genotype au phénotype (English: From genotype to phenotype)	
Chapter 1: Le phénotype dépend des protéines (the phenotype depend on proteins)	<p>1.1. Le phénotype observe à différentes échelles. (the phenotype observed at different levels).</p> <p>1.2. l'origine moléculaire d'un phénotype (Molecular origin of phenotype)</p> <p>1.3. Phénotype moléculaire et séquence nucléotidique (Molecular phenotype and nucleotide sequence).</p> <p>1.4. Quelques exemples du rôle des protéines (some examples on the role of proteins).</p>
Chapter 2: La mitose, un processus commun aux cellules eucaryotes (Mitosis a common process of eukaryotic cells)	<p>2.1. Avant la mitose, l'information génétique est répliquée (before replication, genetic information is replicated).</p> <p>2.2. Observations microscopiques de cellules en mitose (microscopic observations of cells during mitosis)</p> <p>2.3. La mitose, un partage équitable du contenu cellulaire (mitosis, an equal sharing of cellular contents)</p> <p>2.4. La confirmation du mécanisme de</p>

	<p>replication de l'ADN</p> <p>(the confirmation of the mechanism of DNA replication)</p>
<p>Chapter 3: La synthèse des protéines (protein synthesis).</p>	<p>3.1. Du gène à la protéine, un intermédiaire indispensable (From gene to protein, an indispensable intermediate)</p> <p>3.2. La transcription, fabrication de copies de gènes exprimés (Making copies of expressed genes).</p> <p>3.3. Le code génétique : un système de correspondance (The genetic code is a system of correspondence).</p> <p>3.4. La traduction de l'ARN messager en protéine (Translation of messenger RNA to protein).</p>
<p>Chapter 4: Les relations entre gènes, phénotypes et environnement (the relation between genes, phenotype and environment)</p>	<p>4.1. Deux allèles pour un même gène (Two alleles for the same gene)</p> <p>4.2. Plusieurs gènes pour un seul caractère (Many genes for one character)</p> <p>4.3. L'effet des allèles dépend aussi de facteurs externes (the effect of alleles depends also on environmental factors).</p> <p>4.4. Le phénotype dépend de multiples facteurs (The phenotype depends on multiple factors).</p>

**Key ideas and Sub-ideas of the Chapters Related to our Topic
Presented in SVT, 1ère S, Bordas, 2007 Edition**

Chapter 4: The Relation between Genes, Phenotype and Environment	
Essential questions:	
<i>What phenotype might result from the coexistence of two alleles for the same gene? How can different genotypes lead to the same phenotype? Does the possession of an allele give inevitable consequences? Genetic predisposition and multi-factorial determinism of phenotype: what cover these expressions?</i>	
Activities	Major concepts and processes
Two alleles for the same gene	<ul style="list-style-type: none"> - The phenotype depends to a large extent on the genotype but the relation between them is complex. First reason is that in most species each gene presents two exemplars: an individual possesses two alleles of each gene. - Albinism is a genetic anomaly due to general defect in pigmentation. - Several forms of albinism characterized by absence of melanin pigment. - Diverse mutations of the gene of tyrosinase enzyme responsible for albinism. The mutant allele does not allow the synthesis of functional enzyme. - For each gene there are two identical or different alleles located on two chromosomes of the same pair. - Albinism as hereditary disease transmitted from carrier parents to their offspring.
Many genes for one character	<ul style="list-style-type: none"> - It is rare that a phenotypic trait is determined by one gene. - Most often the same apparently simple

	<p>character results from the intervention of many genes. So FOR THE SAME phenotype many genotypes are possible.</p> <ul style="list-style-type: none"> - Melanogenesis is a process that needs several genes. - Tyrosinase enzyme catalyzes the synthesis of melanin and myosin VA that is responsible for migration of melanin. Mutations at the level of any of these two genes can cause albinism. - Many genes might favor obesity: the gene that codes for leptin hormone and a gene that code for receptor proteins of leptin
<p>the effect of alleles depend also on environmental factors</p>	<ul style="list-style-type: none"> - A number of examples show that the effects of alleles of a gene depend also on environmental factors. - Sickle cell anemia is a genetic disease due to a defected allele that causes the synthesis of abnormal hemoglobin (HbS) leading to sickle RBC. - Environmental factors like oxygen concentration, temperature and PH can affect the formation of HbS. - The temperature affects the activity of the tyrosinase enzyme in Siamese cats.
<p>The phenotype depends on multiple factors</p>	<ul style="list-style-type: none"> - Certain phenotypic characters although genetically determined does not appear unless certain conditions are satisfied. - Genetic predisposition increases the risk of breast cancer. - Many genes can play a role in the development of cardiovascular diseases interacting with environmental factors like diet, smoking, and sports. - Preventive medicine

Appendix XXXI: Sequence of the contents of the genetic concepts presented in SVT, 1ère S, Bordas, 2011 edition

Part I : Expression, stabilité et variation du patrimoine génétique (Expression, stability and variation of genetic patrimony)	
Chapter 1 : Reproduction conforme et réplication de l'ADN (confronted reproduction and DNA replication)	<p>1.1. Les chromosome, élément permanents des cellules (the chromosomes, permanent elements of the cell)</p> <p>1.2. Les division cellulaire: une reproduction conforme (cellular division : a confronted reproduction)</p> <p>1.3. La mécanisme de la réplication d'ADN (the mechanism of DNA replication)</p> <p>1.4. Les étapes des cycles cellulaires (the steps of the cell cycle)</p>
Chapter 2 : Variabilité génétique et mutation de l'ADN (genetic variability and DNA mutation)	<p>2.1. L'origine d'une variabilité de l'ADN (Origin of DNA variability)</p> <p>2.2. L'influence d'une irradiation par les UV (influence of UV radiation)</p> <p>2.3. Réparation de l'ADN et mutations (DNA repair and mutation)</p> <p>2.4. Mutations et biodiversité (mutation and biodiversity)</p>
Chapter 3 : L'expression du patrimoine génétique (Expression of genetic patrimony)	<p>3.1. La découverte des relation entre protéines et ADN (the discovery of the relation between proteins and DNA)</p> <p>3.2. Le transfert de l'information génétique (the transfer of genetic information)</p> <p>3.3. La langage génétique (the genetic language)</p> <p>3.4. La traduction de l'ARN message en protéine (the translation of mRNA into protein)</p> <p>3.5. Du génome au "protome" (from genome to « protome »)</p>

Chapter 4 :Génotype, phénotype et environnement (genotype, phenotype and environment)	4.1. La phénotype se définit a différentes échelles (the phenotype is defined at different levels)4.2. Phénotype moléculaire et expression génétique (Molecular phenotype and genetic expression)4.3. l'influence de l'environnement sur le phénotype (the influence of the environment on the phenotype)
Part IV- Corps humain et santé (Human body and health)	
Chapter 3 : Variation génétique et santé(Genetic variation and health)	3.1. La mucoviscidose, un exemple de maladie génétique (Cysttic fibrosis, an example of genetic disease) 3.2. Les traitement médicaux de la mucoviscidose (Medical treatment of Cystic fibrosis) 3.3. Maladies génétiques et facteurs environnementaux (genetic diseases and environmental factors) 3.4. Une altération du genome peut conduire au cancer (An alteration of genome can lead to cancer) 3.5.La cancérisation, un processus complexe (cancerization is a complex process) 3.6. La résistance bactérienne aux antibiotique (Bacterial resistance to antibiotics)

**Key ideas and Sub-ideas of the Chapters Related to our Topic
Presented in SVT, 1ère S, Bordas, 2011 Edition**

Chapter 4 : Genotype, Phenotype and Environment

Essential questions :	
<i>The molecular scale of the organisms' cell. How gene expressions translate it? What factors determine the presence of proteins found in the cell? How can the environment influence the phenotype?</i>	
Activities	Major concepts and processes
the phenotype is defined at different levels	<ul style="list-style-type: none"> - Phenotype is the set of characters that determine any living organism: morphological, anatomical and physiological characters, qualitative as well as quantitative. - Sickle cell anemia the most frequent genetic anomaly is characterized by low count of RBCs, sickle shaped RBC due to abnormal Hb. - Xeroderma pigmentosa a rare genetic disease is characterized by cancer at the level of epidermal skin cells when exposed to UV light which causes the appearance of a defective DNA repair protein. - The molecular phenotype determine the cellular phenotype which in turn is responsible of the phenotype that appear at the level of the organism.
Molecular phenotype and genetic expression	<ul style="list-style-type: none"> - The sum of proteins found in a cell constitutes its molecular phenotype - The phenotype of Sickle cell anemia is the result of molecular phenotype, the presence of different B- globin, B globinS different from the normal globin A in the RBCs, as a consequence of allelic mutation. - The software anagene allows comparison between the alleles. - Software for molecular visualization allows the differentiation between Hb S and Hb A.

	<ul style="list-style-type: none">- Mutation at the level of the allele of a gene causes the synthesis of a protein with a different amino acid sequence.- Selective genetic expression in a cell, the cells do not express the same genes.- The expression of a gene can vary with time, during the life of the organism
	<ul style="list-style-type: none">- Environmental factors can modulate the expression of the gene- The transcription of certain genes varies in function of the conditions of the medium. Due to activation of certain proteins that control the fixation of RNA polymerase on DNA during transcription- The environmental factors can influence the properties of proteins. In Sickle cell anemia the Hb S can be present in a soluble or insoluble form depending on the concentration of oxygen. The formation of fibers of HbS causes the deformation of RBC leading to the phenotypic characteristics of sickle cell anemia.

Appendix XXXII: Sequence of the contents of the genetic concepts presented in National biology textbook for grade 11 (Scientific)

Part I: Functional characteristics of living things at the cellular level	
A-Biological identity and genetic information	
Chapter 1: The diversity of organisms and the uniqueness of the individual (Suspended)	<p>A.1.1: The diversity of the living world. (suspended)</p> <p>A.1.2: Polymorphism within a population (suspended)</p> <p>A.1.3: Biological identity of organisms</p> <p>A.1.4: Renewal of cells and maintenance of their (suspended)</p>
Chapter 2: DNA Genetic information and cell cycle	<p>A.2.1: The karyotype</p> <p>A.2.2: Mitosis, an equal; division of the chromosomal set</p> <p>A.2.3: The structure and the chemical components of chromosomes</p> <p>A.2.4: Identical reproduction and cell cycle</p>
Chapter 3: Protein synthesis and enzymatic activity	<p>A.3.1: Proteins, an association of amino acids</p> <p>A.3.2: the gene structure and information unit</p> <p>A.3.3: transcription :First step of protein synthesis</p> <p>A.3.4: Translation: second step of protein synthesis</p> <p>A.3.5: Fate of synthesized proteins</p> <p>A.3.6: Enzymes, proteinic biological catalysts</p> <p>A.3.7: Reaction rate and optimum conditions</p> <p>A.3.8: Specific and mechanism of enzyme</p>

	action
Chapter4: Biological identity and genotype	A.4.1. Phenotypes and proteins. A.4.2. Genes and alleles. A.4.3. The genotype

Key ideas and Sub-ideas of the Chapters Related to the Topic of the Study in the National Biology Textbook Grade 11 SC

Chapter 4: Biological identity and genotype

Essential questions: *How is the individual's phenotype expressed? What is mutation? What are the consequences of mutations*

Activities	Major concepts and processes
Phenotypes and proteins	<ul style="list-style-type: none"> - An individual's phenotype is the set of characteristics that are either visible (eg. Skin color), or hidden at the cellular level (eg. Sickle cell anemia) and molecular level (eg. Blood group, identity markers). - Cause of albinism: absence of a functional protein, melanin. - Cause of Duchene muscular dystrophy, DMD: lack of a structural protein, dystrophin. - Cause of sickle cell anemia: presence of abnormal hemoglobin Hb S.

Genes and alleles	<ul style="list-style-type: none">- Modified proteins and the appearance of new phenotypes: Types of Hb related to different versions of B-globin gene.- Genetic mutations and gene polymorphism (normal individual); individuals with sickle cell anemia, B-Thalassemia and Chinese B-Thalassemia- Types of mutations: point substitution; deletion; insertion
The genotype	<ul style="list-style-type: none">- Definition of genotype, phenotype, dominant trait, recessive trait.- Relation between genotype and phenotype (ABO system; MHC markers)- Biological identity and genetic printing (autoradiogram of identical twins and related individuals).- Gel electrophoresis.

**Appendix XXXIII: Sequence of the contents of the biology book for grade 11 S
elaborated by Fadi**

Unit I: Diversity and Complementarity of Metabolism	
Chapter one: The chlorophyllic plants: primary producers	Activity 1: The structure of an ecosystem Activity 2: Autotrophy and heterotrophy Activity 3: Necessary factors for photosynthesis Activity 4: Photosynthesis and liberation of oxygen Activity 5: Stomata: site for CO ₂ entry
Chapter two: From inorganic compound to organic compound	Activity 1: Effect of light radiation on photosynthesis Activity 2: light radiation and chlorophyll Activity 3: Chloroplast: Organelle of photosynthesis Activity 4: The first phase of photosynthesis: Photochemical phase Activity 5: The second phase of photosynthesis: Chemical phase Activity 6: The fate of synthesized organic materials: Consumption and storage
Chapter three: ATP: An indispensable molecule for cellular activity	Activity 1: Certain aspects of cellular life Activity 2: The striated muscle fibers: Highly specialized cells Activity 3: Muscular contraction: a result of molecular interaction
Chapter four: Respiration and fermentation: sources of ATP	Activity 1: Experimental identification of cellular respiration Activity 2: Mitochondria; site of cellular respiration Activity 3: The different steps of cellular respiration Activity 4: Fate of Pyruvic acid: Fermentation or anaerobic respiration Activity 5: Fate of Pyruvic acid: Aerobic respiration Activity 5: Conversion of energy in eukaryotic cells

Unit II Biological Identity and Genetic information	
Chapter one: Diversity of organisms and uniqueness of the individual	<p>Activity 1: Prokaryotic and eukaryotic cells</p> <p>Activity 2: Polymorphism within a population</p> <p>Activity 3: Biological identity of organisms</p> <p>Activity 4: Renewal of cells and maintenance of their characteristics</p>
Chapter two: Genetic information: DNA and cell cycle	<p>Activity 1: The karyotype</p> <p>Activity 2: Mitosis: an equational division of the chromosomal set</p> <p>Activity 3: Chemical and physical structure of chromosomes</p> <p>Activity 4: DNA replication and cell cycle</p>
Chapter three: Protein synthesis	<p>Activity 1: Structure and function of protein</p> <p>Activity 2: The gene: structure and unit of formation</p> <p>Activity 3: Transcription: the first step of protein synthesis</p> <p>Activity 4: translation: the second step of protein synthesis</p> <p>Activity 5: the fate of synthesized proteins (omitted)</p>
Chapter four: Enzymatic activity (Suspended)	<p>Activity 1: Enzymes: highly efficient biological catalysts</p> <p>Activity 2: Double specificity of enzymes</p> <p>Activity 3: enzymatic activity and its spatial configuration</p> <p>Activity 4: Influence of medium conditions on the reaction rate</p>

Chapter five: The relation among genes, phenotype and environment	<p>Activity 1: Genes and alleles</p> <p>Activity 2: The genotype: two alleles for one gene</p> <p>Activity 3: A character coded by several genes</p> <p>Activity 4: External factors impact on the expression of an allele</p> <p>Activity 5: Multiple factors determine a phenotype</p> <p>Note: activities 2, 3, 4 and 5 of chapter five were not explained during the academic year 2011-2012 due to lack of time.</p>
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