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Interactions between Digital Resources and Biology Teachers‟ Conceptions about Genetic Determinism: A Case Study of two Lebanese Teachers

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Abstract: ***In this study teachers' conceptions were analyzed as KVP interactions(K: knowledge; V: values; P: practices) during their documentary work. The persistent follow-up for two successive years of the documentary work of two Lebanese biology teachers, Tania and Maya, allowed the identification of the critical resources and critical situations related to their preparation/teaching practices of genetic determinism of phenotype. The analysis of these critical resources and the output of critical situations according to a specific grid allowed us to infer teachers' conceptions about genetic determinism. The results showed that the updated scientific knowledge of Tania (K) due to her constant interactions with updated resources including digital resources, the social practices (P) of her school implementing updated French textbooks illustrating the environmental influence on gene expression in addition to collective and collaborative work among teachers and with the coordinator reinforced her epigenetics' conception. While in the case of Maya the interaction with digital resources caused an evolution of her documentary work (P), in addition to an evolution in her scientific knowledge (K) leading to a non-stabilized evolution of her conceptions from hereditarianism to epigenetics. This study has important implications on teachers' preparation and training programs.***

Keywords: Digital resources, critical resources, critical situations, documentary work, KVP model, conceptions, genetic determinism

1. Introduction

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 Unique reference to genetic determinism has been replaced by the interaction between genes and their environment (i.e., epigenetics).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. These scientific evolutions related to genetic determinism of phenotype occurred after the implementation of the renewed Lebanese curriculum in 1997 and which has not been updated till now. Moreover, despite the emergence of the new paradigm of epigenetics, previous research has shown that old genetic deterministic conceptions still prevail in school textbooks, including the Lebanese national textbooks (Castéra *et al.*, 2008) and among teachers in various countries including Lebanon(Abou Tayeh 2003; Castéra, Munoz & Clément, 2007; Clément, Quessada & Castéra, 2012;Kochkar 2007; Kochkar *et al*., 2002).

Nowadays, 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 white boards (IWB) and USBs on the other. This evolution leads to major changes in preparation/teaching practices (Sabra & Trouche, 2011). 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. Moreover, new technologies have made diffusion, sharing, exchange and transport of resources faster among teachers and between one medium and another. 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. 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).In the study of Shaaban (2014) the analysis of the results of a questionnaire filled by 116 Lebanese biology teachers showed that they integrate digital resources in addition to textbooks in their preparation/teaching practices to facilitate and enhance the teaching and learning process of difficult and evolving genetics concepts like genetic determinism. Based on the above the use of digital resources might be a way to update teachers‟ scientific knowledge in relation to genetic determinism to be aligned with the modern epigenetics conceptions. Therefore, this study aims to investigate the interactions between biology teachers and

resources, particularly digital resources, and to explore the influence of these interactions on teachers‟ practices and conceptions about genetic determinism of phenotype.

2. Theoretical background and literature review

For the purpose of this study, two theoretical frameworks were articulated, namely, the documentational approach and the KVP model. In the documentational approach, researchers study teachers‟ professional evolution where the attention is focused on the resources, particularly digital resources, and their appropriation and transformation by a teacher or group of teachers working together.This approach studies teachers‟ documentary work which refers to the analysis of teachers‟ collection, selection, appropriation, transformation, sharing and implementation of various resources which include digital resources.Documentation refers to the documentary work in addition to the outcome (documents) generated during this work. There is 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”.This 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 (i.e., teacher‟s knowledge and belief) and the observable part corresponds to usages (Gueudet & Trouche, 2009).Thus this approach allows the investigation of the interactions between teachers and digital resources during their professional activities inside as well as outside the classroom.

On the other hand, Clément (2006) 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). 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. As for the value systems (V), it refers to opinions, faiths, ideologies, and philosophical and moral positions. 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. In this study, teachers‟ conceptions of the relationship between genotype and phenotype (i.e. genetic determinism) was analyzed as an interaction between the three poles: scientific knowledge related to human genetics specifically the expression of genotype (K); values as either hereditarianism or epigenetics (V); and teaching practices and social practices (school, media…) (P).

In order to analyze teachers‟ conceptions through their documentary work, particularly their interaction with digital resources, a new model integrating the documentation genesis process with the KVP model was elaborated in the study of Khalil, Shaaban and Trouche (2015) as illustrated in figure 1. This model was used to analyze teachers‟ conceptions as KVP interactions during their search, choice, and appropriation of resources as well to analyze the conceptions of the resources‟ authors as KVP interactions and its effect on teachers‟ conceptions. Thus, the first author 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 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.

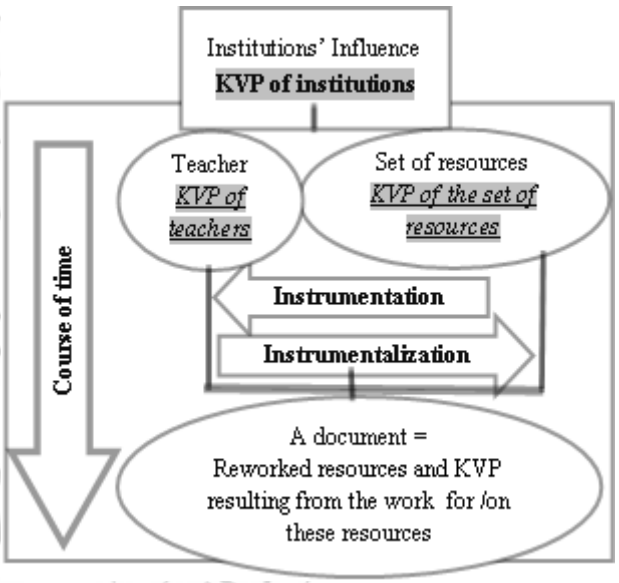

Figure 1: Schema of the documentation genesis process integrating the KVP model

2.1 Categorizing Teachers' Conceptions on Genetic Determinism

Several studies have proposed three models for the categorization of teachers‟ conceptions on genetic determinism (Agorram et al., 2010; Castéra, 2010; Castéra & Clément 2009, 2012; Forissier & Clément, 2003; Kochkar, 2007). 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: 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: Genotype + Environment □Phenotype.

Finally, in the interactive model, 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: Genotype□□Environment□Phenotype.

2.2 Epigeneticsin the Lebanese context

The Lebanese curriculum has not been renewed since 1997 and the national biology textbooks published in 1999 and 2000 are still implemented in Lebanese public schools till now. However, Lebanese private schools have the freedom to implement other updated textbooks like French books. The interaction with the environment to determine our phenotype is not tackled neither in the curriculum nor in the national biology textbooks. In the national textbooks for secondary classes the concept of "gene" is introduced in grade 11 scientific section (S). 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 According to Castéra et al. (2008), Lebanese national biology textbooks show implicit evidence of hereditarianism conceptions in which, for instance, genetic factors of hereditary diseases are not taught as influenced by the environment. The frequent occurrence of the term "genetic program" and the lack of consideration of the interaction among genotype, phenotype and the environment indicate that Lebanese textbooks maintain the conceptions of genetic determinism. Thus, textbook‟s content not only conveys scientific knowledge but also implicit messages related to values (i.e., hereditarianism). Consequently, in accordance with Clément‟s KVP model, there is a strong interaction between knowledge (K) and values (V). Similarly, studies related to Lebanese teachers‟ conceptions about genetic determinism of phenotype highlighted a strong persistence of the ideology of hereditarianism among practicing and prospective teachers (Abou Tayeh, 2003; Castéra, Munoz & Clément, 2007). Within the context of the European project Biohead-Citizen several studies indicated differences in teachers‟ conceptions of different areas of human genetics including genetic determinism. These differences were evident in the type of school (public/private), the teaching language (French/English/Arabic), teaching experience, and geographic region (Khalil, El Hage & Clément, 2007; Khalil, Munoz, Clément, 2007a, 2007b).

Based on all the above and in the context of a digitalization era where information and communication technology (ICT) is considered part of a wider range of available teaching resources it seemed crucial to conduct a study related to the consequences of teachers‟ interactions with digital resources. This study will help us to answer the following research question: **1) How does Lebanese biology secondary teachers' documentary work- particularly their interaction with digital resources- influence their conceptions related to genetic determinism of phenotype?**

3. Methodology

This study is a qualitative research applying a case study design following the purposive sampling technique. In line with the purpose of the research and in order to study the consequences of interactions with digital resources on teachers‟ documentary work and conceptions related to genetic determinism, the two participants of the research, Maya and Tania, were selected based on the following criteria:

- Having adequate technology skills to use computers and Internet. This is important for the integration of digital resources in their preparation/teaching practices.
- Integrating digital resources in their teaching practices in general and particularly in teaching genetics concepts.
- Having more than ten years of teaching experience based on the assumption that teachers with more experience will have a more developed system of resources. Teaching in public and private schools, with English and French as languages of instruction, in order for them to be representative of the Lebanese context.

3.1 Data Collection Tools and Procedure

Data was collected from various tools for triangulation, they include: interviews, schematic representation of the resource system (SRRS), classroom observation (during the explanation of genetic determinism), and logbook.

Several unstructured and semi-structured interviews were performed at different intervals of time before and after the follow- up period during the explanation of the genetic part for two consecutive years. These interviews applied the principle of monitoring teachers‟ documentary work outside school. All the interviews were conducted in person, 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. The researcher and another biology teacher separately analyzed teachers‟ answers (analysis triangulation) (Hittleman & Simon, 2006). A discussion between the two analysts was done to reach inter-rater agreement.

The SRRS and the logbook are new tools adapted from the reflective investigation methodology elaborated by Gueudet and Trouche (2012) in coherence with the "documentational

approach of didactics". They are utilized in order to involve the teachers in data collection and to show their reflections on their own resources and documentary work. In the SRRS the teachers were asked to mention all the available, mobilized and implemented resources in their teaching practices and to illustrate how those resources are organized and related. The two teachers drew an SRRS at the end of the first year of follow- up and at the end of the second year of research teachers were given the opportunity to add or change their first SRRS. In the logbook the teachers were asked to report all their daily professional activities related to their preparation/teaching practices of genetic determinism of phenotype, and they were asked to specify for each activity: the time, place, actors, resources used, what was produced, what was archived and additional comments, if any.

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). 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. 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 follow- up 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 sessions were observed during the explanation of genetic concepts including the genetic determinism of phenotype.

3.2 Data analysis procedures

For the purpose of this study, specific notions to articulate the two theoretical frameworks ("documentational approach" and "KVP model") were used to investigate the possible evolution of teachers‟ conceptions based on their interactions with resources during their documentary work. These notions were elaborated in the research done by Shaaban (2014) and they include: the mobilized resources that are actually implemented or used by teachers during their preparation practices for teaching a specific topic or lesson. The elaborated resources designed by the teachers for a specific topic or lesson after selecting, combining and reshaping the mobilized resources. The implemented resources that are actually put in action in class during teaching; they can be either mobilized resources or elaborated resources. The critical resources they include the resources that are 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. Finally, critical situations are 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. Cross analysis and verification of all the data allowed the identification of critical resources and critical situations, then a specific grid was elaborated to categorize teachers‟ conceptions related to genetic determinism based on the three models presented in the literature: linear, additive and interactive model. The first author searched in critical resources and the output of critical situations for specific verbs like: causes, implies, gives rise to, controls, determines interacts, regulates, adds…; specific terms like: genetic information and genetic program; specific diagrams; and specific pictures. These were used as indicators to infer the possible conceptions of the authors of critical resources and that of the research participants. This was also done by another researcher for analyst triangulation.

4. Results and Discussion

The documentary work of the two participants, Tania and Maya, was monitored by the first author for two successive years. This study focused on the preparation and implementation of the resources, particularly digital resources, about gene expression and its relation to the phenotype. The data collected utilizing several complementary tools allowed the first author to identify the critical resources mobilized, elaborated or implemented by the teachers related to genetic determinism. The analysis of these critical resources in addition to the output critical situations in the classroom and during interviews allowed the first author to infer the possible conceptions of the two participants about genetic determinism. Analysis of Tania‟s documentary work and conceptions and then that of Maya‟s are presented below.

4.1 Tania's Documentary Work and Her Conceptions about Genetic Determinism

Data collected from the interviews, logbooks and SRRS during the two successive years of follow-up show that throughout her professional career Tania has built a big archive of digital resources through several years of extensive search on the Internet, in addition to resources exchanged with her colleagues and with the coordinator of her school. In the private school of Tania collective work between teachers and coordinators is efficient, the teachers exchange resources with each other and with the coordinator, who always supplies them with updated resources, books, software, animations and videos. In addition, training sessions are done regularly at school to update teachers‟ scientific knowledge and teaching strategies. Collective and collaborative work plays an essential role in Tania‟s teaching practices and documentary work, Tania discusses with her colleagues the resources, strategies and knowledge to be taught, and she practices collaborative work with the coordinator to search and select resources and strategies to be implemented in class. Thus, Tania‟s interactions with digital resources and her collective work with the coordinator and other teachers in her school seemed to have enriched her

system of resources and led to evolution of her documentary work.

In her preparation/ teaching practices Tania relies on her archive as she said: "my archive is very big and I rely a lot on it" and on the updated French textbooks implemented in her school and mentioned as primary resources in her SRRS. Cross-analysis of the data collected from the various tools showed that Tania‟s critical resource for teaching genetics during the first year of follow-up was Bordas, SVT 1ère S (2007).This textbook contains a genetic part entitled: "Du Genotype au Phenotype" (From Genotype to Phenotype). Content analysis of this part based on the elaborated grid 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. Below are some excerpts from the textbook, translated by the first author:

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

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

Environmental determinism of phenotype is also 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 the interventions of a protein in the realization of the phenotype (sickle cell), which is dependent on environmental factors (concentration of oxygen, PH and temperature) that can modulate the effect of the gene, are mentioned. 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. 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, noise and ears. 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. Therefore, content analysis of this critical resource showed 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 follow-up Tania used another critical resource, the new French textbook - Bordas SVT 1ère (2011) - that is based on the new French syllabus implemented in 2010. The new syllabus emphasizes on the environmental determinism of phenotype in many themes: "Expression, Variation and Stability of Genetic Patrimony" and "Genetic Variation and Health". Analysis of this new textbook (Bordas, 2011) shows that it contains a chapter about the relationship among genotype, phenotype and the environment. Content analysis of this chapter shows that 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. Similarly, 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 conceptions of the authors of the textbook.

The persistent follow-up showed that during the two successive years of research Tania utilized only the documents of the textbooks (Bordas, 2007, 2011) that illustrates the environmental determinism of phenotype in teaching the chapter of the relation between genotype, phenotype and environment. The epigenetic conceptions of the French textbook authors might have influenced Tania‟s conceptions after interacting with and implementing these critical resources. Moreover, cross-analysis of the data collected from the output of critical situations in the classroom and in interviews, and from the logbook showed the epigenetic conceptions of Tania. When asked about the relation between genotype and phenotype (critical situation during the interview) Tania drew a diagram that explicitly indicates the interactive model, as illustrated in figure 2.

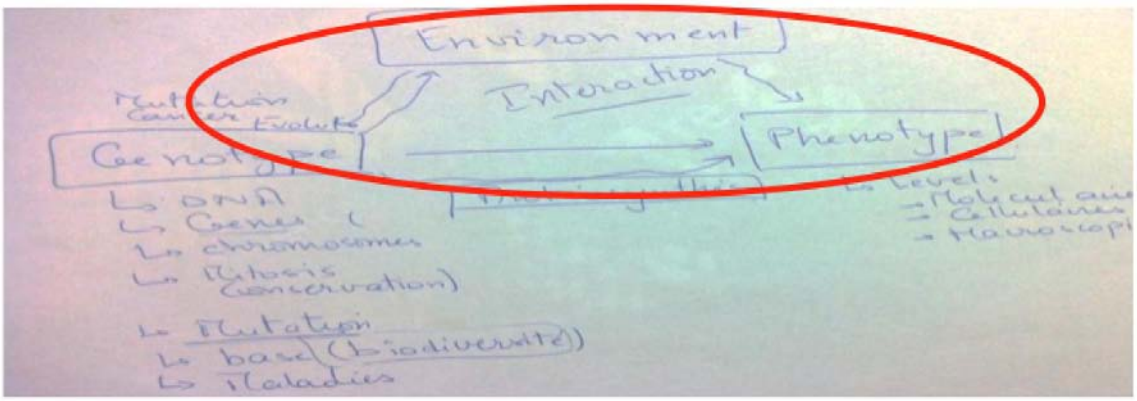

Figure2: Schema drawn by Tania representing the relationship between genotype and phenotype

This was also evident when Tania was asked to define a gene (critical situation in the interview). The diagram illustrated in figure 3 shows that many proteins might interfere to determine phenotype; phenotype has different levels and at each level there is interaction with the environment.

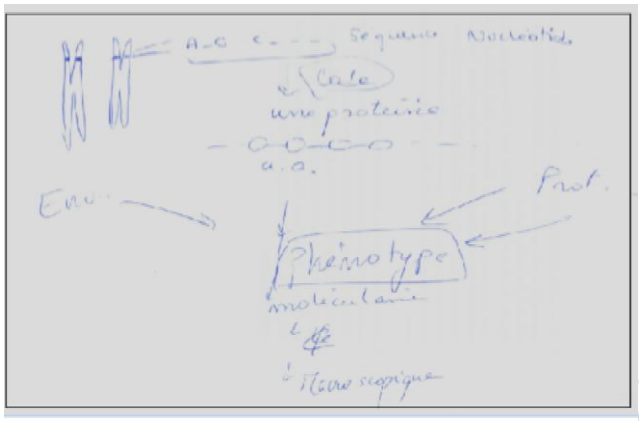

Figure 3: Schematic representation of a gene as drawn by Tania

Similarly, in critical situations in the classroom during her explanation of the chapter of interaction between genotype phenotype and environment, 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. Tania gave the example of Siamese cats to emphasize the influence of temperature on the activity of a gene. 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 the epigenetic conceptions of Tania. Thus the evolved documentary work of Tania due to the constant interaction with scientifically updated resources including digital resources and French books, implemented in her private school, illustrating the influence of the environment on gene expression in addition to the collective and collaborative work with the coordinator and other teachers caused and reinforced her epigenetic conceptions.

4.2 Maya's documentary work and her conceptions about genetic determinism

Data collected from Maya‟s interviews, logbooks, classroom observations and SRRSs during two successive years showed that she is now in the phase of renewing and updating her resources. In the public school of Maya no additional resources are provided for the teachers, and there is limited exchange of resources between them. However, the CAPES (Certificat d‟Aptitude Pédagogique à l‟Enseignement Secondaire) studies at the Lebanese university-Faculty of education to earn a certificate of qualification in education for secondary school teaching caused a turning point in the documentary work of Maya. During her studies Maya acquired technological skills, interacted with digital resources and exchanged resources with her colleagues. This allowed her to elaborate new resources, particularly digital resources that enriched her system of resources and lead to evolution of her documentary work.

In addition, Cross-analysis of the data collected during two consecutive years from the two SRRSs, the two logbooks, interviews and classroom observations enabled the inference of two critical resources utilized by Maya to prepare and explain the expression of genotype and genetic determinism: the national biology textbook for the 11th grade scientific section (CERD, 1999) and the slide show “Genetic Program and Its Expression” elaborated by her during the first year of follow-up. The analysis of the genetics‟ content of the national textbook shows that 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), and 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. This explicitly reflects hereditarianism conceptions of the authors of the textbook and the 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”. 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. 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 Lebanese 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). Similar results were also 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. 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), innate 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 indicates the hereditarianism conceptions of the textbook‟s authors.

Similar to the national textbook for the 11thgrade content analysis of the elaborated critical resource shows that, both terms “genetic program” and “genetic information” are utilized by Maya. In fact, the term “genetic program” is present in the title indicating that everything is programmed by our genes. 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 4.

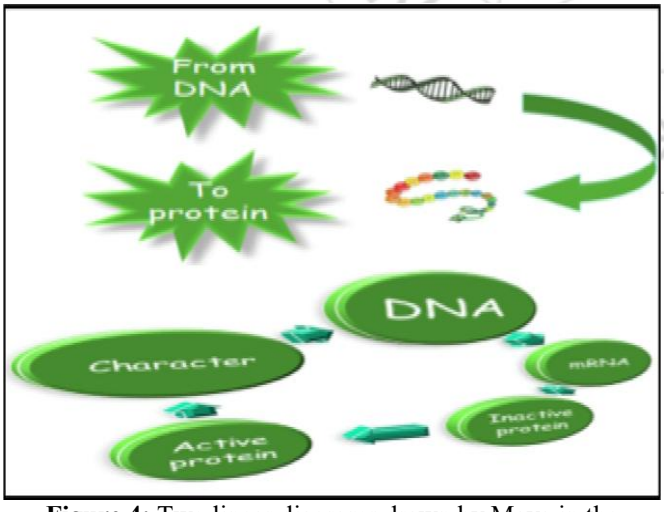

Figure 4: Two linear diagrams drawn by Maya in the elaborated slide show

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 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. Similarly, when asked about the relation between genotype and phenotype (critical situation in the interview) compared to Tania Maya drew a diagram that explicitly indicates the linear model as illustrated in figure 5.

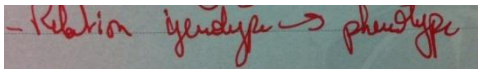

Figure 5: Linear diagram drawn by Maya

This was also evident when Maya was asked to define a gene (critical situation).According to her, the gene is a fragment of DNA that may express itself and the produced proteins determine characters 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 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

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. In sum, analysis of the output of the critical situations in interviews emphasizes the predominant hereditarianism conceptions of Maya. Moreover, during the explanation of the gene expression in the classroom for two years, Maya utilized the elaborated slide show which reflects her hereditarianism conceptions. 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. 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

On the other hand, some seeds of evolution in Maya‟s conceptions were evident based on the analysis of the output of some critical situations during the second year of research and a critical resource elaborated at the end of follow-up. Maya mentioned the influence of the environment (20 %) in

addition to the influence of genes (80%) in determining the phenotype indicating the additive model. Percentages of contributions from both genotype and environment are still very popular in students‟ conceptions (e.g. Lewis, Leach, & Wood-Robinson, 2000a&b; Lewis, 2004) and even in school textbooks and teachers‟ conceptions (Clément & Forissier, 2001; Forissier & Clément, 2003). Nonetheless, this conception remains closer to hereditarianism because it does not evoke any interaction between genotype and the environment. 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). In the classroom she illustrated many examples of the influence of the environment on gene expression while explaining genetic diseases, particularly Albinism. 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. 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 Maya introduced in her teaching practices the additive and the interactive model about genetic determinism compared to the linear model presented in the national Lebanese textbooks clearly indicates an evolution in Maya‟s scientific knowledge about the environmental influence on phenotype. This evolution was mainly due to her interactions with digital resources; however, this did not lead to a steady evolution of her conceptions from hereditarianism to epigenetics.

5. Conclusion

The aim of the study was to investigate teachers‟ interactions with resources, particularly digital resources, and the evolution of their documentary work and conceptions about genetic determinism of phenotype as a result of those interactions. Our methodology enabled us to monitor the professional activities of the two research participants, Tania and Maya, outside as well as inside the classroom. Cross-analysis of the data collected from interviews, logbooks, SRRSs and classroom observations allowed the identification of critical resources related to preparation and teaching of genetic determinism in addition to critical situations during interviews and in the classroom. The analysis of these critical resources and the output of critical situation according to a specific grid allowed us to infer the participants‟ conceptions about genetic determinism based on their KVP interactions. However, in this study conceptions inferred focused on teachers‟ scientific knowledge (K) and practices (P) more than their values (V). Tania‟s epigenetic conceptions maybe the result of interactions of several factors during her documentary work: the social practices (P) of her private school that implements updated French textbooks illustrating the interactive model of genetic determinism (Genotype□□Environment □Phenotype), her collective work with other teachers, her collaborative work with the coordinator of her school to elaborate new resources and implement new teaching strategies, in addition to her updated scientific knowledge (K) due to her interactions with updated French books and digital resources. While Maya‟s hereditarianism conceptions is mainly due to the social practices of her public school (P) implementing the Lebanese national textbooks illustrating the linear of genetic determinism (genotype□ phenotype) and her outdated scientific knowledge (K). However, her interactions with digital resources, particularly Internet resources and media during and after her CAPES studies allowed Maya to learn more about the influence of the environment and caused an evolution in her scientific knowledge (K), as well as an evolution in her documentary work (P) leading to a non-stabilized evolution of her conceptions from hereditarianism to epigenetics. This answers our question of research.

In addition, despite the limitations of this study, the number of cases and their advanced documentary work, its results shed light on important factors that might influence the evolution of teachers‟ system of resources, documentary work and conceptions. The most important factors were the interaction with proliferating digital resources, the collective and collaborative work between teachers related to resources and the implementation of scientifically updated resources aligned with modern concepts.

This study has important implications on teachers‟ preparation and training programs for professional development. It showed the necessity of renewing these training programs to focus on teachers‟ documentary work, teachers‟ should be trained to search, select and appropriate resources. 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 of resources in training programs might allow teachers to develop a reflective attitude on their own conceptions.

Finally, the articulation of two new theoretical frameworks in didactics the KVP model (Clément, 2006) and the documentational approach (Gueudet & Trouche, 2009) resulted in new concepts (critical resources and critical situations) and models (integration of KVP interactions during the documentary genesis process) used to infer teachers‟ conceptions related to genetic determinism of phenotype through their documentary work, particularly their interaction with digital resources. Future researches can utilize these concepts in studying teachers‟ documentary work and conceptions related to other concepts in biology as well as in other disciplines.

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