Semiotic Pedagogy and Students Cognitive Development: Does the Order of Multiple Representations Play a Role in Meaning Making?

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The European Conference on Language Learning 2022
Official Conference Proceedings

Abstract
The present doctoral research project studies what mental mechanisms are formed by students to understand scientific concepts and whether and to what extent Semiotic Pedagogy and semiotic systems facilitate the representation of scientific concepts. Specifically, we focus on the way in which students construct cognitive schemata through semiotic resources, organize them in a broader mental context and construct mental fields and new cognitive patterns. A key research question is which combination of semiotic systems are more efficient than others and in which order, so that students recognize the cognitive procedures they follow to understand a scientific notion, when they use different semiotic representations. The present study proposes a theoretical model of cognitive representations through semiotic systems that can be applied in every subject domain. This way, aspects of the learning process are illuminated, as different semiotic systems are combined. At the same time, students become aware of the processes they use while constructing new knowledge. The results from the first phase of the research show that visual representations help more in teaching specific concepts and help students to recognize the cognitive processes they follow. However, they are not sufficient for the production of meaning. Students seem to prefer visual semiotic systems first and then their verbal explanations as texts, as visual semiotic resources are more abstract shapes but allow students to think more deeply, because these semiotic resources activate higher cognitive processes.

Keywords: Student Cognitive Development, Semiotic Pedagogy/ Edusemiotics, Semiotic Resources, Cognitive Science

Introduction

New findings in the field of Educational Studies focus on the students' internal perceptions and conceptions, studying students' cognitive and mental representations. From the field of Cognitive Neuroscience to the field of Cognitive Psychology and Cognitive Semiotics, researchers do not only study the students' observable actions of learning but also students' cognitive functions during their involvement in learning processes.

With this research doctoral project, we try to combine to different fields of Educational Studies the recent findings from Cognitive Psychology and the new field of Semiotic Pedagogy, as we research the use of semiotic systems and the role of multiple representations in the interpretation of new knowledge. We focus on how different representations affect students' cognitive development in order to help them to interpret, represent and acquire new knowledge. We attempt to understand student's mental system of representations, in order to study which mental mechanisms are constructed to deconstruct knowledge and reconstruct it a new one again, integrating and expanding pre-existing student representations with new structures and constructed concepts.

Our aim is to study the contribution of all semiotic systems to learning, but also how they can be systematized, in order to lead to the proposal of a new theoretical model of cognition and semiosis. The new scientific field of EduSemiotics is applied to help teachers understand how students approach new knowledge (Seif, 2021, Lackovic, 2020, Atoofi, 2019, Ferguson, 2019, Olteanu and Campbell, 2018, Deely & Semetsky, 2017, Oltenau, 2016, Reinertsen, 2015).

Theoretical Framework

From the Cognitive Psychology to the Cognitive Theories of Knowledge Representation

Cognitive Learning Theories research students' mental representations and the procedure of conceptualization: how does a student conceive and assign meaning to external stimuli (e.g a new scientific notion, word, information etc.)? How can we change students' initial representations/misconceptions and how can students interpret and represent new knowledge with different ways (semiotic systems)? These questions are at the heart of cognitive sciences.

The theories of representations mention that each student has his/her own internal representations shaped unconsciously, during the years. Students are usually not able to name these representations. External representations refer to verbal or non-verbal descriptions of phenomena/objects etc., for example graphics, pictures, models, software/microworlds etc. Students can see and describe these representations (Vergnaud, 2009) but that does not mean that a student can interpret and analyze a new notion.

A superior mental procedure is symbolization, which means the representation with multiple semiotic systems. At this research project we argue that when a student can use different ways to represent the same notion, this leads to meaning making and cognitive development. These cognitive skills can be applied to every new knowledge, and every subject domain in the education system, as it refers to the way that students learn (Zazkis, & Liljedahl, 2002).
Cognitive theories pay attention on the interior mechanisms of the cognitive system (Smyrnaiou & Weil-Barais, 2003). Modern cognitive theories recognize students as agents

(Agency) of acquiring their knowledge, as they build and rearrange their cognitive representations to approach new knowledge. Therefore, at this research study we assume that students affect the object of learning through semiotic tools, construct cognitive topics and organize them in broader mental frameworks and new cognitive schemas.

Multiple representations are a key tool for scientific knowledge. The acquisition of scientific concepts and the construction of scientific discourse by the students means that the latter cultivates the higher cognitive skills of explanation, justification, comparison, coding and concluding to reasonable conclusions (enculturation in Jiménez-Aleixandre, & Erduran, 2007).

The role of Representations in the Construction of Cognitive Concepts - Schemata – Fields

The student's mental conceptions (Weil - Barais & Vergnaud, 1990) is a dynamic system with regulatory mechanisms, constantly evolving, so that a student passes from the state of incomplete learning to the state of balance of cognitive structures. The individual's cognitive frames capture the cognitive processes for conceptualizing and acquiring knowledge (Weil-Barais, 2001). The concept of mental representations is fundamental in cognitive development, as the modification of the original representations and their symbolic expression in many semiotic systems can lead to the cognitive change (Smyrnaiou, Georgakopoulou et al. 2021, 2020, 2019). Internal representations address the internal configurations of individuals that are not directly observable. In this case student can describe his/her internal processes, but these will be incomplete and imperfect. Verbal descriptions or gestures are part of this introspection. External representations refer to observable structures, such as graphs, images/visual representation or computer microcosmos and in our research project they function as semiotic tools. The interpretation of external representations depends on internal representations. Between the two types of representations there is an interaction relationship, that we try to research during the first phase of this research study.

According to Vergnaud (2009), representation is characterized, initially, by a level of consciousness. Visual, auditory, kinesthetic and verbal perception of a concept - even if it is not formed - is an indication of mental perception. A second characteristic of representations is language and symbols, since without verbalization and symbolization representations cannot be communicated. The process of symbolization differs from that of representation, as it is the expression of the latter in different semiotic systems. That is the reason we assume that the multiple semiotic tools that a student can use, lead to the acquisition of knowledge.

At the same time, the representation of a concept is completed through the conceptual content, which is shaped and enriched gradually during the learning process. The conceptual contents are then organized into systems of topics and sub-topics, as the perceptual ability is synchronized with other semiotic systems. According to Vergnaud (2009), the student's mental schemata are not formed from the beginning, as they include a semiotic system, but they evolve during the learning process. The student's mental perception includes the signified concepts, which are activated when the learner approaches a body of knowledge.

Many times, these initial perceptions of students create obstacles to understanding knowledge, as they lead to misconceptions of a concept, but on the other hand, they are indicative of the student's cognitive functions, as they are responsible for the initial approach

to the concept. Thus, the students code situations, concepts and mental patterns and create conceptual fields.

The processes of organization, coding and classification of mental concepts in broader mental/conceptual fields follow the triple coexistence of the following features:

a) Conceptual fields are made up of situations related to the content.
b) Preconfigured students' misconceptions are taken into account.
c) The symbolic representation of the content and its properties is required.

Representational systems can develop and evolve based on three stages (Goldin 1996, 2000, 2002):

a) the creation stage (inventive - semiotic stage): in this stage new internal, unconscious mechanism are created to start symbolization.
b) the stage of structural development (a period of structural development): the construction of new cognitive topics is based on the previous stage, including the old mental concepts and the new representations.
c) the stage of autonomy (an autonomous stage): the union of old and new concepts/themes/structures will lead to the formation of a now unified cognitive field. At this stage, the generalization of the cognitive field takes place and the knowledge/skill/ability is transferred to other cognitive areas.

At this research study we suggest that the cognitive development of learner is achieved:

a. when a semiotic system of representation allows three kinds of operations:
    i. the formation of representations,
    ii. the handling of these representations within the framework of the specific system,
    iii. and the transformation of the representation into another semiotic system
b. when there is a combination of different semiotic systems (Smyrnaiou, Georgakopoulou et al, 2020, 2021).

At this research study, students are involved in cognitive activities in which they try to work on different "texts", make hypothetical scenarios, represent the notions verbally and visually through diagrams and pictures and transfer their knowledge into real circumstances in which this new knowledge can be explained.

The theory of Semiotic Systems in the Construction of Representations

Semiotic Pedagogy, as a scientific field, studies the meaning making and analyzes how a person constructs meaning. (Lagopoulos and Boklund-Lagopoulou 2020). It also studies the theory of signs and sign systems/symbolic representations/communication through symbols, the structure of signs-symbols-codes and the meaning of symbols. This scientific field deals with anything that can be considered a sign, such as words, images, sounds and gestures, anything that "symbolizes" or "represents" something else (Chandler, 2007).

Researchers engaged in modern semiotic theory examine "signs" as systems in order to investigate how meanings are created and how reality is represented. According to Chandler (2007), the science of semiotic theory is very important as it gives us the opportunity to

understand how reality is directly related to the way people interpret it. Information and various meanings are not automatically transmitted to us, but we create it through the interpretation of a system of codes presented to us without realizing it.

Semiotics is initially based on the theoretical documentation of Saussure (Joseph, 2012) and Peirce (2012), and it is related to three basic concepts, according to Mingers & Willcocks (2014):

a) with the student's personal interpretation with the production and interpretation of signs and symbols (personal world),
b) with the material world (material world, semiotic system of visual representation/ Embodied Learning), as signs can be transmitted through "physical resources", i.e. the use of the body, gestures, etc.
c) and with the social world, because semiotic systems are also socially meaningful.

Cognitive, embodied and social intelligence constitute the basic triplet of semiotics. Batu (2012) describes the stages of analyzing the functioning of semiotic systems:

i. In semiotics the subjects to be analyzed are seen as a structure and we try to explain their production in a conceptual framework.
ii. The semiotic method uses a scientific meta-language. Its aim is to determine the different cognitive paths of the meaning in a text and to check whether, by using metalanguage, the symbol has been systematized.
iii. Semantic approaches focus on construction of meaning rather than on the concepts themselves. They try to understand meaning-making processes.
iv. In semiotic systems, in addition to analogical, common connections, the deviations between them are also studied, in order to decide which semiotic system is appropriate for each concept.
v. Many times, a new model is developed.
vi. In semiotic analysis we move from the inside to the outside, because we study the deep connections within the symbol, we analyze its individual signs and new patterns are identified through comparison.
vii. Either a new mental model is constructed or the symbol is transformed into a cognitive subject, they are considered in a more abstract form.
viii. Knowledge fields are formed.

A proposed Theoretical Model for the role of Semiotic Systems in Cognitive Development: The Cognitive Semiotic Model for Students' Conceptualisation (The Cog-S Model)

In the context of The Semiotic Pedagogy or Cognitive Semiotics, this research argues that in order for a student to acquire new knowledge, he/she has to represent the concept with three or more ways, using semiotic tools. We try to research the ways that students interpret a text, analyze the signs, search for denotations and connotations in order to produce their own scientifically acceptable meaning and the ways that different signs (semiotic representations) may improve meaning making and how students can produce their own meaning. We have designed a theoretical model of knowledge acquisition for the purposes of this research study.

The Cognitive Semiotic Model for Students' Conceptualization (The Cog-S Model) (Georgakopoulou, 2022) assume that semiosis is a cognitive procedure which leads to the

understanding of scientific notions and finally to the way that student interact to the real world (Figure 1).

Multiple representational systems (verbal, visual and kinesthetic representations like Embodied Learning) structure the student's cognitive development, as they explain the multiple mental structures under which knowledge is registered.

The conceptualization of knowledge by the student is a higher cognitive process and today it is achieved in multiple ways. Preformed mental schemata are formed and developed only when the student acts through multiple semiotic resources, passing through the triple level of action, the real world, the mental world, and the symbolic level. Student's targeted action in these three entities helps the student to conceptualize the offered knowledge and categorize it, in order to structure new fields of knowledge.

The connection of different representational languages in the perceptual and symbolic stage inscribes the new knowledge in the student's cognitive structures. At the same time, the student utilizes his/her cognitive background, his emotional involvement and the socio-cultural factors involved in order to categorize and evaluate knowledge. Their mental categories direct the student's actions, motivate him/her to investigate strategies of active cognitive search and finally to combine the stimuli towards the formation of new concepts. It is also accepted that a student's alternative understanding of a scientific concept does not necessarily mean that it lacks internal coherence. For this reason, the existence of multiple representational systems can also be captured with synthetic models of cognitive change. Semiotic systems help to create semantic, as nearby, related cognitive topics are organized, compared, and construct a new cognitive field. Thinking is constituted by representational acts, which in turn result from the organization of internal and external representations.

It is worth pointing out that an important aspect of this study is the question of how different types of representational systems activate different kinds of thinking. This fundamental question leads to the finding that multiple types of semiotic systems lead to a more complete construction of knowledge. The multiplicity and coexistence of representational systems has been the subject of research (Smyrnaiou, Georgakopoulou, et all. 2017), the results of which have shown that in concepts difficult to interpret and explain, students employ multiple representational systems. It is also noteworthy that all representational systems must:

1. to be in absolute balance and harmony, as long as the basic principles, techniques and philosophy of the two objects are not altered, but one gains from the other
2. to co-exist simultaneously, when a concept is presented, and not asynchronously, as then the necessary cognitive connections and meaningful relationships between the characteristics of a concept and its performance are not made.

At this research we assume that semiotic systems present the relations or better organize the relations between representational units. In order to achieve learning, these units must be connected to at least two semiotic systems.

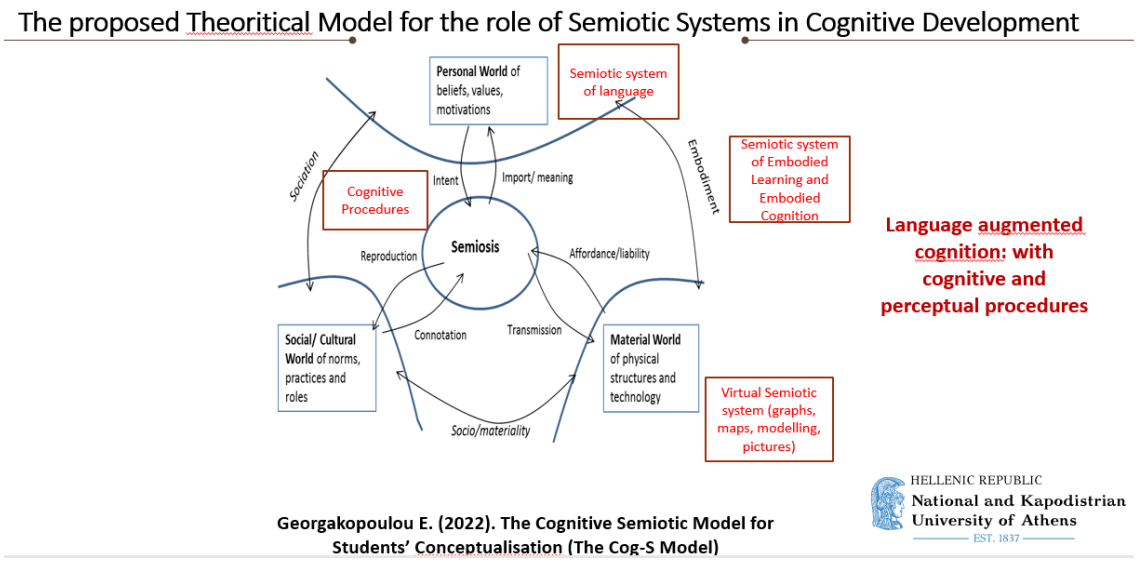

Figure 1: The Cognitive Semiotic Model for Students' Conceptualisation (The Cog-S Model)

Conclusion

The educational practice needs a transition from traditional educational goals to pedagogical goals that will activate students' internal and external mental representations and take into consideration their cognitive development and their socio-cultural development. The choices of the school material, teaching methods, subject domains, school knowledge and activities both at the macro level of educational policy and Curricula and at the micro level of school reality must be structured on the basis of the student overall development. The acquisition of scientific concepts and further all the internal cognitive mechanisms activated in the learning process build abstract, structured, transferable and effective skills that can be activated in any learning environment. The student through the development of an early scientific competence will be able to ask questions, identify solutions, justify their conclusions and structure scientific thinking. With the present proposal, a shift from decontextualized knowledge and the logic of "mistake stigma" (McNeill, & Pimentel, 2010), where the teacher handles the learning process, will be attempted, towards a discovery process of structuring thought for the production of meanings. Decoding and understanding students' cognitive fields will help to understand how students learn and this is the trigger, the basis for the global construction of educational designs.

Conflict of Interest

There is no conflict of interest in the current research.

Ethics Statement

The proposed theoretical model that is described in this study is the main part of a doctoral research study and it is researched with research under the official approval of the University committee for educational research. The research was held in two Experimental Schools in Greece, and all the research subjects agreed to data collection. During the transcription of the audio recordings, we removed or decoded any identification of students and stored the files in university hard drives. The photos, taken with the approval of students and parents, do not reveal any representative information of student identity. Parts of the data can be provided after a request and a justification of use to the authors. The aim of this article is to present the

Cognitive Semiotic Model for Students' Conceptualisation (The Cog-S Model). The results of the research will be published. The transcriptions are currently available in the Greek language but parts of them can be translated.

Acknowledgments

The research work of Georgakopoulou Eleni has been financially supported as an official PhD Scholarship. "This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Program "Human Resources Development, Education and Lifelong Learning" in the context of the project "Strengthening Human Resources Research Potential via Doctorate Research" (MIS -5000432 , implemented by the State Scholarships Foundation (IKY)".

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