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ANALYSIS OF THE SCIENCE LEARNING OBJECTS OF THE GREEK DIGITAL LEARNING OBJECT REPOSITORY FROM A LEARNING ACTIVITIES PERSPECTIVE

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Abstract:
In recent years, learning objects have been playing a crucial role in the teaching process. However, research focused on the analysis of science learning objects is particularly limited. The present study aims to analyze the science learning objects of the Greek Digital Learning Object Repository that are intended for primary school from a learning activities perspective. A total of 178 learning objects were analyzed. The analysis of learning objects from the perspective of the learning activities (cognitive and metacognitive) they activate in the students was carried out in line with the analysis framework of Overman, Vermunt, Meijer, Bulte and Brekelmans (2013). The analysis of learning objects showed that they are dominated by low level cognitive learning activities, while the learning objects that activate high level cognitive learning activities are limited. Finally, no learning objects activating metacognitive learning activities in the students were detected.

Keywords: question analysis, learning objects, science teaching, learning activities

1. Introduction

This study belongs to the wider field of research that is focused on the analysis of science instructional material. In particular, the present study centres on the analysis of science learning objects.

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The science learning process is largely shaped by the instructional material, which directly affects students' learning as the students interact with it. It also indirectly affects students' learning through its effects on the teachers and their teaching choices (Reyes, Reys, Lapan and Holliday, 2003). The activities included in the instructional material could encourage the students to focus on the content they offer and could significantly contribute to the learning process (Kahveci, 2010; Overman et al., 2013). They affect but also guide the students to choose, codify and process information (Davila and Talanquer, 2010). They can also contribute to building new knowledge and developing students' skills (Giordan and Vecchi, 1996). Apart from their content, the cognitive level of the activities is an important factor that can affect the process of linking the new information acquired by the students with the knowledge they already possess (Davila and Talanquer, 2010). As a result, research intending to analyze science instructional material from the perspective of learning activities (cognitive and metacognitive) should be carried out.

Although the importance of the instructional material in science education has been recognized, the research that is focused on its analysis from a learning activities perspective is limited. The studies that have been published are mainly focused on the questions of school textbooks (Davila and Talanquer, 2010; Overman et al., 2013; Pizzini, Shepardson and Abell, 1992). However, due to the great progress in digital technologies in recent years, the use of digital learning objects has gained ground. Considerable amounts of money have been invested, aiming at the development of learning objects and the creation of learning object repositories that can manage collections of learning objects (Friesen, 2004). Nevertheless, there are no research papers analyzing science learning objects from a learning activities perspective, which shows the need to conduct this research. This study is particularly important because it provides information to the teachers and the designers of learning objects about the kinds of questions and the learning activities these questions activate in the students.

2. Theoretical Framework

2.1 Learning Objects

In recent years, there has been heated debate about the construction of modern and effective digital instructional materials. Such materials are often described as *Learning Objects*. They are special digital entities that actually serve as educational resources for the teaching processes.

A learning object is a digital entity that can be used in learning, education and training (IEEE, 2002). According to Wiley (2000), a learning object is any digital resource that can be reused in order to support learning. The learning object is a reusable entity with clear educational objectives and internal structure, accompanied by a structured amount of information that describes it (Chiappe et al., 2007). As a result, the learning object is an autonomous unit of educational content, which is connected with one or more learning outcomes and has been developed in order to provide the opportunity to be reused in different educational frameworks.

The use of learning objects called for the creation of digital learning object repositories. The creation of national learning object repositories has become a common strategy in all countries. Digital repositories are generally systems providing infrastructure for storing, managing, retrieving and delivering digital resources. The "*Photodentro*" is the Greek digital learning object repository for primary and secondary education. It is the central web service of the Greek Ministry of Education for collecting and distributing to the educational community digital educational content intended for school education. The web address is http://photodentro.edu.gr/lor.

2.2 Learning Activities

Teaching does not necessarily lead to learning (Overman et al., 2013). The learning activities that are activated by the students to a great extent define the learning outcomes. The intention of teaching is to encourage the students to activate high level learning activities. Learning activities are the thinking activities the students activate in their attempt to learn (Vermunt, 1996). Vermunt and Verloop (1999) divided the learning activities activated by the students into cognitive and metacognitive. Cognitive activities are the thinking activities the students use in order to process subject matter and directly lead to learning outcomes that are related to changing their pre-existing knowledge. Metacognitive activities are the thinking activities the students use in order to make decisions with regard to the content they will learn, to exert control over their processing and to steer the outcomes of their learning (Vermunt and Verloop, 1999).

Table 1 shows a taxonomy of cognitive and metacognitive activities.

Table 1: Kinds of Cognitive and Metacognitive Activities (Vermunt and Verloop, 1999)

Cognitive Activities	Metacognitive Activities
Selecting	Orienting / Planning
Memorizing / Rehearsing	Monitoring / Testing / Diagnosing
Concretizing	Adjusting
Applying	Evaluating / Reflecting
Analyzing	
Structuring	
Relating	
Processing Critically	

3. Literature Review

This section is a literature review of research studies focused on the analysis of the questions that are included in instructional material intended for science teaching. These studies are dominated by the analysis of the questions included in science school textbooks. Shepardson and Pizzini (1991) as well as Pizzini, Shepardson and Abell (1992) analyzed the questions of science school textbooks in the USA with regard to their cognitive level, on the basis of the analysis framework of Costa (1985), which classifies the questions into three categories: "input," "processing" and "output." "Input" questions are focused on memorizing information. "Processing" questions are focused on processing information and on understanding the relationships among the different items of information. "Output" questions ask from the students to draw conclusions and judge opinions and theories. The results of the research showed that school textbooks are dominated by "input" questions. Kahveci (2010) used the same analysis framework to analyze the level of questions included in secondary education science school textbooks in Turkey and found that the textbooks were mainly dominated by "input" and "processing" questions.

Davila and Talanquer (2010) analyzed Chemistry school textbook questions in the USA. The analysis was conducted according to the classification of Bloom and Krathwohl (1956). This classification divides the questions into the types of "knowledge," "comprehension," "application," "analysis," "synthesis" and "evaluation." The results showed that the majority of the questions were included in the categories of "application" and "analysis". Nakiboglu and Yildirir (2010) investigated the questions of Chemistry school textbooks that referred to gas laws. They found that most questions of these school textbooks belong to the algorithmic category, which mainly requires the use of formulas and calculations. Vasconcelos et al. (2012) analyzed the questions of science school textbooks and found that there were very few questions of higher cognitive level.

Overman et al. (2013) analyzed the questions of four secondary education Chemistry school textbooks from the Netherlands from a learning activities perspective, on the basis of the framework of Vermunt and Verloop (1999). It was found that school textbooks are dominated by questions focused on the cognitive activity of "applying," namely applying relevant algorithmic and mathematical knowledge and skills to solve Chemistry problems. A small number of questions are related to higher cognitive or metacognitive activities. However, it emerged that school textbooks that were written on context-based Chemistry curricula included a comparatively larger number of questions related to metacognitive activities than school textbooks that were written on the basis of traditional curricula. Moreover, Skoumios and Diakos (2015) analyzed the questions of two secondary education Chemistry textbooks from Greece from a learning activities perspective on the basis of the framework of Overman et al. (2013). The results of the research showed that the questions of secondary education Chemistry textbooks were mainly focused on the cognitive activities of "memorizing/rehearsing." Furthermore, no questions activating metacognitive activities in the students were detected.

All the above research dealt with science school textbooks. As for science learning objects, research that is focused on their analysis is particularly limited. More specifically, frameworks within which the learning objects can be analyzed have been proposed. These frameworks can be applied in existing learning objects and can provide indications of their quality. In particular, the learning objects have been analyzed with regard to the quality of the content, correlation with learning objectives, feedback and adaptation, motivations, presentation, usability of interaction, accessibility and reuse (Kay and Knaack, 2009; Nesbit and Li, 2004; Sinclair et al., 2013; Vargo et al., 2003). However, despite the above research on the analysis of learning objects, no research on analyzing the science learning objects from the perspective of the learning activities they activate in students was detected.

After all, it is found that the research that has been conducted on the analysis of science questions from the perspective of the learning activities (cognitive and metacognitive) they activate in the students has been focused on the analysis of school textbook questions rather than of the learning objects. The originality of this paper lies in the fact that it focuses on the analysis of science learning objects from the perspective of the learning activities they activate in the students, a field without research data so far.

4. Purpose and Research Questions

The present study is focused on science learning objects and aims to analyze primary school science learning objects of the "Photodentro" Greek Digital Learning Object Repository from a learning activities perspective.

In particular, this study aims to answer the following research questions:

a) what is the distribution of primary school science learning objects of the "Photodentro" Greek Digital Learning Object Repository into categories with regard to the cognitive activities they activate in the students?
b) what is the distribution of the questions of primary school science learning objects of the "Photodentro" Greek Digital Learning Object Repository into categories with regard to the metacognitive activities they activate in the students?

5. Methodology

5.1 Overview of the Study and Sample

This is a quantitative research study and was organized in two stages. The first stage included the concentration of the learning objects that were to be analyzed. The second stage included the analysis of the learning objects from the perspective of the learning activities they activate in the students.

The research sample included the science learning objects of the "Photodentro" Greek Digital Learning Object Repository that were intended for primary school students. Every learning object was considered an analysis unit. A total of 178 analysis units were counted.

5.2 Research Instrument

The analysis of learning objects from the perspective of the learning activities they activate in the students used the analysis framework of Overman et al. (2013). According to this, the questions are classified into categories with regard to the opportunities they offer to the students to engage in cognitive or metacognitive activities.

The questions that activate cognitive activities are classified into the following categories (Overman et al., 2013):

a) Selecting: They require the detection of one or more items of information among other information included in a learning object.

b) Memorizing / Rehearsing: They aim at the memorization of material, definitions, formulas, information and theories included in the learning object.
c) Applying: They require that the students use the acquired school knowledge in new circumstances relevant to those they have negotiated. They also require the use of a mathematical formula and mathematical operations.
d) Concretizing: The students are asked to combine "school knowledge" with the "world beyond school," that is, everyday life. The students refer to practical applications of knowledge or propose examples from everyday life, mentioning personal experiences related to the subject under investigation.
e) Analyzing: They require that the students analyze a set of information into its individual items.
f) Structuring: They require that the students organize various elements into a single set. They should represent the main concepts of a text in a well-organized graph, trying to compress its meaning.
g) Relating: They require that the students investigate the relationships between knowledge and facts and detect them. The students are asked to find similarities and differences between theories and compare information from the text with knowledge included in other texts.
h) Processing Critically: They ask the students to examine whether some conclusions or views are in line with science facts or theories, to identify the criteria that will help them determine the above, and explain why these criteria are necessary or construct an interpretation based on knowledge and arguments.
i) The questions that activate metacognitive activities are classified into the following categories (Overman et al., 2013):
    (a) Orienting / Planning: They require that the students plan an activity and identify, among others, the learning objectives, the action plan that is to be followed, and the required knowledge.
    (b) Monitoring / Testing / Diagnosing: Monitoring occurs when the students test whether the process they have followed is carried out in accordance with a predefined action plan. Testing investigates whether the new knowledge has become understood and can effectively be applied. Diagnosing refers to specifying the gaps in the knowledge and capabilities of a student as well as to investigating the possible reasons that could cause learning difficulties or successes.
    (c) Adjusting: They aim to make the students adjust the learning process through the introduction of changes in an initial action plan of theirs, with the changes being based on testing the existing learning outcomes.

(d) Evaluating / Reflecting: They aim to evaluate the extent to which the final learning outcome is in line with the scheduled learning objectives and the extent to which the learning process proceeded as it had initially been planned. Reflecting is focused on contemplating the learning activities and, in particular, on all that happened throughout these activities.

5.3 Data Analysis

The 178 learning objects were analyzed from the perspective of the learning activities (cognitive and metacognitive) they activate in the students, in accordance with the framework of Overman et al. (2013).

The analysis of the learning objects was made by two researchers who worked independently. They agreed by 89.9% before they settled their disputes through discussions. After all learning objects were analyzed, the frequencies and the percentage frequencies (percentages) of the categories of the learning activities were identified.

6. Results

Table 2 shows the frequencies and the percentages of the categories of learning activities the learning objects of the "Photodentro" Greek Digital Learning Object Repository can activate in the students. Table 2 also shows that cognitive activities included in the category of "Memorizing/Rehearsing" are the majority (82.02%). Cognitive activities included in the category of "Structuring" follow far behind (4.49%). Even lower are the percentages of the cognitive activities of the categories of "Selecting" (3.93%), "Applying" (2.81%) and "Analyzing" (2.81%).

Table 2: Categories of learning activities that can be activated in the students by the learning objects of the "Photodentro" Greek Digital Learning Object Repository: frequencies and percentages

Categories	f	%
"Selecting"	7	3.93
"Memorizing/Rehearsing"	146	82.02
"Concretizing"	2	1.12
"Applying"	5	2.81
"Analyzing"	5	2.81
"Structuring"	8	4.49
"Relating"	3	1.69
"Processing Critically"	1	0.56

Table 3 shows the frequencies and the percentages of the categories of metacognitive activities that can be activated in the students by the learning objects of the "Photodentro" Greek Digital Learning Object Repository. Table 3 also shows that only one learning object can activate in the students metacognitive activities that are included in the category of "Adjusting." There are no learning objects that can activate the rest of the categories of metacognitive activities in the students.

Table 3: Categories of metacognitive activities that can be activated in the students by the learning objects of the "Photodentro" Greek Digital Learning Object Repository: frequencies and percentages.

Categories	f	%
"Orienting / Planning"	0	0.00
"Monitoring / Testing / Diagnosing"	0	0.00
"Adapting"	1	0.56
"Evaluating / Reflecting"	0	0.00

7. Discussions and Conclusion

The present study aimed to analyze the science learning objects of the "Photodentro" Greek Digital Learning Object Repository that are intended for primary school from the perspective of the learning activities these objects activate in the students.

The results showed that cognitive activities related to memorizing information are prevalent. The presence of the other categories of cognitive activities is particularly limited, while metacognitive activities are almost missing. Consequently, there are no opportunities for the students to work out learning objects that can activate high level cognitive activities, such as "Structuring," "Analyzing," "Relating" and "Processing Critically," or metacognitive activities.

The above results are different from the results of the study by Overman et al. (2013), which analyzed two Dutch Chemistry school textbooks written on the basis of traditional curricula and another two Dutch Chemistry school textbooks written on the basis of context-based chemistry curricula (one Chemistry school textbook that was focused on processing subjects involving both technological and social issues, and a second school textbook that was focused on processing subjects related to the development of chemical research in a socio-historical context). More specifically, it was found that although there are more questions activating the cognitive activities of "Memorizing" and "Applying," the percentages of the cognitive activities belonging to the categories of "Relating" and "Processing Critically" are comparatively higher than their respective percentages in the learning objects that were analyzed in the present study. The percentage of the cognitive activities of "Processing Critically" in the Dutch Chemistry school textbook, which emphasizes on processing subjects involving technological and social issues, is particularly high. Another important difference between Dutch school textbooks and Greek learning objects is related to metacognitive activities. The presence of questions activating metacognitive activities in the students in Dutch school textbooks is evident.

The results of this study are in line with the results of the study by Skoumios and Diakos (2015), who analyzed the questions included in two Greek Chemistry school textbooks from the perspective of the learning activities they activate in the students. It was found that the Chemistry school textbook was dominated by cognitive activities requiring that the students memorize information and apply their knowledge by solving Chemistry problems with algorithms. The presence of the other categories of cognitive activities was limited, while there were no metacognitive activities at all.

Nakiboglu and Yildirir (2011) underline that the questions requiring from the students to memorize and apply knowledge do not necessarily lead to conceptual understanding because the students often adopt mechanistic practices while processing questions. In addition, when students engage in questions of the category of "Memorizing" neither higher skills are developed nor deeper understanding is promoted, as they engage in a surface approach to learning (Nakiboglu & Yildirir, 2011). The cognitive level of the questions is decisively important and could contribute to contrasting new with already existing knowledge (Wixson, 1983). Questions of low cognitive level discourage the students "*from making meaningful connections between prior knowledge and textual information*" (Shepardson and Pizzini, 1991, p. 674). Pizzini et al. (1992) underline that the extensive use of low level questions makes the students memorize information without conceptual understanding. A large number of researchers believe that questions of low cognitive level urge the students to focus only on information related to the question and, as a result, they fail to establish relationships between concepts and ideas (Anderson et al., 1971; Holliday et al., 1984). On the other hand, questions of high cognitive level make the students analyze information, construct theories, evaluate solutions and think critically. Students' engaging in questions requiring critical thought is a main aim of science education (Gilbert et al., 2011; Kahveci, 2010; Nakiboglu and Yildirir, 2011). Furthermore, the questions that activate metacognitive activities make the students more responsible in testing and evaluating learning processes and, thus, they improve their learning (Overman et al., 2013).

After taking into account the material we collected and analyzed in this study as well as the conclusions we have drawn, we can put forth some propositions that can further be investigated. The analysis of other secondary education science learning objects (from Physics, Chemistry, Biology) both in Greece and in other countries would be interesting for research so that it could be investigated whether the categories of learning activities that are activated in the students differ from the learning activities that are activated in the students by Greek primary education learning objects. Furthermore, the present study was only focused on analyzing learning objects rather than on applying them in school classes. Further research is required so that not only the learning objects but also the questions the teachers use during science teaching with the help of learning objects can be analyzed from a learning activities perspective.

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