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DEVELOPMENT AND PRECODIFICATION OF A LITHOSPHERE QUESTIONNAIRE AS A TOOL IN EDUCATIONAL RESEARCH (GEOSCIENCES)

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Abstract

This paper presents the theoretical approach and the technical steps for the development of a questionnaire on lithosphere for the 1st class of Greek junior high school. It, also, discusses the importance and the multifunctional role of such a questionnaire (i.e. GCI tool). Furthermore it presents an innovative precodification of open-ended questions based on the set question - control question, which offers valid data for a qualitative study like this. The cognitional control table offers abundant data about students' cognitional structure and about whether conceptual change has been achieved.
***Keywords**: codification, open-ended questions, generative questions, action questions, didactics of geology.*

Περίληψη

Στην παρούσα εργασία περιγράφονται το θεωρητικό και το τεχνικό πλαίσιο για την δημιουργία ενός ερωτηματολογίου στο κεφάλαιο της λιθόσφαιρας που απευθύνεται σε μαθητές της Α τάξης του γυμνασίου. Αναδεικνύεται ο πολυδιάστατος ρόλος και η σπουδαιότητα αυτού. Επίσης, εισάγεται ένας νέος τρόπος προκωδικοποίησης των ερωτήσεων ανοικτού τύπου, ο οποίος στηρίζεται στην ύπαρξη των ερωτήσεων ελέγχου. Ο "πίνακας γνωσιακού ελέγχου" προσφέρει ποσοτικά αλλά και ποιοτικά δεδομένα στην έρευνα αλλά κυρίως διαπιστώνει το γνωσιακό επίπεδο των μαθητών και εάν έχει επέλθει η εννοιολογική αλλαγή για τους ζητούμενους διδακτικούς στόχους.
***Λέξεις κλειδιά**: ερωτηματολόγιο, κωδικοποίηση, ερωτήσεις ανοιχτού τύπου, ερωτήσεις δράσης, παραγωγικές ερωτήσεις, διδακτική γεωλογίας.*

1. Introduction

Questionnaire development is a fascinating but also arduous process which demands specialized knowledge. According to Davidson (1970), an ideal questionnaire can be resembled to an ideal law, in the sense that it must be distinct and minimize the possibility of probable false responses. Questions should intrigue students' imagination and reveal honest responses close to the truth.

Paraskevopoulos (1993), argues that close-ended questions are much easier and less time consuming to be answered, analyzed and codified. Open-ended questions encourage the respondents to unfold their inner feelings and ideas about a subject and unveil their wider conceptual basement. However, open-ended questions need more effort and time to be answered, a fact that impedes the questionnaire completion. Furthermore, the responses to open-ended questions are much more difficult to be analyzed and codified, a fact that influences data validity.

Cohen *et al.* (2000), mention that data validity depends not only on the responses but also on properly developed questions. Precodified questions rise high validity data. Close-ended questions are easily procodified and thus bear high validity. On the other hand, precodification of open-ended questions is a laborious procedure but the fact that open-ended questions exhibit the deepest perceptions without limitations and prompts, calls for a reliable precodification of open-ended questions.

The purpose of this paper is to describe the theoretical and technical approach of developing a questionnaire on lithosphere and to present its importance. Furthermore it aims to introduce an innovative precodification of open-ended questions. The development of the questionnaire intends to i) retrieve students' alternative ideas which constitute the base for the design of the teaching process, and ii) to assess the effectiveness of a new experimental teaching procedure on lithosphere for the 1st class of the Greek junior high school. The questionnaire precodification aims to the best codification of students' answers, so that the best quantitative and therefore qualitative results on our survey can be achieved.

2. Questionnaire development

2.1. Theoretical approach

The theoretical approach of the questionnaire development was based on the GeoCause - PaP - CoRe method (Bakopoulou *et al.*, 2015). This method studies the geologic events within the wider terms of Planet Earth geosystem**.** It also focuses on the cause of the phenomenon, the parameters affecting it, the accompanying processes, the correlations and interactions among them, and their results on Earth's surface. A questionnaire based on this approach is scientifically and geosystemically integrated because it reveals precisely students' concepts on a sequence of facts about lithosphere and it also stimulates students' causal reasoning and geosystem thinking. Therefore, it reveals whether students organize their knowledge within their conceptual framework incidentally and lack events' sequence, or their concepts are correlative and bear continuity.

The objectives of the experimental teaching procedure are related to lithosphere processes (e.g., earthquake, volcano, mountain formation, etc.) and constitute the base for the questionnaire development. Firstly, the questionnaire was placed within the broader terms of Earth Planet geosystem, so the whole sequence of questions tends to point out if students have affiliated the sense of geosystem. The objectives of the teaching procedure developed according to the keywords of the GeoCause - PaP - CoRe approach, i.e. cause, parameters, processes, correlation and results. Therefore, the questions are based on these keywords and their goal is to explore if students have realized a) what is the main cause of lithosphere processes, b) what are the processes that take place inside Earth and on Earth's face, like convective currents and plate movement, c) what are the parameters that influence these processes (i.e., we focus on temperature only because of the cognitional level of 1st class students at junior high school), d) what is the correlation and interaction among processes (temperature, heat, convective currents, plate motion), and finally e) what are the results of all the above processes on Earth surface, such as earthquake-volcano-mountain formation, constant change of Earth topography.

For example one of the questions is like *Could you dig a hole so deep into the Earth so that you reach the other side of it?* This question intends to elicit students' ideas about the extremely high temperatures inside the Earth.

A journey between Europe and America will last longer after a few million years. Could you explain why? Or the question '*The Mediterranean region is going to be different in a few million years. How do you think it will look like and why?'* These two questions try to retrieve students' conceptions about the geodynamic processes happening (i.e., plate movements) and about their results on Earth surface (i.e., constant topography change).

If Earth core was hollow, then could earthquakes occur? Explain. The aim of this question is to investigate if students have reached the cognitional level to describe the main cause of geodynamic processes and then to correlate processes among them (heat, convection currents, plate motion, earthquake occurrence). Furthermore, it can distract concepts about what procedures take place inside the Earth and their results on the Earth's face.

It is noteworthy that these types of questions (concerning plate motion and convective currents) were not included in the questionnaire from the beginning of the survey because they seemed extravagant to be addressed to students of 1st class of junior high school, because of their age and conceptual level. But during the pilot implementation of the questionnaire, students described such concepts by themselves without being asked in open-ended questions. This fact led to the conclusion that students have been exposed to such information through TV, the internet and generally social media. Thus, these questions were added to the questionnaire because it was a challenge a) to investigate how students managed and incorporated such information into their cognitional basement without teacher guidance away from school environment, and b) to elicit students' ideas on the processes happening inside Earth and their results on the Earth's surface, according to the GeoCause - PaP - CoRe approach before and after the experimental teaching procedure.

2.2. Technical development of the questionnaire

As far as the technical development of the questionnaire is concerned, we describe below some rules that are necessary to be followed in order to elicit the deepest students' ideas and therefore to obtain the best qualitative and quantitative results.

1. We preferred written questions and responses rather than oral and interview-based ones in order to avoid a) the researcher's guidance, and b) the stress of the student when asked orally, and therefore to keep the procedure as objective as possible.

2. We tried to design a delightful and interesting questionnaire, organized in short units, with attractive questions for those who may be bored to answer it and assuring for the privacy for those who hesitate to. Questions were categorized in units according to the objectives and the structure of the experimental teaching procedure. Students were also ascertained that it was not a test to affect their school performance but just an educational survey where their contribution was valuable, a fact that made them feel important and responsible. Furthermore, it was emphasized that all answers are acceptable so that students would feel free to answer spontaneously.

3. Questions were distinct with plain words, understandable by all students. Scientific vocabulary included in the questions was avoided so that students would not be guided. Questions were organized in a specific order so that each answer could not be influenced by the previous one. In that way we tried to avoid interaction between order and content of the questions (Paraskevopoulos, 1993) in order not to predispose students on the subject and allow them to give a spontaneous answer.

4. One of the main characteristics of the questionnaire is the wide usage of open-ended questions which demand an exclusive and free answer from the student without any kind of restrictions or influence -guidance - prompt by the researcher. The answers to open-ended questions depict the exact concepts of the students and flourish a qualitative research like this. Close-ended questions are standardized, the answers to the questions are given by the researcher and students have only to choose (very often accidentally if they do not know the answer). Furthermore, close-ended questions often use scientific vocabulary and do not allow students to answer spontaneously and independently. The main disadvantage of open type questionnaire is its difficulty to be codified and the possibility of disoriented codification (Cohen *et al*., 2000), thus low data validity.

5. Vosniadou and Brewer (1992), in order to examine the range of children's knowledge about the earth, asked children two kinds of questions: factual and generative. Consider, for example, the question "What is the shape of the earth?" It is possible that children who have been told that the

earth is a sphere answer this question by simply repeating the information they have received from adults. Questions of this sort, which is "factual," provide information regarding children's exposure to certain theoretically important facts, but not about their ability to use these facts in a generative way. Generative questions have a far greater potential for providing information about children's underlying conceptual structures. These questions ask children to explain phenomena which they cannot directly observe and about which they are not likely to have received any direct instruction. Consider, for example, the questions "If you were to walk for many days in a straight line, where would you end up?" "Would you ever reach the end or edge of the earth?" and "Does the earth have an end or an edge?" In order to answer these questions, children cannot rely on some unassimilated piece of information they have received from adults. Rather, they need to create a mental representation of the earth which includes information about its shape and use this mental representation to provide an answer to the question.

During the pilot implementation of the questionnaire, we used both factual and generative questions. We confirmed that factual questions, which are plain ones that ask for the students' point of view directly (i.e., What is the temperature inside Earth?), offer poor qualitative data about real concepts and impede the learning process and the survey. The answers to factual questions are simple memorized scientific terms that students probably have not understood. On the contrary, generative questions which usually involve students into fantastic activities, provide abundant qualitative data about students' concepts (i.e., *Could you dig a hole so deep into the Earth so that you reach the other side of it?* or *If you could go on a journey deep inside Earth how would you feel?).* Such questions challenge students' interest and provoke their imagination. Students enjoy themselves by participating in the 'adventure' and subconsciously reveal their deeper perceptions of their conceptual structure. We call these questions *action questions*. That means that one question developed in two different ways (factually and generatively) can be answered with two completely different and contradictory responses by the same student. For example, if a student has not assimilated the real concept of plate movements but he has been exposed to this information, he is probably going to answer the following to the next questions: *factual question: Do lithospheric plates move? answer: YES,* but if we ask *the generative question: A journey between Europe and America will last longer after a few million years. Could you explain why?* the answers could be either *(1): It is not going to last more but less because airplanes are going to be faster due to technology evolution* or *(2): Nothing is going to change.* Another example of generative and factual questions is: *Do we meet volcanoes in Greece? Why? (generative) - What is the geographical distribution of volcanoes? (factual).*

6. Close-ended dichotomous questions which necessitate for a 'yes' or 'no' answer are used rarely. This type of questions is enriched with the answer 'I don't know' because it is undeniably an acceptable and real answer. Furthermore, this way we avoid a random response by the students. This type of questions is coded easily and quickly and generate high response frequencies and accurate statistical results (Cohen *et al.*, 2000). The importance of these questions is that they usually function as control questions.

7. Control questions are those who repeat a previous generative or factual question but formulated in different words. The aim of these questions is to reveal whether students' responses are random and contradictory or they are systematic and bear continuity (Vosniadou and Brewer, 1992). Consider the example, action question: *Could you dig a hole so deep into the Earth so that you reach the other side of it?* Control question: *If you could go on a journey deep inside Earth how would you feel?* and the given answers are (i) *cold, (ii) hot, and (iii) something else.* The objective of these two questions is common, to reveal whether students are able to describe the high temperatures inside Earth. If students' answers are in accordance with both questions, then their responses present continuity and are systematic. So it is obvious that students have incorporated into their cognitional framework the concept of high temperatures prevailing within the Earth. If students give one false and one right answer to the set generative question - control question, then responses are

contradictory and random, which means that students have not consolidated the information and thus have not achieved their conceptual change.

Another set of question - control question is: *Do we meet volcanoes in Greece? Why? (1st question), Russia or Greece is more probable to suffer from an earthquake? Why? (2nd question).* The objective to both questions is the geographic distribution of geodynamic phenomena, which is the lithospheric plates' boundaries. Both questions are generative and either can be the control question to each other. The goal of these questions is to identify if students have realized where volcanoes and earthquakes occur.

Another set of question - control question is: *A journey between Europe and America will last longer after a few million years. Could you explain why? (1st question), The Mediterranean region is going to be different in a few million years. How do you think it will look like and why? (2nd question).* Again either question can be the control one to each other and their objective is to elicit and verify students' ideas about plate motion.

If Earth core was hollow, then could earthquakes occur? Why? (1st question), If the inner part of Earth was frozen, then could mountains be formed? Why? (2nd question). This is another set of question - control question, the objective of which is to reveal if students are able to correlate the main cause of geodynamic phenomena to plate motion, to convective currents and to their surficial occurrence. In other words, to assure that students can attribute earthquake, mountain and volcano formation to Earths' inner processes. So far it is obvious that one question can very often be the control question to more than one questions.

During the development and the implementation of the questionnaire we realized that students have been exposed to geological information about volcano and earthquake occurrence and plate movements through the internet and social media. Thus, it was quite interesting to discover how students have managed and structured such information into their conceptual framework without teacher and school guidance. So, all the aforementioned questions are developed and organized a) to point out how students have included into their conceptual framework the scientific information they have been exposed to by internet or media and away from school environment *before* the experimental teaching procedure, and b) to extract students' concepts in order to investigate if the objectives and the conceptual change have been achieved especially *after* the experimental teaching model.

8. *You fill up a glass pot with water. You warm it over fire. Water starts heating. Inside the pot and exactly above the fire you drop food coloring. What is going to happen to the coloring? What process inside Earth do you think resembles to this experiment?* The objective to this question is to find out a) if students understood the processes and seized the concepts during the convective currents' experiment, and b) if the experiment contributed to the assimilation of processes happening inside Earth and thus to the achievement of conceptual change. The response to this question can be confirmed or refuted by three control questions of the questionnaire, ie *If Earth core was hollow, then could earthquakes occur? Why?*

9. *Would you compare Earth's structure to a) an onion, b) an orange, c) an egg, d) something else?* The goal to this question is to reveal how the teaching procedure and the geography textbook of 6th class of primary school have shaped students' conceptual structure. It is a quite interesting question because this textbook bears ambiguities that often lead students to develop confused cognitional frameworks, which are difficult to be reconstructed.

2.3. Importance of the questionnaire

The initial purpose of the development of the questionnaire tool was to elicit students' alternative concepts on lithosphere and to enhance the teaching process. During the procedure of implementation and improvement of the questionnaire, it was revealed that the data acquired exceeded the initial expectations and that the questionnaire had a multiple role. So after the questionnaire pilot implementation, we deduced that the questionnaire can be used as a tool to serve multiple and different functions, such as:

a) to elicit students' alternative concepts on lithosphere so as to develop a teaching model based on the constructive theory.

b) to evaluate efficiency of the teaching and learning procedures on lithosphere and improve them through the comparison of students' concepts before and after the experimental teaching procedure.

c) to discover how students have managed and incorporated new information by social media into their cognitional structure without teacher guidance.

d) to enhance the curriculum objectives on lithosphere through the improvement of the experimental teaching model (Bakopoulou *et al.*, 2015).

e) to be used as a **GCI tool** (Libarkin and Anderson 2005, 2006; Bakopoulou *et al.*, 2015), in order to continuously evaluate the progress of teaching and learning processes on lithosphere at school, and to use the results to feedback and refine the lithosphere curriculum development constantly.

So, it is obvious that the importance of a questionnaire tool, like this GCI tool with multiple usages, is invaluable to the educational procedures on lithosphere but also on geoscience in general, because they are dynamic and must be resupplied and revised continuously.

3. Questionnaire precodification

Generally, researchers prefer to develop close-ended questions rather than open-ended ones during a survey because the first are easier to be codified and offer plentiful quantitative data. Our survey focuses on qualitative data and thus we developed open-ended questions. These questions demand a spontaneous response, elicit deeper preconceptions and map precisely students' cognitional structure. Open-ended questions can offer "diamond" data to a qualitative survey (Cohen *et al.*, 2000). Besides, during the pilot implementation of the present questionnaire it was the responses to the open-ended questions that offered ample information and turned our questionnaire to an irreplaceable GCI tool with multiple usages.

Despite the difficulty to precodify open-ended questions, we introduce an innovative precodification method, in order to have best qualitative and quantitative results. Our method depends on the fact that each generative or factual question corresponds to at least one control question. The aim of the control questions is to verify whether students' responses are inductive and systematic or not. If the responses to both, generative or factual and control, questions are in agreement then students have conceived the knowledge and the conceptual change has been achieved. If the responses to both questions are contradictory, then students' answers are random. Thus students have not incorporated the knowledge into their cognitional framework and they have constructed a false conceptual structure (see above). We name this type of precodification of open-ended questions *"control question precodification"* because it is based on the usage of control questions.

Each objective corresponds to a question - control question pair, which is organized in a table called "*cognitional control table*". We call it cognitional control table because the set question - control question reveals if the knowledge is incorporated into the students' cognitional structure or not, as described above. In the following example of *cognitional control table* (Table 1) on lithosphere we use number 1 for the factual or the generative question and number 2 for the control question. Note that the position (1 or 2) of a question within the set is interchangeable.

So far the precodification of open-ended questions has been an arduous and time consuming procedure with doubtful results. According to the *control question precodification*, open-ended questions in lithosphere questionnaire could be easily and reliably precodified which facilitated students' responses codification. The importance of *control question precodification* is based on to the facts that (i) it offered best and valid qualitative and quantitative results to our survey, (ii) it ascertained whether students had answered randomly or systematically, and (iii) it verified whether students managed to bridge the cognitional and conceptual gap or not, and thus if the conceptual change has been achieved on lithosphere**.** Thus it is a challenge to try *control question precodification* of open-ended questions on geoscience educational studies generally.

Table 1 - Cognitional Control Table: Precodification according to the set question - control question.

1:question ***2:control question***	***Experimental team***		***Control team***	
	Correct answer	***Wrong answer***	***Correct answer***	***Wrong answer***
Earth temperature				
1. Could you dig a hole so deep into the Earth so that you reach the other side of it?				
2. If you could go on a journey deep inside Earth how would you feel? (i) *cold, (ii) hot, (iii) something else.*				
Mountain formation				
1. How do you think that mountains have been formed?				
2. Do you believe that mountains will be formed again in the future? Explain.				
Earthquake occurrence				
1. What do you think that happens and earthquakes occur?				
2. Do you think we could stop earthquakes from happening?				
Earthquake and volcano geographic distribution				
1. Russia or Greece is more probable to suffer from an earthquake? Why?				
2. Do we meet volcanoes in Greece? Why?				
Lithosphere motion				
1. A journey between Europe and America will last longer after a few million years. Could you explain why?				
2. The Mediterranean region is going to be different in a few million years. How do you think it will look like and why?				
Convective currents – Cause				
1. If Earth core was hollow, then could earthquakes occur? Why?				
2. If the inner part of Earth was frozen, then could the mountains be formed? Why?				

4. Conclusions - Proposals

After the development of lithosphere questionnaire and precodification of open-ended questions it is deduced that despite the complexity, the questionnaire offered abundant qualitative and quantitative data to the lithosphere educational process. Concluding, it is noteworthy to emphasize that:

1. The questionnaire is the most valuable tool in our educational research on lithosphere. Its development is a complicated but exciting procedure.

2. The GeoCause - PaP - CoRe approach constitutes the base for the development of a geosystemically integrated lithosphere questionnaire with no conceptual gaps. It reveals whether students have developed causal reasoning and geosystem thinking or not.

3. The more precise and organized the development, the more accurate and valid the data acquired. Students' responses are more fruitfully descriptive when open-ended, generative, control and action questions are used.

4. Almost all of the questions are *action questions* which stimulate students' interest and lure them to participate into the questionnaire filling.

5. The questionnaire can have a multidimensional role. A questionnaire like this can offer information on students' alternative ideas and on the efficiency of the experimental teaching procedure.

6. It can also be used as a *GCI tool* which constantly resupplies the curriculum development and continuously evaluates learning and teaching techniques on lithosphere.

7. The *control question precodification* is an innovative method for codifying open-ended questions and provided us with valid qualitative and quantitative results on lithosphere.

8. The *cognitional control table* offered precise information of the real conceptual framework of the students and whether conceptual change on lithosphere has been achieved or not.

All the aforementioned conclusions are significant for the educational procedures on lithosphere, so we propose that: a) The theoretical and technical methodology followed for the development of the lithosphere questionnaire can be used for the development of questionnaires on geosciences generally (i.e., GeoCause - PaP - CoRe approach, generative - control - action questions), b) The control question precodification on lithosphere can be implemented generally to geoscience open-ended question precodification.

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