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Comparing the Plate-tectonics-related Misconceptions of High School Students and University Undergraduates

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Abstract

International research into the nature, emergence, and development of geographical misconceptions is substantial. However, Hungarian educational research lags behind in exploring this phenomenon in detail. The present study identified some plate-tectonics-related misconceptions of three distinctive groups of students: ninth-grade secondary school students as well as university undergraduates consisting of geography B.Sc. students and B.A. students. Employing a cross-case-based approach, multiple kinds of data were collected for triangulation. A three-part diagnostic test was administered to students, and results were evaluated by comparative content analysis. While culturally induced misconceptions were not present, mistakes in textbooks, the linguistic characteristics of the Hungarian language as well as extensive media coverage of certain topics and informal learning interfere in the emergence of geographical misconceptions. The authors argue that both secondary and tertiary education should move to a more practical and innovative pedagogy where geographical knowledge is organically anchored into everyday life with the direct refutation of possible misconceptions.

Keywords

Misconceptions , Conceptual Change , Plate Tectonics , Geographical Literacy, Content Analysis

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Teachers of geography have experienced an increasingly alarming sign of insufficient geographical knowledge despite thorough and detailed formal education in Hungary. Incorrect or partially correct definitions, inaccurate explanations of different geographical phenomena, illogical interpretations of geographical notions, cycles–all elements that have become more and more common even among geography undergraduates. It also happens frequently that the geographical knowledge of students is adequate when tested at school or university, but as soon as they face a geographical phenomenon in real life, they fail to recognize, understand, or explain it properly. There seems to be a gap between formal knowledge and its application in everyday life. The reasons this experience originates in are numerous. One possible explanation is that students do not simply lack sufficient geographical knowledge, but they live with misconceptions.

Theoretical Background

Misconception research is closely connected to the research on conceptual change that started in the 1960s with the introduction of the term *conceptual change* itself. It was Thomas Kuhn (1962) who first used this term stating that "[…] the concepts embedded in a scientific theory change their meaning when the theory (paradigm) changes" (Vosniadou, Vamvakoussi, & Skopeliti, 2008, p. 3). His work has been developed (and criticized) over and over again, with each researcher adding a new aspect to conceptual change (cf. Pfundt & Duit, 2009). Conceptual change is a very broadly defined process even in academic circles (Murphy & Alexander, 2008; Vosniadou, Vamvakoussi, & Skopeliti, 2008; Pozo, 1997). Its mechanisms can either include bottom-up, implicit and additive processes, or top-down, deliberate and intentional learning ones (Vosniadou, Vamvakoussi, & Skopeliti, 2008).

Also, cognitive constructs such as the learners' (previous) knowledge, beliefs, and interests are also significant in this process (Murphy & Alexander, 2008; Korom, 1999, 2000, 2002, 2005). By exploring these conceptions, we can reveal what kind of conceptual structure children have when they enter formal education, and we can also study how this structure changes over time. This conceptual structure is primarily based on each individual's experiences and observations, which become embedded into a meaningful structure by means of reflection, experience or observation. It will accompany them when they go to kindergarten and later to school, where they interact with new knowledge. Children then incorporate these new pieces of information into their cognitive structure (Murphy & Alexander, 2008; Korom, 1999, 2000, 2002, 2005). Social mechanisms, such as collaborative work and discussions in groups can also facilitate conceptual change (Miyake, 2008; Hatano & Inagaki, 2003).

When children enter formal education, they already have a working conceptual structure of the world in their mind. The information on which this structure is based on has many sources: everyday experience, fairy tales, parents, friends, myths, religious ideas (Korom, 2002, 2005; Samarapungavan, Vosniadou, & Brewer, 1996; Vosniadou & Brewer, 1992; Ross & Shuell, 1990). When confronted with different scientific concepts at school, students try to internalize new pieces of information into their own cognitive structure. Whenever this process is successful, we speak of conceptual change, but when something "goes wrong", students have a "wrong" idea about a certain scientific concept (Korom, 1999, 2002). Subsequently, if a student does not develop a correct understanding of a scientific concept, it will interfere with her/his later learning (Korom, 1999, 2002, 2005; National Research Council, 1997).

Misconceptions

The terminology and definitions of misconceptions show great diversity. In their article, Murphy and Alexander (2008) conducted a synthesis and meta-analysis of research on conceptual change. They found that the definitions even for the terms *concept* and *conceptual change* were rarely defined neither explicitly nor implicitly. The definitions were often results of the researchers' points of view. Their findings show that misconceptions themselves have a very wide variety of definitions and characteristics. The National Research Council (1997) also categorized misconceptions based on their investigation. Table 1 shows a compilation of these misconception definitions.

Table 1
Terms and definitions of misconceptions (Murphy & Alexander, 2008; National Research Council, 1997)

Term	Definition	Synonyms	Source
Conceptual mis-understanding	Science teaching does not provoke conceptual change, preconceived notions and nonscientific beliefs remain intact, and students construct faulty models of scientific phenomena.		National Research Council (1997)
Erroneous belief	It is based on misconceptions.	intuitive belief	Hayes et al. (2003); Eryilmaz (2002)
Factual misconceptions	Falsities often learned at an early age and retained unchallanged into adulthood.		National Research Council (1997)
Intuitive conception	An understanding formed as a result of students' interactions with the world, it influences how they interpret and construct new conceptions.	alternative conception, preinstructional conception, preconception, everyday conception	Eryilmaz (2002); Park & Han (2002); Schur et al. (2002); Duit et al. (2001); Nieswandt (2001); Wiser & Amin (2001); Vosniadou & Brewer (1992)
Misconception	Students' understandings, conceptions, or beliefs that are different from scientific conceptions.		Alsparslan, Tekkaya & Geban (2003); Eryilmaz (2002); Sungur, Tekkaya & Geban (2001)
Nonscientific	Views learned by students from sources other than scientific		National Research

Term	Definition	Synonyms	Source
belief	education.		Council (1997)
Preconceived notion	Popular conceptions rooted in everyday experiences.		National Research Council (1997)
Prior knowledge	Topic-focused declarative and procedural understanding relative to a specific text or lesson which is not necessarily wrong.		Cheng & Shipstone (2003); Bigozzi et al. (2002)

However, these terms cannot be equally applied to different age groups as most of them are of specific nature. Everybody can have preconceived notions or vernacular misconceptions, but they may differ on the grounds of culture, language, or other factors. The misconceptions of pre-school children differ from those of secondary school students, whoes may also differ from the misconceptions of an undergraduate student. Which term can be considered as the proper one to be applied, if we want to analyze (mis)conceptions, such as for example why summer is usually warmer then winter with different age groups? The question is relevant as researchers may receive from pre-school children intuitive or alternative conceptions, but similar answers given by older students or adults may prove to be factual misconceptions or conceptual misunderstandings. In consequence, we aimed for a general working definiton based on which changes in the nature of misconceptions according to age can be determined.

For the purposes of this study, the definition by Korom (2002) was chosen as it both covers the main aspects of the terms listed above and it can be applied to a wide range of age groups ranging from young childen to adults. According to Korom (2002, p. 139), "[…] misconceptions are such flaws in the definitions, concepts, and models in the cognitive structure of children and adults alike that are incompatible with the current scientific concepts, and are so deeply embedded in the cognitive structure that they can hardly be changed". Based on the above and along the lines of the origin of misconceptions and the age when they appear in the cognitive structure of a person, five groups were defined. In contrast to Korom's (2002) general misconceptions, we call these groups specific misconceptions (cf. Table 2).

Table 2
A comprehensive list of misconception terms (sources included in the table)

Type	Term	Definition	Synonyms	Source
General	Misconception	Deeply embedded cognitive structures in a person's mind which are incompatible with current scientific notions and are difficult to change.	alternative conception , factual misconcept ion	Chang & Pascua (2015); Korom (2002, 2005); National Research Council (1997)
Specifi c	Vernacular misconception	A concept arising from the use of words meaning one thing in	linguistic misconcept	Dolphin & Benoit (2016); National

Type	Term	Definition	Synonyms	Source
		everyday life and another in scientific context, which leads to the misinterpretation of a certain phenomenon.	ion, metaphor	Research Council (1997)
Specific	Preconception	A concept based on everyday experience, everyday interaction with the world; it is usually formed before formal education of a specific topic begins. It is not necessarily wrong.	alternative conception, intuitive conception, preinstructional conception, everyday conception, preconceived notion, prior knowledge	Cheng & Shipstone (2003); Bigozzi et al. (2002); Eryilmaz (2002); Park & Han (2002); Schur et al. (2002); Duit et al. (2001); Nieswandt (2002); Wiser & Amin (2001); National Research Council (1997); Vosniadou & Brewer (1992)
Specific	Cultural misconception	A concept based on cultural heritage that is strongly present in everyday life.	nonscienti-fic belief	Alsparslan, Tekkaya, & Geban (2003); Eryilmaz (2002); Sungur, Tekkaya, & Geban (2001); Samarapungavan, Vosniadou, & Brewer (1996); Vosniadou & Brewer (1992)
Specific	Conceptual misunderstanding	Science teaching does not provoke conceptual change, preconceived notions and nonscientific beliefs remain intact, and students construct faulty models of scientific phenomena.	alternative conception, erroneous or intuitive belief	Chang & Pascua (2015); Hayes et al. (2003); Eryilmaz (2002); National Research Council (1997)
Specific	Popular misconception	A conception at least partially based on contemporary media, news, (science-fiction) novels, comics, movies.		Barnett et al. (2006)

Methodology

Aim and Research Questions

Research on misconceptions in Hungary dates back into the 1990s. Most of the studies focused on revealing misconceptions in physics (Korom, 2002, 2005; Radnóti, 2005; Radnóti & Nahalka, 2002; Korom & Csapó, 1997), chemistry (Kluknavszky &

Tóth, 2009; Dobóné, 2007; Ludányi, 2007; Kluknavszky, 2006; Korom, 2002, 2005; Juhász, Márkus, & Szabó, 1999; Tóth, 1999a, 1999b; Korom & Csapó, 1997) and biology (Malmos & Revákné, 2015; Banai, 2004; Nagy, 1999). Regarding geography, only a limited number of studies were carried out (cf. Dudás, 2008; Horváthné, 1991). Therefore, we decided to start studying geographical misconceptions in 2011.

The main emphasis of our research is on the geographical misconceptions of Hungarian students. This paper focusses on plate-tectonics-related misconceptions of three age groups, namely geography B.Sc. students (specialists), B.A. students (laymen), and ninth-graders (secondary school students). Thereby, our research questions were as follows:

1. What is the content of plate-tectonics-related misconceptions identified in our sample?
2. What type(s) of misconceptions do the three above-described groups display?
3. What is the main source of geographical information students use?

The underlying hypothesis is that B.Sc. students possess the highest level of understanding among the three groups. Still, teaching experience over the last years showed not only insufficient levels of knowledge, but also a deterioration in terms of professional content knowledge over time. Therefore, the underlying predicition was that ninth-graders and B.Sc. students enrolled into the gepgraphy progam at the University of Szeged displayed very similar misconceptions concerning their content and typology. In contrast, students enrolled into B.A. programs of the same university were expected diverging content and types of misconceptions due to the fact that their professional development did not require as much geographical literacy.

Research Design

The nature of the present study is qualitative, and it focuses on the comparison of the content and structure of plate-tectonics-related misconceptions of three different groups. After studying the research design of other Hungarian studies (cf. sub-heading Misconceptions), multiple data with the aim of triangulation was collected. The diagnostic tool consisted of a word association test and six open questions. We also asked the students to rank their sources of geographic information and provided them with examples of such resources. The diagnostic tool was pilot tested in 2012 (n = 139). Subsequenty, necessary changes were made to enable participants to fill it in within 45 minutes. The changes also included the reducation of the number of both stimulus words and open questions as well as the re-formulation of some open questions.

Sample

Three age groups were part of the sample. Participants ($n_{tota\ l}$= 133) were recruited from geography major students (B.Sc.) and B.A. students (majoring in English and Law) from the University of Szeged. While the former two groups represented higher education, the third group consisted of secondary students (ninth-graders) from a volunteering grammar school in Kiskunhalas, Hungary (Table 3). Data collection happened during 2013.

The sampling process exhibited a number of challenges. Particularly secondary schools were reluctant to assist the researchers during data collection mentioning obligations of administrative and educational nature.

Table 3
Sample structure (Source: authors' representation)

Sample	Number of participants	Average age of sample (years)
Ninth-grade secondary students	44	14.7
B.Sc. undergraduates	49	22.3
B.A. undergraduates	40	21.9

The concept of plate tectonics and related topics are part of Hungary's ninth-grade curriculum. Participating students completed the prior mentioned thematic units before data collection happened. B.Sc. students had also attended introductory courses on plate tectonics. In contrast, B.A. students had not had any formal education concerning plate tectonics since they left secondary school.

Findings

In what follows, we will proceed to describe both the data analysis methods and the findings. The reason for this lies in the design of research methods chosen, which consist of several small steps meant to complement each other in case a misconception surfaced. Our presupposition was that a seemingly wrong association detected within the word lists of the word association test will not be considered a misconception until it is proven to be one by the answers given to the open questions. In the following, we will proceed to describe the individual steps taken.

Word Association Test

Participants were asked to respond to six stimulus words, namely: the interior structure of the Earth (A), mountain formation (B), tectonic plate (C), volcano (D), earthquake (E), and plate tectonics (F). The words "tectonic plate" correspond in Hungarian to *"kőzetlemez"*, while *"lemeztektonika"* stands for "plate tectonics". Both words share the compositum *"lemez"* (plate), however, their difference is much stronger as the one of their English counterparts. The word *"kőzetlemez"* (tectonic plate) is used frequently throughout the geological part of the geography curriculum, while the use of the word (and not the term) *"lemeztektonika"* (plate tectonics) is less frequent.

Regarding data collection, in a first step we performed a qualitative evaluation of the associations. Subsequently, we computed the Garskof-Houston relatedness coefficient of the stimulus words (Kluknavszky & Tóth, 2009; Garskof & Houston, 1963), and, based on the results, we prepared graphs depicting the knowledge structure of each group. Finally, we visualized the associations by employing Feinberg's word cloud generator that operates on the basis of frequency distribution (Feinberg, 2010).

Our hypothesis was that word associations would not directly reveal geographical misconceptions, but incorrect scientific notions may surface. Proof of these incorrect scientific notions was to be delivered by the qualitative analysis of answers given to the open questions. Furthermore, the Garskof-Houston relatedness coefficient also indicated both incorrect connections between any pairs of the notions and notions that were too isolated. The open questions in Part III of the diagnostic tool were centered round the geographical concepts of the stimulus words. It allowed us to do data triangulation in order to see whether a seemingly wrong association was a misconception or not.

***Qualitative Evaluation of the Word Associations*.** Qualitative evaluation of the word associations revealed that incorrect scientific notions surfaced, but they were not necessarily geographical misconceptions. “Upfolding” (*“felgyűrődés”*) and continental drift were the two surfacing possible misconceptions. The word “upfolding” is problematic in Hungarian, as it implies that tectonic plates are folded like a scarf or a blanket when they collide. The word associations given by the B.Sc. students were more scientific and more textbook-based than those of the B.A. and secondary school students in general. The former group also included references to movies (e.g. *2012*, *Ice Age 4*, *The Core*).

***Garskof-Houston Relatedness Coefficient*.** The Garskof-Houston relatedness coefficient (RC) represents the strength of relationship between two notions. The following two examples, which are rely on studies by Garskof & Houston (1963) and Kluknavszky & Tóth (2009), show how the procedure works (cf. Tables 4-5).

Table 4
Calculating the Garskof-Houston relatedness coefficient with the same number of associations (Source: authors’ representation)

Associations	Rank	Associations	Rank
Mountain formation (stimulus word) B	8	Mountain formation (stimulus word) D	8
Magma	7	Lava	7
Volcano	6	Magma	6
Earthquake	5	Heat	5
The Alps	4	Rock	4
Time	3	Tuff	3
Uplift	2	Destruction	2
Tectonic plate	1	Ash	1.9

$\bar{B}$ = [7 6] → common associations in the mountain formation (B) chain

$\bar{D}$= [8 6] → common associations in the volcano (D) chain

$n = 8$

$$RC = \frac{7 \cdot 8 + 6 \cdot 6}{8^2+7^2+6^2+5^2+4^2+3^2+2^2}$$

RC = 0.45

Table 5
Calculating the Garskof-Houston relatedness coefficient with different number of associations (Source: authors' representation)

Associations	Rank	Associations	Rank
Mountain formation (stimulus word) B	7	Volcano (stimulus word) D	7
The Andes	6	Stratovolcano	6
Oceanic trench	5	Lava	5
Volcano	4	Tuff	4
Stratovolcano	3	Rhyolite	3
Time	3	Tuff	3
		Basaltic volcanism	2

$\bar{B} = [4\ 3]$ → common associations in the mountain formation (B) chain

$\bar{D} = [7\ 6]$ → common associations in the volcano (D) chain

$n = 8$

$$RC = \frac{4 \cdot 7 + 3 \cdot 6}{7^2+6^2+5^2+4^2+3^2+2^2}$$

RC = 0.33

The RC can be commputed with different or the same number of associations. The stimulus word and the associations are ranked in a descending order. In case of the same number of associations the total number of the associations equals with the highest rank whereas in case of different number of associations the first word of the longer association chain is assigned a rank that is one number higher than the total number of associations found in the longer association chain. RC values range between 0 and 1. The stronger the relationship between two notions, the closer the RC value will be to 1.

However, the method does not explain the nature of the relationship, it has to be revealed by the answers to the open questions and the alternative responses. Figure 1 shows a proportional representation of the three groups' RC values (RC values are included in Appendix I).

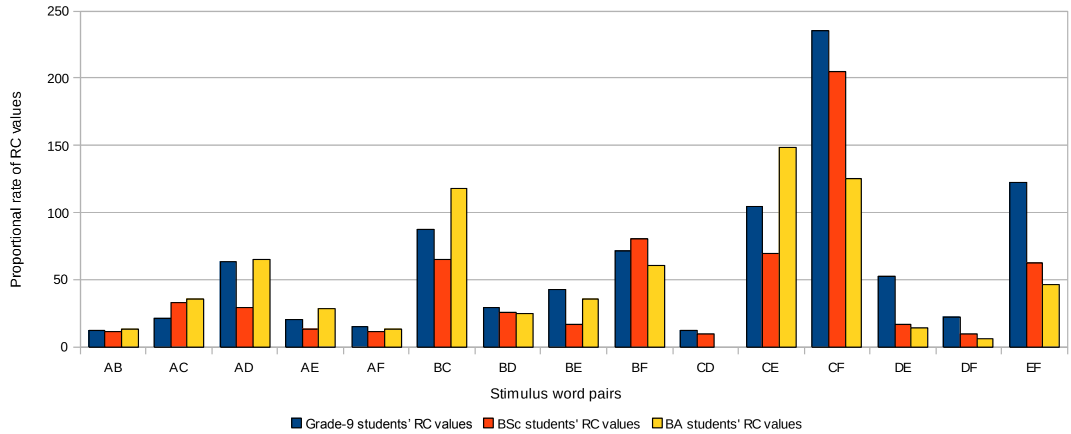

Figure 1. A proportional representation of the three groups' RC values (Source: authors' representation)

The RC results also allow the depiction of the students' knowledge structure in graphs (Figures 2-4) by computing the mean RC of the whole group based on the individual values. The link between two nodes of the graph shows the strength of the relationship between the stimulus words, but it does not explain why they are connected. The answers given to the open questions could explain their connection.

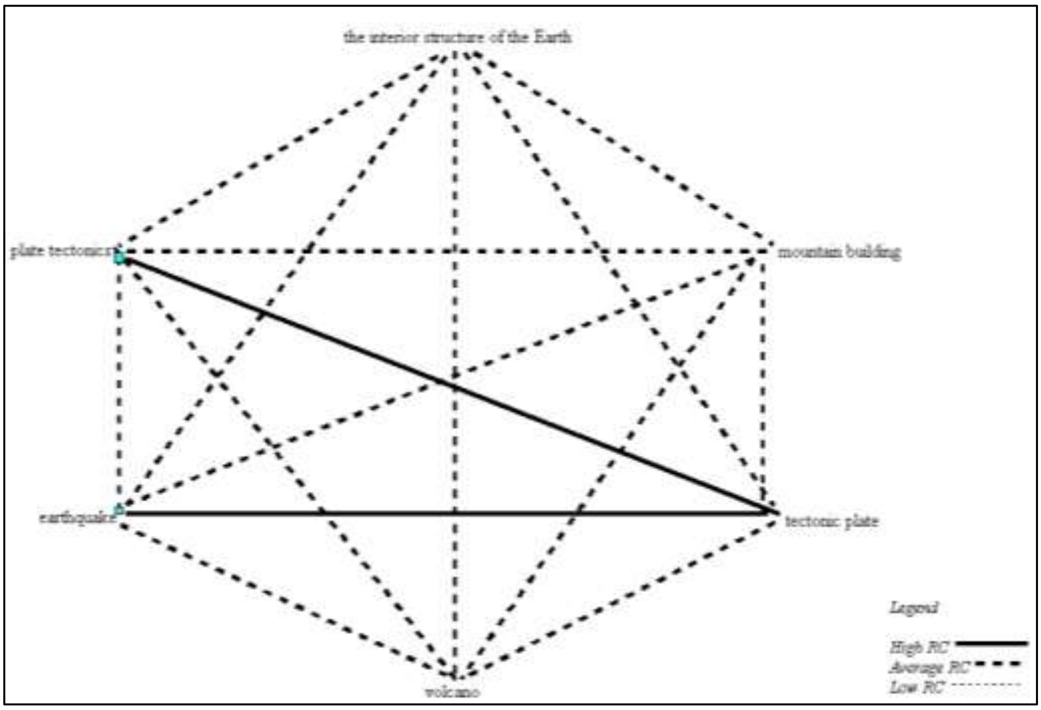

Figure 2. The plate-tectonics-related associational graph of ninth-grade secondary students (Source: authors' representation)

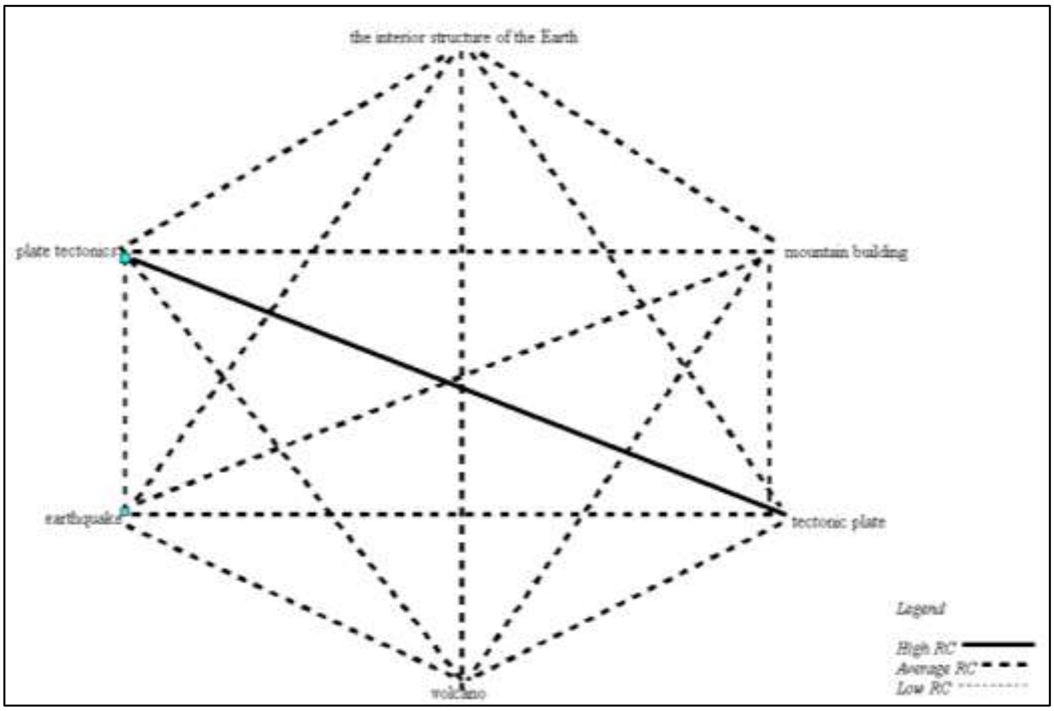

Figure 3. The plate-tectonics-related associational graph of B.Sc. students (geography) (Source: authors' representation)

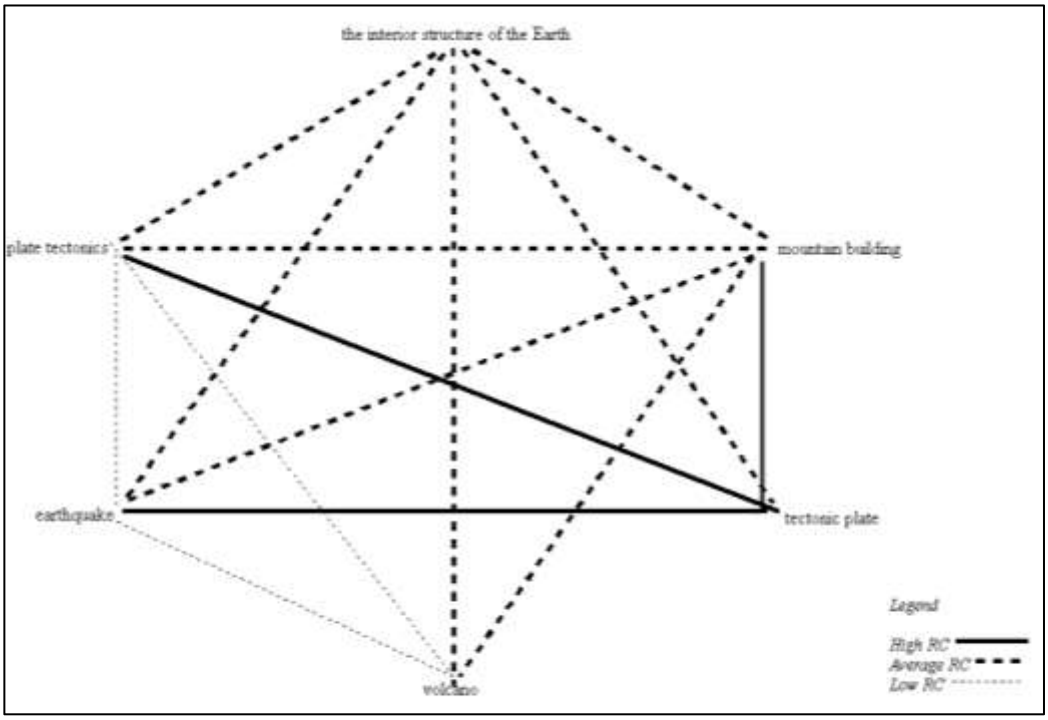

Figure 4. The plate-tectonics-related associational graph of B.A. students (Source: authors' representation)

The word pair “plate tectonics” – “tectonic plate” had the highest RC value in all groups. The associations of both secondary and B.Sc. students showed an overall interconnectedness of all concepts. In contrast, B.A. students’ results indicated no connection between the tectonic plates and volcanos. In addition, B.A. students also displayed three relatively low RC values associated with the word pairs volcano–earthquake, volcano–plate tectonics, and earthquake–plate tectonics. These results alone do not show whether students fail to connect these phenomena or not. Answers given to the open questions should offer further insight.

***Word Clouds*.** Feinberg’s (2010) Wordle online software served to visualize word associations for all three groups of participants. Visualizing the associations helped to show the construction, similarities, differences, and emphases of each group’s knowledge structure. The word clouds (Figures 5-7) not only bare aesthetic value, they can also be used to visualize change (if administered to students at different times during a course, for example, or in longitudinal studies).

Figure 5. Ninth-grade students’ earthquake word cloud (Source: authors’ representation)

The results showed that B.Sc. students usually tend to have a much higher number of more specific and scientific associations as compared to the other two groups. While the Richter scale, tectonic plates/movement, epicenter, hypocenter, and the San Andreas Fault are featured in the Hungarian curriculum, other elements, such as Japan, tsunamis, and Fukushima are likely to have their origins in informal (e.g. media) and formal (e.g. teachers who use them as examples) sources.

Figure 6. B.Sc. students' earthquake word cloud (Source: authors' representation)

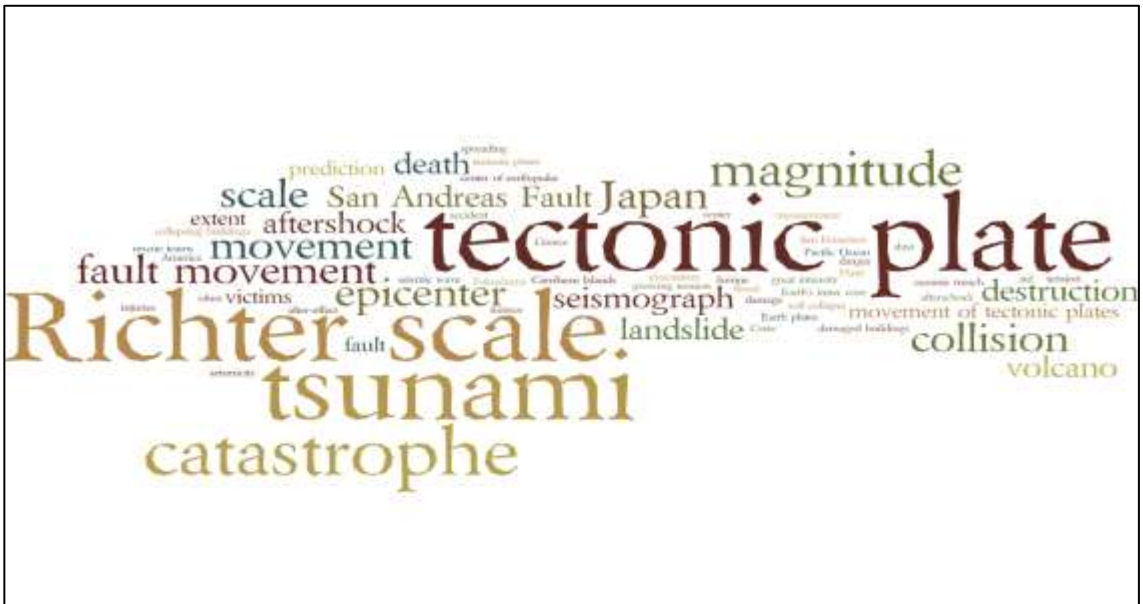

Figure 7. B.A. students' earthquake word cloud (Source: authors' representation)

Open Questions

Participants were requested to answer the following six questions:

Q1: What causes earthquakes?

Q2: The characters of Jules Verne's *Journey to the Center of the Earth* descend into the bowel of the Earth through a volcano. Is such a journey possible? Why?

Q3: Draw a picture of a volcanic eruption and explain how it happens.

Q4: Why are the western coastline of Africa and the eastern coastline of South America similar to each other? (A map was included in the questionnaire)

Q5: Draw a picture of mountain formation, and explain how it happens.

Q6: If we could travel to the center of the Earth by means of a special lift, what would we see during our journey? Draw a picture and explain.

The answers were coded and evaluated based on the studies by Abraham et al. (1992) and Korom (1999) (cf. Table 6). We expected the answers to reveal both common and individual misconceptions. In addition, answers to open questions were expected to explain any occurrence of possible misconceptions already surfacing in the word association test.

Table 6
Categorization of answers to open questions (Korom, 1999; Abraham et al., 1992)

Level of comprehension	Criteria of evaluation	Value of answer (points)
No answer (NA)	• Blank space • "I do not know." • "I do not understand."	0
No comprehension (NC)	• Repetition of the question. • Answers either do not relate to question or are irrelevant. • Reporting own experience	1
Misconception (M)	• Answers are illogical, scientifically incorrect.	2
Partial comprehension with misconception (PCM)	• Answers show partial comprehension but they also contain misconception(s).	3
Partial comprehension (PC)	• Answers cover one or more aspect(s) of the correct answer but not all of them.	4
Full comprehension (FC)	• Answers cover all aspects of the correct answer.	5

Coding during text analysis followed the cartegories presented in Table 6. In addition, individual answers were grouped based on their content to detect age-group specific misconceptions. The type of misconception was also discussed:

- If the incorrect answer originated from the use of the Hungarian language, we considered it to be a vernacular misconception.
- If the incorrect answer was based on Hungarian culture, we considered it to be a cultural misconception.
- If the incorrect answer showed elements of not understanding or misunderstanding (which manifested in giving incorrect explanation) a plate-tectonics-related phenomenon despite receiving formal education, we considered it to be a conceptual misunderstanding.
- If the incorrect answer was at least partially based on contemporary media or novels, comics, movies, we considered it to be a popular misconception.

- If the incorrect answer was based on everyday experience rather than scientific explanation, we considered it to be a preconception.

Figures 8-10 show the frequency distribution of misconceptions and partial comprehension with misconceptions concerning all questions as well as the frequency distribution of all misconceptions (M and PCM).

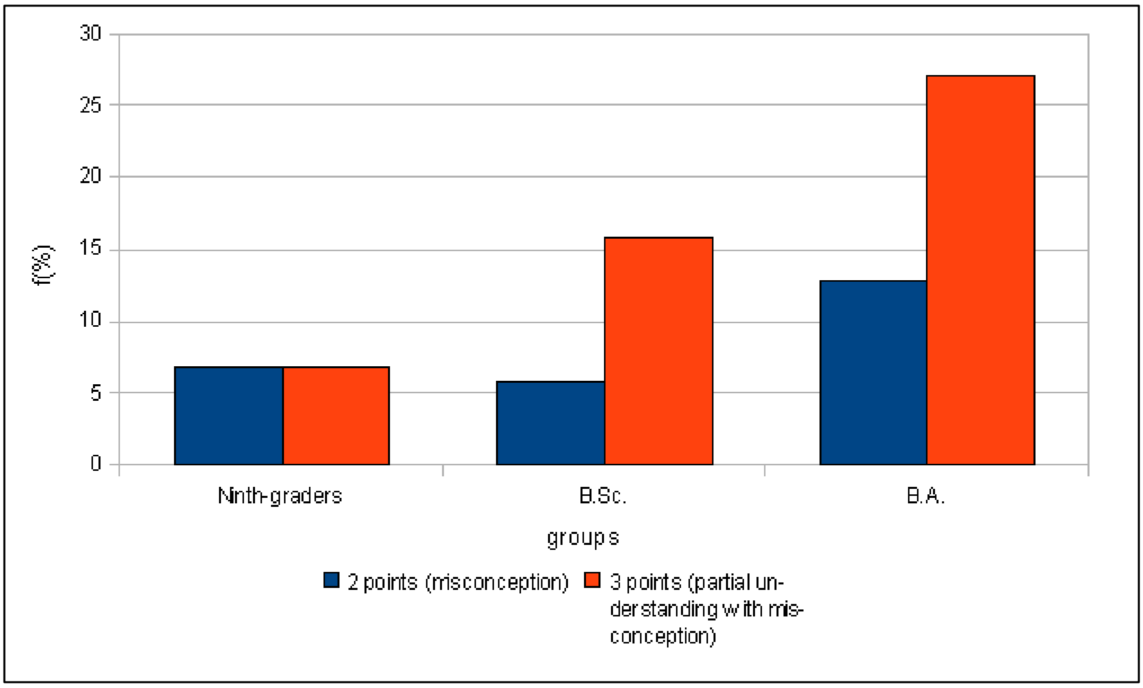

Figure 8. Frequency distribution of all misconceptions (M and PCM) found in the open questions (Q 1-6) (Source: authors' representation)

Ninth-grade secondary students showed low levels of both misconceptions (M) and partial comprehension with misconceptions (PCM). While the frequency distribution of M stayed low among B.Sc. students, the distribution of PCM grew among both groups of university undergraduates and achieved the highest scores among B.A. students.

Q1: What Causes Earthquakes? B.Sc. students gave the most incorrect answers identified as misconceptions to this question. The content of these misconceptions was characterized by individual misconceptions. For example, a B.Sc. student wrote that earthquakes are caused by "tectonic plates breaking into small pieces" (as if they had associated tectonic plates with real plates from a kitchen), and another one stated that "the inner pressure of the Earth" causes earthquakes. A common misconception of all groups was that earthquakes are caused by "a kind of energy in the inner part of the Earth". Although the word associations contained expressions like "the sliding of the Earth's axis" (ninth-graders), "Earth plates" (B.A. students), "soil collapse" (B.A. students), these associations did not surface in the answers to the open questions.

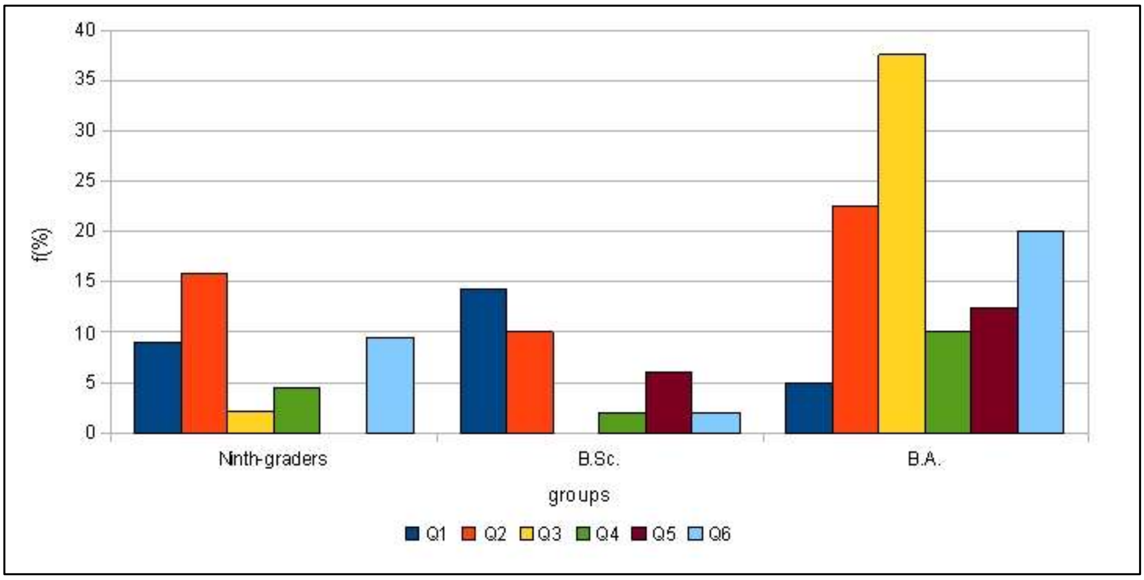

Figure 9. Frequency distribution of misconceptions (M) found in the open questions (Q 1-6) (Source: authors' representation)

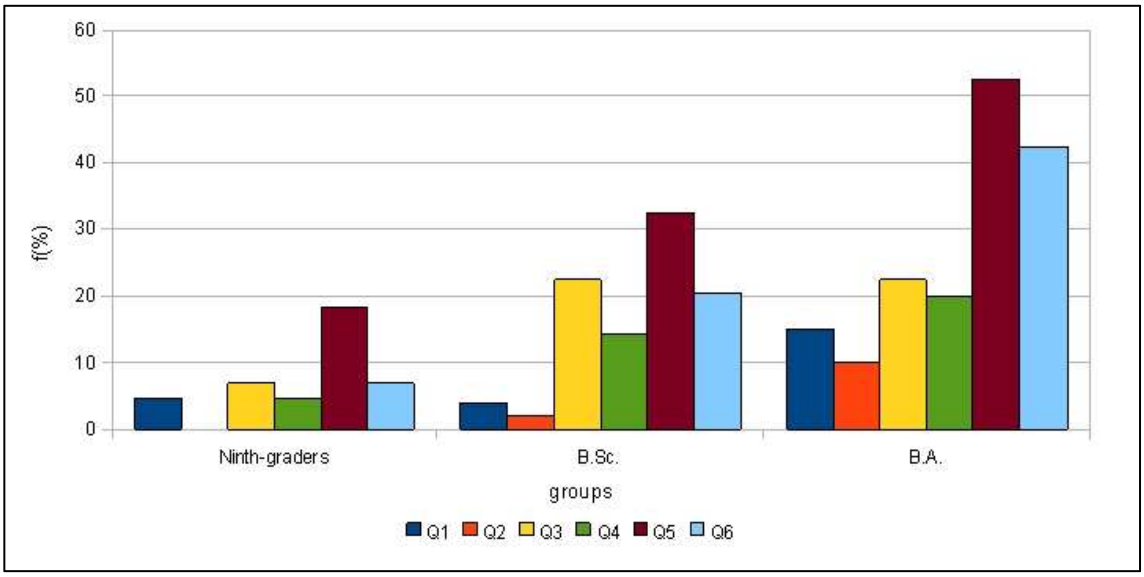

Figure 10. Frequency distribution of partial comprehension with misconceptions (PCM) found in the open questions (Q 1-6) (Source: authors' representation)

The identified misconceptions were labeled as conceptual misunderstandings because the answers showed that the students failed to internalize the causes of earthquakes. Although they strived to use scientific concepts, their definitions lacked scientific accuracy. We labeled answers according to which earthquakes are caused by "tectonic plates breaking into small pieces" as a mixture of vernacular misconception and conceptual misunderstanding as we assume that the use of the Hungarian language affected the learning process of that particular student.

Q2: The characters of Jules Verne's Journey to the Center of the Earth descend into the bowel of the Earth through a volcano. Is such a journey possible? Why? Misconceptions about volcanoes were similar among ninth-graders and B.A. students. A total of three common conceptual misconceptions were identified: (1) volcanoes may reach the Earth's core because (2) "they really go that deep as magma comes from there/from the core", and (3) because "the Earth's core is made up of magma and/or lava". These answers indicate that the conceptual understanding of the difference between magma and lava is missing. They also imply that there is no stable understanding of how a volcano works, and how the interior of the Earth is structured, although all the above are part of the secondary school curriculum. Another isolated conceptual misconception, namely "the inner parts of the Earth are liquid", was formulated by a B.A. student. As "liquid" was the only association that surfaced in the word lists, the answers given to this open question were labeled as misconceptions. Overall, B.Sc. students displayed less misconceptions as their two peer groups. One answer pointed out that "it is impossible to gather information about the inner parts of the Earth", while two other answers hinted that it indeed was possible to travel through the pipe of a volcano to the center of the Earth, which, in the case of geography B.Sc. students was a conceptual misunderstanding.

Q3: Draw a picture of a volcanic eruption and explain how it happens. Regarding the frequency distribution of misconceptions concerning volcanic eruption, the highest values were computed for B.A. students, while B.Sc. students displayed no such misconceptions. Similarly, ninth-grade secondary students also showed high percentage of comprehension.

However, the distribution of partial comprehension with misconception was the same among B.Sc. and B.A. students, while ninth-graders showed a high level of understanding as well. General conceptual misunderstandings were as follows: "lava originates from the inner core of the Earth" (ninth-graders), "high temperature causes the tectonic plates to move" (ninth-graders), magma and lava are the same (B.Sc. and B.A. students), magma/lava originates from anywhere below the lithosphere (B.Sc. and B.A. students), "magma reaches the Earth's surface in the form of gases" (B.Sc. students), "volcanic eruptions cause tectonic plates to move" (B.A. students), the mechanism of a volcanic eruption and that of a geyser eruption are mixed (B.A. students). The word associations did not reveal any misconceptions.

Q4: Why are the western coastline of Africa and the eastern coastline of South America similar to each other? The most common misconception or partial comprehension with misconception was continental drift (all three groups). There were isolated examples of these misconceptions: "sea waves cause the continents to drift" (B.A. students), "earthquakes cause the continents to drift" (B.A. students), and "rocks cause the continents to drift" (B.A. students). In our opinion, these answers show conceptual misunderstandings as well as a mixture of preconceptions and vernacular misconceptions. Overall, both direct observation of plate tectonics and its speed are slow even in geological terms, reason why this content can be considered as a rather difficult topic of the geography curriculum. Therefore, students are likely to give answers based on easily observable (and more accessible) everyday experience such as wood drifting on water. Continental drift often appeared in the word associations as well.

Q5: Draw a picture of mountain formation, and explain how it happens? The most frequent answer given was upfolding, which is a vernacular misconception originating from the everyday use of the Hungarian language as well as from a widely used geography textbook at the time of data collection. Regarding coding, the category misconception (M) was only chosen when the explanations proved that an underlying conceptual understanding of orogeny was missing. The reason for this was that most of those students who gave "upfolding" as an explanation, usually demonstrated partial comprehension of orogeny both in their writings and drawings. Other conceptual misconceptions and preconceptions included "tectonic plates being folded" (both undergraduate groups), "earthquakes cause mountains to be built" (B.A. students), "one tectonic plate lifts the other high" (ninth-graders). Upfolding was one of the most frequent word associations given to the stimulus words mountain building, tectonic plate and plate tectonics. These three geographical concepts had the strongest RC-values too (BC, CE, and CF).

Q6: If we could travel to the center of the Earth by means of a special lift, what would we see during our journey? Draw a picture and explain. Misconceptions about the inner structure of the Earth showed the greatest variety. Overall, there were less misconceptions (M) than partial comprehension with misconception (PCM). The frequency distribution of PCM was the highest among B.A. students. Despite the mentioning of magma and lava, the word associations did not reveal possible misconceptions. This is due to the fact that the mere presence of these words did not prove that they would be misconceptions. However, the answers to the open questions included "the Earth's core is liquid" (all three groups), "magma exists below the lithosphere" (ninth-graders) or "magma can be found in the core" (ninth-graders and B.A. students). Other misconceptions were as follows: the terms "crust" and "mantle" were usually mingled (ninth-graders); the asthenosphere consists of magma (B.A. students); "the inner core is liquid; the outer core is solid" (B.A. students); there are several crusts (B.A. students); "hot spots originate from the core" (B.Sc. students). Also, informal sources of geographical information, such as movies (as the associations like *The Core*, *2012*, and *Ice Age* indicated) may have contributed to the formation of misconceptions (Barnett et al., 2006).

Summarizing the findings of the word association test and the answers to the open questions, we found that the answers given to the open questions only further strengthened the misconception nature of the surfacing incorrect associations. None of the identified misconceptions could be declared as age-specific, as the three groups showed similarities. Upfolding and continental drift–used by all three groups–also appeared in the word associations as possible misconception. Conceptual inclarity regarding magma and lava was yet another misconpcetion all three group shared. So was the idea that lava and magma are located beneath the Earth's crust. As misconceptions in general are deeply embedded cognitive structures, they both persist for a long time and are difficult to change (cf. Korom, 2002, 2005). Upfolding and continental drift might be such misconceptions; however, longitudinal studies are required to verify this hypothesis.

We also concluded that a clear classification of the encountered misconceptions into types is difficult. For example, we categorized upfolding as a vernacular misconception due to the specifics of the Hungarian language, though the likelihood of this being a conceptual misunderstanding as well is rather high. In consequence, clear categorizations of misconceptions require operationalizations based on additional methods.

Sources of Geographical Information

Another aspect this study dedicated special attention to were the sources of information students used when learning geography. In order to gain insight into student practice, the participants were required to number the sources according to their importance (Figure 11). In addition, they had to give examples of the sources.

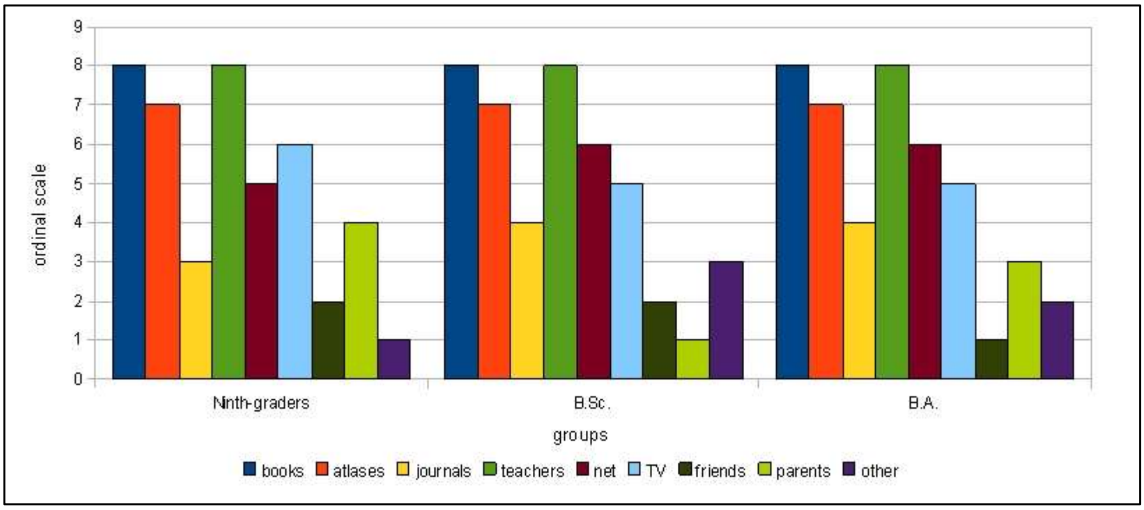

Figure 11. Ordinal scale of geographical information sources (Source: authors' representation)

The sources of geographical information showed great similarity in all three groups. Formal sources, such as textbooks and teachers' explanations were the most significant ones, closely followed by atlases. Informal sources, such as the Internet and the televison, especially movies like *The Core* (the movie also surfaced in the word association test), were the second, while journals were the third most important group of sources.

With textbooks and teachers being the most significant sources of geographical information, we must emphasize the responsibility of textbook authors and teachers alike. One of the most frequently used geography textbooks at the time data collection was carried out, also used the term "upfolding" *("felgyűrődés")*. It is highly likely that improper language use, as exhibited by this example, may also lead to the formation of misconceptions.

Conclusions

The aim of this study was to identify plate-tectonics-related misconceptions by analyzing the answers of three different groups, namely ninth-grade secondary school, geography B.Sc. and B.A. undergraduate students from Hungary. Thereby, the research questions aimed at 1) identifying the content of plate-tectonics-related misconceptions; 2) identifying the type of misconceptions; 3) and identifying the sources of geographical information students used when learning geography.

One of the key finding was that students from all three groups had partly similar misconceptions concerning mountain formation, volcanic activity, and tectonic plate movements. This finding emphasizes that misconceptions are not only stable, but also very difficult to change.

A second finding of this study was that plate-tectonics-related misconceptions were of three major types, namely conceptual misunderstandings, vernacular misconceptions, and preconceptions. Some participants exhibited a mixture of these misconception types. There were no cultural misconceptions or misconceptions that could have been strongly influenced by contemporary media, literature, movies, or television. However, the methods were not suitable for identifying the structure of misconceptions (how and why a certain misconception was formed). Additional in-depth interviews and longitudinal studies might offer a depper insight into the underlying cognitive structures.

A third finding concerns vernacular misconceptions. As shown in this study, these types of misconceptions can originate in language use. In consequence, both geography teaches and authors of geography textbooks should pay close attention to aspects of language use.

The fourth central finding of this study was that teachers and textbooks are the most important sources of geographical information. Therefore, we recommend that teachers be aware of their students' geographical conceptions before they start a certain topic. They must find out what kind of misconceptions their students have, and they have to design teaching in a way that it facilitates conceptual change. Inquiry-based learning, the purposeful use of ICT, challenging students' notions with planned film watching and relating exercises, using atlases, globes, geographical experiments, group work, and different projects are good pedagogical practices. If necessary, teachers have to correct textbook mistakes in order to avoid, for example, the formation of vernacular misconceptions. It is also necessary for teachers to identify their own misconceptions to foster their own professional development.

Although we might be prejudiced to think that informal sources of information, such as the Internet, films, news, may have a greater impact on student understanding than formal sources, it was not the case in our study. However, their importance is the second greatest among the sources, so we recommend that teachers plan their lessons accordingly. Teachers must be ready to include blockbusters and recent news into their lessons so that they can challenge their students' misconceptions, or they can point out where and why these sources are false.

This study confirmed the findings of previous work stating that misconceptions can persist even through adulthood despite thorough formal education (Chang & Pascua, 2015; Korom, 2002, 2005; Mark, 2013). Misconceptions cannot be eradicated totally, but their number could be reduced by employing various teaching techniques that are in accordance with the skills and knowledge level of the students. Also, students need more time to understand such abstract concepts as plate tectonics, thus longer time for knowledge consolidation is necessary. A substantial reduction of the curriculum would enable teachers to provide students with the extra consolidation time needed. Finally, Geography educators should encourage students to develop critical thinking, creative and problem-solving attitude that enable them to understand geographical models and apply these models to their everyday life.

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Appendix I.

RC values of the three groups (Source: authors' representation)

Word pairs	Ninth-graders' RC value	B.Sc. stundents' RC value	B.A. stundents' RC value
the interior structure of the Earth – mountain building	.013	.012	.014
the interior structure of the Earth – tectonic plate	.022	.033	.036
the interior structure of the Earth – volcano	.064	.03	.006
the interior structure of the Earth – earthquake	.021	.014	.029
the interior structure of the Earth – plate tectonics	.016	0.12	.014
mountain building – tectonic plate	.088	.066	.118
mountain building – volcano	.03	.026	.025
mountain building – earthquake	.043	.017	.036
mountain building – plate tectonics	.072	.081	.061
tectonic plate – volcano	.013	.01	0
tectonic plate – earthquake	.105	.07	.149
tectonic plate – plate tectonics	.235	.205	.125
volcano – earthquake	.053	.017	.015
volcano – plate tectonics	.023	.01	.007
earthquake – plate tectonics	.123	.063	.047