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# Pre-Service Primary School Teachers' Understanding of Biogeochemical Cycles of Elements

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**Abstract:** Understanding environmental issues such as biogeochemical cycles of substances on a local and global level is important in order to be able to act responsibly and sustainably. Inadequate teacher training has proven to be the main reason why environmental education has failed to reach its full potential. The aim of the present study is therefore to investigate students' level of knowledge about biogeochemical cycles in relation to their secondary school achievements in chemistry, biology, and physics, their individual interest for learning these topics, and their self-esteem regarding cycles of substances on Earth. A total of 145 undergraduate pre-service primary school teachers attending their first or third year of an undergraduate teacher education program at the Faculty of Education, University of Ljubljana, in 2024 participated in this quantitative study, which uses the causal non-experimental method of pedagogical research. The data were collected using a three-tier achievement test and a paper–pencil questionnaire, which were both developed by the researchers. The results show that pre-service primary school teachers possess roughly adequate knowledge of the environmental topic of biogeochemical cycles. Their individual interest and self-esteem related to learning biogeochemical cycles were found to be significant predictors of their performance in an achievement test on biogeochemical cycles. Their final grade in biology may also be a significant predictor of their knowledge of this topic. Finally, pre-service primary school teachers' misconceptions related to the topic of biogeochemical cycles were determined. Although the number of their misconceptions on this topic is low, teachers' environmental education nevertheless needs to be improved in order to optimize their work in the classroom and help environmental education reach its full potential.

**Keywords:** sustainable development goals; environmental education; misconceptions; pre-service teachers

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## 1. Introduction

Teachers play an important role in educating younger generations on environmental literacy (Brundtland, 1987; Potočnik & Devetak, 2018), as they can enhance students' interest in science learning (Hobbs & Behenna, 2024; Potočnik, 2020). Inadequate teacher training has been identified as the main reason for the weakness of environmental education (Knapp, 2010). Environmental education plays an important role in equipping younger generations with better environmental literacy by educating them about environmental topics such as biogeochemical cycles (BGCCs), thus facilitating more rapid progress toward sustainable development (Varela-Candamino et al., 2018). One of the multidisciplinary sciences that is part of environmental education and combines physics, chemistry, and biology is environmental chemistry (Artemieve, 2011). Therefore, the topic of BGCCs lends itself to the integration of physics, chemistry, and biology. It is important to equip people with adequate knowledge about environmental topics, such as geochemical cycles, in order to encourage a responsible attitude toward the environment (Sukma et al., 2020). People need environmental literacy if they are to take a position with regard to environmental issues and to achieve sustainable development goals (Janouškova et al., 2020).

Geological processes transfer material from one place to another in the biosphere. In this way, the Earth's surface is modified for organisms and supplied with the elements required for biochemical processes (Schlesinger et al., 2011). Biogeochemical cycles (BGCCs) describe this transformation and the movement of chemical substances in a global context (Jacobson et al., 2000). Elements such as nitrogen, carbon, hydrogen, oxygen, etc. are similarly cycled in predictable and definable ways (Maier, 2015). The BGCCs of these elements are descriptions of their transport and transformation through various segments of the Earth system called geospheres. In order to compartmentalize the Earth into more manageable parts, we define three major geospheres: the atmosphere, which is the gas envelope that surrounds the globe of the Earth; the hydrosphere, which includes all water bodies; and the lithosphere, which is formed from rocks. Above the lithosphere, there is also a sphere called the pedosphere, which consists of soil; this is literally what we walk upon (Brundtland, 1987). Over the last century, land use and agricultural activity have had a great effect on geochemical cycles in the Earth's crust. To really understand our effect on these cycles, a good understanding of the natural and anthropogenic sources is required (Schulze et al., 2001). These topics also lend themselves to sustainable development goals, e.g., goals for sustainable cities and communities, responsible consumption and production, clear water and sanitation, good health and well-being, etc. (Sustainable Development Goals, n.d.).

A number of studies have already been conducted on pre-service primary school teachers' environmental literacy and their knowledge about environmental problems. Teksoz et al. (2010) found that their level of knowledge about the environment is low, while a study by Yavetz et al. (2009) also showed low environmental knowledge among this group. However, a study by Salleh et al. (2015) found that pre-service primary school teachers' environmental knowledge was adequate in some respects. In-service teachers tend to accept the views of others rather than accepting science (Lammert, 2024). These results indicate the need for the better preparation of primary school teachers in order to effectively incorporate science topics in the classroom (Lammert, 2024). Salleh et al. (2015) also emphasize the importance of adequate environmental knowledge among pre-service primary school and in-service primary school teachers; adequate knowledge will enhance their ability to implement and design effective environmental education in the future. Moreover, it is important to foster teachers' emotional affinity with nature (Selby, 2017) and their self-regulated learning for effective science teaching (Avsec & Ferk Savec, 2022). A study by Fridberg and Redfors (2024) sheds light on the usefulness of augmented reality technology to improve the teaching of science-related topics, as this technology does not totally overlay our real-world environment with a computer-generated environment. Thus, users can learn in an environment that has some imperfections and is therefore much more authentic.

Studies such as those by Turan (2019) and Ural et al. (2017) aimed to investigate pre-service primary school teachers' understanding of BGCCs. The study by Ural et al. (2017), which investigated pre-service primary school teachers' understanding of the carbon cycle, found that they possess conflicting and scientifically incorrect ideas, revealing many misconceptions related to the subject. The study by Turan (2019) also focused on the understanding of the carbon cycle. It found that teachers primarily connect this cycle with the lithosphere and only rarely with the atmosphere and the hydrosphere. Moreover, teachers were unable to identify the dynamics and relationships between different cycles. A study by Yilmaz Yendi (2019), which was conducted with experienced science teachers, found a lack of knowledge in the topic of BGCCs. Furthermore, it was observed that teachers have problems linking this topic to sustainable development goals, instead associating sustainable development exclusively with the carbon cycle. Some studies have also been conducted on students' understanding of BGCCs. A study by Soltis et al. (2019) revealed a biocentric view of the carbon cycle and limited conceptions of the nitrogen and phosphorus cycles. These previous studies suggest that environmental education has not reached its full potential. A sufficient environmental education program is essential for better implementation of environmental topics such as BGCCs in schools (Brundtland, 1987).

The environmental curriculum in Slovenian primary schools, in which the topics of environmental chemistry are listed, is structured intersubjectively, as the explanation of problems related to environmental education lies at the intersection of several sciences (Šorgo & Kamenšek, 2012). However, the topic of BGCCs in primary schools is mostly covered in the subject of chemistry, although the subjects of biology and natural sciences within the Slovenian primary school system also integrate environmental education topics (Ministry of Education, n.d.). Studies have been conducted investigating primary school students' understanding of environmental topics, such as those by Ribič et al. (2024) and Majer et al. (2019). Both of these studies identified a lack of knowledge and the presence of misconceptions. Slovenian primary school students usually have altruistic environmental concerns, primarily centered on the biosphere (Torkar et al., 2021). Altruism has been found to be a mediator in the relationship between an empathic tendency and nature relatedness (Yurtsever & AngÄn, 2022). Taken together, the aforementioned studies show that environmental education in primary school is far from reaching its full potential. One explanation for this could lie in primary school teachers being unable to successfully incorporate environmental topics in the classroom due to their lack of knowledge (Lammert, 2024). A literature review found an absence of studies investigating pre-service primary school teachers' understanding of BGCCs. The aim of the present study is therefore to investigate the level of knowledge that Slovenian pre-service primary school teachers possess on the environmental topic of BGCCs. The study also focuses on how factors such as final grade achievement, individual interest, and self-esteem affect pre-service primary school teachers' level of knowledge on the topic of BGCCs, while their misconceptions about this topic were also investigated.

## 2. Theoretical Framework

A literature review by Tzung-Jin et al. (2024) found that learner characteristics and teacher education are the most cited research topics in environmental education. Improving the quality of teacher training is a crucial factor in improving the quality of environmental education (Heinitz & Nehring, 2022) and fostering sustainable environmental action (Liefländer et al., 2015) (33). A study by Sabel et al. (2016) showed the importance of teachers' content knowledge for their teaching; however, their knowledge can be affected by multiple factors (Cheung, 2016; Karpudewan et al., 2014).

### *2.1. Individual Interest*

Previous studies have found that individual interest in a certain topic is an important factor influencing teachers' content knowledge (Evans et al., 2002). It enables the learner to persist in a learning situation despite the frustrations they may face during the learning activity. Moreover, it facilitates the integration of new knowledge and helps learners to be more relaxed and focused during the learning process (Renninger, 2000). Renninger (1998) emphasizes the importance of students' prior knowledge for their individual interest, while Laine et al. (2020) and Renninger (2000) also recognize the importance of final grade achievement as a factor influencing students' level of individual interest. However, these results contradict the findings of Cheung (2016), who found that final grade achievement did not have a significant impact on students' level of individual interest. Individual interest promotes learning. It is important to enhance students' individual interest, as it can contribute to better knowledge acquisition (McIntyre et al., 2021). However, Rotgans and Schmid (2018) found that individual interest is not a significant predictor of learning, while a study by Delmoro (2022) found individual interest to be a non-significant factor in students' learning achievements in science. Overall, students' interest in science learning is low (Hemmer et al., 2007), but it can be increased when the topic is presented in the context of the environment (Hemmer et al., 2007).

### 2.2. Self-Esteem

Previous studies have also found a positive relationship between teachers' self-esteem and learning achievements (Jayanthi et al., 2018; Acosta-Gonzaga, 2023). Self-esteem serves as a protection for the individual to remain interested in a situation (Cast & Burke, 2002). Although it is an individual self-evaluation that reflects perception rather than reality (Zeigler-Hill, 2013), it is nonetheless an accurate predictor of academic achievement (Pullman & Allik, 2008), as it enables the individual to persist in a learning activity despite the frustrations s/he may face (Cast & Burke, 2002) and therefore improve his/her own content knowledge (Jayanthi et al., 2018). Cheung (2016) found that students' self-esteem is an important predictor of their level of individual interest; however, a study by Baumeister et al. (2003) found only a small correlation between self-esteem and academic performance. A literature search revealed that no study has yet been conducted on learners' self-esteem when learning the topic of geochemical cycles, although some studies (Palmes, 2023; Delmoro, 2022; Jatmiko et al., 2023) have been conducted on students' self-esteem when learning science. The results of these studies are contradictory: Jatmiko et al. (2023) found that self-esteem correlates with students' learning outcomes in science, while Palmes (2023) and Delmoro (2022) found that self-esteem has no-significant effect on students' learning outcomes in science. Abu Eideh and Taqatqa (2003) conducted a study on pre-service primary school teachers' self-esteem in which significant differences were found between pre-service primary school teachers' self-esteem and their final grade as well as their attitude toward teaching science subjects.

### 2.3. Misconceptions

Children's conceptions about the world are sometimes quite different from scientific conceptions (Eaton et al., 1984); they have been identified as faulty intuitive theories that need to be replaced by scientifically correct ones (Vosniadou, 2020). Misconceptions can become an obstacle to the acquisition of new knowledge. Therefore, it is important for educators to check for misconceptions before teaching new content (Borghini et al., 2019). Misconceptions that arise in school are caused by misleading explanations of concepts with oversimplification and generalization (Dolenc-Orbanič & Batelli, 2011). Such misconceptions are not necessarily related to the learning topic; they can also be related to the nature of the task. Harirorh et al. (2024) and Veloo and Julinamary (2015) found that students have difficulty reading graphs, while Veloo and Julinamary (2015) determined that students have even more difficulty when they have to interpret different symbols. Both studies found that tasks requiring students to make observations using pictures caused more problems for students.

No study has yet been conducted on learners' misconceptions related to the topic of BGCCs. However, some studies have tested misconceptions on topics that are similar or related to geochemical cycles. Vasconelos et al. (2020) found that students lacked a holistic view of the world and had problems connecting the Earth's cycles. Moreover, students had difficulty linking the food chain. Mead (2014) also investigated misconceptions about biogeochemistry and found that students have misconceptions about topics involving the carbon and oxygen cycles. Studies have also been conducted on ion concentrations in water (Mulford & Robinson, 2002). It was found that students do not understand changes in ion concentrations during evaporation, that they have problems understanding chemical equilibria related to environmental processes, and that they are unable to transfer concepts they have learned to the natural environment. Karpudewan et al. (2014) found that there are major misconceptions about environmental chemistry topics such as the greenhouse effect, global warming, ozone layer depletion, etc.

### *2.4. Purpose of the Study*

Studies have already been conducted on pre-service primary school teachers' understanding and public understanding of BGCCs (Turan, 2019; Ural et al., 2017). However, some questions remain unanswered, including the understanding of global BGCCs (Hedges, 1992). It is important to educate people on this topic, as only individuals equipped with reasonable knowledge can make smart decisions (Torres et al., 2019). BGCCs are also connected to climate problems, such as the greenhouse effect (Wollas & Mackenzie, 1989). It is important to equip younger generations with adequate knowledge about environmental issues so that they will act sustainably (Sukma et al., 2020), and the topic of BGCCs lends itself to the goals for sustainable development (Sustainable Development Goals, n.d.). In the Slovenian school system, the topic of BGCCs is addressed in the seventh grade, in the subject of natural sciences, where students learn about the circulation of matter between different ecosystems, as well as in the eighth grade, in the subject of chemistry, where they learn about element sources. In the lower grades, students learn about cycles in Earth spheres in the subject of natural sciences and technology, which is a subject that is taught by classroom teachers rather than specialized teachers (Ministry of Education, n.d.). It is therefore important for classroom teachers to possess adequate knowledge of BGCCs in order to properly educate younger generations about these processes (Heinitz & Nehring, 2022; Sabel et al., 2016). The need to strengthen teachers' knowledge of environmental topics has already been pointed out (Knapp, 2010); this will enable younger generations to act more sustainably (Artemieve, 2011; Liefländer et al., 2015).

The aim of the present study is to investigate the level of knowledge that Slovenian pre-service primary school teachers possess about the topic of BGCCs and to determine which factors have a significant impact on their level of knowledge about this topic. Following this aim, five research questions were developed:

(1) What level of knowledge do Slovenian pre-service primary school teachers possess about BGCCs?

(2) Does individual interest in learning about BGCCs have a significant impact on pre-service primary school teachers' level of knowledge about BGCCs?

(3) Does self-esteem in learning about BGCCs have a significant impact on pre-service primary school teachers' level of knowledge about BGCCs?

(4) Are there significant differences between pre-service primary school teachers' final grade achievements in the subjects of chemistry, biology, and physics and their performance on the 3t-BGCCs?

(5) Do pre-service primary school teachers possess misconceptions about BGCCs?

## 3. Materials and Methods

A quantitative research approach using the causal non-experimental method of pedagogical research was used in this research.

### *3.1. Participants*

A total of 145 Slovenian pre-service primary school teachers attending first-year (88) and third-year (57) university classes in 2024 participated in the study. The average age of the participants was 20.3 years (SD = 1.0 year) for the first-year students and 21.84 years (SD = 0.77 year) for the third-year students.

The students were divided into four groups according to their final grade achievement in chemistry (Che), biology (Bio), and physics (Phy) in high school: (a) students with a final grade of 5 (excellent); (b) students with a final grade of 4 (very good); (c) students with a final grade of 3 (good); and (d) students with a final grade of 2 (sufficient). There were no students with a final grade of 1 (insufficient).

Participation in the study was voluntary and anonymous.

### *3.2. Instruments*

A three-tier achievement test on the topic of biogeochemical cycles (3t-BGCCAT) and a paper–pencil questionnaire on individual interests and self-esteem were used as data collection instruments. Both instruments were developed by the authors. At the beginning of the three-tier achievement test, the students provided information about their final grade achievement in chemistry, physics, and biology in high school.

The 3t-BGCCAT included ten three-tier tasks to identify misconceptions. The first tier consisted of multiple-choice questions with one correct alternative. In the second tier, the students had to select the correct explanation for the selected answer given in the first tier from four alternatives. In the third tier, they had to indicate how confident they were in choosing the correct answer and the rationale in the first and second tiers. Their level of confidence was determined using a 6-point Likert-type scale (1—just guessing, 2—not sure, 3—pretty sure, 4—sure, 5—very sure, 6—absolutely sure). A sample question is shown in Figure 1. The Cronbach alpha coefficient was 0.4 for the first tier, 0.4 for the second tier, and 0.9 for third tier of the task. The validity of the 3t-BGCCAT was assured by forming tasks based on the objectives and content of the chemistry curriculum in lower secondary school and was confirmed by constructing the specification tables for each achievement test. It was also evaluated by three experts in the field of chemistry and chemical education.

**4. Which processes are important for oxygen circulation?**
**A** The processes of photosynthesis, fermentation and dieback.
**B** The greenhouse effect, dieback and cellular respiration.
**C** The processes of cellular respiration, fermentation and photosynthesis.
**D** The processes of decay, the greenhouse effect, and fermentation.

**4.1 Why did you chose that answer?**
**A** In the processes of dieback and cellular respiration oxygen is produced, which is a main cause of the greenhouse effect.
**B** Oxygen is consumed in the processes of fermentation and cellular respiration and produced in the process of photosynthesis.
**C** Oxygen, which is a main cause of the greenhouse effect, is consumed in the process of decay and fermentation.
**D** Oxygen is produced in the process of photosynthesis and consumed in the processes of dieback and fermentation.

***4.2 How confident are you in the correct answer?***

| *1* | *2* | *3* | *4* | *5* | *6* |
|---|---|---|---|---|---|
| Just guessing | *Unconfident* | *Pretty confident* | *Confident* | *Very confident* | *Absolutely confident* |

**Figure 1.** Example of a three-tier task in the 3t-BGCCAT.

The questionnaire on individual interest in the topic of BGCCs consists of eleven items. For each item, the participants had to express their agreement with a statement on a 5-point Likert-type scale. A sample question is shown in Figure 2. The questionnaire on the students' self-esteem consists of four items in which they were asked to express their agreement with a particular statement on a 5-point Likert-type scale. Cronbach's alpha was calculated for both instruments. According to Pallant (2016), alpha coefficients of 0.7 are considered acceptable and values above 0.8 are preferable. In the current study, the Cronbach's alpha coefficient was 0.9 for the individual interest questionnaire and 0.8 for the self-esteem questionnaire. The validity of the questionnaire was assured by three experts in chemical education research, pedagogical psychology, and pedagogical methodology, respectively.

| No. | Statement | I completely agree | I agree | I somewhat agree | I disagree | I completely disagree |
|---|---|---|---|---|---|---|
| 1. | Learning content about biogeochemical cycles interests me. | 5 | 4 | 3 | 2 | 1 |
| 2. | Learning content abut biogeochemical cycles is not too difficult for me. | 5 | 4 | 3 | 2 | 1 |

**Figure 2.** Example of items in the individual interest and self-esteem questionnaires.

None of the instruments used in this research had previously been used for students of the same or similar age group.

### *3.3. Research Design*

The pre-service primary school teachers' performance on the 3t-BGCCAT was calculated according to their score achieved in the first and second tiers of the task. The participants received one point for each correct answer and zero points for each incorrect answer. The maximum possible number points on the achievement test was 20, and a percentage was calculated based on the number of points achieved. Gilbert's (1977) knowledge level scale, which is primarily used in physical science courses at secondary and tertiary levels, was adopted to assess the pre-service primary school teachers' level of knowledge. The scale was calculated according to the mean facility indexes, which led to the grouping of the questions as presented in Table 1.

**Table 1.** Knowledge level table adopted by Gilbert (1977).

| Percentage of Correctly Solved Tasks | Level of Knowledge |
|---|---|
| **75–100%** | Adequate knowledge |
| **50–74%** | Roughly adequate knowledge |
| **25–49%** | Inadequate knowledge |
| **0–24%** | Completely inadequate knowledge |

The pre-service primary school teachers' level of individual interest and self-esteem was calculated based on their agreement with the questions about individual interest and self-esteem expressed on a 5-point Likert-type scale. According to the number of points obtained in each category, the pre-service primary school teachers were divided into three groups (Table 2).

**Table 2.** Criteria for dividing the pre-service primary school teachers into three groups.

| | |
|---|---|
| $<M - SD$ | Low level of individual interest/self-esteem |
| $<M \pm SD>$ | Middle level of individual interest/self-esteem |
| $>M + SD$ | High level of individual interest/self-esteem |

On the questionnaire about individual interest, the pre-service primary school teachers scored an average (M) of 29.0 out of 55 possible points. The standard deviation (SD) was 8.3. Accordingly, they were divided in three groups (Table 3).

**Table 3.** Groups of pre-service primary school teachers according to the number of points scored on the questionnaire about individual interest.

| Number of Points | Level of Individual Interest |
|---|---|
| **<17.7** | Low level of individual interest (*Gp1i*) |
| **17.7–34.3** | Medium level of individual interest (*Gp2i*) |
| **>34.3** | High level of individual interest (*Gp3i*) |

The maximum number of possible points on the questionnaire about self-esteem was 20. The pre-service primary school teachers scored an average of 10.6 points with a standard deviation (SD) of 3.1. According to these results, they were divided into three groups (Table 4).

**Table 4.** Groups of pre-service primary school teachers according to the number of points scored on the questionnaire about self-esteem.

| Number of Points | Level of Self-Esteem |
|---|---|
| **<7.6** | Low level of self-esteem (*Gp1s*) |
| **7.6–14.4** | Medium level of self-esteem (*Gp2s*) |
| **>14.4** | High level of self-esteem (*Gp3s*) |

The misconception table by Milenković et al. (2016) was used to determine the pre-service primary school teachers' misconceptions. Misconceptions were determined based on the correctness of the students' answers in the first and second parts of the task and their confidence in the correctness of their answers (Table 5).

**Table 5.** Table for detecting misconceptions with the three-tier diagnostic test adopted from Milenković et al. (2016).

| First Tier: Correctness of the Answer | Second Tier: Correctness of the Justification | Third Tier: Confidence in the Correctness of the Answers | Level of Knowledge |
|---|---|---|---|
| Correct | Correct | >3 | Knowledge |
| Correct | Correct | <3 | Luck |
| Wrong | Correct | <3 | Guessing |
| Correct | Wrong | <3 | Guessing |
| Wrong | Wrong | <3 | Lack of knowledge |
| Correct | Wrong | >3 | Misconceptions |
| Wrong | Correct | >3 | Misconceptions |
| Wrong | Wrong | >3 | Misconceptions |

The percentage of misconceptions in each task was calculated based on the number of misconceptions in each task. Based on Pratama et al. (2021), the percentage of misconceptions was divided in three groups (Table 6).

**Table 6.** Level of misconceptions based on Pratama et al. (2021).

| Percentage (%) | Category |
|---|---|
| 0–30 | Low percentage |
| 31–70 | Moderate percentage |
| 71–100 | High percentage |

### 3.4. Data Analysis

The data collected with the questionnaires were transferred to Excel, and statistical analysis was carried out using SPSS Statistics Data Editor software. The Kolmogorov–Smirnov test was used to determine the distribution of the data. The normality of the distribution of the results of performance on the 3t-BGCCAT and the results of the questionnaire on individual interest in the topic of BGCCs was tested. The Kolmogorov–Smirnov test showed that the results of performance on the 3t-BGCCAT are not normally distributed ($p < 0.001$) nor are the results of the questionnaire on individual interest normally distributed. Therefore, the non-parametric Mann–Whitney and Kruskal–Wallis tests were used to calculate statistically significant differences in the students' performance on the 3t-BGCCAT. When the Kruskal–Wallis test was used, the contrast analysis (post hoc multiple comparisons) was performed. If the *p*-value for the differences between the means was less than 0.05, the difference was considered statistically significant. In addition, descriptive statistics were used to determine the median, and interquartile ranges were used to determine the central tendency and variability of the data.

## 4. Results and Discussion

The results are presented according to the research questions outlined above, thus ensuring a structured and coherent analysis. Each finding is accompanied by a detailed discussion, providing context and interpretation within the framework of the research objectives.

### 4.1. Pre-Service Primary School Teachers' Knowledge About BGCCs

An analysis of the students' answers on the 3t-BGCCAT is presented in Figure 3.

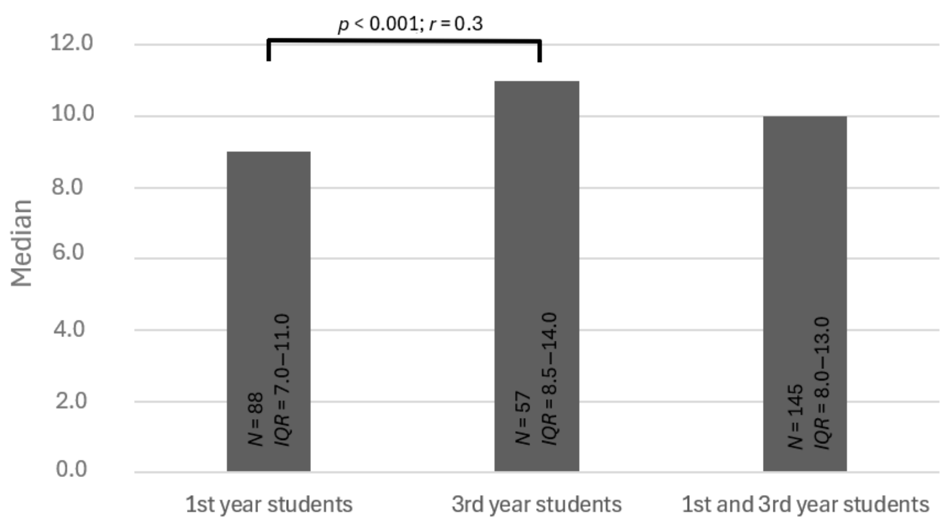


**Figure 3.** Students' points achieved on the 3t-BGCCAT.

The students achieved an average of 10.2 out of 20 possible points, which corresponds to 50.8% of the possible points. According to Gilbert (1977), this percentage represents the lowest limit for roughly adequate knowledge. However, a separate comparison of the level of knowledge of the first- and third-year students shows that the first-year students achieved an average of 47.0% of the possible points and the third-year students achieved an average of 56.7%. These results confirm the findings of earlier studies by Teksoz et al. (2010) and Yavetz et al. (2009), which also found a low level of environmental knowledge among pre-service primary school teachers. A comparison of the results of the present study with other studies on pre-service primary school teacher knowledge of BGCCs (Turan, 2019; Ural et al., 2017) reveals similar findings, as all of the studies found a lack of knowledge of BGCCs among pre-service primary school teachers. In addition, the Mann–Whitney test was conducted to test the significance of the scores achieved on the 3t-BGCCAT by first- and third-year students. The Mann–Whitney test (U = 1705.5; $p < 0.001$; r = 0.3) revealed statistically significant differences between the first-year (N = 88; IQR = 7.0–11.0) and third-year (N = 57; IQR = 8.5–14.0) students in terms of scores achieved on the 3t-BGCCAT. These results are in some ways encouraging, as the pre-service primary school teachers' knowledge of this topic improves vertically during their studies. However, the level of knowledge of the third-year pre-service primary school teachers is still only roughly adequate, and inadequate teacher training has been recognized as the main reason for the weakness of environmental education (Knapp, 2010). Therefore, an adequate environmental program for pre-service primary school teachers is essential to ensure a better implementation of environmental issues in schools (Brundtland, 1987; Lammert, 2024).

### 4.2. Pre-Service Primary School Teachers' Level of Individual Interest Compared to Their Level of Knowledge About BGCCs

The Kruskal–Wallis test (H = 6.808; $p = 0.033$) revealed statistically significant differences between the students with different levels of individual interest with regard to their scores on the 3t-BGCCAT. In addition, a Mann–Whitney test was conducted to test the significant differences between the groups of students with different levels of individual interest. The participants were divided into three groups according to how many points they scored on the questionnaire about individual interest in learning BGCCs content (Table 3). The results of the Mann–Whitney test are shown in Figure 4.

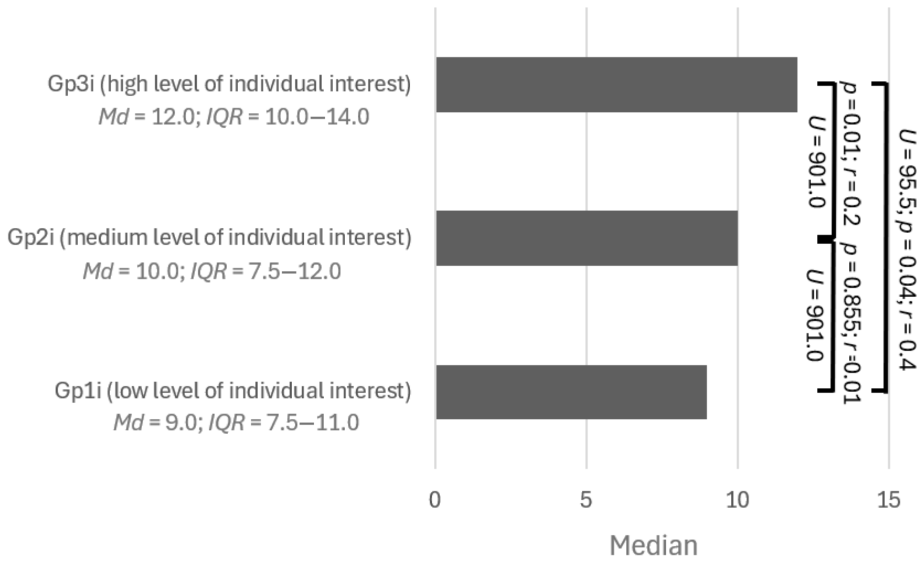


**Figure 4.** Comparison of students with different levels of individual interest.

As can be seen in Figure 4, statistically significant differences were found between Gp2i and Gp3i as well as between Gp1i and Gp3i. These results are consistent with the findings of Evans et al. (2002) and McIntyre et al. (2021), who also identified individual interest as a predictor of learning achievements that can help with knowledge acquisition. However, no statistically significant differences were found between Gp2i and Gp1i. This result is somewhat confusing, but it can be explained by contradictory results from previous studies, as Rotgans and Schmid (2018) and Delmoro (2022) found individual interest to be a non-significant factor for learning achievements. Furthermore, according to Cohen's (1988) criteria, the effect size varies from a medium effect between Gp3i and Gp1i to a small effect between Gp3i and Gp2i. Therefore, these results should be interpreted with caution due to the small effect size. In addition, a Mann–Whitney test was conducted to test the significance of individual interest between the first- and third-year students. The first-year students (Md = 31.5; IQR = 27.0–36.0) showed significantly higher individual interest (U = 1751.0; $p$ = 0.002; r = 0.3) than the third-year students (Md = 28.0; IQR = 22.5–32.0). These results further support the idea that individual interest is not a significant predictor of learning achievements, as noted by Rotgans and Schmid (2018) and Delmoro (2022).

### *4.3. Pre-Service Primary School Teachers' Level of Self-Esteem Compared to Their Level of Knowledge About BGCCs*

The Kruskal–Wallis test (H = 11.429; $p$ = 0.003) revealed statistically significant differences between the students with different levels of self-esteem with regard to their scores on the 3t-BGCCAT. In addition, a Mann–Whitney test was conducted to test the significant differences between the groups of students with different levels of self-esteem. The participants were divided into three groups according to how many points they scored on the questionnaire about self-esteem in learning BGCCs content (Table 4). The results of the Mann–Whitney test are shown in Figure 5.

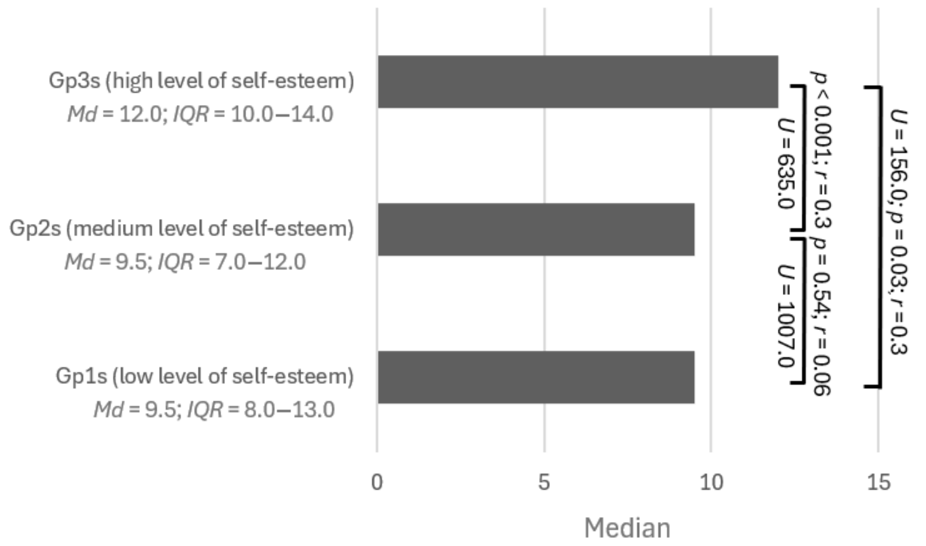


**Figure 5.** Comparison of students with different levels of self-esteem.

As can be seen in Figure 3, statistically significant differences were found between Gp2s and Gp3s as well as between Gp1s and Gp3s. However, no statistically significant differences were found between Gp2s and Gp1s. The results are therefore somewhat contradictory, as are the results of previous studies. Jayanthi et al. (2018) and Acosta-Gonzaga (2023) found a positive relationship between self-esteem and students' learning achievements. Jatmiko et al. (2023) also found a positive relationship between self-esteem and learning achievements in science. In contrast, the results of Palmes (2023) and Delmoro (2022) show no significant differences between students' self-esteem and their learning achievements in science. These results can be explained by a medium effect size between Gp2s and Gp3s as well as between Gp1s and Gp3s according to Cohen (1988). Baumeister et al. (2003) found a small correlation between self-esteem and learning achievement, but their study was not from the field of science education. The present results should therefore be interpreted with caution. In addition, the Mann–Whitney test was conducted to test the significance of self-esteem between the first- and third-year students. The Mann–Whitney test (U = 2296.0; $p = 0.388$; r = 0.05) revealed no statistically significant differences between the first-year (Md = 11; IQR = 9.00–13.00) and third-year students (Md = 10.0; IQR = 9.00–13.00). Thus, the first-year students had slightly higher self-esteem but scored lower on the 3t-BGCCAT than the third-year students. These results show that higher self-esteem is not a predictor of better learning achievements, as found by Palmes (2023) and Delmoro (2022).

Self-esteem has been recognized as a predictor of students' attitude and their individual interest in a learning topic (Cheung, 2016; Abu Eideh & Taqatqa, 2003). The Kruskal–Wallis test was therefore conducted to test the significant effect of self-esteem on the students' level of individual interest. The Kruskal–Wallis test (H = 48.248, $p < 0.001$) revealed statistically significant differences between students with different levels of self-esteem and their individual interest. In addition, a Mann–Whitney test was conducted to determine the significant differences between the groups of students with different levels of self-esteem. The results are shown in Figure 6.

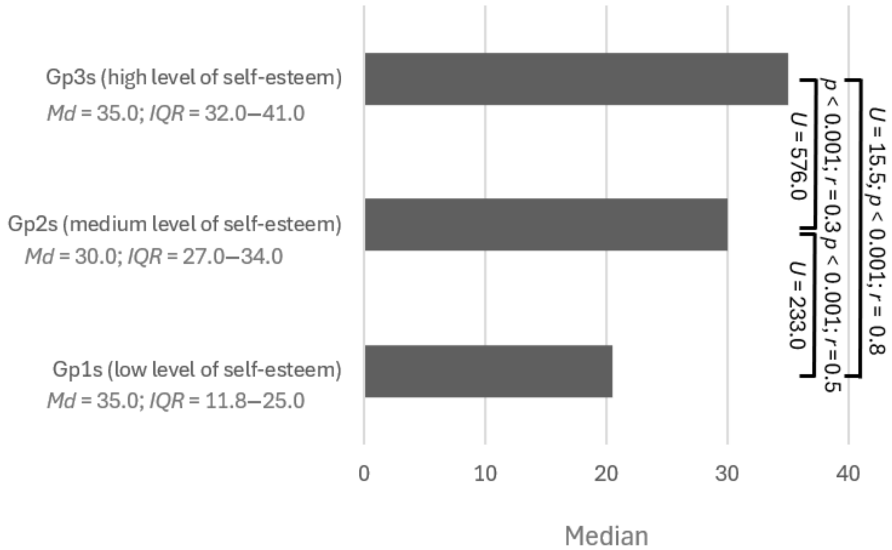


**Figure 6.** Comparison of students with different levels of self-esteem and their levels of individual interest.

Figure 6 shows that the Mann–Whitney test reveals significant differences between all groups of students with different levels of self-esteem. The effect size between the pairs also varies from medium to strong. It can therefore be concluded that self-esteem has an influence on students' individual interest, which in turn has a significant effect on their learning performance. These results are consistent with the findings of previous studies by Cheung (2016) and Abu Eideh and Taqatqa (2003).

### *4.4. Students Final Grade Achievement in Biology, Chemistry, and Physics, and Their Performance on the 3t-BGCCAT*

The Kruskal–Wallis test (H = 13.624; $p = 0.004$) revealed statistically significant differences between students with different final grades in biology. However, no statistically significant differences were detected between students with different final grades in chemistry (H = 6.387; $p = 0.094$) and physics (H = 3.485, $p = 0.323$). In addition, a Mann–Whitney post hoc test was performed to test whether there were significant differences between the pairs (Figure 7).

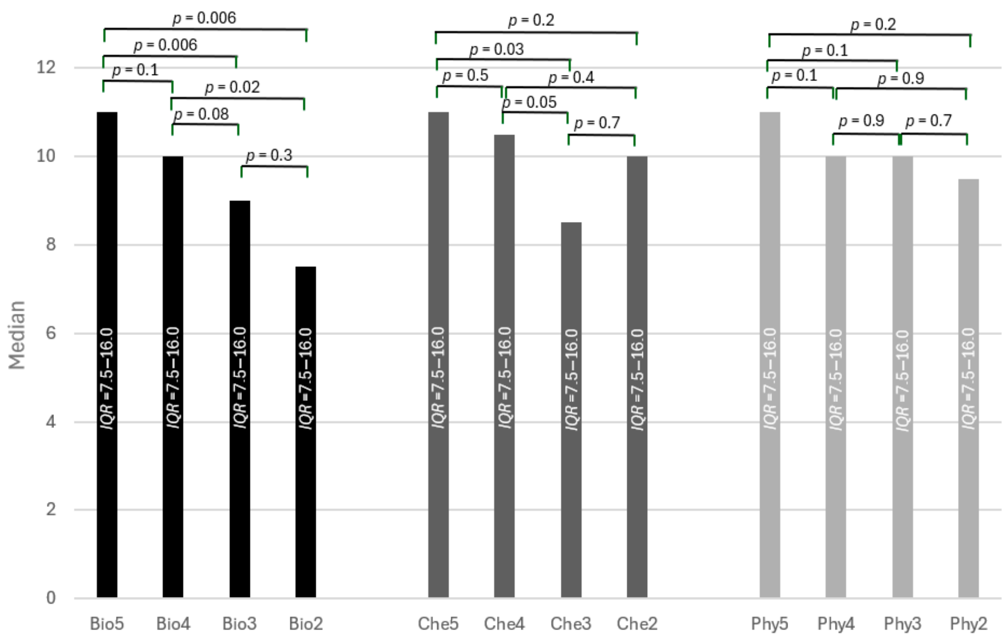


**Figure 7.** Comparison of students with different final grade achievement and their performance on the 3t-BGCCAT.

With regard to students with different final grades in biology, the Mann–Whitney test revealed statistically significant differences between Bio5 and Bio2 (U = 82.5; $p = 0.006$; r = 0.4), Bio5 and Bio3 (U = 362.5; $p = 0.006$; r = 0.3), and Bio4 and Bio3 (U = 152.0; $p = 0.02$; r = 0.3). With regard to students with different final grades in chemistry, the Mann–Whitney test revealed statistically significant differences between Che5 and Che3 (U = 406.5; $p = 0.03$; r = 0.3). No statistically significant differences were found between groups of students with different final grades in physics. These results are somewhat confusing, as the topic of BGCCs is mainly covered in the chemistry curriculum (Ministry of Education, n.d.). However, Šorgo and Kamenšek (2012) found that the environmental curriculum is structured intersubjectively and therefore environmental topics are also integrated into the subjects of biology and natural sciences (Ministry of Education, n.d.). It is interesting to note that there are no statistically significant differences between the students' performance on the 3t-BGCCAT and their final grade in chemistry and physics, as the BGCCs subject lends itself to the integration of physics, chemistry, and biology (Artemieve, 2011). The Kruskal–Wallis test was therefore conducted to examine whether there are significant differences between the first- and third-year students with different final grades in chemistry and physics with regard to their performance on the 3t-BGCCAT. However, the Kruskal–Wallis test revealed no statistically significant differences between the first-year students with different final grade achievements in chemistry (H = 6.1; $p = 0.1$) and physics (H = 3.3; $p = 0.4$). Similarly, no statistically significant differences were found between the third-year students with different final grades in chemistry (H = 2.6; $p = 0.5$) and physics (H = 2.1; $p = 0.6$). It is important to note that previous studies on students' final grade achievement and their level of knowledge were not conducted on pre-service primary school teachers, so the results can be somewhat contradictory with those of previous studies.

### *4.5. Pre-Service Primary School Teachers' Misconceptions About BGCCs*

Some misconceptions were identified with the 3t-BGCCAT. The number of misconceptions is shown in Figure 8.

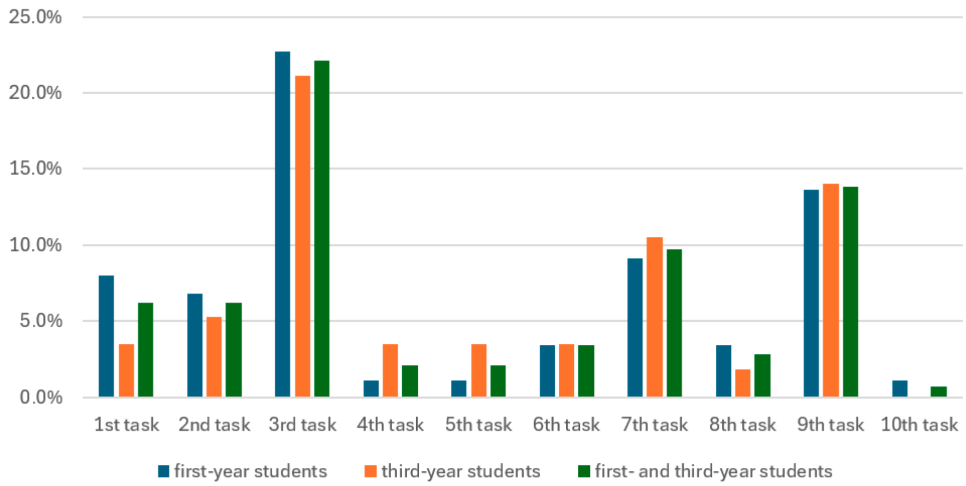


**Figure 8.** Number of students' misconceptions in each task.

According to Pratama et al. (2021), the level of the students' misconceptions is low in all of the tasks. Only in five of the tasks did the number of misconceptions exceed 5%, i.e., tasks 1, 2, 3, 7, and 9. One explanation for the higher percentage of misconceptions in tasks 1, 2, 7, and 9 could be that in these tasks, the students had to link the Earth's cycles to three different spheres—the hydrosphere, the lithosphere, and the atmosphere—which has been shown to be problematic for in-service teachers in previous studies by Turan (2019) and Vasconelos et al. (2020). Therefore, it is possible that the students possess misconceptions due to receiving misleading information from their teachers. In tasks 1 and 2, the students had to define which parts of the Earth are connected to the biogeochemical cycles, and in task 2, they needed to know the characteristics of these cycles. Tasks 7 and 9 consist partly of images, and Veloo and Julinamary (2015) and Harirorh et al. (2024) have previously found that tasks requiring observations based on pictures cause more problems for students. The picture in task 9 depicts the nitrogen cycle: it contains a rabbit that is part of the food chain and students have problems relating it to the Earth's cycles. Task 7 consists of a picture with the pyramid representing energy levels, and the participants had to determine which organisms are on the first energy level. Therefore, the students had to link BGCCs to the energy cycle, which has also proved to be problematic in the past (Turan, 2019). The highest percentage of misconceptions was found in task 3, in which the students had to choose which of the suggested chemical equations correctly represents the equation of photosynthesis. Veloo and Julinamary (2015) found that students have difficulty interpreting symbols, while Mulford and Robinson (2002) and Krause et al. (2024) also found in one of their earlier studies that students have problems understanding chemical equations related to environmental processes.

## 5. Conclusions

The present study investigated the level of knowledge of first- and third-year pre-service primary school teachers about BGCCs. In addition, the influence of factors such as students' self-esteem, individual interest, and final grade achievement were tested. Finally, students' misconceptions about BGCCs were also determined. The results of the study show that the participating students scored an average of 10.2 of a possible 20 points on the 3t-BGCCAT. This result corresponds to 50.8% of the possible points, indicating a roughly adequate level of knowledge. In addition, the students' first- and third-year knowledge levels were compared and significant differences were found, indicating that students' knowledge of BGCCs improves vertically over the course of their studies. When the students' level of individual interest was compared to their performance on the 3t-

BGCCAT, the results indicate that individual interest may be a significant predictor of learning performance. However, the effect size varied from medium to small among the groups of students with different levels of individual interest. In addition, the first-year students showed significantly higher individual interest in learning the BGCCs topic, although their performance on the 3t-BGCCAT was significantly lower. This could indicate that these results should be interpreted with caution, as individual interest was recognized as an important predictor of students' content knowledge, which means that the results are somewhat contradictory. Furthermore, it is possible that the third-year students found this topic rather uninteresting after having already learned about it in the first year of university. Similar results were found when comparing students with different levels of self-esteem with regard to their performance on the 3t-BGCCAT. Students with higher self-esteem performed significantly better on the 3t-BGCCAT, but the effect size between the different groups of students varied from medium to small. Interestingly, no significant differences were found between the first- and third-year students with regard to their self-esteem, although the third-year students performed significantly better on the 3t-BGCCAT. In addition, self-esteem was found to be a predictor of individual interest. Last but not least, the students' final grades in chemistry and physics in high school did not prove to be a significant factor influencing their performance on the 3t-BGCCAT. However, statistically significant differences were found between students with different biology final grades in high school with regard to their performance on the 3t-BGCCAT. In addition, significant differences were found between first- and third-year students with different final grades in chemistry and physics with regard to their performance on the 3t-BGCCAT, although the weaker performance of the third-year students could be due to forgetfulness. Students were found to have misconceptions about BGCCs, revealing that they have problems solving tasks that require image observation and recognizing different symbols. Tasks where students had to connect all of the spheres of the Earth with the cycles of the Earth and show a holistic view of the topic also proved to be problematic. The main problem occurred when students had to relate a chemical equation and to an environmental process. However, it is encouraging that in no task did the number of students' misconceptions exceed 25%, which shows that the their level of misconceptions about the BGCC topic is low.

The results show that environmental education is far from reaching its full potential. It is important to improve environmental education, as it plays an key role in educating younger generations about the environment, and its topics lend themselves to the integration of the sustainable development goals. Teachers play an important role in educating young people about these issues. Therefore, proper teacher training is needed in order to inform pre-service primary school teachers about environmental issues. It is important for teachers to incorporate more graphs and pictures in their learning material, as tasks that include graphs and pictures proved to be more problematic for students. Furthermore, teachers need to teach chemistry content using all three levels of chemical presentation so that students learn to link chemical equations to a particular phenomenon, such as photosynthesis. Pre-service primary school teachers need to learn how to promote factors such as self-esteem and individual interest, which are important for students' learning achievement in these areas. Together, these measures will lead to the achievement of social development toward a greener and more sustainable future.

*Limitations and Future Work*

The present study was conducted at the faculty during laboratory work. The students' responses could therefore be superficial, as they tried to complete the instruments as quickly as possible. In addition, their participation did not benefit them, so they put as little effort as possible into their responses. Moreover, the study only included pre-service primary school teachers who will be teaching grades 1–5 in primary school. Further research is needed to include in-service classroom teachers, as well as specialist teachers of biology, chemistry, and natural science, as these subjects usually cover environmental topics. Further research is also needed to include different environmental topics that lend themselves to the sustainable development goals. In addition, there is a need for the development of new learning approaches that use more graphs and pictures in order to improve teacher training and to optimize teachers' work in the classroom. Furthermore, it is important to incorporate all three levels of chemical phenomenon in teacher training in order to link the macroscopic world with sub-microscopic and symbolic levels of presentation. According to some authors, one possible way to achieve this is through the use of augmented reality technology, which enables the learner better immersion. However, further research is needed to test the effectiveness of this learning approach.

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**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki and was reviewed and approved by the Ethics Commission of the Faculty of Education of the University of Ljubljana. Approval code 16/2024, on 2 April 2024.

**Informed Consent Statement:** Informed consent was obtained from all of the subjects involved in the study.

**Data Availability Statement:** The data used in this study are available on request from the corresponding author. The data have been anonymized, but are not publicly available due to privacy issues related to their qualitative nature.

**Conflicts of Interest:** The authors declare no conflicts of interest.

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