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EFFECTIVENESS OF FLIPPED LEARNING AND TEACHING: KNOWLEDGE RETENTION AND STUDENTS' PERCEPTIONS

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ABSTRACT

Aim/Purpose	This paper addresses the effectiveness of flipped learning and teaching as a didactic innovation in math instruction. We are interested in comparing traditional and flipped learning and teaching in terms of acquired knowledge and retention and students' perceptions of flipped learning and teaching.
Background	Traditional lessons, in which frontal instruction prevails, cannot sufficiently address all students, especially in more complex subjects where it is necessary to follow the didactic principle of learning differentiation and individualization. Flipped learning and teaching is a didactic innovation with a high potential for implementing the said didactic principle, as it can be adapted to the students' needs to a greater extent. There is no single mode of implementation for flipped learning and teaching, which means that the effects depend largely on the specific learning activities, resulting in the fact that previous research does not report conclusive results. Thus, it is important to continue to examine this innovation to provide a better and more detailed understanding of it.
Methodology	We present a study in which 13-year-old primary school students took part in a pedagogical experiment in mathematics instruction. In the control group (n =

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26), lessons were taught in the traditional way, while in the experimental group (n = 26), lessons were taught according to the principle of flipped learning and teaching. After the experiment, the same posttest was administered to both groups to assess the students' knowledge of the subject matter after the treatment. Another posttest was administered after three months to determine whether the knowledge acquired through flipped learning and teaching was permanent. All three tests consisted of 13 tasks, with the first 6 tasks relating to the perimeter of polygons and the second 6 tasks relating to the area of polygons. The last task focused on the perimeter and area of polygons. A short survey was also conducted to find out how the students in the experimental group perceived this didactic innovation in terms of motivation to learn, interest in the subject matter, level of knowledge acquired, and so forth.

Contribution

Our research on flipped learning and teaching focusing on primary schools is significant as previous research on the topic has often been conducted on a sample of high school students and even more often on university students. Our particular contribution is the fact that we tested not only the students' immediate knowledge after the intervention but also the retention of knowledge after a period of three months, which provides an additional perspective on the effectiveness of flipped learning and teaching.

Findings

With this research, we have answered three research questions. First, we found that there are no statistically significant differences between the two groups in terms of acquired knowledge. Thus, we found that both the traditional approach and the flipped learning and teaching approach were equally successful in transferring knowledge to the students. In addition, we found that there were differences between the two groups in terms of retention of knowledge. The group taught with the flipped learning and teaching approach showed higher levels of knowledge retention than the group taught with the traditional approach. Finally, it was found that the students were quite satisfied with this approach and would like to see such innovations in the future.

Recommendations for Practitioners

The results suggest better knowledge retention when using flipped teaching and learning, so based on our findings, we recommend teachers try this innovation in their classrooms. However, all innovation should be implemented with thorough consideration and gradually; thus, we believe that training courses on flipped learning and teaching should be organized for teachers to learn about this innovation, find out about its effectiveness, and reflect on how they can incorporate it into their own practice.

Recommendations for Researchers

We recommend that research in the future focus more on primary school students, with particular attention to experimental design. We suggest that researchers focus on investigating the contribution of the different learning activities with the flipped instructional design to the overall effectiveness of the innovation.

Impact on Society

The results of our research thus represent an important contribution to the field of pedagogy and general didactics at primary and lower secondary levels. Based on our findings on knowledge retention in the experimental group, we consider flipped learning and teaching to be an effective innovation that could contribute to a higher quality of teaching and, thus, to better student knowledge.

Future Research

Future research would be important to determine which factor ensures a higher level of knowledge retention in a flipped learning and teaching approach than in a traditional learning and teaching approach. It would also be important to determine the effects of flipped learning and teaching in other subject matters in the mathematics classroom, in other age groups of students, and in other subjects in primary school.

Keywords didactic innovation, flipped learning and teaching, mathematics, knowledge retention, students' perceptions, primary school students

INTRODUCTION

Traditional lessons, in which the whole class, i.e., frontal instruction format prevails, may not sufficiently appeal to all students even with an extremely high-quality implementation (Bergmann & Sams, 2014), especially in the case of more complex subjects. Therefore, for students to achieve the educational goals of modern schooling, the teacher's competence to professionally combine various forms of within-class student grouping (Plešec Gasparič, 2019; Plešec Gasparič & Valenčič Zuljan, 2019) and instructional methods (Valenčič Zuljan & Kalin, 2020) is important, as well as openness to didactic innovations and the search for teaching approaches that would promote the greatest possible mental engagement and emotional involvement of students.

Flipped learning and teaching is a didactic innovation that has an extremely high potential for implementing the didactic principle of differentiation and individualization (Strmčnik, 2001; Valenčič Zuljan & Plešec Gasparič, 2021), as it can be adapted to the learning needs of students to a great extent (Sota, 2016; Valenčič Zuljan & Plešec Gasparič, 2019) and shows positive impact on students' academic achievement. As a result, it has attracted a lot of attention from practitioners and researchers. Nevertheless, there are several reasons to explore this innovation further. First, Förster et al. (2022, p. 1) state that "there is limited evidence on the relationship between engagement in pre-class video watching and later achievement and particularly in knowledge retention in the flipped classroom," with the lack of research on the impact of flipped learning and teaching on academic achievements even more evident in the Slovenian context (Plešec Gasparič, 2019). Second, researchers report ambiguous results on the effectiveness of this innovation. Many studies confirm positive effects on students' knowledge (Betihavas et al., 2016; Giannakos et al., 2014; Lo & Hew, 2017), while some claim that the effects are neutral (Chen et al., 2017). It is, therefore, necessary to investigate further and possibly identify the determinants more clearly. Third, while research at the secondary and higher education level dominates (e.g., Al Ghawail & Ben Yahia, 2021; Foldnes, 2016; Lee et al., 2022; Murillo-Zamorano et al., 2019; Pastes Urbano et al., 2020; Sharp & Sharp, 2017; Sommer & Ritzhaupt, 2018; Xiu & Thompson, 2020; Yang, 2017; Yelamarthi et al., 2016), there is less research at the primary school level (Plešec Gasparič, 2019), which is why we have focused on this level of schooling. We were interested in comparing traditional and flipped learning and teaching from the point of view of acquired knowledge and its retention, as well as students' perceptions of flipped learning and teaching. For this reason, we designed an experiment in which one group of 13-year-old primary school students was taught mathematics in the traditional way, and the other group learned the same material using the flipped learning and teaching approach. Thus, the purpose of the study was to test the differences in acquired knowledge of the subject matter between the two groups and the differences in retention of acquired knowledge between the groups. We also wanted to use a questionnaire to find out how the students perceived the flipped learning and teaching approach.

Our research on flipped learning and teaching in primary school is important because it contributes to understanding this innovation on a less researched schooling level. Furthermore, our findings are based on the results of an experiment and not only on the self-reported views of the students and teachers involved. Our particular contribution is the fact that we tested not only the students' immediate knowledge after the intervention but also the retention of knowledge after a period of three months, which provides an additional perspective on the effectiveness of flipped learning and teaching.

The structure of the article is as follows. In the next section, the conceptual framework is presented, including our research questions. Then, the following section explains the methodological framework for the research. This is followed by the section in which we present and discuss the results. The final section summarizes the results, explains the limitations of the study, and provides suggestions for future research on this topic.

LITERATURE REVIEW

The need for innovation in teaching and schooling is much greater today than in the past. We live in a world in which different cultures and values are interwoven and in which there is a multitude of changes and advances every day. The rapid change in society requires teachers to be willing and able to face and solve multiple pedagogical challenges, which is closely related to the introduction of innovation and change by teachers.

Didactic innovations are the result of deliberate, intentional, and creative work (by researchers and teachers), the implementation of which should enable a change in existing pedagogical practice (Valenčič Zuljan & Kalin, 2007). Mandić (1983, p. 192) defines didactic innovation as "a synchronized system of pedagogical, social, organizational and economic measures that consciously draws on pedagogical and other sciences and aims to improve the quality of pedagogical work while making rational use of personnel, time and resources, to democratize school relations, to develop to the maximum the inventiveness, originality and creativity of teachers and students, to create the conditions for appropriate pedagogical evaluation, programming, standardization and grading of pedagogical work, to find the most appropriate material factors that motivate students and teachers for their work."

Didactic innovation is important for several reasons: research findings on teaching and learning (e.g., a meta-analysis of research on instruction, learning differentiation, and individualization), changing and diverse student needs, more challenging goals of schooling, and the speed of change and obsolescence of information (Jorgenson, 2006; Valenčič Zuljan & Kalin, 2007). In recent decades, pedagogical innovations have often been associated with the use of ICT (Cetin, 2016; Kukey et al., 2019; Nachmias et al., 2004; Ottestad, 2010; Wang et al., 2023) as student-centered instructional models have been promoted (e.g., active and self-regulated student learning (Bakkenes et al., 2010)). The following is a discussion of one of the didactic innovations, namely the flipped learning and teaching approach.

The concept of flipped learning and teaching has evolved from the concept of the flipped classroom and, later, flipped learning. The flipped classroom is similar to traditional teaching in that the focus is on the teacher and their knowledge transfer (Plešec Gasparič, 2019). There are various definitions of the flipped classroom. For Lage et al. (2000, p. 32), the flipped classroom means that events that traditionally take place at school now take place at home, and events that traditionally take place at home now take place at school. This concept merely brings about a reversal of what happens in the classroom and what happens outside the classroom. However, it has not yet brought about any changes in terms of greater student involvement and participation in the classroom. Nor does it place them at the center of attention, as the later developed concept of flipped learning (Abeysekera & Dawson, 2014).

The beginnings of the flipped learning concept, which is based on the use of videos, can be dated back to 2006 when high school chemistry teachers Bergmann and Sams (2012) taught their students via videos that students watched at home. They introduced flipped learning as a pedagogical approach in which direct explanation is shifted from the group learning space or collaborative learning environment to the individual learning space or personal learning environment. The collaborative learning environment is thus transformed into a dynamic, interactive space in which the teacher guides students in the practical and creative application of concepts. The first notable academic discussion dates back to Strayer (2007), who addressed this topic in his doctoral thesis. He drew on the work of Baker (2000) and Lage et al. (2000), among others. However, these authors dealt with flipped classrooms and not flipped learning (Abeysekera & Dawson, 2014). Bishop and Verleger (2013, p. 7) define flipped learning as an educational technique consisting of two parts: an interactive group learning activity in the classroom and direct individual computer instruction outside the classroom. This definition strictly excludes all formats that do not include videos outside the classroom. Such a definition, which includes a technological component, is also given by Hamdan et al. (2013, p. 4).

In this paper, we propose that 'flipped learning and teaching' is a more appropriate term than 'flipped learning' as it encompasses both the students' and the teacher's activities in the classroom (Blažič et al., 2003; Plešec Gasparič, 2019; Plut-Pregelj, 2015). The characteristics of flipped learning and teaching can be summarized in five points (Hwang et al., 2015):

1. Changed use of classroom time: content that was traditionally taught through direct explanations and that students can understand themselves is now presented in a different way, usually as a video. This allows students to learn outside the classroom.
2. Discussions, projects, and problem-solving take place in the classroom, and this helps students to apply what they have learned.
3. The use of time outside the classroom is changed: time that would otherwise be used for homework is shifted to the classroom. Before coming to class, students practice different types of independent learning at home by watching videos.
4. Time outside the classroom is used to acquire knowledge at the level of memorization and comprehension.
5. In the classroom, the importance of interaction between students and between teachers and students is emphasized. Knowledge related to problem-solving is also emphasized. In the classroom, students acquire knowledge at the level of applicability, analysis, and evaluation.

As already mentioned, many authors also include in the definition the mandatory use of videos, the viewing of which is, of course, only possible with the help of ICT. The videos that teachers use for flipped learning and teaching can either be commercially produced, publicly available educational videos (e.g., on YouTube), or videos that teachers create themselves (Heo & Min, 2014). Bergmann and Sams (2014) argue that the most popular approach with students is the one that involves teacher-created videos.

Bergmann and Sams (2014) and Hamdan et al. (2013) list some other key factors to consider when planning and implementing flipped learning and teaching, namely, the professionalism and didactic qualification of the teacher, student-centered learning, optimized learning spaces, gradual implementation and self-reflection of teachers, collaboration between teachers and the support of the school administration.

However, the problem that can occur with flipped learning and teaching is the motivation of students at home, and the fact that flipped learning and teaching can have a negative impact on knowledge growth if students do not watch the video and do the required work because they miss the content presented in the video. For this very reason, teachers need to develop strategies to ensure that homework has actually been completed (Abeysekera & Dawson, 2014).

A common mistake teachers make when implementing flipped learning and teaching is to simply hand students a video and expect them to watch it. It is necessary to teach students how to watch the video as this is the only way to achieve the positive effects of flipped learning and teaching and the use of ICT. This is because many students will initially find this process unfamiliar and will take up to three weeks to master the skill of watching the video (Bergmann & Sams, 2015). It is, therefore, important to provide teachers with pedagogical training on how to implement this didactic innovation. An international study conducted with 634 teachers from Spain, Hungary, and the Czech Republic confirmed that teachers also consider pedagogical training to be necessary and even more important than ICT training for the successful implementation of flipped learning and teaching (Villalba et al., 2018), with particular attention paid to a thorough introduction, gradual implementation and in-depth evaluation with student participation (Plešec Gasparič et al., 2023; Valenčič Zuljan & Plešec Gasparič, 2018). Furthermore, research shows that flipped learning and teaching using videos to transfer knowledge can also have a significant positive impact on students' (Leem & Kim, 2016) and teachers' (Weinhandl et al., 2020) ICT literacy.

As discussed above, flipped learning and teaching entails a number of changes in the learning process that affect the teaching time (Bergmann & Sams, 2014), instructional stages (Plešec Gasparič, 2019), the learning objectives (Bormann, 2014; Krathwohl, 2010), and the teaching methods (Plešec Gasparič, 2019; Valenčič Zuljan & Kalin, 2020). Table 1 shows a concise comparison between traditional instruction and flipped learning and teaching.

Table 1. Comparison between traditional instruction and flipped learning and teaching

	Traditional instruction	**Flipped learning and teaching**
Learning space	Studying the subject matter at school during lessons.	Studying the subject matter at home.
Class time	Class time used to teach content.	Class time used for discussions, projects and problem solving – applying what the students have learned at home.
Instructional stages	Practice/exercise and repetition takes place on a smaller scale at school.*	Practice/exercise and repetition takes place on a larger scale at school.
Direct/indirect learning, forms of students' grouping	Direct learning in a collaborative learning environment.**	Direct learning in a personal learning environment.***
Instructional methods	The explanation method is more commonly used in class.	The conversation method is more commonly used in class.
Instructional aims	Acquiring knowledge at the level of memorization and understanding at school.	Acquiring knowledge at the level of memorization and understanding at home.
	Using knowledge at the level of application, analyzing and evaluating at home.	Using knowledge at the level of application, analyzing and evaluating at school.
	Bloom's levels analysis, synthesis and evaluation are carried out at home, while knowledge, understanding and application take place at school.	Bloom's levels analysis, synthesis and evaluation are carried out at school, while knowledge, understanding and application take place at home.

* It is, of course, important to note that even in traditional lessons, some lessons are devoted entirely to practice/exercise and repetition, especially before marking.
** By the term collaborative learning environment, we mean the classroom as a physical space where students learn together.
*** By the term personal learning environment, we mean the home as a physical space where students learn alone.

Instructional approaches aside, the overall desired outcome of instruction (and innovation of this process) is the quality of knowledge, a complex concept that is beyond the scope of this article. Marentič Požarnik (2011) mentions a large quantity of knowledge and adds a list of some other aspects of quality knowledge, one of which is the retention of knowledge – long-lasting knowledge that resists forgetting. The author also speaks of knowledge that enables individuals to better understand themselves and the world around them. High-quality knowledge, according to the author, should be useful and holistic. Declarative and procedural dimensions of knowledge should be closely interwoven, contributing to critical, creative, analytical, and practical thinking. The author also talks about dynamic knowledge, which motivates the individual to learn more, and metacognition – reflection on one's own cognitive process. Marentič Požarnik (2011) adds another dimension of quality knowledge, namely the ethical aspect, which includes the responsible use of knowledge for the common good.

We will now demonstrate how the characteristics of flipped learning and teaching described above are related to students' academic performance, knowledge retention, and attitudes toward this innovation.

Bormann (2014) notes that the world outside school is changing rapidly and that the traditional classroom is often unable to adapt to these changes. The author drew his conclusions from a meta-analysis of more than 30 peer-reviewed articles using a sound research methodology. Teachers in these studies often see the flipped learning environment as one that is closer to the real world of students outside the classroom than traditional learning environments. At the same time, the question of the effectiveness of such a way of working arises, with a focus on the improvement or deterioration of students' performance in various knowledge tests. In several studies included in the meta-analysis, watching the video at home elicited a wide range of reactions from students. Some students rejected the activity because it did not have a direct impact on their grades, while other students felt that it helped them achieve a better grade because they were able to watch the explanatory video several times before the knowledge test. In all the studies considered, the majority of students rated that they were more active in the flipped learning and teaching process than in the traditional learning process, so the content was more meaningful to them, and the instruction was higher quality and more effective. The studies included in Bormann's (2014) review measured student achievement in flipped learning and teaching in different ways. The quantitative data show a slight (statistically insignificant) advantage of flipped learning and teaching compared to traditional instruction.

In the following, we present the results of some studies which, like ours, aimed to examine the learning performance of students in primary school.

Beronja (2017) carried out a study in Slovenia involving 6th-grade students (12-year-olds). She conducted an experiment that lasted two weeks. First, the students completed the pretest, and after the intervention, they completed the posttest. She found that the students in the experimental group performed better on the posttest than the students in the control group and that they understood the more difficult concepts better.

The study conducted in the United Arab Emirates by Khadragy (2016) included 9th-grade female students. A quasi-experiment was conducted on the subject of English. There were 27 students in the experimental group and 28 in the control group. The students completed the pretest before the experiment began and the posttest at the end of the experiment, which lasted eight weeks. The aim of the study was to determine the relationship between flipped learning and teaching and learning success in the area of reading competence in English as a second language. Statistically significant differences were found in the academic performance of the female students in favor of the experimental group. Within the experimental group, it was found that the subgroup of academically successful female students made the greatest progress, while the progress of the subgroup of academically average and less academically successful female students was lower.

Leo (2017) conducted an action research study in the United States that lasted six weeks. The sample included 23 7th-grade students with low academic achievement in math. In the study, he determined the effects of flipped learning and teaching on students' understanding, attitudes toward innovation, and flipped learning and teaching. He compared the results by gender and ethnicity. Students solved the pretest and the posttest. Students' overall learning outcomes in math improved in the posttest compared to the pretest. In the beginning, the students showed resistance to the innovation, but by the end, they were found to have a positive attitude toward flipped learning and teaching.

Statistically significant differences in learning outcomes in favor of the experimental group receiving flipped learning and teaching are also evident in other similar studies conducted on a sample of secondary or tertiary students (Chipps, 2012; Diab & Abdel, 2016; Farah, 2014; Marlowe, 2012).

Apart from students' short-term academic performance, in our study, we also focused on another indicator of the quality of knowledge: knowledge retention. Previous research has confirmed that flipped learning and teaching contribute to more permanent and higher-quality knowledge (Graham et al., 2019; Mithun & Evans, 2018), particularly through the effective use of instructional time focused on meaningful learning experiences that enable students to learn in depth. A meta-analysis by Tutal and Yazar (2021) considered 177 studies that looked at flipped learning and teaching and related to learning outcomes, 9 studies on knowledge retention, and 17 studies on attitudes towards the course. The results show a moderate main effect size for the impact of flipped learning and teaching on academic achievement ($g = 0.764$), knowledge retention ($g = 0.601$), and attitude toward the course ($g = 0.406$). Based on their meta-analysis, the authors draw some conclusions about the effectiveness of flipped learning and teaching – that it is more effectively implemented in small classes, that it is most effectively applied in primary schools, that its effectiveness decreases with the duration of implementation, that it is effectively implemented in almost all subjects, and that it is also more effective than traditional instruction in terms of attitude toward the course and learner retention.

There are several factors that affect the retention of knowledge in flipped learning and teaching, e.g., students learn individually (at home) at their own pace, they can pause the video, watch it several times, and take time to reflect on it, while classroom instruction should also be adapted to the student's needs and pace as much as possible. This has been confirmed in studies by Eppard and Rochdi (2017) and Plešec Gasparič (2019).

Among other factors that influence the retention of knowledge in flipped learning and teaching, we can also highlight the difference that this innovation brings to instructional stages. Compared to traditional instruction, more time is spent in school on practicing, training, and repetition (Plešec Gasparič, 2019), i.e., on the stages that are strongly related to knowledge retention – if students engage with this to a greater extent under the guidance of the teacher, this can have a positive effect.

Since knowledge retention is also related to students' motivation (Marentič Požarnik, 2011), it is important to examine students' perceptions of flipped learning and teaching. We hypothesize that students who have a more positive attitude towards innovation are more motivated and engaged and complete their assignments responsibly and thoroughly at home and at school, which helps them retain their knowledge better. G. B. Johnson (2013) studied a sample of 63 students between the ages of 14 and 18. The flipped learning and teaching lasted five months, and the author was interested in the students' perceptions of it. Students reported a generally positive attitude towards flipped learning and teaching, a reduction in their workload at home, and saw the video as an effective means of learning new content. Positive student perceptions of flipped learning and teaching have also been shown in research by Farah (2014), Hantla (2014), Vaughn (2014), Bell (2015), Prefume (2015), and Leo (2017). However, some researchers also report contradictory (Hunley, 2016; L. Johnson & Renner, 2012; Willis, 2014) or even negative attitudes (Bishop, 2013).

Abeysekera and Dawson (2014) argue that students are motivated by flipped learning because it makes them feel competent (knowledge and skills to succeed in a particular social setting), autonomous (the feeling of being in control and independent), and connected to others (being part of a social group) (Pintrich, 2003, as cited in Abeysekera & Dawson, 2014; Ryan & Deci, 2000a, as cited in Abeysekera & Dawson, 2014). The authors also claim that flipped learning and teaching help students control their cognitive load.

The main disadvantage of flipped learning and teaching for students that could contribute to more negative perceptions is the fact that they cannot ask the teacher questions while working on the new learning content at home (Bergmann & Sams, 2012; Plešec Gasparič, 2019). Bergmann and Sams (2012) suggest teaching students how to watch videos, take notes, and write down comments and questions for the teacher at the beginning of the year. Other disadvantages for students listed by Plešec Gasparič (2019) could also be that students' workloads increase at home when many teachers are constantly flipping their lessons. As this innovation is strongly related to the use of ICT, another obstacle could be that students do not have computer equipment, have poor or no internet connection, and have low digital literacy. To minimize the negative impact of these factors, the teacher should participate with the students in all phases of the innovation process – planning, implementation, and evaluation.

Flipped learning and teaching is a relatively recent didactic innovation, so it is important to examine its effectiveness from different angles. In our study, we decided to focus on students' learning outcomes, their knowledge retention, and their perceptions of this didactic innovation. The aim of the present study was to determine whether there are differences in knowledge about the subject of mathematics in the 7th grade (13-year-olds) between the group taught the topic of the area of polygons in the traditional way, and the group taught this topic using the flipped learning and teaching approach. For the purpose of the study, we asked the following research questions:

> Research Question 1: What are the differences in the knowledge gained by the students taught using a flipped learning and teaching approach compared to the students taught using a traditional approach?
>
> Research Question 2: What are the differences in retention of acquired knowledge between students in the two groups?
>
> Research Question 3: How do students perceive flipped learning and teaching (aspect of satisfaction, perception of advantages and disadvantages, etc.)?

Method

Design

We used the descriptive and the causal-experimental methods of educational research. We used the quantitative approach. In part, we used the qualitative approach when analyzing the answers to the open questions of the questionnaire.

Participants

The research sample was comprised of 55 students of 7th grade in the selected Slovenian primary school (13-year-olds). It was a convenience non-probability sample: students of two 7th grade parallel classes (7.a and 7.b) were included. For the sake of flexible differentiation in class, the students of both parallel classes had already been divided into two sections, heterogeneous by preknowledge (i.e., knowledge on the topics later taught in two different ways), before they were assigned to one of the two groups in the experiment. We further divided each section into two groups, one of which was a control group (CG) and the other experimental group (EG); this time, we split the students of each section in half based on the alphabetical order of their surnames, so that the first half was assigned to the CG and the other half to the EG. As shown in Figure 1, the groups were mixed by gender (M = male; F = female).

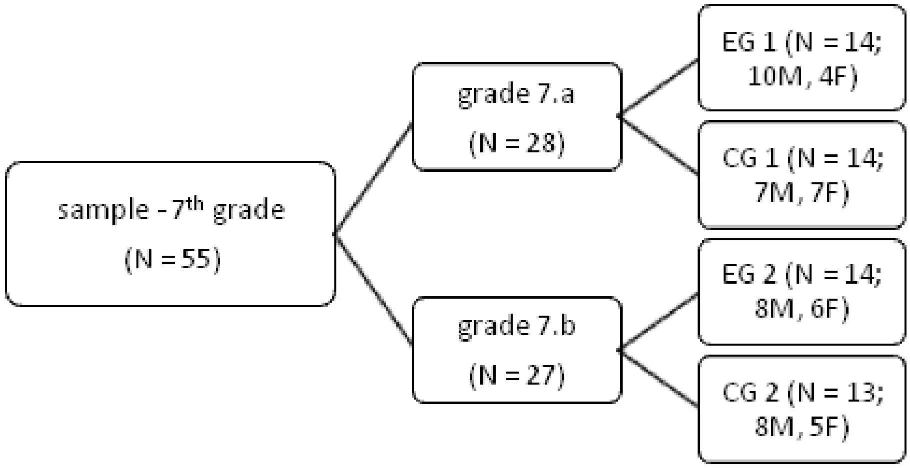

Figure 1. Participants – groups and subgroups

DATA COLLECTION

Experiment

First, a pedagogical experiment was conducted to collect data. The experiment was conducted during a math class, where the topic of the area of polygons was discussed. Parental consent was obtained before the experiment began, and participation in the experiment was voluntary. We used a pretest, a posttest, and a second posttest to collect data.

In the study, we were only interested in the effects of flipped learning and teaching on learning outcomes. Therefore, it was important to control all possible aspects and thus try to isolate the effect of flipped learning and teaching as much as possible. For this reason, the students were divided into groups CG and EG based on their last names and not on other criteria that could be related to their prior knowledge, skills, motivation, and so forth. The tests were administered to both groups simultaneously; the posttest was administered just before the end of the school year, while the second posttest took place after the summer holidays when the students were expected to have the least contact with each other.

All groups were given the same pretest before the start of the experiment, in which the students' knowledge of the subject matter before studying it was assessed. This was followed by the main part of the experiment. In the CG, the lessons were conducted in the traditional way so that the study of the new material was carried out at school during the lessons.

In the EG, the approach was different, and flipped learning and teaching were used. An explanatory video was pre-recorded that was as similar as possible to the explanation that the first group received at school. The EG students were instructed to watch the video at home and take notes. This was the only way to ensure that the students actually watched the video at home. At school, there was an adapted lesson that included different types of practice and repetition, with the teacher primarily playing the role of a motivator for learning and the moderator of students' collaboration. In addition, both groups had another lesson dedicated to practice and repetition (the course of both lessons was as similar as possible). Within two or three days after the pedagogical experiment, a posttest followed, the questions of which were at least partially comparable to those of the pretest. The posttest was conducted in both the CG and the EG. After about three months, the second posttest was conducted to determine the retention of the acquired knowledge. The timeline of the experiment is shown in Figure 2.

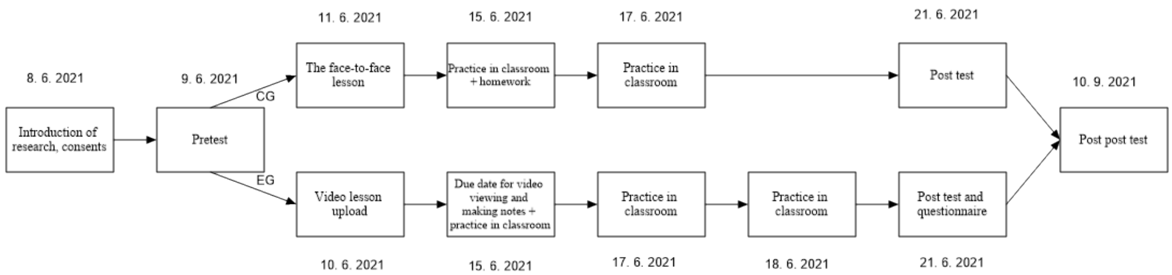

Figure 2. The research model

Pretest, posttest and second posttest

A pretest, a posttest, and another posttest were used to check the students' knowledge. All three tests consisted of 13 tasks, with the first six tasks relating to the perimeter of polygons and the second six tasks relating to the area of polygons. The last, more complex task focused on the perimeter and area of polygons. The maximum score for each test was 30.

Written survey

At the end of the experiment, a short survey was also conducted to determine the satisfaction of the students of EG with the flipped learning and teaching approach. The questionnaire consisted of four parts. In the first part, students indicated on a Likert scale how they perceived flipped learning and teaching. In the second part, a dichotomous question was used to get an insight into whether the students would be willing to participate in a class with a flipped learning and teaching approach in the future. In the third part, they expressed how much they would participate in class if flipped learning and teaching were used in the future, and in the last part, they wrote down their answers about the advantages and disadvantages of the approach using open-ended questions.

DATA ANALYSIS

Two sets of data were analyzed, namely the data obtained using the pretest, the posttest, and the second posttest, and the data obtained using the questionnaire. The descriptive and inferential statistical analyses were performed using the IBM SPSS Statistics 25 program. We began the statistical analysis by combining the two EGs into one EG and the two CGs into one CG. With this grouping, we tried to mitigate the influence of the prior knowledge of each part on the final results of the analysis as much as possible. In all of the analyses, performance was represented by the total number of points achieved in the selected test. The pretest, posttest, and second posttest data followed a normal distribution for both EG and CG (see Table 2).

Table 2. Normality test for pretest, posttest and second posttest scores for experimental and control group

	Shapiro-Wilk test						
	Statistics			df	Statistical significance		
	Pretest	Posttest	Second posttest		Pretest	Posttest	Second posttest
EG	0.956	0.954	0.961	26	0.319	0.290	0.420
CG	0.976	0.962	0.961	26	0.784	0.425	0.420

The variances of the scores in both groups were homogenous (see Table 3). Additionally, the number of observations for each group was $n > 15$ (Frost, 2020, p. 49), which allowed us to use the independent *t*-test to check for the statistical significance of the differences in achievements between both groups. Similarly, the normal distribution of the data from the pretest, posttest, and second posttest allowed for the use of a dependent *t*-test (the requirement of minimum number of observations was also met: n > 20 (Frost, 2020, p. 46)).

Table 3. Homogeneity of variances test for pretest, posttest and second posttest scores for experimental and control group

	Levene statistics	df1	df2	Statistical significance
pretest	0.195	1	50	0.661
posttest	0.088	1	50	0.768
second posttest	0.786	1	50	0.380

Further, we performed an analysis of covariance to find the differences in the knowledge students achieved in EG and CG in case we eliminated the influence of preknowledge.

Quantitative analysis of the data obtained through the survey questionnaire was carried out with the help of IMB SPSS Statistics 25; we looked at the frequency distributions of the answers to each question in the first three parts of the questions. For the analysis of the questions from the fourth part, we followed a more qualitative approach by performing a content analysis of the answers given by the surveyed students.

RESULTS AND DISCUSSION

In this section, we present the results of the study. We have organized the results according to the research questions posed. In the following, we answer these questions and propose possible interpretations of the results in the discussion.

THE DIFFERENCES IN GAINED KNOWLEDGE OF STUDENTS IN EXPERIMENTAL AND CONTROL GROUPS

To determine the differences in knowledge of students taught with a flipped learning and teaching approach compared to students taught with a traditional approach, we first tested students' prior knowledge in the EG and CG in the pretest (Table 4).

Table 4. Descriptive statistics for pretest achievement for experimental and control groups

	Mean	Frequency	Standard deviation	Minimum	Maximum
EG	19.9038	26	5.08531	6.50	28.00
CG	19.5192	26	5.37863	8.00	29.00
Total	19.7115	52	5.18609	6.50	29.00

However, the analysis showed that there were no statistically significant differences in the average scores on the pretest $t(50) = 0.27$, $p = 0.792$.

The analysis showed that there were no statistically significant differences in pretest achievement means, with $p>0.05$. The results of the SPSS analysis are shown in Table 5. We proceeded with the analysis of covariance, in which we were interested in finding the differences in the knowledge students achieved in the EG and CG, in case we eliminated the influence of preknowledge.

Table 5. Analysis of covariance for posttest achievement for experimental and control groups

Source	Type III Sum of Squares	df	Mean square	F	Statistical significance
Corrected model	687.107	2	343.553	22.777	0.000
Intercept	119.280	1	119.280	7.908	0.007
Points on pretest	687.063	1	687.063	45.550	0.000
EG and CG	1.414	1	1.414	0.094	0.761
Error	739.100	49	15.084		
Total	22166.250	52			
Corrected Total	1426.207	51			

From Table 5, we can see that when we exclude the effect of prior knowledge on the posttest result, the posttest results did not differ significantly between the EG and CG ($p>0.05$). From the obtained results, we conclude that the two groups did not differ significantly in the short-term knowledge measured directly after the experiment. Abeysekera and Dawson (2014) pointed out the lack of empirical evidence for the positive effects of flipped learning and teaching. So far, empirical research has shown ambiguous results when it comes to the impact of this approach on students' learning outcomes. Some comparable studies (Beronja, 2017; Betihavas et al., 2016; Giannakos et al., 2014; Khadragy, 2016; Leo, 2017; Lo & Hew, 2017) as well as some meta-analyses (see Birgili et al., 2021; Bormann, 2014; Kozikoglu, 2019) confirm positive effects of flipped learning and teaching on student achievement, while others find no statistically significant differences in learning outcomes compared to traditional instruction (Bell, 2015; Bishop, 2013; Dixon, 2017; Glynn, 2013; L. Johnson & Renner, 2012; Prefume, 2015; Saunders, 2014; Willis, 2014).

Despite some encouraging results regarding the effects of flipped learning and teaching on academic achievement, some studies have found no statistically significant differences between experimental and control groups, which is consistent with the results we obtained, so we can conclude that in our case, the flipped learning and teaching approach proved to be as successful as the traditional approach in terms of test results.

In the following subsection, we look at the long-term effects of our experimental intervention and reflect on the possible reasons for the results we obtained.

The Differences in Knowledge Retention for Students in Experimental and Control Groups

To determine the differences in retention of acquired knowledge between students in the two groups, we first tested students' performance on the posttest and the second posttest for the EG and CG (Table 6).

Table 6. Descriptive statistics for posttest achievement for experimental and control group

	Mean	Frequency	Standard deviation	Minimum	Maximum
EG	19.9423	26	5.13094	10.50	28.00
CG	20.0000	26	5.54256	11.00	30.00
Total	19.9712	52	5.28818	10.50	30.00

In Table 6, we can see that in the posttest, the CG's average score was slightly higher (M = 20.00, SE = 5.54) than the EG's (M = 19.94, SE = 5.13), yet the differences were statistically insignificant, $t(50) = -0.04$, p = 0.969.

In the second posttest, on the other hand, the EG's average score was slightly higher (M = 18.48, SE = 5.06) than the CG's average score (M = 17.06, SE = 5.95). However, the differences proved to be statistically insignificant, $t(50) = 0.93$, p = 0.357 (see Table 7).

Table 7. Descriptive statistics for second posttest achievement for experimental and control group

	Mean	Frequency	Standard deviation	Minimum	Maximum
EG	18.4808	26	5.06059	9.50	27.00
CG	17.0577	26	5.95202	7.50	27.50
Total	17.7692	52	5.51687	7.50	27.50

Comparing the achievements in the posttest and the second posttest for the CG, we can see that, on average, the students scored lower on the second posttest (M = 17.06, SE = 5.95) compared to the posttest (M = 20.00, SE = 5.54). The differences in the achievements proved to be statistically significant, $t(25) = 3.30$, p = 0.003.

Comparison of the achievements in the posttest and the second posttest for the EG, on the other hand, shows a smaller difference in the average scores between the second posttest (M = 18.48, SE = 5.06) and the posttest (M= 19.94, SE = 5.13), with differences being statistically insignificant, $t(25) = 1.88$ p = 0.072.

Thus, through analysis, we found that the knowledge of students who were taught the subject matter through the flipped learning and teaching approach was more durable than the knowledge of those who were taught through the traditional approach. Knowledge retention is inherently extremely important; Marentič Požarnik (2011, p. 31) characterizes it as one of the main traits of quality knowledge. A study by Beers and Bowden (2004) analyzes the difference between traditional and problem-based approaches to learning and teaching. Admittedly, it is not the same case as here, but it is interesting that the two authors came to similar conclusions. In the test conducted immediately after the intervention, there were no significant differences in the results, but after one year, it was shown that the students who had participated in the innovative approach achieved better results in the tests. One of the possible explanations could be that the better retention of the students' knowledge in the EG is related to the fact that in this approach, the learning pace is adapted to each student individually, as they choose it themselves. This can be linked to the idea of "mastery learning," popularized by Bloom in the 1960s (Bloom, 1968, as cited in Eppard & Rochdi, 2017). Although this idea is not directly related to flipped learning and teaching, it can be understood as something that supports such innovation. Similar to mastery learning, in flipped learning and teaching, students acquire the learning material at their own pace (Eppard & Rochdi, 2017), so we presume this had a positive impact on knowledge retention in our case.

One explanation for this could also lie in certain changes that flipped learning and teaching bring to the learning stages – particularly in terms of the order of the stages. The study of new material is shifted to the home environment, while more time is spent at school on practicing, training, and repetition (Plešec Gasparič, 2019). Repetition, practice, and training are, of course, stages that are strongly related to the retention of knowledge. If students engage with this to a greater extent under the guidance of the teacher, this can have a positive impact.

Previous research has similarly confirmed that flipped learning and teaching contribute to knowledge retention (Graham et al., 2019; Mithun & Evans, 2018). However, Kapur et al. (2022) caution that there is no singular form of implementation in flipped learning and teaching, but it can involve many different instructional methods, approaches, activities, etc., not all of which may contribute to the quality of knowledge. Therefore, it is crucial that the teacher prepares meaningful learning experiences for students that allow them to be cognitively active, engage with the content, think creatively and critically, and solve problems.

The better retention of knowledge could also be related to the fact that students are more engaged due to new and unexpected learning situations, which causes their higher motivation to learn and a more positive attitude towards learning, which will be discussed in the next subsection.

Students' Perceptions of Flipped Learning and Teaching

To find out how students perceived flipped learning and teaching, we asked them four sets of questions: (a) satisfaction with the approach; (b) whether students would like to see such a way of learning and teaching in the future; (c) whether students would participate more in class if the flipped learning and teaching approach were implemented more often; and (d) what students liked and disliked about the flipped learning and teaching approach, or where they see advantages and disadvantages (Table 8).

Table 8. Frequency distribution for students' agreement with statements about flipped learning and teaching

Level of agreement Item	I do not agree	I partly agree	I agree	I completely agree
1. *I liked learning by watching recorded explanations more than listening to the explanations in class.*				
Frequency	2	8	8	8
Percentage	7.69%	30.77%	30.77%	30.77%
2. *My motivation for work was higher.*				
Frequency	6	8	8	4
Percentage	20.08%	30.77%	30.77%	15.38%
3. It was easier to follow the explanation in the video than in school.				
Frequency	2	4	12	8
Percentage	7.69%	15.38%	46.15%	30.77%
4. The classes that were done face-to-face were more interesting than usual.				
Frequency	6	5	10	5
Percentage	23.08%	19.23%	38.46%	19.23%
5. *I was more eager to do the in-class tasks than usual.*				
Frequency	7	6	10	3
Percentage	29.92%	23.08%	38.46%	11.54%
6. I learned more than I usually do.				
Frequency	8	16	2	0
Percentage	30.77%	61.54%	7.69%	0%

Table 8 shows that, overall, the students evaluated flipped learning and teaching positively. For most of the statements related to motivational aspects, the rating "I agree" is represented by the largest proportion, while for the item where students rated the knowledge acquired, the rating "I partly agree" came first (but no one chose the rating "I completely agree").

If we look at the first statement ("I liked learning by watching recorded explanations better than listening to the explanations in class"), we can see that the students were generally satisfied with the video presentation of the topic, although this satisfaction was not so pronounced. The same proportion of students partly agreed, agreed, and completely agreed with this statement. Only 7.69% of the students disagreed with this statement.

With regard to the second statement ("My motivation for work was higher"), we were particularly interested in the motivation to work. The motivation to work does not appear to be significantly higher with a flipped learning and teaching approach than with traditional instruction. Only 15.38% of students completely agreed that motivation to work was higher with the flipped learning and teaching approach, while 20.08% disagreed, and 30.77% agreed or partially agreed with the statement.

For the third statement ("It was easier to follow the explanations in the video than at school"), we were interested in whether the students found it easier to follow the topic in the video than at school. We found that the students were able to follow the topic more easily in the video than at school, as 46.15% of students agreed with this statement, and 30.77% completely agreed with it.

In the next statement ("The classes that were done face-to-face were more interesting than usual"), we were interested in how interesting the students found the lessons conducted at school. We found that students found the lessons in school with the flipped learning and teaching approach more interesting, as 38.46% of students agreed with this statement, and 19.23% strongly agreed. Nevertheless, there is a non-negligible proportion of students who disagreed with this statement, namely 23.08%.

For the fifth statement ("I was more eager to solve the in-class tasks than usual"), we were interested in whether the students enjoyed solving the assignments more with the flipped learning and teaching approach than in the traditional format. We found that a significant proportion of the students agreed with this statement – 38.46%; however, 29.92% disagreed with this statement.

For the last statement ("I learned more than I usually do"), we were interested in whether the students felt that they learned more with the flipped learning and teaching approach than with the traditional approach. The majority of students, 61.54%, only partially agreed with this statement, only 7.69% agreed, and no one completely agreed.

In the second part, we were interested in whether students would like to see a flipped approach to learning and teaching in the future. Students could answer yes or no to this question. We found that 80.77% of students would like more lessons with a flipped learning and teaching approach in the future.

In the third part, we were interested in whether the students would participate more in class if the flipped learning and teaching approach were used more often. There were two answers to this question, namely that they would participate just as much as they do now or that they would participate more than they do now. We found that slightly more students – 53.85 % – felt that they would participate more than they do now if more classes were conducted using a flipped learning and teaching approach.

In the fourth part of the survey, we wanted to know what students liked and disliked about the flipped learning and teaching approach. Here, there were two open-ended questions ("Write down what you liked about the way you were taught in the last week – from receiving the new material to classroom teaching and write down what you did not like about the way you were taught in the last week – from receiving the new material to classroom teaching"). Table 9 shows the most frequent positive aspects that students expressed about flipped learning and teaching.

Table 9. The most frequent positive aspects of flipped learning and teaching exposed by the students

Positive aspects	Frequency
You can hear explanation several times	8
You can stop the video	7
Less time is needed for content treatment (video is short)	5
More cooperation	2

The students emphasized the positive aspects (all 26 surveyed students highlighted at least one positive aspect) much more than the negative aspects of the flipped learning and teaching approach (only 4 of all students surveyed highlighted at least one negative aspect, with 3 of them noting that it bothers them that they cannot ask the teacher questions while watching the video).

One of the findings from the students' answers is that the students follow the topic presented in the video more easily and also enjoy doing the tasks at school more. The effectiveness of the presentation of the topic through the video is also shown by the fact that the students emphasized, as a positive aspect of flipped learning and teaching, the fact that they could watch the video with the explanation several times. A similar advantage of flipped learning and teaching was also emphasized by the students in the study by Plešec Gasparič (2019).

One of the negative aspects of the flipped learning and teaching approach is related to the home phase and teaching the subject matter via video, namely that they cannot ask the teacher questions at home; also, in this case, similar negative aspects of flipped learning and teaching were highlighted by the students in Plešec Gasparič's (2019) research. At the same time, we can also wonder how effectively students can follow the explanations if they have problems understanding the basic concepts in the explanation – this is even more difficult if there is no teacher by their side who can notice this and help solve the problem. Similar to what we found, Bergmann and Sams (2012) also pointed out that the fact that the teacher is not available to answer questions at home is a negative aspect of the flipped learning and teaching approach. They believe that the solution to this problem is simple, which is to teach students at the beginning of the year how to watch videos in which the subject matter is presented as effectively as possible. This includes teaching them to take notes as they watch and to write down their questions for the teacher. At the beginning of the lesson at school, the teacher should take some time to answer exactly these questions from the students. Similarly, Xiu and Thompson (2020, p. 57) also claim that one of the key findings of their research is that the teacher needs to "model, encourage, and monitor students' before-class preparation to ensure they are ready for in-class activities, with which they scaffold students' success in a digitally-based learning environment" (Sharp & Sharp, 2017, p. 224).

Another interesting fact we can point out is that although the students' knowledge proved to be more durable in the second posttest, they themselves were not as convinced of it. As can be seen from the ratings of the statement "I learned more than I usually do," the students generally leaned towards disagreement. Nevertheless, they expressed that they want this type of approach to continue in the future, which suggests the students' openness to innovation.

Similarly to our findings, positive student attitudes toward flipped learning and teaching have also been confirmed by other authors (Al Ghawail & Ben Yahia, 2021; Bell, 2015; Farah, 2014; Hantla, 2014; Leo, 2017; Prefume, 2015; Tanner & Scott, 2015; Vaughn, 2014; Yang, 2017). However, the research conducted by Xiu and Thompson (2020) was inconclusive as to whether they want this type of implementation to continue in the future, similar to some other contradictory results (Hunley, 2016; L. Johnson & Renner, 2012; Willis, 2014). In the research conducted by Sommer and Ritzhaupt (2018), it was even shown that students were dissatisfied with flipped learning and teaching and were more in favor of traditional implementation and that flipped learning and teaching had no impact on their higher academic achievement compared to traditional implementation. Further limitations of the approach are highlighted by Tanner and Scott (2015), namely that students find it difficult to take personal responsibility for their own learning and to participate in class discussions.

The findings of our research provide insight into the effectiveness of flipped learning and teaching in a specific learning situation. Based on the positive outcomes of the second posttest, these results encourage math teachers, as well as teachers of other subjects in Slovenia, to use flipped learning and teaching more widely. This is further supported by the students' positive perception of this approach. Finally, the findings of our research are informative for teacher educators when planning undergraduate learning processes and teacher training.

CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH

The aim of the study was to find out whether there is a difference in the knowledge of the subject of mathematics in the 7th grade between the group of students that was taught the material of the area of polygons in the traditional way and the group that was taught this material using the flipped learning and teaching approach.

We found that there were no statistically significant differences between the two groups in terms of acquired knowledge. Thus, it appeared that both the traditional and flipped learning and teaching approaches were equally successful in imparting knowledge to students.

On the other hand, the results showed that there were statistically significant differences between the knowledge retention of the two groups. The group that was taught the subject matter using the flipped learning and teaching approach retained more knowledge than the group that was taught using the traditional approach.

Furthermore, the study revealed that the students were quite satisfied with this approach and wanted such innovations to be part of instruction in the future. It is also interesting to note that they only mentioned one negative aspect of this approach (the fact that it is not possible to ask the teacher), which can be mitigated quite easily with more detailed instructions on how to watch videos and learning to learn.

Through our analysis, we were not able to determine what caused the knowledge of the students in the experimental group to be more durable than the knowledge of the students in the control group. It could have been what the students themselves described as one of the positive aspects of flipped learning and teaching, namely the opportunity to see and hear the explanation of the learning material several times (it is important to note that the students no longer had the learning material available after the posttest and therefore could not view it before the second posttest). Knowledge retention could also be influenced by the method of practical work during the face-to-face lessons, which aimed to make the students apply the knowledge in a more practical way. From the survey, we can also conclude that they were more satisfied with this approach, which could also have a positive effect on knowledge retention.

The circumstances under which the experiment was conducted prevented us from fully isolating the experimental factor (flipped learning and teaching). The students involved in the experiment came from the same school and were classmates, so there was no possible strategy to prevent their contact and exchange of information and experiences. However, the fact that they participated in an experiment at school speaks to their overall motivation to participate in the research activities.

Due to the aforementioned limitations of the study and also due to the fact that there is no single mode of implementation for flipped learning and teaching, which means that the effects on academic achievement, knowledge retention, and students' perceptions largely depend on the specific learning activities, the results cannot be generalized for all schools, all subjects and not even for all content in mathematics, but the findings can serve as a suggestion and warning to teachers when introducing flipped learning and teaching into their classrooms.

In the future, it would be important to examine what this factor is that ensures a higher level of knowledge retention under a flipped approach to learning and teaching than under a traditional approach. It would also be important to determine the impact of flipped learning and teaching on other topics in mathematics classrooms, in other age groups of students, and in other subjects in primary school classrooms.

The results of this study contribute to the body of knowledge about the relatively recent didactic innovation of flipped learning and teaching. They emphasize the contribution of flipped learning and teaching when it comes to providing quality knowledge, especially knowledge retention. Moreover, its effectiveness is also reflected in the students' positive attitudes towards such instruction, which, in the case of repeated positive experiences with the learning process, gives a better prospect of their readiness for lifelong learning.

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