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Using Flipped Classroom as an Active Teaching Method for Teaching Engineering Graphics

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Abstract. Specialists in engineering must effectively communicate their ideas using technical drawings. To develop students' technical drawing skills, the subject of engineering graphics aims at using appropriate teaching methods. This study proposes a novel approach to teaching engineering graphics, that is, an active method of Flipped Classroom (FC) that incorporates H5P tools. These tools have been shown to effectively support self-directed learning and enable in-class activities, ultimately enhancing the effectiveness of the FC method. The study results demonstrate a positive impact of the FC method on students' knowledge levels. By integrating the FC method with H5P tools, the study establishes a powerful learning environment that promotes deep learning and increases student engagement in engineering graphics.

Keywords: Flipped Classroom method, Engineering Graphics, H5P tools

1. Introduction

The formation of the professional thinking of an engineer, on which the success of a person's professional activity partially depends, begins with university studies (Krasovskaya, 2018). In the training of future construction specialists and engineers, a particular emphasis is placed on the teaching of engineering graphics. This is because the ability to express ideas and objectives in an engineering language is one of the most critical competencies for professionals in this field. The ability to communicate graphically is essential to other technical areas that foster spatial thinking and the need to master various simulation techniques (Lopez-Pena and Lopez-Chao, 2017). Basic engineering drawing skills are commonly used to create rapid two-dimensional drawings during discussions to showcase ideas (Langenbach et al., 2015). Professional training of specialists is closely related to the study of descriptive geometry, engineering graphics, computer graphics, and other related disciplines.

Students often enrol in technical specialities without any prior knowledge of the subjects they will be studying or the challenges they will face (Metraglia et al., 2015; Khoza, 2014; Vilkevič, 2022). Many of these students have little to no background in engineering graphics, making it difficult for them to adapt to higher education. Teachers face the challenging task of finding effective teaching methods without the opportunity to give special attention and additional time to students who lack primary preparation. Therefore, finding appropriate teaching methods and activities and their application is one of the most critical elements in the organisation of the teaching process (Droessiger and Vdovinskienė, 2020).

In the age of technological breakthrough, there must be a fundamental change in education, especially engineering education delivered to current and future generations so that engineering graduates are prepared to face the challenges of a rapidly changing world (Wang et al., 2021). Tools and methods of teaching engineering graphics depend on a number of factors: content and objectives of the subject, teacher competence, number of students, study time (Lopez-Pena and Lopez-Chao, 2017; Wang et al., 2021).

One of the rapidly growing popular methods of active learning is the Flipped Classroom (Cho et al., 2021). This method allows students to master the subject material independently, at their own pace, and at a location of their choice. In-class sessions are then used to consolidate this knowledge through active activities. By analysing new learning material at home, students can use contact hours to clarify any unclear issues and explore topics in greater depth. For engineering graphics lecturers, it is crucial to prepare teaching materials and plan activities that encourage student participation in the learning process.

Literature review of this paper indicates a shortage of active learning methods in teaching engineering graphics that effectively involve students in deeper learning. The purpose of this paper is to reveal the effectiveness of applying the active FC method in teaching engineering graphics. The following two research questions were posed to guide this study: (1) What is the impact of Flipped Classroom on students' knowledge acquisition in Engineering Graphics compared to traditional learning methods? (2) Which H5P tools are suitable for fostering student engagement and promoting interaction when implementing the Flipped Classroom method for teaching Engineering Graphics?

2. Overview of learning methods and tools of engineering graphics

Motivation is a crucial factor in achieving successful learning outcomes (Nadelson, 2015). To enhance student motivation in Engineering Graphics education, it is important to apply engaging learning tools. Game-based elements integrated into the instructional environment (Gomez-Jauregui, 2016) may serve as an effective tool for this purpose. An experiment conducted in a Spanish higher education institution demonstrated that the incorporation of such elements resulted in an improvement in knowledge acquisition for up to 87% of the participating students. Visualisation plays a critical role in the effective teaching of Engineering Graphics, and educators are exploring various visual teaching methods to enhance the learning experience. To make the learning process more engaging and facilitate better understanding, popular leisure tools among young people are being incorporated into the curriculum (Sampaio et al., 2010). Virtual reality is recognised as a particularly powerful tool to promote imagination development, and the use of games such as Minecraft has been recommended by Spanish educators for this purpose (Klerk et al., 2019). To prepare students for technical specialist roles in various engineering fields, close collaboration with industry partners is crucial (Motyčka et al., 2014). This approach allows students to apply theoretical knowledge to real-world examples, and working with construction companies can help future engineers in the field of construction develop spatial thinking skills and gain a better understanding of construction project drawings. In cases where physical objects are not available for examination, a variety of visual tools can be used to facilitate understanding (Langenbach et al., 2015; Martínez and Morales-Segura, 2018). The use of any computer graphics program is an integral part of teaching engineering graphics. Each higher education institution chooses that according to its purpose and the advantages of the program. However, first it is necessary to learn how to use computer graphics software so that it becomes a simple and uncomplicated drawing tool, and only then to familiarise oneself with the requirements of formation of engineering drawings. Computer training will proceed more smoothly if minimal interim surveys that determine the student readiness to accept information during the formation of computer skills are used (Tel'noy and Tsareva, 2012). Furthermore, graphic collaboration among teams has a major influence on forming computer skills (Huaiwen et al., 2013).

In the domain of higher education, it is common occurrence for students to possess diverse levels of fundamental knowledge in the area of engineering graphics. Basic concepts such as geometric shapes and their interrelationships may prove challenging to some learners. To address this issue, introductory courses need to be offered to standardize the initial graphic knowledge of students (Cobos-Moyanoa et al., 2009; Khoza, 2014; Metraglia et al., 2015). Such courses play a crucial role in bridging the gaps in students' foundational knowledge and enhancing their comprehension of the fundamentals of engineering graphics (Cobos-Moyanoa et al., 2009). Those students who have taken advantage of such courses acknowledge their usefulness as they facilitate the understanding of the significance of the basic principles of engineering graphics and the use of computer software in the creation of drawings (Khoza, 2014).

The process of learning is closely intertwined with the memory retention capacity of students, which requires the use of tools that aid in the recollection of information. The probability of memorisation increases when learning involves multiple senses (Droessiger and Vdovinskienė, 2020). It is recommended to offer a tactile experience, in addition to the usual visual and auditory techniques. This enables students to grasp the object that needs to be depicted. Providing students with the opportunity to dismantle a real product and subsequently generate drawings of its constituent parts is recommended (Kosse and Senadeera, 2012).

In recent times, the Moodle platform has emerged as one of the most effective e-learning systems. It is suitable for presenting subject material online and offers the possibility of conducting specialised tests or expressing opinions that can enhance the learning process (Osadcha et al., 2021; Speranza et al., 2017). Additionally, Moodle provides an environment to incorporate interactive tools, such as H5P, which facilitates gaming quizzes (López, 2021).

Spatial thinking is an essential factor in assessing the proficiency of engineering graphics. Development of spatial thinking skills involves enhancing students' ability to identify and articulate problems, think creatively, and communicate ideas effectively. This process demands a significant amount of attention from the learner. In particular, solving problems in descriptive geometry is considered one of the most effective approaches to cultivating these abilities (Krasovskaya et al., 2018).

The interactive whiteboard is an efficient pedagogical tool that facilitates the presentation of learning material. It serves as a universal platform that can be used as a stationary drawing board and a computer. Additionally, it provides access to the internet and allows teachers to incorporate online resources into their teaching (Šipailaitė - Ramoškienė, 2012). This technology has been used extensively in education for several decades. Nonetheless, it has been observed that there are some mechanical challenges associated with its application, including difficulties in making large drawings and faster depreciation compared to traditional blackboards. To address these concerns, it is recommended to adopt a hybrid teaching system that combines the use of a traditional blackboard, which can serve not only as a drawing platform but also as a screen for displaying projector images (Banias and Milincu, 2019).

Technical practice places greater value on individual creativity and ingenuity, as opposed to precise knowledge of rules and standards for preparation of technical documents. As a result, there is a need to prioritise the promotion of student intelligence in this regard. Innovative teaching approaches for CAD/CAE systems advocate for the organization of training programs that require students to first create a three-dimensional model of an object and subsequently analyze the technical regulations for generating a two-dimensional drawing (Kuna et al., 2018).

In light of the widespread adoption of IT technologies in various sectors of society, it has become imperative to incorporate them into the education system. iPad tablets have proved to be useful for presenting electronically submitted structural drawings. Although the precise impact of these technologies on improving student performance has not been clearly established (Escamilla et al., 2018), the adoption of innovative technologies in education serves as a motivating factor for student learning. American researchers suggest the use of interactive paper for smartphones and computer screens to create drawings, providing an effective interaction method between smartpens and small mobile computing devices, such as smartphones and tablets (Lee and Stahovich, 2014). IT technology facilitates creativity and innovation, making the learning process more engaging and less routine (Lopez-Pena and Lopez-Chao, 2017). Furthermore, the use of augmented reality applications enables students to visualise virtual 3D objects integrated into a real-world camera view, thus enhancing the learning experience (Suselo et al., 2019).

When teaching of engineering graphics is limited, it becomes crucial to adopt effective teaching methods that incorporate both traditional and innovative techniques for creating technical drawings (Jianqing and Zibin, 2015). In modern times, graphic editors such as tree diagrams or mind maps are widely used to present learning material, evaluate the assimilation of outcomes, and promote students' innovative skills. By converting information and ideas into graphics, students can better understand the topic. Creating a mind map, for instance, requires a focus on the relationship between the elements and an examination of each meaning (Svanstrom et al., 2018).

Active learning approaches favour student-centred learning, where students actively participate in the learning process (Kadam et al., 2021; Mingxia, 2021). One of such methods is project-based teaching, when students work on a project while the teacher acts as a guide and supervisor. This approach allows students to connect theoretical knowledge with practical applications and promotes a professional mindset. Qualified teachers, selected for their expertise in a given area, can share their knowledge with students to facilitate learning (Mingxia, 2021).

Spatial thinking is a crucial aspect in developing students' perception of engineering graphics. Therefore, methods that enhance spatial thinking are vital. Brainstorming exercises, accompanied by visualizations created using Blender program tools, help students develop spatial imagination and find solutions to tasks (Kadam et al., 2021).

The TIMeR program is a hands-on training initiative designed to improve mental rotation skills. The program is divided into three phases: the Preparatory Phase (Phase 1), the Training Phase (Phase 2), and the Transfer Phase (Phase 3). Each phase comprises various training activities that involve active manipulation of a 3D object displayed on a computer screen. These activities are designed to enhance mental rotation skills (Kadam et al., 2021).

In the case of insufficient teaching hours, it is recommended to use the blended teaching model when the chosen online platform enables the presentation of learning materials (both text and visual). A certain amount of subject material can be absorbed independently (Zhang and Hu, 2021). To achieve effective results, it is recommended to update the assessment system; for example, in the case of blended education, it is recommended to assess the tasks completed at home studying a new topic, in class, and at home while deepening of the information heard in class ("before class + in class + after class") separately (Zhang and Hu, 2021).

Descriptive geometry is an essential component of engineering drawings and is typically integral to the teaching of engineering graphics. However, many students find it challenging, not only due to the extensive theoretical material involved, but also because of the lack of spatial thinking ability, particularly when imagining the intersection of bodies (Vilkevič, 2022; Zhang et al., 2021). To address these difficulties, it is recommended to use visualisation tools that can effectively convey complex concepts in a clear and immediate manner (Vilkevič, 2022). A crucial factor in the reformation of graphics content system lies in the effective combination of three-dimensional modelling and traditional graphics content (Zhang et al., 2021). Given that some students may lack basic graphical knowledge, it is essential to begin the study process by developing spatial thinking skills through the use of various computer programs (Guo and Zhu, 2021).

3. Specific features of the Flipped Classroom method

Based on the literature review, it is evident that various tools are used in teaching engineering graphics. However, these tools are applied primarily in the conventional mode of classroom instruction, where the lecturer plays the leading role in presenting the instructional content. Typically, students take notes during the lecture and complete their assignments independently. The teacher serves as the main source of information and is the focus of the learning process. Traditional teaching and learning models frequently adopt a theme-based approach and restrict student involvement in activities, where students are tasked with completing assignments solely prepared by the teacher (Wang et al., 2021).

In the Flipped Classroom model, the learning process is restructured to be centred on the student, who studies new topics independently at home (Fig. 1), while opportunities for deeper analysis of topics are opened in classrooms (Cho et al., 2021). Learning materials are presented online, making the classroom a convenient place for discussion, problem solving, and active learning (Bhata et al., 2020). However, educators face a significant challenge in organising the learning environment to meet the expectations of both the group and individual students, monitoring learning progress, and adjusting the complexity of the content (Bhata et al., 2020).

The method of presenting lesson content has evolved from traditional reading materials to more engaging and effective tools such as video films. Various online platforms such as Khan Academy and Canvas offer the opportunity to create video lessons (Bhata et al., 2020). Additionally, digital animation is a powerful tool for illustrating complex concepts and can be created using platforms like GoAnimate (Díaz et al., 2021). According to Díaz et al. (2021), the use of active tools in teaching fosters student cooperation, creates positive emotions, and strengthens student motivation.

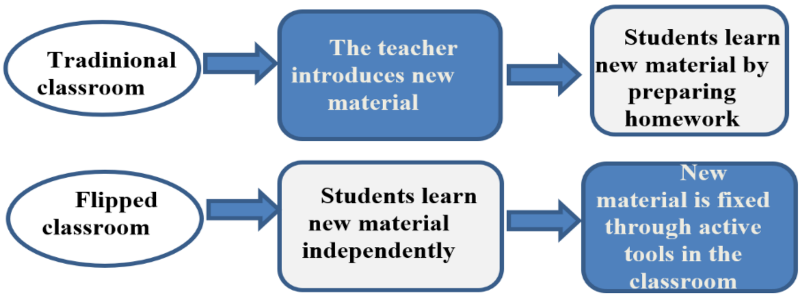


Figure 1. Comparison of Traditional and Flipped Classrooms

4. Application of the Flipped Classroom method in classes of engineering graphics

A study was conducted at Vilnius Gediminas Technical University to implement the Flipped Classroom method for teaching Applied Engineering Graphics to second-year students in the field of mechanics. The course consisted of eight topics, and each topic was assigned two academic hours. Due to the limited contact hours, it was a challenge to cover all the learning material and complete all the assignments for each topic. In this context, students were required to study independently at home, which posed a motivational challenge. The Flipped Classroom method is seen as an effective solution because one of its fundamental principles is self-learning.

When using the Flipped Classroom method, it is recommended to present a detailed work plan before the start of the semester, as illustrated in Figure 2. This plan should include the number of topics and questions to be covered in the course of engineering graphics as well as the planned activities for the course.

No	*TOPICS*	*STUDENTS ACTIVITIES BEFORE LECTURE*	*STUDENTS ACTIVITIES DURING LECTURE*	*TEACHER'S ACTIVITIES BEFORE LECTURE*
3	DRAWING PRINCIPLES	The detailed analysis of the material presented in Moodle. Self-analysis tests. Preparation for the T3 test.	T3 test. Writing and discussing the most important statement on the material read at home. Crossword solution.	Preparation for T3 test. Preparation of the material on topic 3 and uploading it to the interactive H5P book on the Moodle system. Uploading self-analysis tests to the Moodle system.

Figure 2. Fragment of the FC work plan

Interest is a crucial but intangible factor that significantly affects the learning process (Wang et al., 2021). Therefore, educators must present the learning materials in an engaging and comprehensible way. To achieve this goal, the H5P interactive tools were used to present the learning material to the students, which was made available on the Moodle platform (Fig. 3).

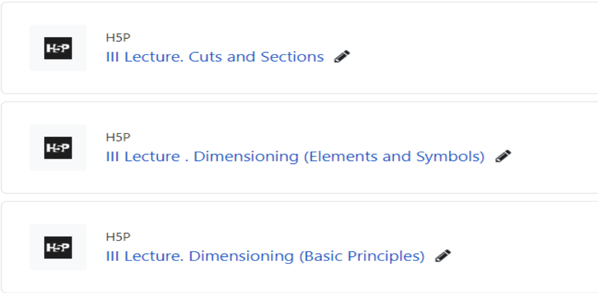


Figure 3. Learning material for the third lecture on the Moodle platform

5. H5P tools application

H5P is a user-friendly platform that enables the creation of interactive tasks using pre-designed templates. Interactive tools have become increasingly popular among students due to their engaging nature and ability to enhance comprehension of academic material (López, 2021). The use of computer quiz games has been implemented as a means of facilitating teaching and learning in academic contexts (Ling et al., 2021; Low et al., 2021).

The H5P platform uses the HTML5 format to display all its components, enabling its use on any internet-connected device, including smartphones and laptops, which is particularly advantageous for younger students. Vilnius Gediminas Technical University recommends using the Moodle platform, which supports H5P tools and is effective in both distance education and blended learning settings (Gudkova et al., 2021; Sáiz-Manzanares et al., 2021), making it an appropriate means of delivering learning materials for home-based learning and classroom activities. The H5P platform provides a variety of interactive tools that can be customised to suit different learning topics. Given that engineering graphics is related to the creation of drawings, visual aids are optimal. Among them, interactive books are particularly well-suited for delivering learning material, offering the flexibility to incorporate various formats, such as text, video, and self-study tests (Fig. 4).

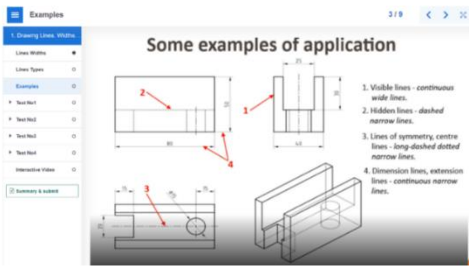


Figure 4. Example of an Interactive book

Students are recommended to assess their understanding of the study material through self-control tests when studying independently at home. These tests come in various forms, with the simplest being the multiple-choice format (Fig. 5a), where students choose one correct answer of the given options. For more challenging questions, students are presented with image cards in which they are requested to write the answer to the question themselves (Fig. 5b). Tests that incorporate interactive features such as the drag function are more engaging to students (Fig. 5c) and are more likely to be attempted during the study of the material.

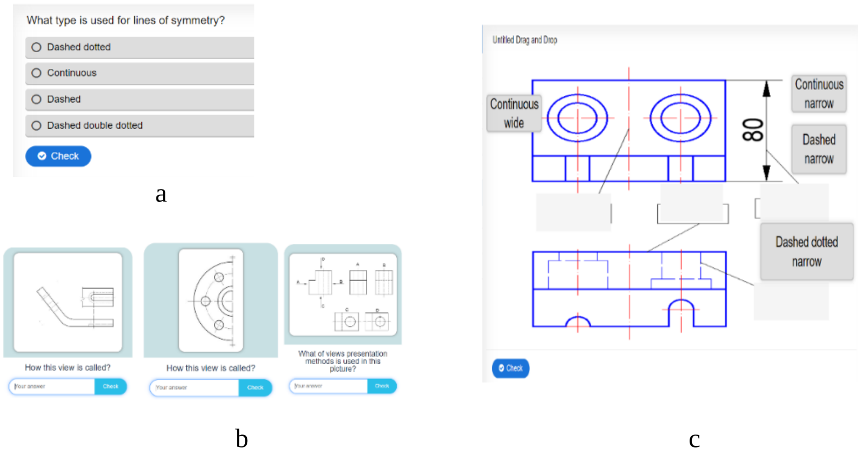


Figure 5. Examples of tests

6. Student activities during contact class using H5P

The Flipped Classroom approach provides the opportunity to foster discussion and critical thinking among students by allowing them to learn new concepts independently before coming to class where they can engage in collaborative and interactive activities (Droessiger and Vdovinskienė, 2020). In this approach, the teacher serves as a facilitator, guiding and supporting students as they work through challenging concepts. Since students are expected to learn new concepts independently, the teacher must address any confusion or misunderstanding during class time to ensure that all students have a solid foundation on which to build their knowledge. As the focus is on active learning, the teacher must be creative in selecting engaging and relevant activities that encourage student participation and foster group cooperation. The Flipped Classroom approach not only deepens students' understanding of the subject matter but also enhances their communication skills through collaborative learning.

Currently, students have a strong affinity for digital technologies and thus it is expected that their preferred activities be related to digital technologies. Traditional manual writing and drawing have been largely replaced by digital technologies, which make it impractical to create drawings using the conventional line-by-line method on a phone. Therefore, the question is how to teach drawing techniques solely on the screen of a smart device. One of the appropriate and engaging ways to present learning material is through the use of interactive tools, particularly those provided by H5P. These game tools are popular with students, particularly when there is an opportunity to compete with each other to complete tasks quickly and correctly. Memory activation during these games can result in better retention of the material learnt. The H5P platform offers a wide range of game tests, with memory cards being particularly effective for engineering graphics classes. In these games, users must match pairs of images, requiring students to first learn the theory of detail views before engaging in the game (Fig. 6.).

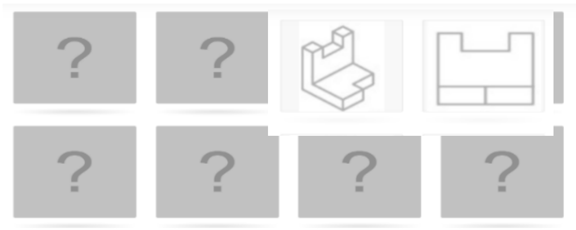


Figure 6. Example of memory games

The game involves the provision of suitable responses within designated blank spaces. The primary aim of this instructional tool is to facilitate not only comprehension of subject matter but also the retention of learnt material while fostering a positive attitude towards learning.

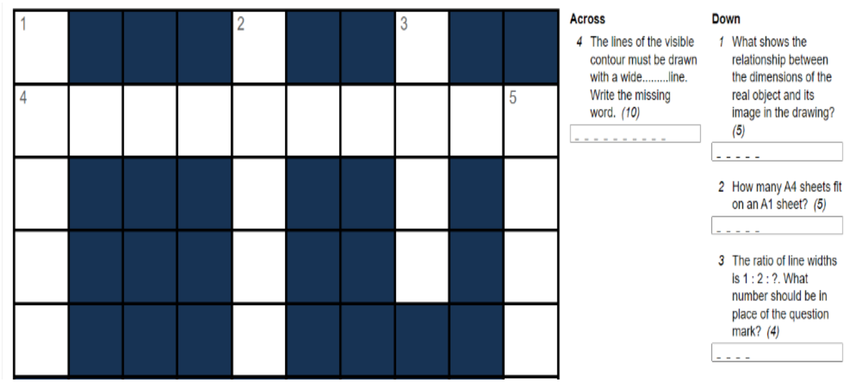


Figure 7. Fragment of a crossword

7. The challenges and benefits of using the Flipped Classroom method

7.1. Study participants

During the academic year 2020-2021, a qualitative investigation was conducted to analyse the effectiveness of the Flipped Classroom approach in learning engineering graphics. The FC methodology was implemented during the practical sessions of the Applied Engineering Graphics course, and the assessments of individual works, tests, and exams were investigated. The study included 38 second-year students in mechanical engineering from Vilnius Gediminas Technical University. Additionally, students were invited to participate in the research and provide feedback on the advantages and disadvantages of the FC method.

Qualitative responses

Before the interview, the students were provided with a detailed overview of the study goals. Participation was voluntary, confidentiality measures were employed to ensure anonymity for all interviewees. Open-ended questions were employed to enable the collection of diverse responses and to afford interviewees greater flexibility and motivation (Yilmaz, 2013). A total of 38 students contributed their perspectives on the effectiveness of the Flipped Classroom approach (Table 1).

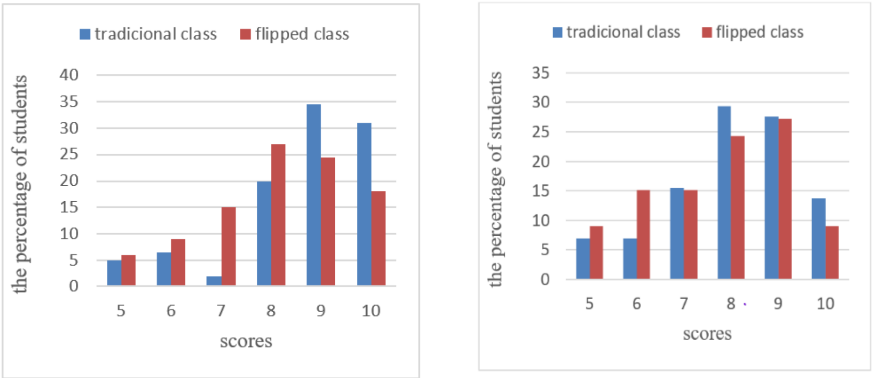
Table 1. Students' opinion on the features of using the Flipped Classroom method

	Comments	Number of responses
Advantages	It is possible to choose the right time and place to study the learning material	9
	Everyone can work at his/her own pace	7
	Independent learning is developed	6
	The material studied is better understood and remembered	5
	An interesting and useful way of learning	5
	Lecture time is used more productively because the learning material has been studied at home	3
	Learning topics are studied faster	3
Disadvantages	It is difficult to force yourself to learn independently	8
	It is difficult to find answers to questions that arise at home	4
	Discomfort in activities that require speaking	3

Most of the participants (23 responses) did not identify any negative aspects of the Flipped Classroom approach. The most commonly cited advantage was the ability to control the time, location, and pace of material review (16 responses). Independent learning was also frequently mentioned as a positive outcome (6 responses), although a subset of students (12 respondents) expressed dissatisfaction with their independent work, citing difficulties in finding correct answers to the questions (4 responses). Several students (5 responses) perceived an improvement in the quality and retention of the material studied. Students reported a higher level of engagement in the course, resulting from the interesting and effective nature of this learning modality (5 responses). Furthermore, the participants agreed that the lecture time was used more efficiently (3 responses) and that the topic material was covered more quickly (3 responses). Some of the students had difficulty communicating and expressing their thoughts loudly (3 responses).

Comparison of the results of the Traditional Classroom and the Flipped Classroom

Assessment of students' knowledge is often based on tests and exams. According to Fig. 8, there is a slight difference in the performance of students on control assessments (Fig. 8a) and exams (Fig. 8b) between the Traditional Classroom and the Flipped Classroom.



a b

Figure 8. Comparison between the Traditional Classroom and the Flipped Classroom for control (a) and exam (b) assessments

An important measure of students' academic progress is the cumulative assessment of their individual work conducted over the course of a semester. Figure 9 provides a comparison of the total assessments of individual work between the Traditional Classroom and the Flipped Classroom.

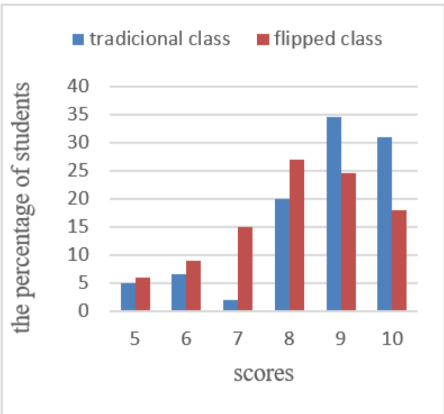


Figure 9. Comparison between the Traditional Classroom and the Flipped Classroom for the total assessment of individual works

The results indicate that the use of the Flipped Classroom approach resulted in an approximately 15% increase in the total number of scores above 8, as well as a double increase in the number of the highest evaluations.

8. Discussion

The analysis of student knowledge did not reveal a significant difference between the Traditional Classroom and the Flipped Classroom. However, it should be noted that the topics of the control test were not discussed using the Flipped Classroom method, which may have influenced the results. The exam results did not show significant differences, possibly because the exam assessed not only the knowledge acquired through the Flipped Classroom method.

Despite some of the reported challenges of the study participants, such as difficulties with independent work and reduced live communication skills, the Flipped Classroom approach was evaluated positively by most participants. They emphasized several advantages, including training flexibility, independent learning, and efficient use of lecture time. These factors promote active student involvement in the learning process (Low et al., 2021; Wang et al., 2021). Self-directed learning in the FC approach has been shown to improve students' skills (Cho et al., 2021; Low et al., 2021), leading to more effective learning outcomes and better ability to overcome difficulties (Díaz et al ., 2021). When students have access to the lecture material beforehand, they can tackle challenging questions during class meetings more effectively.

Research suggests that the knowledge acquired through the Flipped Classroom approach is more likely to be retained in long-term memory (Cho et al., 2021; Díaz et al., 2021), which is a crucial aspect of the learning process. Retention of knowledge is one of the primary goals of learning, as it enables students to apply what they have learnt in different contexts and over an extended period.

9. Conclusions

This study aimed to evaluate the effectiveness of the Flipped Classroom approach in learning engineering graphics as well as to assess how students perceive this method. The results demonstrate that the Flipped Classroom model, which provides an independent learning environment, promotes active student participation and enhances the learning experience. The study confirms the usefulness of this approach in preparing engineering graphics specialists.

The study findings also indicate that H5P tools are suitable for developing engaging and appealing learning materials. Despite the time constraints faced by instructors when implementing the FC method, they have the flexibility to create and search for innovative and modern learning tools.

The combination of the FC method and the H5P tools can establish a powerful learning environment that fosters deeper learning and enhances student engagement in engineering graphics.

To gain further insights into the effectiveness of the FC method on long-term student outcomes in engineering graphics, future research should be conducted over an extended period. The findings of this study provide valuable insights into the benefits of the FC method in engineering education and highlight the importance of creating engaging and independent learning environments.

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