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Research Article

Flipped Classroom Based on Blum's Modeling and its Impact on Autonomous Learning Experienced by Mathematics Students from a University in Lima, Peru

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Abstract

Introduction. The flipped classroom method represents an avant-garde approach to the learning process, in which students acquire the fundamental concepts of a subject outside the traditional classroom environment. In this work, Blum's modeling was used, based on discovery learning, where students are initially faced with problems or situations that require a solution, encouraging the search for information and the application of various strategies to solve them. This combination enhances learning autonomy by offering greater opportunities for practice and feedback. Objective. The research aims to determine the impact of the flipped classroom method as a tool to promote autonomous learning. Method. A mixed methodology was used, integrating elements of quasi-experimental and phenomenological design, with an explanatory scope. Results. The study revealed a 65% effectiveness in the development of autonomous learning among students who participated in the flipped classroom implementation. In addition, participants reported an increase in motivation, ability to set goals, identification of challenges and strengths, availability of resources and an environment conducive to learning, as well as selection of effective study strategies and increased reflection on the effects of their learning. In conclusion, the findings support the usefulness of flipped classroom as a valuable tool for fostering autonomous learning in university students.

Keywords: Flipped classroom, autonomous learning, higher education, Blum's modeling

1. Introduction

The learning process is threatened by a variety of factors, such as attention problems, information overload and lack of motivation (Aguilera, 2020). These elements entail serious repercussions on the educational achievement of students, which leads to a domino effect that has an impact not only on their professional but also on their personal future. It is therefore crucial to find solutions that enable an autonomous and efficient learning process.

As a result, the educational scene has undergone a constant evolution, brought about by the emergence of teaching methods that challenge the traditional model. These new strategies not only empower the students, but also significantly enrich their learning process.

The flipped classroom approach is gaining popularity. This method involves students reviewing material before class and then actively participating in discussions and hands-on activities during class. This flip from the traditional model encourages the development of important 21st century skills, such as critical thinking and collaboration. The purpose is to prepare students for current challenges, where adaptability and continuous learning are essential (Latorre et al, 2021).

Research in Saudi Arabia found that only 16.8% of university students have the potential to be autonomous learners. 63.1% preferred a combination of pre-recorded videos and constant tutoring from professors, whereas only 6.1% would prefer to be autonomous learners (Khan et al., 2022). In Indonesia, during COVID-19 lockdown, students showed positive attitudes toward autonomous learning (Maru et al., 2021). In Russia, 51.5% of professors were willing to implement the flipped classroom approach (Samusenkov et al., 2021).

Within the regional Chilean context, a variety of universities face recurrent challenges related to student dropout and low academic performance (Concha et al., 2019). Consequently, the application of the flipped classroom approach has been observed to have a significant impact on academic performance (Rivero, 2019). Likewise, it has been highlighted the importance of employing technological tools and social networks with the aim of promoting the capacity for autonomous learning among university students in Peru (Cjuno et al., 2021).

From the preceding analysis, it became necessary to establish an educational plan focused on the use of the flipped classroom in order to evaluate its effectiveness in promoting autonomous learning in university students. In this context, the research question formulated is: What is the impact of flipped classroom use on the development of mathematics autonomous learning in students at a private university in Lima?

The research has a solid theoretical value, based on Piaget's constructivist theory. This theory seeks to encourage students' participation in the construction of their own knowledge by involving them in the search for information and problem solving outside the traditional classroom environment (Binali et al., 2021). The didactic usefulness arises by allowing students to access content prior to in-person classes, giving them the opportunity to familiarize themselves with the concepts and prepare questions to discuss in the classroom (Arrieta et al., 2022).

This research has a significant social relevance for the student community, since it was conducted in an environment where all students, without exception, had access to technological tools and were able to participate in the established activities, thus benefiting from the results obtained. Furthermore, from a pedagogical perspective, this study is justified by allowing students to acquire fundamental knowledge independently. This encourages self-discipline, self-regulation, and research skills, thereby enabling them to take an active role in their own learning process. It also reinforces their intrinsic motivation and responsibility towards their educational development.

A study conducted by Tsai (2021) investigated the impact of the flipped classroom on the autonomy of English language learners. In this research, no significant differences were found in autonomy prior to instruction. Afterwards, differences were noted in three of five autonomous learning constructs. The analysis confirmed that the flipped classroom facilitated the use of technology and student-professor interaction.

Likewise, Zainuddin and Perera (2017), found that the flipped classroom, compared to the

traditional classroom, improved autonomous learning skills, enhanced peer participation, and increased students' intrinsic motivation, resulting in greater competence in handling online activities and in controlling their learning.

The flipped classroom teaching method also has significant effects on both motivation and learning outcomes, as demonstrated by Jian (2019) through an experimental study, in which three experimental and one control group were formed.

The use of digital tools, especially during online teaching due to the pandemic, has played a relevant role in strengthening autonomous learning. This phenomenon is supported by studies like the one by Eberle and Hobrecht (2021), who, through qualitative research on the satisfaction of basic psychological needs for learning, reported an increase in the autonomy of university students in terms of time management and self-regulation. However, they also identified overwhelming experiences associated with the difficulties inherent to this context.

Similarly, Anthonysamy and Singh (2023) analyzed four autonomous learning strategies and their impact on academic performance of college students during the COVID-19 pandemic. In this research it was found that interactive engagement and study environment are significantly related to academic performance, whereas satisfaction and self-efficacy showed no relationship, possibly due to the challenging context of the pandemic.

Rahman et al. (2022) explored perceptions of both professors and university students about the desirable level of student autonomy. Researchers found that both groups view autonomy as a result of collaboration with each other, although students show greater support for more extensive autonomy. This discrepancy could limit actual student autonomy if opportunities to acquire the necessary skills are not provided.

The research is based on the constructivist theory of learning, which postulates that students construct their knowledge by interacting with their environment (Milad, 2021). This theory is closely related to autonomous learning, as it emphasizes active comprehension, reflection, and self-regulation. The use of technology as a support tool in autonomous learning, from this perspective, allows for greater personalization and adaptation to the individual differences of students, stimulating creativity and innovation in their learning process.

The educational methodology involves exchanging roles during the teaching and learning process (Fernández et al., 2020). Students learn from materials prepared by the tutor, such as videos or readings, and participate in practical activities and classroom discussions (Jahr, 2022). This approach promotes meaningful learning and learner autonomy (Xiao et al., 2018).

Nowadays, technology facilitates access to learning materials such as podcasts, videos, and online activities (Abubakar et al., 2021). Students manage their time and pace, adapting the material to their learning styles (Lai et al., 2021). In addition, professors can monitor and evaluate progress efficiently, providing personalized feedback (Islam et al., 2023).

In the context of the flipped classroom, autonomous learning is promoted by providing students with the resources to investigate, discover, and understand concepts on their own (Li & Jin, 2020).

According to Hinojo et al. (2020), there are four key characteristics of autonomous learning: awareness of the learning environment, goal setting, choice of study strategies and self-assessment. On the other hand, Silverajah et al. (2022) highlight that student autonomy leads to independence from the lecturer, enhancing their academic and professional development.

Five dimensions were identified to measure autonomous learning: motivation, learning strategies, self-monitoring, self-assessment, and learning environment. Within motivation, Lai et al. (2021) emphasize the importance of active awareness, value awareness, self-responsibility, and self-efficacy. These aspects reflect the active search for knowledge, the connection of learning with personal reality, confidence in completing tasks, and the ability to attribute either success or failure to self-effort (Su et al., 2023; Ni, 2020).

In the learning of strategies, one of the most common is repetition (Tautz et al., 2021), which involves practicing repeatedly to retain information. Another one is the completion strategy, which requires making inferences or associations to understand information. Organizational strategy allows

the learner to systematically classify, organize, and summarize information (Huam & Yang, 2022). Strategic review helps to consolidate acquired knowledge.

Self-monitoring involves managing time and overcoming psychological barriers to achieve academic goals (Li & Jin, 2020), and self-assessment implies that the students value their own learning and work (Kambourova, et al., 2021).

The learning environment encompasses physical, social, and digital environments, promoting conducive conditions, social interaction, and effective search for resources (Anthonysamy & Singh, 2023). Educators, as facilitators, guide students in goals and assessment (Sun, 2021). Despite internal motivation, students may need external incentives and opportunities to develop skills autonomously (Hernández-Sellés, 2022; Rahman et al., 2022). Professors should provide quality material and promote critical thinking through classroom discussions (Kang, 2020).

In conclusion, fostering autonomous learning in the university environment not only empowers students, but also prepares them to face real-world challenges with confidence and solid skills. Since they can adapt to their own pace and preferences, allowing them to explore topics in more depth and delve deeper into areas of personal interest. Additionally, it helps students acquire autonomous learning skills, such as time management, self-regulation and problem solving.

2. Method

Research focused on investigating how the use of flipped classrooms influences the development of autonomous learning in students of a mathematics course at a private university in Lima. The specific objectives were the following: First, it was sought to evaluate the level of autonomous learning of students before and after the implementation of the flipped classroom. Second, it was intended to identify significant differences in the dimensions of autonomous learning between the experimental group and the control group after the implementation of the flipped classroom. Finally, it was attempted to analyze the experiences of university students in relation to the use of the flipped classroom and its impact on the development of autonomous learning.

The implementation of the approach, based on the flipped classroom model, provided students with access to course materials, discussion forums, and other learning resources. At first, educational resources relevant to the mathematics course were collected online. However, it was noted that the information available on platforms was confusing and presented in technical terminology that was too advanced for students. Consequently, a customized website was developed that integrated content from various open online sources, adapting it to make it more accessible and understandable.

The website interface was designed with simplicity and user friendliness in mind, organizing resources by topic according to the course curriculum and class schedule, including fundamental math concepts. Topics were assigned so that students could provide feedback on their use of the website, allowing them to share their ideas and experiences. This process facilitated students to review the knowledge acquired in their lessons and provided them with the opportunity to exchange creative projects, personal experiences, and emotions with their peers.

The study adopted a mixed approach, combining quantitative and qualitative elements to address complex research questions. This methodology allowed for a comprehensive understanding of the phenomenon under study, leveraging the strengths of both approaches and enriching the research (Mehrad et al., 2019). On the quantitative side, a quasi-experimental design was used to investigate the feasibility of a pure controlled experiment, involving manipulation of the independent variable (Gopalan et al., 2020). This allowed patterns and trends of cause-and-effect relationships to be identified and understood (Bloomfield, 2019).

In the qualitative approach, a phenomenological design with in-depth interviews was used to explore experiences and meanings around the research object, allowing for an in-depth understanding of participants' perspectives and revealing nuances that may not be detected in quantitative analysis (Urcia, 2021).

The instrument used was a questionnaire created according to the research criteria. The

questionnaire consists of 38 items distributed in five dimensions to measure autonomous learning in university students. Questions 1 to 8 assess learning motivation, questions 9 to 16 address learning strategy, questions 17 to 24 focus on self-monitoring, questions 25 to 30 explore self-adjustment, and questions 31 to 38 assess the learning environment. Responses are rated on a Likert scale, where 1 represents "never" and 5 represents "always." Scores are interpreted as follows: those with less than 139 points have not yet developed autonomous learning, between 140 and 159 points indicate an ongoing process, and more than 160 points reflect successful development of autonomous learning.

To validate the instrument, a rigorous process was conducted. Initially, five experts evaluated its clarity, coherence, and relevance, obtaining an Aiken V coefficient of 0.93, which confirms its validity. Subsequently, a pilot test was conducted to evaluate the instrument's reliability. The Cronbach's Alpha coefficient turned out to be 0.94, meeting the necessary standards for its application (Robles, 2018).

A structured interview guide with 19 open-ended questions, previously reviewed by Spanish language experts, was used to explore experiences and perspectives in detail. The initial population consisted of 500 students, from which a sample of 194 students was selected. The selection criteria included being enrolled in the extracurricular mathematics course and having regular class attendance. Restrictions were established for the experimental group, excluding students who did not complete the course. The experimental group comprised 119 university students, while the control group consisted of 75 undergraduates.

During the academic semester, a documentary record was used (grade record) to evaluate and diagnose the academic performance level of the students. In addition, a non-structured field diary was kept by the professor to identify weaknesses and strengths, which contributed to the design of the approach.

For sample selection in the qualitative phase of the research, a purposive sampling approach was adopted (Moser & Korstjens, 2018). This method involves making deliberate choices to select participants who bring diverse and relevant perspectives on the phenomenon under study. In total, 29 students were interviewed as part of the selected sample.

The flipped classroom approach, based on Blum's modeling, excels as an effective strategy to enhance autonomous learning in university students. By providing activities focused on advanced levels of the taxonomy, such as construction, structuring, mathematization, mathematical work, interpretation, validation, and exposition (Londoña et al., 2018), instructors have the opportunity to cultivate critical, problem-solving, and creative skills in students (Carrillo-Yalán et al., 2023).

To achieve the objectives of the study, activities were implemented in the flipped classroom based on Blum's modeling. Data were collected between June and July 2023, observing ethical principles. Electronic questionnaires were used to collect responses from 194 participants, processed anonymously. During the interviews, an atmosphere of trust and empathy was promoted. Accurate recordings and transcriptions ensured the thoroughness of the analysis with Atlas.ti 23 software.

3. Results

Table 1 presents the descriptive statistics in two stages of the implementation process of the flipped classroom methodology, detailing the minimum and maximum scores achieved. Additionally, the table provides information on the normality of the data obtained through Kolmogorov - Smirnov statistical tests.

Table 1: Descriptive values of autonomous learning and its dimensions before and after the application of flipped classroom.

	Sample size (N)	Minimum	Maximum	Mean	Standard deviation	Statistics	df	Asymptotic (bilateral)
Pre-test Autonomous learning (EG)	119	103.00	185.00	143.35	19.35	.091	119	.018
Post-test Autonomous learning (EG)	119	107.00	190.00	155.94	19.32	.091	119	.017

	Sample size (N)	Minimum	Maximum	Mean	Standard deviation	Statistics	df	Asymptotic (bilateral)
Pre-test Autonomous learning (CG)	75	95.00	190.00	140.84	20.16	.055	75	.200*
Post-test Autonomous learning (CG)	75	95.00	190.00	142.95	21.89	.087	75	.200*
Pre-test Learning motivation	119	24.00	40.00	32.36	3.97	.086	119	.032
Post-test Learning motivation	119	24.00	40.00	34.03	4.01	.123	119	.00
Pre-test Learning strategies	119	17.00	40.00	30.15	4.85	.116	119	.00
Post-test Learning strategies	119	18.00	40.00	32.71	4.94	.090	119	.019
Pretest Self-monitoring	119	21.00	39.00	30.17	4.44	.116	119	.00
Post-test Self-monitoring	119	24.00	40.00	33.10	4.33	.113	119	.001
Pretest Self-assessment	119	11.00	30.00	21.55	3.85	.077	119	.080
Post-test Self-assessment	119	15.00	30.00	24.23	3.80	.112	119	.001
Pre-test Learning environment	119	15.00	40.00	29.12	4.97822	.080	119	.059
Post-test Learning environment	119	22.00	40.00	31.87	4.49021	.111	119	.001

Before the implementation of the flipped classroom method, both the experimental and control groups showed unfavorable beliefs toward autonomous learning, with an average of 143.35 and 140.84, respectively. After the implementation of flipped classroom, a notable increase in autonomous learning was observed for the experimental group, with an average that went from 143.35 to 155.94. In contrast, the increase in the control group was not significant.

In all dimensions of autonomous learning, there was an increase in scores: motivation for learning went from 32.36 to 34.03 points; learning strategies increased from 30.15 to 32.71 points; while self-monitoring, self-assessment, and learning environment showed similar increases, going from 30.17 to 33.10, 21.55 to 24.23, and 29.12 to 31.87 points, respectively, after the implementation of flipped classroom.

Finally, Table 1 statistically evidences the non-normal distribution of the data, both the study variable and its dimensions for the experimental group, with a p-value less than .05, which required the application of the nonparametric Wilcoxon U test. On the contrary, the control group showed a p-value greater than .05, which required the use of the parametric inferential Student's T-test (Yang & Berdine, 2021).

Table 2: Frequency of autonomous learning data before and after implementation of the flipped classroom.

|	Pre-test		Post-test	
	Frequency	Percentage	Frequency	Percentage
No developed	48	40.3	21	17.6
In process	45	37.8	51	42.9
Achieved	26	21.8	47	39.5
Total	119	100.0	119	100.0

After the flipped classroom was applied, the percentage of students who had not developed autonomous learning decreased significantly, from 40.3% to 17.6%. In addition, the number of students with complete autonomous learning increased by 80.77%, reaching 39.5% of the total.

Table 3: Assessment of the effects of the flipped classroom on dimensions of autonomous learning of university students.

	Learning motivation	Learning strategies	Self-monitoring	Self-assessment	Learning environment
Z	-4.72	-5.21	-6.66	-6.44	-5.81
Asymptotic Sig (bilateral)	.00	.00	.00	.00	.00
Cohen's D	0.42	0.52	0.67	0.70	0.58

Inferential analysis using the Wilcoxon U test revealed significant differences in the five dimensions of autonomous learning before and after the implementation of the flipped classroom (Table 3), with significance less than .05 (Fay & Malinovsky, 2018). In addition, Cohen's D statistic was employed to assess the effect of the flipped classroom on autonomous learning of university students. According to Table 3, the dimensions of learning strategies, self-monitoring, self-assessment, and learning environment showed coefficients between .5 and .8, indicating a moderate effect according to Goulet and Cousineau (2018) However, motivation for learning presented a coefficient of .42, considered small. In summary, the flipped classroom generated a positive impact of 42% on the learning motivation dimension, 52% on learning strategies, 67% on self-monitoring, 70% on self-assessment and 58% on learning environment.
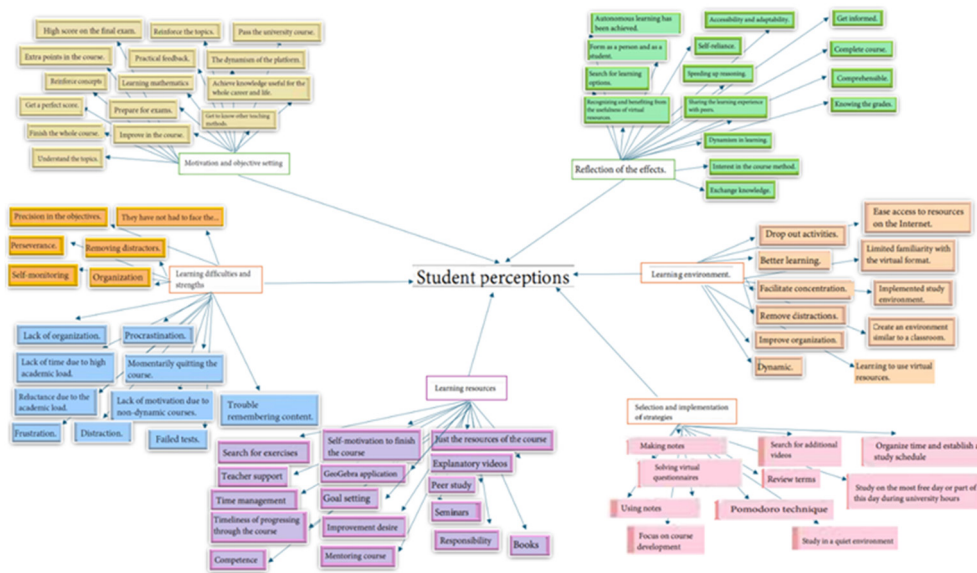
Figure 1. Students' experiences regarding the use of the flipped classroom in their autonomous learning.

Interviews with students who participated in the flipped classroom revealed diverse motivations and learning goals, as well as challenges such as procrastination and lack of time. They highlighted perseverance and self-monitoring as key strengths. They used a variety of learning resources, from virtual tools to social interaction. They adopted study strategies and created environments favorable for learning, combining virtual and physical resources. Learners experienced a greater sense of autonomy, improved reasoning, and group cooperation thanks to the flipped classroom.

> *It contributed a lot to my learning process because it added to what I was being taught at the university during my classes, but what motivated me the most was learning new skills that will be necessary for future courses, such as calculus and physics, skills that will help me not to get lost in the topics and to know how to solve the exercises. (Interview Sayumi, 17 years old)*

> *After the videos there were almost always interactive games and I think that caught my attention because you could practice before taking the graded practice test. I took it as a game because if you answered well, you were scored well, but all this was achieved by the knowledge that had been given to you previously. So yes, I was motivated. On the one hand because I was not the only one who was part of the course, but there were also other classmates, but mostly because I knew that this process was going*

to help me get better grades. Also, it bothered me a little bit because in the practices, I remember, in one, for example, it became difficult and I got a little frustrated. I went back to watch the video to do the practice again (Interview Mariana, 18 years old).

The course helped me a lot in reinforcing and reviewing the points I was already seeing in my classes. The graded practice tests also helped me a lot to maintain a constant practice since it was quite difficult for me because I didn't have much time. It motivated me every time I felt I was making progress in the course. Every time I moved from one topic to another, I felt like I was learning and that was what motivated me until the end. (Interview Isabel, 17 years old)

What kept me motivated was to keep in mind that I am learning, that I am not memorizing formulas and that I am not simply going to the final exam to apply formulas, but that I will be able to use these lessons later, in the following academic semesters. I could even teach my siblings or people who also ask me for help (Interview Kiara, 17 years old).

Sometimes I was working on the exercises and suddenly I got a message and after I reviewed it, I got distracted and got sidetracked from what I was learning and sometimes that's tedious because you're trying to fight between procrastination and wanting to learn something. Somehow or another, it has been a challenge that did get accomplished. I ended up understanding the topics and also the program (Interview Vanessa, 17 years old).

According to the previous quotes, students showed interest in learning through the flipped classroom and in a recreational way, reinforcing the topics worked on in class and acquiring the basis for learning a new topic. In addition, it allowed them to acquire autonomous learning skills, such as time management, self-regulation and problem solving applied to everyday life.

Table 4: Assessment of the effects of the flipped classroom on autonomous learning of university students.

		Autonomous learning
Experimental Group	Z	-7.06
	Asymptotic Sig (bilateral	.00
	Cohen's D	0.65
Control Group	T	-.89
	Asymptotic Sig (bilateral	.38
	Cohen's D	None, since there is no difference

Table 4 revealed that unlike the control group, the experimental group did not follow a normal distribution. In order to determine differences between the pre- and post-intervention periods, Wilcoxon's U and Student's T-tests were applied, respectively.

In the experimental group, a significant difference was found between the pre and post periods, with a p value of .00, indicating an effectiveness of 65%, considered a moderate influence. In contrast, the control group showed no significant changes, with a significance value greater than .05 (Mishra et al., 2019).

4. Discussion

This study explored the effect of the flipped classroom, based on Blum's modeling, on the development of autonomous learning in university mathematics students at a private university in Lima. Data from an experimental group, which used a flipped classroom, were compared with a control group that received traditional instruction. The results revealed a positive impact of the flipped classroom on autonomous learning. The experimental group experienced a significant increase in their level of autonomy, unlike the control group which showed no noticeable change. In addition, students in the experimental group expressed satisfaction with their learning and claimed

to have greater control over their learning.

The findings support previous studies by Zainuddin and Perera (2017) and Tsai (2021), who highlight how the flipped learning environment promotes online task proficiency and the ability to control learning outcomes, as well as enhances learner autonomy in using social strategies and resources. In general, these results underscore the effectiveness of the flipped classroom at encouraging autonomous learning in university students. This methodology offers students the opportunity to learn at their own pace, practice what they learn and receive feedback from the professor (Cjuno et al., 2021), which allows them to develop the skills and abilities necessary to be autonomous learners.

Students, by previously accessing the study materials and participating in hands-on activities in the flipped classroom, developed key skills such as self-monitoring, self-assessment, and critical thinking, essential for autonomous learning. In addition, an increase in their motivation was observed, as well as an improvement in their learning environment and strategies; likewise, Zainuddin and Perera (2017) conclude that the flipped classroom promoted greater peer interaction and autonomous learning skills, in addition to having a positive impact on students' intrinsic motivation.

Furthermore, Anthonysamy and Singh (2023) found that the interactive collaboration of learners and the learning environment have a significant impact on their own learning achievement. Similar to the present study, Rahman et al. (2022) demonstrated that learner autonomy success is influenced by motivation, as well as ability, willingness, and opportunity (Jian Q. , 2019); both females and males agreed on the use of social resources for their autonomous learning, such as tutoring, group work, and collaboration with classmates, thus facilitating knowledge sharing and dissemination. Thereby coinciding with the study of Zainuddin and Perera (2017) who found that the use of the flipped classroom promoted interaction among classmates. This suggests that the flipped classroom is an effective strategy to stimulate both individual and group learning.

The complement between a virtual and physical environment made it easier for students to take advantage of the tools and opportunities of both spaces, which was considered an effective learning strategy. This is consistent with the study by Eberle and Hobrecht (2021) where online teaching encouraged students to seek a quiet and distractor-free environment to increase concentration; likewise, in Hoshang's (2021) research, it was pointed out that having a virtual environment favors the accessibility and usefulness of technological resources.

Students suggested that the implementation of the flipped classroom should begin in the initial stages of the academic semester to allow a longer period of development and assimilation of the course content. This contrasts with the exclusive focus on passing, especially as final exams and submission of assignments approach. Although they expressed enthusiasm for the flipped classroom method, they felt that the implementation period was short and expressed a desire for this strategy to be applied in other courses. Students emphasized that, initially, their motivation was focused on passing, but then they discovered that the flipped classroom allowed them to understand the topics more deeply, an experience they would like to repeat in other subjects.

Findings confirm the positive impact of the implementation of an innovative method based on technological tools in the classroom, strengthening autonomous learning and proposing an educational approach radically different from the traditional one (Zainuddin and Perera, 2017). The study confirms that the flipped classroom method improves understanding and consolidates knowledge, increases motivation, and promotes the development of skills such as planning, organization, and information sharing, thus promoting a higher level of learning in students (Alharbi, 2022). Also, it has been confirmed that, as stated by Su et al. (2023), the flipped classroom, as a teaching strategy, involves students accessing learning materials before class, researching independently on a specific platform, performing tasks in collaborative groups, and receiving individual guidance and support from teachers during class.

It is concluded that the implementation of the flipped classroom, based on Blum's modeling, was highly effective in promoting autonomous learning in mathematics students. The experimental

group showed a significant increase of 65% in the effectiveness of the strategy, highlighting its positive influence. In contrast, the control group did not show any notable changes. Likewise, the application of the flipped classroom generated significant improvements in all dimensions of autonomous learning. The results suggest a substantial growth in the students' capacity for self-regulation, evidenced by the increase in the planning, monitoring and evaluation of their own learning process. Positive student perceptions support the effectiveness of the strategy, promoting a participatory and student-centered environment. These findings have important implications for higher education, highlighting the contribution of the flipped classroom to the comprehensive development of students in mathematics.

However, it is important to highlight some potential limitations associated with the implementation of the flipped classroom model: firstly, not all students manage to complete the assigned activities within the deadline because they lack experience in using technology, which means that additional training is required to use the flipped classroom effectively, and secondly, distraction with online games could affect progress on the assigned topics within the time frame.

Further research on the identified knowledge gaps is recommended, considering additional factors such as individual student characteristics, material design, and teaching strategies. In addition, the analysis of students' emotions in future research could provide valuable insights to improve the quality of autonomous learning in various educational contexts.

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