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Factors that mediate the success of the use of online platforms to support learning: the view of university teachers

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Abstract

The goal of this research is to analyze the factors that mediate the success of the use of online learning support platforms, based on the perceptions of a focus group of university professors, with a qualitative methodological approach. The sample consisted of 11 mathematics professors who taught three subjects to 9 240 incoming students, during seven semesters between 2018 and 2021. Through open coding, 17 factors were identified that mediate the success of the online learning support platform. Through axial coding, 5 categories were determined that summarize the relationships between the different factors, namely: *obstacles*, impediments that teachers must face when teaching; *teacher contribution*, factors that indicate the added value that teachers find in the classroom from the implementation of online training; *student*, reception given by students to the online training; *reinforcement*, factors related to the medium used to develop the online training; *platform*, factors related to the strategy itself and how to improve it. Finally, through selective coding, it was possible to integrate and redefine the central categories, obtaining as a result an implementation model of the online platform, which can explain and contribute to the success of other similar experiences at the university level.

Keywords Focus group · Grounded theory · ICT · Mathematics learning · University professors

1 Introduction

Information and Communication Technologies (ICT) facilitate the use of virtual personalized training environments that can be massively implemented (Lawrence & Tar, 2018), such as the online platform to support learning subject of this research. This

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platform is free and interactive, it is channeled through Khan Academy, and it represents an initiative that promotes autonomous learning to strengthen the mathematical knowledge required at higher education level and, in turn, improve the academic performance of incoming students (Courtney et al., 2022a; Díaz & Rueda-Gómez, 2020; Mullen et al., 2021). To foster a successful relationship between students and an online platform, offering a proper infrastructure for users is crucial (Akbari et al., 2022; Gray & Lindstrom, 2019). For instance, it may be beneficial to conduct workshops or training sessions that focus on introducing students to the virtual tools and incorporating them into the university curriculum (Akbari et al., 2023). By ensuring that the online environment is well-suited to students' requirements and is backed by competent administrators, students will be encouraged to engage more actively. In this sense, Gray and Lindstrom (2019) explain that to successfully integrate Khan Academy into teaching activities, it is crucial to introduce it in a hands-on session, use external motivators to engage students, help them understand the learning benefits of Khan Academy, utilize it to optimize teaching activities, and consider its role as a valuable addition to the toolkit of learning resources. Besides, students' computer self-efficacy also influences the use of online learning (Akbari et al., 2022). From the teachers' point of view, these types of platforms also offer benefits (Mullen et al., 2021). For example, Courtney et al. (2022b) present the case of a teacher who uses Khan Academy to generate her course notes because she knows that this online platform is familiar to students from their pre-college days. Despite the potential benefits of online teaching, teachers may develop unfavorable attitudes towards working in digital environments due to feelings of frustration, incapacity, or limitations (Mullen et al., 2021).

In the Unidades Tecnológicas de Santander, a Colombian higher education institution, it was considered whether more autonomous learning from the incorporation of ICT could serve as a factor to reduce the high cancellation and loss rates in mathematics subjects, offering incoming students the opportunity to cover their training gaps through Khan Academy. Thus, an online platform to support learning was designed with the participation of the mathematics teachers teaching the subjects Basic Mathematics and Mathematics I at the Faculty of Socioeconomic and Business Sciences, and Higher Algebra at the Faculty of Natural Sciences and Engineering. So far, the platform has been massively implemented (9 240 incoming students) and periodically (during seven consecutive semesters). To the best of the authors' knowledge, the analysis presented in this document can be regarded as groundbreaking.

Data regarding performance and its relationship with students' self-concept were analyzed in Rueda-Gómez and Rodríguez-Muñiz (2020) and Rueda-Gómez et al. (2023). From that analysis and given that students with similar characteristics obtained different results in the same subject, the need to identify which factors intervene and promote success in the efficient use of the platform arose. Therefore, the question that guides the research is: what factors mediate the success of the use of online platforms to support learning, according to the perception of teachers who teach subjects in the area of mathematics? In this sense, success is understood as those elements that improve academic performance, increase students' mathematical self-concept, awaken their motivation, and promote classroom participation, among others.

2 Theoretical framework

ICT has made massive inroads into the educational scenario, generating the need to seek strategies to expand the creation, adaptation, and application of pedagogical designs. Thus, blended learning models have emerged from the need to add face-to-face to the already-known e-learning and, in turn, add virtuality to traditional pedagogical models (Geng et al., 2019; Valverde-Berrocoso et al., 2020). The present study is framed within the blended learning model called the face-to-face conductive model, in which most of the training takes place in the classroom and online resources are used as an additional tool (Gray & Lindstrom, 2019; Rasheed et al., 2020).

The need to reinforce the previous mathematical knowledge of students entering higher education is a common concern worldwide (Büchele, 2020; Rodríguez-Muñiz et al., 2020). Previous research reports multiple elements that directly affect the activities for facing this growing problem, such as students' previous knowledge and affective domain regarding mathematics (conceptions, attitudes, values, self-concept, etc.), teachers' motivation, training and, stability, the proper identification of students' difficulties, the leveling of knowledge or the use of online platforms and measures of effectiveness (Bañeres et al., 2023; Beltrán-Pellicer & Godino, 2020; Castro López et al., 2020; Mello-Román & Gómez-Chacón, 2022; Rodríguez-Muñiz & Díaz, 2015; Rueda-Gómez et al., 2023). Different higher education institutions have designed and implemented virtual learning environments with interactive modules that have resources, such as videos, summaries of the theory, exercises of examples solved step-by-step, and evaluative questionnaires, among others, to level incoming students' mathematical knowledge. Some examples are described below.

In the Ibero-American context, Benavidez Lozano et al. (2019), Hernández et al. (2018) and Ramírez (2012) analyzed the creation of their own material, the use of technological resources, such as Moodle or EdX, to organize a digital learning environment, and the voluntary completion of a course by students, although with differences regarding the implementation of the strategy. For example, at the University of Alicante (Benavidez Lozano et al., 2019) and at the Catholic University of Chile (Hernández et al., 2018) they opted for a self-taught and purely virtual methodology without the teacher being part of the process. While at the Universidad Central de Venezuela, they opted for face-to-face sessions in a computer room with the teacher playing the role of mediator (Ramírez, 2012). On the other hand, in Benavidez Lozano et al. (2019) and Ramírez (2012), the design focused on strengthening previous knowledge, while in the case of Hernández et al. (2018), previous knowledge and contents of the university subject were combined. Despite these differences, these authors concluded that the completion of an online course to support learning has a positive impact on students' academic performance.

In the German context, the study by Hasan et al. (2020) at the University of Kassel indicated students' participation as one of the success variables of the leveling courses, reflected in attendance and in the development of the proposed activities. In the United States, Dey's (2018) study corroborates that participation in leveling courses depends on more difficult observable variables, such as students' motivation and previous skills. Furthermore, Dey (2018) pointed out that ignoring these variables in the implementation of the course can bias the success of the strategy, suggesting the design of bonus policies that encourage students to develop the course.

There are different Open Educational Resources (OER) that institutions can incorporate into training processes (Hung et al., 2019; Otto, 2019), such as, for example Procomún, Curriki, or Open Education Europe. Also noteworthy is the Khan Academy platform, which promotes personalized learning, allowing students to advance at their own pace in the completion of activities accompanied by videos, theoretical and interactive summaries, and practice problems, rewarding good performance with badges like those of a video game (Arruabarrena et al., 2021; Díaz & Rueda-Gómez, 2020; Mariano-Dolesh et al., 2022; Vidergor and Ben-Amram, 2020). In addition, the Khan Academy website offers software that generates instant feedback on the answers and the step-by-step solution for each exercise (Vidergor & Ben-Amram, 2020). Khan Academy has a learning system based on artificial intelligence that allows identifying strengths and weaknesses in learning through mastery challenges that allow increasing or decreasing, on the one hand, the overall performance in a course and, on the other hand, the level of the different skills assessed (Radcliffe et al., 2016). Once students answer the questions without making mistakes, the platform automatically recommends new topics according to the level and previous knowledge mastered so far, thus allowing the self-regulation of learning (Rueda-Gómez & Guzmán-Duque, 2018).

3 Methodology

The research design was based on the use of focus groups (Cohen et al., 2000) for data collection and grounded theory (Glaser & Strauss, 1967) for the qualitative analysis, using MAXQDA®, version 2022 (Kuckartz & Rädiker, 2019).

3.1 Context

The online platform to support learning that motivates this research has been implemented in a Colombian higher education institution since the second semester of 2018 during seven semesters and is called "PREIN online training". A group composed of three teachers supported each training implementation. The functions of the support group were to involve and accompany teachers throughout the implementation process, as well as to execute and measure the impact of the strategy in the classroom. This training was based on the face-to-face model described above and involved the participation of teachers of three mathematics subjects: Basic Mathematics, Mathematics I, and Higher Algebra, taught in university studies of business administration, accounting, finance, fashion design, sports, and various engineering (electronics, electromechanical, environmental, industrial, electrical, telecommunications, systems, surveying), covering a wide variety of student profiles (Rueda-Gómez et al., 2023).

Students had access to the web page (https://preinuts.es.tl/), which contained instructions on the enrollment process and a description of the online training. Previous research highlights the positive impact of PREIN online training on students' academic performance, reflected in increased pass rates and reduced cancellation and loss rates (Rueda-Gómez & Rodríguez-Muñiz, 2020). In addition, preliminary studies also show that students' academic performance is directly related to mathematical self-concept, progress in PREIN online training, and other socioeconomic factors (Rueda-Gómez et al., 2023).

3.2 Focus group composition

The random selection of participants from a population of 60 mathematics teachers initially yielded a sample fraction of one-quarter of the population, equivalent to 15 teachers. This sample size was chosen to generate a more intense and detailed conversation. Each teacher was called in advance, on several occasions, and by different means: e-mail, text message, or telephone call. To facilitate attendance, a virtual meeting was planned, using Microsoft Teams®. Eleven of the 15 invited teachers participated, of whom 63.6% were women, 72.7% had a master's degree, 9.1% had a doctorate and the rest were currently studying for a master's degree. The sample was organized into three focus groups, one per subject, with three or four teachers each. All the focus group participants used Khan Academy for the seven consecutive semesters during which the online platform to support learning was implemented. A meeting was organized for each focus group at the end of the seven semesters.

3.3 Script preparation

A preliminary script of 16 questions was designed. The instrument was then refined by two experts and consequently reduced to 12 open-ended questions. These questions refer to those factors that, according to the results of previous research, mediate the success of the use of online platforms to support learning (Benavidez Lozano et al., 2019; Dey, 2018; Hasan et al., 2020; Hernández et al., 2018; Ramírez, 2012). Subsequently, a pilot study was conducted with the support group leading the PREIN online training to assess the form, sequence, and content of the script. None of them intervened in the subsequent focus groups. The result was to keep the 12 questions but to change the order, to make the meeting with each focus group more pleasant, starting with general questions and ending with specific questions (Table 1).

3.4 Data collection process

Focus groups are a qualitative research technique whose purpose is to learn about the attitudes, beliefs, experiences, and reactions of participants regarding the same process (Cohen et al., 2000; Reisner et al., 2018; Wilson, 1997). The central axis of a focus group is the analysis of commonalities and differences in participants' opinions (Salcines-Talledo et al., 2022). One advantage is the interaction among members. Since they are similar to each other, an atmosphere of trust conducive to promoting self-confession is generated (Biggeri et al., 2020). The open and non-directive nature of the conversation offers flexibility to the educational researcher to explore new topics not previously contemplated (Harackiewicz & Priniski, 2018) and, although it

Table 1 Focus group questions

Questions	Factors	References
How are your students mathematically?	Previous knowledge	Büchele (2020); Castro López et al. (2020); Dey (2018); Rodríguez-Muñiz & Díaz (2015)
How do students view themselves in mathematics (confident, anxious, insecure, solvent, etc.)?	Affective domain	Beltrán-Pellicer & Godino (2020); Castro López et al. (2020); Dey (2018); Hung et al. (2019); Rueda-Gómez et al. (2023)
Do you think that the teaching methodology has an impact on students' academic performance?	Methodology	Ramírez (2012); Rodríguez-Muñiz & Díaz (2015); Valverde-Berrocoso et al. (2020)
During the lessons, do you use Khan Academy videos and/or exercises? What disadvantages and/or advantages have you found?	Videos Exercises	Benavidez Lozano et al. (2019); Hernández et al. (2018); Hung et al. (2019); Otto (2019); Rasheed et al. (2020); Rueda-Gómez & Guzmán-Duque (2018)
What kind of interaction do you establish with students regarding the use of Khan Academy during the semester?	Follow-up	Hung et al. (2019); Radcliffe et al. (2016); Rodríguez-Muñiz & Díaz (2015); Rueda-Gómez & Guzmán-Duque (2018); Rueda-Gómez et al. (2023)
Is the structure of the thematic units of the PREIN online training for each cohort appropriate for the subject? What is missing?	Structure	Benavidez Lozano et al. (2019); Hernández et al. (2018); Ramírez (2012); Rodríguez-Muñiz & Díaz (2015)
What type of incentive (intrinsic or extrinsic) do you offer to motivate students to take the PREIN online training?	Intrinsic motivation Extrinsic motivation	Dey (2018); Hung et al. (2019); Ramírez (2012); Rodríguez-Muñiz & Díaz (2015)
Do you think PREIN online training works or not? If you have any specific experience please mention it.	Contribution	Díaz & Rueda-Gómez (2020); Hung et al. (2019); Rodríguez-Muñiz & Díaz (2015); Rueda-Gómez & Guzmán-Duque (2018); Rueda-Gómez et al. (2023)
How do you think students perceive the development of PREIN online training?	Reaction	Dey (2018); Hung et al. (2019); Vidergor and Ben-Amram (2020); Rodríguez-Muñiz & Díaz (2015); Rueda-Gómez & Guzmán-Duque (2018)
Do you consider that the variables of class schedule (day or night) or academic program influence the development of the PREIN online training?	Participation	Dey (2018); Hasan et al. (2020); Hung et al. (2019); Rodríguez-Muñiz & Díaz (2015)
The strategy of choosing a monitor (support student) per course gave results in some groups and not in others, finding cases in which, for the same teacher, the strategy worked for some courses and not for others. How could this strategy be effective?	Human support	Hung et al. (2019)
Would you like to receive training on the Khan Academy platform so that you can show your students their enrollment status and percentage of progress in real-time?	Training	Ramírez (2012); Rodríguez-Muñiz & Díaz (2015)

lacks statistical representativeness, the focus group offers information of high subjective validity (Morgan, 1988).

A session was held for each focus group, developed in three stages: introduction, discussion, and closing. In the introduction, the purpose of the meeting was explained, rules of interaction among participants were established, and consent was requested to record the meeting, emphasizing the confidentiality of personal data. In the discussion, each of the 12 questions was posed, allowing the active participation of all those involved in the dialogue and debate of general and specific issues, without raising other questions outside the script. At the closing, the main themes identified were highlighted, how the results were going to be used was explained, and special thanks were expressed for the voluntary participation of the teachers. Each of the three meetings lasted one hour and fifteen minutes.

3.5 Data analysis process

Grounded theory uses an inductive method to discover theories, concepts, hypotheses, and propositions starting directly from the data (Glaser & Strauss, 1967; Strauss & Corbin, 1997). It was developed in three stages: description, coding, and constant comparison. The description consists of the transcription of the conversation and allows the identification and ordering of key concepts. The coding can be open, axial, or selective. *Open coding* creates a system of codes containing the properties of the key concept. *Axial coding* groups the codes around axes or categories. *Selective coding* makes it possible to integrate and redefine the central categories through their conceptual and theoretical relationship to each other. The constant comparison consists of the continuous comparison of similarities and differences between incidents identified during coding to find patterns and generate explanatory models or theories to interpret the data.

In our case, these phases took place as follows. After the meeting, a transcription of the recordings was made with the typification of the interventions of each participant and of the moderator. Afterward, the keywords or concepts addressed were characterized. Initially, *open coding* was carried out, from which the codes for each key concept emerged and the segments of the text were classified. For example, the code *videos* allowed the grouping of all the segments related to the recordings available in Khan Academy. Through *axial coding*, the relationship and similarity between the different codes were observed and categories were created. With *selective coding*, the categories were integrated, generating central ideas, which allowed the formulation of a theoretical model that explains the interactions between the moderator, the participants, and the online platform to support learning. At the end of each coding stage, a triangulation phase was carried out between the three researchers. In the constant comparison, patterns were sought based on the results of the research and the theoretical framework, in order to propose an explanatory model of the impact of the online platform to support learning in mathematics.

4 Results

In this section, the codes and categories resulting from the qualitative analysis of the focus group transcripts are described.

4.1 Open coding

Data were grouped in 17 codes, shown in Fig. 1, with size proportional to their frequency of occurrence in the focus group. In descending order of importance, a brief analysis of each code is given below.

4.1.1 Extrinsic motivation

Extrinsic motivation is the system of prizes or rewards that teachers give to students for their participation in the online platform to support learning. All teachers agreed that it should be materialized through a contribution to their mark according to the percentage of progress. Even though they managed different percentages (ranging from 5 to 35% of the mark in the subject), teachers assured that the incentive increases students' participation:

> In the first implementation, I considered students' work in the online platform to support learning as optional and participation was awful in all my groups. Then I assigned to this work 30% of the grade of the subject and participation increased.

Fig. 1 Focus group code cloud. Own elaboration

Teachers also referred to the inclusion of gamification methods, like energy points, medals, and avatars as a successful strategy to encourage and increase autonomous work in incoming students.

4.1.2 Contribution

This code refers to the contribution of the online platform to the mathematics teaching-learning process. It highlights technological aspects such as the interactive aids available to students at Khan Academy: videos, exercises with instant feedback, step-by-step hints for solving the exercises, and explanatory texts with examples:

> This makes the lessons more interactive, dynamic and facilitates the way of teaching.

Four participants mentioned that students can strengthen gaps in mathematical previous knowledge, given that Khan Academy covers the thematic axes of the area at all educational levels. Two teachers stated that:

> This strategy is a different way of learning the thematic axes of the subject with didactic tools more in line with the resources currently used by students where they can autonomously strengthen previous knowledge, topics seen in the subject and even get ahead of topics that have not yet been seen.

One participant added that online training reduces the educational gap, enriches participation, and reduces heterogeneity in the learning level of incoming students. Another noted that:

> Khan Academy's videos promote mathematical communication between students and teachers, since by reinforcing topics seen in class, they have tools to generate academic debate around different ways of approaching the same exercise.

This was supported by the anecdote of a participant who, after 20 years of teaching experience, was asked for the first time to explain the factoring of trinomials by the simple root method in a different way than the one explained in class. This teacher reiterated the constant challenge of updating and dynamization that the platform leads to regarding teaching. One teacher affirmed that the online platform goes beyond obtaining a grade, rather encourages students to go beyond.

4.1.3 Follow-up

This code contains the systems for reminding students of the goals of the online training. Three phases were identified. The first consisted of continuous verbal and written announcements of the activities performed in the PREIN online training. The announcements were made on a class-by-class basis, weekly, and/or at the beginning of each cohort, depending on the teacher. A second phase was developed during the autonomous work performed by the students outside the classroom on the Khan Academy platform. To follow up on these activities, students had access to the information page of the online platform (https://preinuts.es.tl/), where they had instructional videos about the training, progress goals, and deadlines for progress reports to teachers. There was a third follow-up phase in which students raised doubts during the lesson and the teacher solved them. This moment was handled in different ways, depending on the teacher. For example, one participant indicated that:

> In these cases, I guide the students on how to approach the exercise but did not give them the answer.

Another teacher stated that:

> I share the exercise on the board and explain the solution.

A third teacher explained that:

> I give bonuses to the student who explains the exercise to his classmates.

4.1.4 Previous knowledge

This code refers to students' previous mathematical knowledge at the time of entering higher education. The teachers unanimously emphasized the lack of leveling in the basic mathematical concepts. According to two participants, incoming students' level of performance presents serious deficiencies, particularly in mathematics, which promotes heterogeneity in the classroom: students with fragile, fragmented, and unconnected previous knowledge, together with students with solid and interconnected previous knowledge. This heterogeneity becomes an obstacle for classroom management.

One teacher also identified a low reasoning level, evidenced by the students' poor ability to argue, formulate, interpret, and represent. This teacher suggested that making students aware of the need to be self-taught through academic demands from day one helps to manage heterogeneity. Another participant asserted that:

> Students have mathematical skills but lack the awareness to understand that they are at a higher level and remain in the school trend, further deepening their shortcomings.

Precisely, a teacher argued that the automatic promotion law implemented by the Colombian Ministry of National Education (Rueda-Gómez & Rodríguez-Muñiz, 2020) has increased the educational gap, generating a cycle of gaps, discouragement, and frustrations in the formative process in mathematics. Additionally, he mentioned that the lack of practice causes students to easily forget processes and have more deficiencies in basic operations. Another participant argued that students become demotivated from learning mathematics because they do not visualize its application in real-life situations.

4.1.5 Videos

This code refers to the explanatory videos available on Khan Academy. The teachers stated that students bring up Khan Academy's videos during classes, through statements such as "just like they explain it in Khan" or "in Khan, they explain it in a different way". These comments led one teacher to say that it was the students who motivated him to review the videos and exercises on the platform to incorporate them in class. According to another participant:

> Working outside the classroom makes it possible for students to bring part of the knowledge to the class, making instruction easier and more interactive.

One teacher said that:

> Sometimes students do not connect with the teacher, but they do connect with the virtual course, achieving effective learning with Khan Academy's videos.

One participant stated that Khan Academy's videos were of great help in the introduction of a new topic:

> I was going to start a topic that I had not taught, and the students already knew something about it because they had already advanced it autonomously. Without telling them anything at all, they knew that with Khan Academy's tools, they could go ahead with the course topics.

This teacher also argued that, in this way, new knowledge is fostered, and mathematical communication is promoted by explaining to the teacher or their classmates how they do it in Khan Academy and intrinsically evaluating what they have learned. In addition, he explained a specific case in which a student told him that she understood Khan Academy's explanation of the chain rule better than the teacher's explanation. He added that there are different ways of approaching a mathematical situation, perhaps due to lack of time, the teacher explains only one method, but the student can independently decide to watch the corresponding Khan Academy's video, finding alternative techniques and choosing the easiest for him. Finally, this participant confessed that it is not easy to accept that some students understand better the explanation through a video than through his explanation and it is this situation that generates curiosity in the teacher to know how else the content was developed in Khan Academy.

4.1.6 Intrinsic motivation

This code refers to the way in which teachers encourage students to fulfill the goal of online training, without resorting to external incentives. One participant pointed out the enormous dependence that any training process has on the students' desire to learn and achieve their professional dreams. Another teacher stated that:

> There are students who, no matter how hard you try to explain it to them, they close themselves off, they are a bit reluctant, or they do not like to go deeper or to strengthen their mathematical skills, which makes it a bit more difficult.

4.1.7 Methodology

When inquiring about the methodology followed by teachers in mathematics classes and its possible influence on students' academic performance, there were three points of view. One participant was against this influence:

> From my personal point of view, I would not believe that the teaching methodology has an impact on performance, because if the student has the willingness, the desire to understand, to learn something, regardless of whether the teacher, let's call him a bad teacher, does not know how to explain something, he will go deeper anyway. This is a double-edged sword because many think that when the teacher is strict, it is because he has a bad methodology, but it is the opposite, he is asking the student to bring out all his potential and it is to his benefit.

On the contrary, other teachers agreed that the methodology used in the classroom had a direct impact on academic performance because the more participative the students were, the better the learning results. In the words of one of them:

> The teacher's methodology has a great influence because the way in which knowledge is transmitted has a direct impact on its internalization.

However, another teacher concluded that:

> The problem is to determine which methodology will best favor a group because all methodologies are valid; however, we all learn differently.

The remaining teachers admitted the influence of methodology but put it on an equal footing with other factors such as disposition, previous knowledge, or motivation.

4.1.8 Participation

Teachers perceived that students' participation depends on different variables, such as academic program, schedule, age, employment status, or gender. Regarding the schedule, it was highlighted that daytime students make better progress in the Khan Academy platform compared to nighttime students, since most nighttime students are older and study and work. However, one teacher reported cases in which the participation of students from both shifts was similar. On some occasions, age has played against participation. Some teachers commented the following:

> Last semester I spoke with an older student with whom I had to implement special alternatives for the adequate development of the content since his age made it difficult for him to use the technologies.

Another participant indicated that:

> Like my colleague, last year I experienced a situation in which an older student had difficulties in using the tool due to lack of time and experience in the use of new technologies.

The teachers were almost unanimous in emphasizing that students who work obtain worse results than those who do not, due to lack of time. Some participants perceived that there is a gender difference in students' participation, in favor of women.

4.1.9 Reaction

This code refers to the way in which students assume the development of the online platform to support learning. Three teachers stated that at the beginning, most of the students complained, claiming that it was too long, tedious, and involved too much time, effort, and dedication. However, as the training progressed, their attitude changed, and they revealed that it was useful because they were able to reinforce previous knowledge and topics previously seen in class or to advance new ones. One participant stated that:

> It is the right way to make them study because it is very difficult for students these days to pick up a book and sit down to study; they prefer videos and more interactive tools.

4.1.10 Human support

Human support refers to the collaboration received by the teacher from the support group or from a student to encourage the level of participation in the online platform. Each teacher was assigned a person from the support group to assist him in solving students' doubts and in the use of the platform. Additionally, each teacher had the option of choosing a student who would help him to solve his classmates' doubts about the platform. Regarding the first type of support, most of the teachers recognized the support received as useful, with some observations regarding the accuracy of the answers or the time to respond. Regarding the second type of support, most of the teachers stated that choosing a student was good as long as they chose charismatic students, with a spirit of service and a bonus for their work. A minimal group of teachers stated that they did not need students' support:

> The choice of a support student is subjective because it is linked to the student's charisma and disposition. Therefore, I believe that in order to make the selec-

> tion more effective, the qualities that the person should have should be made known.

4.1.11 Affective domain

This code refers to the set of attitudes, beliefs, and emotions that students have regarding mathematical skills, which plays an essential role in the mathematics teaching-learning process. In this case, the participants detected that some attitudes, beliefs, and emotions are strongly rooted in incoming students and indicated that, little by little, the affective domain is conditioning success or failure when facing this discipline:

> To find a student confident in their mathematical knowledge is a very strange case, most of them say that learning mathematics is something very difficult, they believe that it is a subject for some geniuses and therefore they do not have the confidence to perform the exercises.

All the teachers perceived fear, insecurity, and anxiety in most of the students and affirmed that insecurity limits the desire to learn more, dragging also an important emotional discomfort, such as sadness, anxiety, and fear, making the student feel, perceive, and behave in an insecure way, which limits his predisposition to learn.

> They start the academic year very anxious because it is their first semester, unsure of their own bases. Some of them have stopped studying a long time ago and, although there is heterogeneity in the groups, they seem very insecure in general.

4.1.12 Structure

This code refers to the organization of the topics addressed in the online platform, which depends on each subject. The teachers of Higher Algebra considered that the training was in line with the syllabus of the subject

> Starting from and guided by the established course plan, what is covered in the online platform is in line with the contents that we have taught.

.The teachers of Mathematics I perceived that it was increasingly consistent with the curriculum:

> It has improved and I liked this semester, I only teach Mathematics I, and the online platform has a lot to do with the program that is within the plan.

However, they pointed out that exercises with trigonometric functions should not be included in a subject at the Faculty of Socioeconomic and Business Sciences. The teachers of Basic Mathematics highlighted the need to go more deeply into operations with real numbers and unit conversion exercises.

4.1.13 Training

This code refers to the training the teachers received on the online platform and at Khan Academy. In this sense, the teachers' attitude was very favorable. In the classroom, the need to provide accurate and timely answers to students' concerns about the use of the platform arose. Consequently, training on the online platform and on Khan Academy for those teaching subjects in which the online training was implemented seemed necessary. Thanks to the training, the teachers had direct access to the Khan Academy databases, allowing them to visualize the enrollment status and percentage level in each activity, to keep a report of their groups. The teachers also indicated that the training was a way to improve their work, but it was necessary to continue counting on those who support the training implementation to solve doubts and inconsistencies in the students' progress reports:

> Yes, I believe that training in the use of the Khan Academy platform is important, but it is also important to continue to have a team of support teachers to resolve certain very specific issues.

4.1.14 Suggestions

The suggestions are the recommendations proposed by the participants in the focus groups to improve the implementation of the online platform. Two teachers recommended training participants, specifically students, in the use of the Khan Academy platform to streamline the implementation of the online training. One participant indicated the possibility of offering training in online training and Khan Academy to new teachers and suggested standardizing extrinsic incentives so that all groups would receive the same percentage of the mark:

> I think it is important to train teachers in the use of Khan Academy, especially for those who are just starting. Then I think it is extremely important to standardize, let's say that if students are going to be given a grade, it should be the same percentage in all groups so that all teachers speak the same language.

The teachers were unanimous in their opinion that the enrollment process should be simplified since it is the most difficult step for students.

4.1.15 Organization

This code refers to the obstacles in teaching management. The discussion focused on time management, since the extensive content, the reduced class hours, the heterogeneity in the students' learning level, and the management and incorporation of different technological tools are factors that teachers must maneuver to achieve the expected objectives. One participant indicated that:

> It is very complicated, quite complicated, to fully comply with everything indicated.

4.1.16 Exercises

Included in this code are practices, quizzes, and unit tests available at Khan Academy. Teachers have different perceptions. For example, one noted that Khan Academy's exercises strengthen the learning of the subject, while others indicated that the exercises were in line with what was seen in class and therefore incorporated them in workshops, quizzes, and evaluations:

> Using some exercises that were on the online platform helped the development of the class.

4.1.17 Technical support

This code refers to the technical assistance needed to make correct use of the online platform. The teachers agreed that the main inconvenience was related to the registration of students, because they omitted steps or did it wrongly, and, at the time of generating the progress report, they did not appear, and complaints were filed. At the same time, they expressed their dissatisfaction with not having access to their Khan Academy accounts to be able to view their students' results online, in real-time:

> We do not have access to verify the registration of students on the platform and how much progress they have made, so when the reports are generated to be able to assign the grade, inconsistencies appear.

4.2 Axial coding

Figure 2 shows the axial coding results, which visualize the relationships between the different codes to identify central axes or categories. The map of codes positions them according to their similarity: the greater the similarity, the greater the proximity in Fig. 2. In addition, the size of the dots is proportional to the relevance of the code. The colors illustrate the groupings and the connecting lines indicate the intersection between codes. The width of the line represents the intensity of the intersections: the greater the width, the greater the number of segments in which the two connected codes are assigned. Five categories were identified: *obstacles*, *teacher contribution*, *students*, *platform*, and *reinforcement*, which are described below.

The *obstacles* category gathers the different impediments that teachers had to face. The *teaching contribution* category groups codes that indicate the added value that

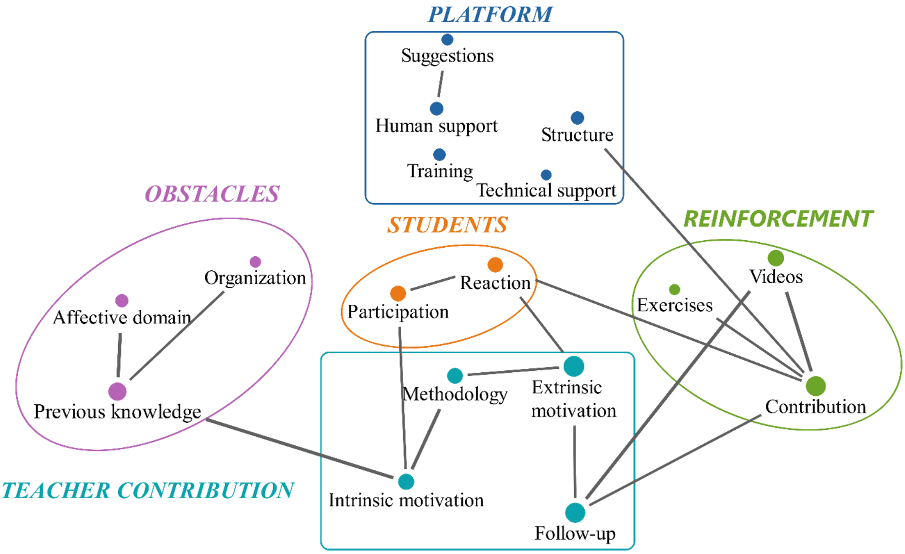

Fig. 2 Axial coding. Own elaboration

teachers found in the classroom after the implementation of the online training. The *students* category includes the reception given by the students to the online training. In *reinforcement*, codes are associated with the medium used to develop the online training, highlighting the tools available and the contribution made to mathematics learning. Under *platform*, codes referring to the strategy itself and how to improve it for future implementations are grouped together.

4.3 Selective coding

Selective coding was carried out to integrate and redefine the central categories, resulting in the model of implementation of the online platform to support mathematical learning shown in Fig. 3. The model constructed suggests that the educational institution should have a support group of teachers trained in the use of Khan Academy, who are responsible for managing the resources, involving, and accompanying teachers throughout the implementation and measurement of the strategy in the classroom. The teacher, for his part, continues to conduct his class as he used to, but refers to the Khan Academy resources to deepen and exercise what was studied in class. In his independent work at Khan Academy, the student has activities available according to his learning level, either to strengthen previous knowledge of the subject, deepen what has been seen in class, or advance in the topics that have not yet been seen. Likewise, on the platform, the student will have access to videos, practices, and self-regulation systems, which favor the effective mastery of mathematics. The generation of progress reports is a source of information in the construction of institutional quality indicators, that can be used for the accountability that every public institution of higher education is subject to.

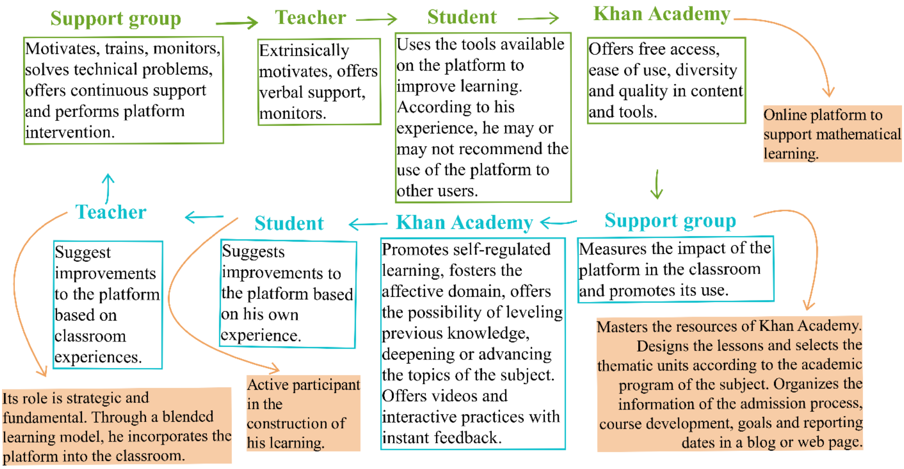

Fig. 3 Model of implementation of an online platform to support mathematical learning. Own elaboration

5 Discussion

The implementation and analysis of the use of an online platform to support learning have been carried out institutionally and massively for seven consecutive semesters, maintaining the alternative of implementing a traditional dynamic classroom, technologically enriched with Khan Academy. The process of reflection through focus groups led to the identification of the factors that must be considered to achieve the successful and sustained implementation of the strategy in the classroom, and its integration into an explanatory model that constitutes the main finding of this research (Fig. 3). The model makes it possible to clarify the factors that influence the success of the implementation of methodologies of these characteristics, which are increasingly used in higher education, although a systematized analysis such as the one revealed by this research is often lacking.

Another of the most relevant findings of the research is the ease with which the platform allows students to learn and explore different strategies to those offered by the teacher in his lessons (those found in the Khan Academy material). In this way, students bring new methods to the classroom and generate a virtuous circle that awakens the teacher's curiosity about alternative ways of explaining or developing certain content, while at the same time challenging him to learn about these new methods to guide his students (Vidergor & Ben-Amram, 2020). In other words, Khan Academy allows to see the way in which other teachers in other countries guide mathematical knowledge, enriching the teaching practice and making the students the ones who promote this challenge in the teacher. For their part, teachers are committed to expanding their specialized knowledge, particularly from the didactic point of view (Carrillo-Yáñez et al., 2018; Mariano-Dolesh et al., 2022) and also their beliefs about learning and teaching mathematics (Aguilar-González et al., 2022). This way of reconstructing knowledge and beliefs by observing foreign didactic-mathematical approaches is placed in the international research agenda on both initial

(Muñiz-Rodríguez et al., 2020) and continuing (Karsenty & Sherin, 2017) mathematics teacher education.

Higher education must face formative challenges such as the diversity of mathematical knowledge of incoming students (Di Martino et al., 2023; Rodríguez-Muñiz et al., 2020) or the leveling of mathematical previous knowledge and its direct implications on early dropout rates (Büchele, 2020; Castro López et al., 2020; Rodríguez-Muñiz & Díaz, 2015). This research shows how university teachers perceive that strengthening previous knowledge is a fundamental factor in learning support strategies and that the possibility of doing so through online platforms improves the adaptive processes that students must face in the transition from secondary to higher education because it fosters autonomy, computer self-efficacy, and self-regulation (Akbari et al., 2022; Courtney et al., 2022a; Hasan et al., 2020; Rueda-Gómez et al., 2023).

The teachers who participated in the focus group also pointed to the value of the self-regulation that occurs with the platform. Students quickly learn to seek help through the feedback tools available on the platform, an idea previously highlighted by Gray and Lindstrom (2019). This process of reflection on their procedures and problem-solving methods makes students feel more confident in their mathematical skills and that translates into greater participation in face-to-face classes. This finding is consistent with Castro López et al. (2020) and supports the quantitative findings evidenced in Rueda-Gómez et al. (2023). This self-regulation is also manifested, according to the teachers, in the possibility of clarifying, through the Khan Academy's videos, doubts about what has been discussed in class and advancing topics that have not yet been seen (something also noted in this regard in Gray and Lindstrom, 2019 and Zotova et al., 2021). In addition, the videos generate in the students the confidence to intervene actively and accurately in the classes, activating an undervalued skill in the formative process in the Colombian university context, such as mathematical communication, fundamental in the development of mathematical competence (Gravemeijer et al., 2017). The autonomous work of students also allows classes to be more fluid and time more efficient, thus managing to cover all the thematic axes (Ferdinand et al., 2020), which contributes to improving the organizational factor of teaching management, instead of being an additional burden.

Unlike Benavidez Lozano et al. (2019) and Hernández et al. (2018), from our research, it is deduced that the role of the teacher is a strategic factor in the implementation of online courses that strengthens the mathematical knowledge or previous knowledge of incoming students because through the different motivational mechanisms, participation is boosted and the student's reaction to the development of online activities is improved. This perception expressed in the focus groups is in accordance with Gray and Lindstrom (2019) and Ramírez (2012).

The proposal of Rodríguez-Muñiz and Díaz (2015) regarding joining efforts to promote a joint web platform or the shared use of current mathematics platforms is materializing worldwide with Khan Academy and the results of this study are proof of this. In this sense, the implementation of an online platform to support learning is the first intervention to be done massively (9 240 incoming students), periodically (during seven consecutive semesters), and applying measures of effectiveness, as suggested in Rodríguez-Muñiz and Díaz (2015). In this sense, the analysis performed in this study can be considered, as far as the authors know, pioneering.

We wish to emphasize that the online platform to support learning mediated by Khan Academy is perceived by teachers as an ally or mediator in the process of didactic transposition and as a dynamizing strategy, which helps incoming students to face the challenges of higher education in mathematics. From the results of this research, a traceability model of the impact of the use of online platforms to support learning on students' academic performance is extracted (Rueda-Gómez & Rodríguez-Muñiz, 2020; Rueda-Gómez et al., 2023) that is exportable to other contexts and that identifies the factors that mediate the success of their use, in order to make the necessary interventions aimed at obtaining the academic objectives of students entering higher education and at the same time minimize implementation costs. Moreover, with the necessary adjustments to analyze the specific characteristics of the subject under consideration, the explanatory model could also be easily adapted to subjects other than mathematics. Consequently, it is up to educational institutions to continue implementing these innovations, with a view to sharing and integrating experiences aimed at making learning more flexible.

Our model underlines that the role of the teacher is essential to guarantee the success of an online platform to support learning since the teacher's contribution through factors such as extrinsic motivation, intrinsic motivation, or follow-up have a favorable impact on the students' reaction and participation. On the other hand, the model also shows that the role of the teacher must be reinforced with continuous training in mathematics and its didactics that allows him to respond to the challenges that the autonomous learning of students, in parallel and with tools outside his lessons, will bring about in the classroom. Notwithstanding, we agree with Mullen et al. (2021) about the need for more research on this topic because the evidence says that, despite the benefits of online platforms to support learning, there are other aspects to deal with.

We conclude by pointing out the main limitations of the study, which derive from the methodology used. Focus groups and grounded theory represent an exploratory approach to the analyzed phenomenon and have made it possible to reveal existing phenomena and opinions, as well as latent preferences and values that explain the discourses and positions. However, even though the data have been permanently triangulated in each of the coding processes, the results may have an interpretation bias on the part of the researchers. On the other hand, we cannot ignore the possible biases of the participating teachers, who, despite being randomly recruited, and their anonymity maintained, are aware that the research is part of a process of accountability at the institutional level, making it difficult to generalize the results.

To summarize, the findings of this study carry significant implications for both theoretical and practical domains. First, the findings allowed the delineation of an explanatory model that clarified the factors that influence the success of the implementation of online platforms to support learning. In this sense, a related contribution is the capacity of Khan Academy to strengthen incoming students' previous knowledge and self-regulation and, additionally, to let students and teachers know alternative strategies when teaching and learning mathematics, favoring more dynamic and efficient classes. Second, this study emphasizes the role of teachers to assist the development of online learning and guarantee the expected success, since extrinsic motivation and reminders have been identified as relevant factors. Third, it is crucial that educational institutions ensure continuous training for teachers that allows them to face the challenges posed by online platforms to support learning.

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Declarations

Competing interests The authors declare that they have no competing interests.

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