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Artículos científicos

Aplicación del ABP y m-learning como estrategias para el aprendizaje de la función lineal en el bachillerato

PBL and M-Learning as Strategies for the Learning of the Linear Function in High School

Aplicação de PBL e m-learning como estratégias para aprender a função linear no ensino médio

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Resumen

La presente investigación tuvo como objetivo construir un curso que conjunte las ventajas que ofrece el *m-learning* con una metodología basada en problemas. En esa línea, se muestran los alcances obtenidos al implementar un microcurso de funciones lineales para la asignatura de Matemáticas IV del bachillerato en México a través de contenidos más adaptados a las preferencias de los estudiantes. Así, los participantes analizaron situaciones propias de su contexto mediante la incorporación de un aprendizaje móvil. Una vez finalizado el diseño y empleando un enfoque cuantitativo, se aplicó un cuestionario que puso a prueba las habilidades adquiridas por los estudiantes al resolver diferentes problemáticas. Los resultados muestran una mejora en el desempeño de los participantes, así como una mejor comprensión del tema de función lineal, por lo que es posible decir que incrementaron sus habilidades procedimentales y nociones conceptuales. Los valores obtenidos permiten asimismo construir una nueva visión para la elaboración de cursos con un método basado en el *m-learning.* Se trata de una perspectiva donde no se prescinde del nivel de exigencia y donde se adaptan las asignaturas a los nuevos recursos digitales que se están desarrollando en el contexto global.

Palabras clave: aprendizaje basado en problemas, función lineal, *m-learning*.

Abstract

The objective of this research was to build a course that combines the advantages offered by m-learning with a problem-based methodology. In this line, we show the achievements obtained by implementing a microcourse of linear functions for the subject of Mathematics IV of high school in Mexico through contents more adapted to the preferences of the students. Thus, participants analyzed situations specific to their context through the incorporation of mobile learning. Once the design was completed and using a quantitative approach, a questionnaire was applied to test the skills acquired by the students when solving different problems. The results show an improvement in the performance of the participants, as well as a better understanding of the topic of linear function, so it is possible to say that they increased their procedural skills and conceptual notions. The values obtained also allow us to build a new vision for the development of courses with a method based on m-learning. It is a perspective where the level of demand is not ignored and where the subjects are adapted to the new digital resources that are being developed in the global context.

Keywords: problem-based learning, linear function, m-learning.

Resumo

O objetivo desta pesquisa foi construir um curso que combinasse as vantagens oferecidas pelo m-learning com uma metodologia baseada em problemas. Nesta linha, os resultados obtidos com a implementação de um microcurso de funções lineares para a disciplina de Matemática IV do bacharelado no México são mostrados por meio de conteúdos mais adaptados às preferências dos alunos. Assim, os participantes analisaram situações específicas de seu contexto incorporando o mobile learning. Uma vez finalizado o desenho e utilizando uma abordagem quantitativa, foi aplicado um questionário que testou as competências adquiridas pelos alunos na resolução de diferentes problemas. Os resultados mostram uma melhora no desempenho dos participantes, bem como uma melhor compreensão do tema da função linear, pelo que é possível dizer que suas habilidades processuais e noções conceituais aumentaram. Os valores obtidos permitem também construir uma nova visão para o desenvolvimento de cursos com método baseado em m-learning. É uma perspetiva onde o nível de exigência não é dispensado e onde as disciplinas se adaptam aos novos recursos digitais que se vão desenvolvendo no contexto global.

Palavras-chave: aprendizagem baseada em problemas, função linear, m-learning.

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Introduction

The teaching of mathematics has been a subject of constant analysis within the educational policies of Mexico. The low results obtained in standardized tests such as the Program for International Student Assessment (PISA), where 44% of students reached level two (they can interpret and recognize the mathematical representation of a simple situation), while only 1% obtained a proficiency level five or higher (Organization for Economic Co-operation and Development [OECD], 2018). The statistics shown show that there is not an adequate level of comprehension or mathematical skills to solve and understand different problems. Therefore, this scenario is an area of opportunity to create better teaching strategies in the classroom.

Establishing mechanisms that increase both academic performance and the development of skills and attitudes of students has become fertile ground for the development of research within this discipline. When analyzing the highest failure levels within the different educational levels, a high incidence is found in upper secondary education (National Institute of Statistics and Geography [Inegi], 2020). One of the disciplinary fields that most presents this situation is that of mathematics, which encompasses all subjects that promote development and mathematical thinking.

In high school, the curricular map stipulates four compulsory mathematics courses, through which topics of arithmetic, algebra, geometry, trigonometry, analytical geometry, precalculus, among others, are addressed. In the case of precalculus, this advanced form of algebra is offered in the last course of the curriculum map (Math IV). It is worth mentioning that the study plan of the General Directorate of Baccalaureate [DGB] (2018b) of this subject establishes as an objective the promotion of critical and reflective elements in students that allow them to propose alternative solutions to human actions with an impact within the context in which they are found.

In the IV mathematics course, one of the blocks where there is a greater connection with situations of daily life is that of Polynomial Functions. And within this, the topic of the linear function is one of the most applicable.

If the mathematics courses within the baccalaureate seek for students to be able to transfer the knowledge acquired in the classroom to everyday situations to create solution models (DGB, 2018b), it is important to do so through a procedural methodology, thanks to which students manage to solve these problems from a personal approach, with a theoretical-procedural support provided within the mathematics classes. This is where problem-based learning (PBL) stands as a viable alternative. Through the incorporation of new technologies and digital tools, the PBL provides a real opportunity to improve the understanding of concepts and greater academic achievement in the field of mathematics (Alzate, Montes and Escobar, 2013).

The PBL is considered a methodology focused on learning, research and reflection that students follow to reach a solution to any problem raised (Espinoza and Sánchez, 2014). Oriented to education, the PBL maintains a multi-methodological and multi-didactic pedagogical approach aimed at facilitating the teaching-learning process (Dueñas, 2001).

Under this strategy, the student must maintain self-learning and constant knowledge management of it with an orientation towards constructivism. It is considered a didactic method that falls into the domain of active pedagogies, within which there is a greater preponderance towards teaching called learning by discovery (Restrepo, 2005), where the student becomes the main protagonist of his training process. .

One of the most complex aspects that the teacher faces when establishing the PBL consists of the selection and approach of a problem that is relevant and is attached to the contents displayed in the course. The problem as such must maintain a high expectation, as well as a constant motivation for the students in such a way that it encourages them to inquire about the connection between their learning and the solution proposal that they must provide. To carry out a problem that meets the characteristics stipulated by the PBL, Albanese and Mitchell (1993) propose that it contain three variables: relevance, coverage, and complexity. Since young people are currently digital natives (Prensky, 2003), it is required that the content of the problems be related to current digital media. Undoubtedly, this type of modality boosts the interest of the students, therefore, the use of the PBL under this mediation maintains a greater openness to the creation of contents and activities due to the current technological impulse. In works such as that of Escobar Ávila and Suárez (2022) it has been shown that an adequate link between current technological developments and PBL in hybrid modalities brings substantial improvements in the understanding of complex topics in the field of engineering. On the other hand, Herrera and Padilla (2020) concluded that in the field of mathematics, including the use of technological resources within the training processes improves the attitudinal and academic performance of students, both essential aspects for the creation of new resources within from the classroom.

Among the emerging technologies is mobile learning (m-learning), which entails the use of a teaching-learning methodology that contemplates the use of mobile devices such as smartphones, electronic agendas, tablets, among others. Its main characteristics provide students with greater flexibility than that which exists in e-learning, since the mobile device allows easier access to the Web, without the need for a computer (Gómez and Pulido, 2015). According to Villa, Tapia and López (2010), the characteristic that differentiates it from other types of models lies in the analysis of two points: the technological one and the educational experience.

In the case of the former, m-learning allows access to courses and their contents from anywhere (Brazuelo and Gallego, 2011), with the advantage of not continuously requiring a fixed Internet service, due to the fact that the devices Smart phones can connect to mobile data without the need for a nearby modem or router. Regarding the educational experience, the contents change given the conditions in which they were created. For example, in e-learning it is common to find files or documents that can only be viewed from a special program for computers or laptops; In m-learning, the material must be totally adapted for its correct visualization and analysis.

Considering the advantages offered by m-learning, Brazuelo and Gallego (2011) establish it as an emerging educational modality that facilitates the construction of knowledge, the resolution of learning problems and the development of skills and abilities in an autonomous and ubiquitous way thanks to the mediation of mobile devices. This characteristic allows us to place this methodology as viable for the implementation of a PBL model where the linear function is instructed from a new perspective: a window for the analysis and reflection on the use of said aspects in high school mathematics courses.

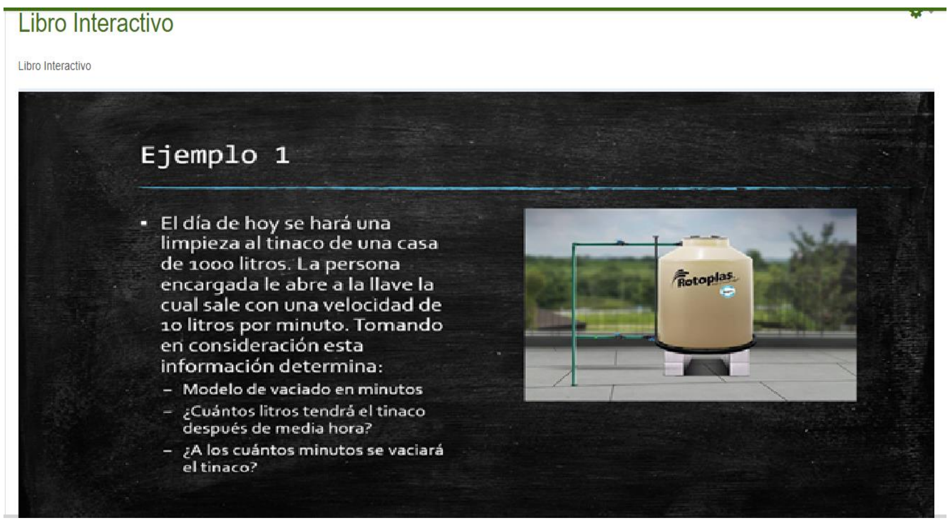
This leads to the following research question: does the academic and attitudinal performance of students in a precalculus course improve by implementing PBL and mobile learning within the analysis of the linear function? So, this is the element that will be analyzed next.

Method

To combine the previously mentioned proposals, it was important to include an instructional design where PBL was present and had different problems applied to daily life that required, for their solution, the linear function. The contents created within the instructional design were adapted so that the presentations, videos, tutorials and additional material were compatible for the students' mobile devices. All the information was uploaded to the institutional platform, which is supported by Moodle.

The analysis of the theme began by proposing exercises as examples in which the function was used as a model for solving the problem (see figure 1).

Figure 1. Instructional design example



Source: Own elaboration

Once the various examples with their respective procedures were analyzed, the students began to carry out the problems raised within the instructional design, which were supported by the interests of the participants, being used in sports, social or financial problems (see figure 2). Each of the response models were shared by the students within a padlet in order to compare results and analyze those coincidences or discrepancies within the solution models.

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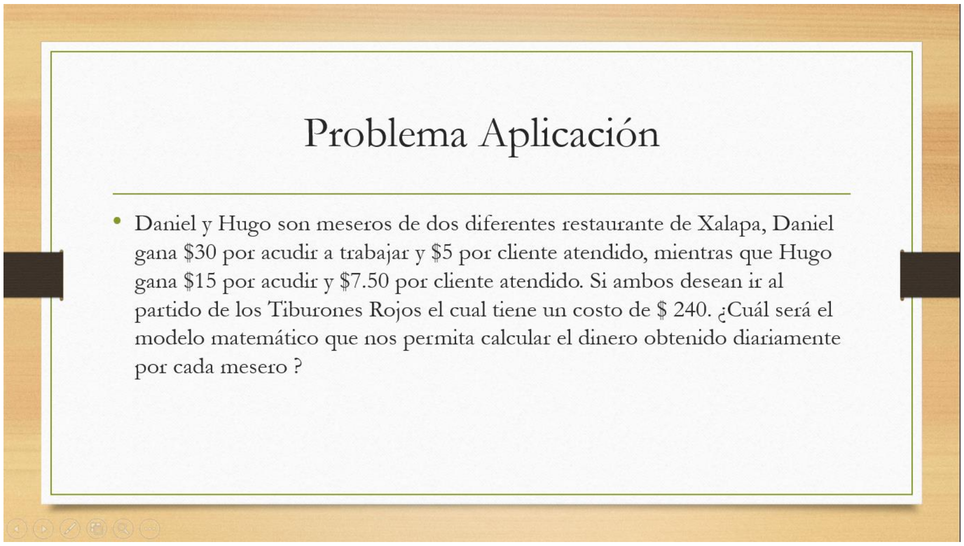
Figure 2. Problema posed by a participant



Source: Developed by the participant A10

Within the solution proposal, the young people preferred to use graphs and tabulations as mechanisms for checking results. In this way, they validated each of their models through these representations. The presentation of the material was left optional, since they could choose between uploading images from their mobile device or including a digitized design (see figure 3).

Figure 3. Resolution of the problem posed

Tabulación

x	F(x)=5x+30	G(x)=7.50x+15
0	5(0) + 30 = 30	7.5(0) + 15 = 15
1	5(1) + 30 = 35	7.5(1) + 15 = 22.5
2	5(2) + 30 = 40	7.5(2) + 15 = 30
3	5(3) + 30 = 45	7.5(3) + 15 = 37.5
4	5(4) + 30 = 50	7.5(4) + 15 = 45
5	5(5) + 30 = 55	7.5(5) + 15 = 52.5
6	5(6) + 30 = 60	7.5(6) + 15 = 60

Source: Developed by the participant A10

Methodology

The methodology chosen in this work was quantitative. Once the instructional design was finished, we proceeded to collect information. For this, a questionnaire was used. For the conformation of the instrument, existing exercises were applied within the book proposed by the DGB Veracruz. Likewise, a pretest was applied with students from a previous generation, this information allowed us to know in greater depth the real context of the school and the student population. Another notable aspect consisted of the elaboration of the problems, which were selected from the course book, this in order to guarantee the validity and adherence of the instrument to what is stipulated by the official study plans and programs of the subsystem.

The information obtained in the questionnaire allowed us to know the impact of the actions undertaken through the analysis of exercises and quantified problems according to the level of procedural skills. In the same way, in addition to the records and representations within the different problems, it is visualized if there is a realization of the objectives stipulated at the beginning of the study.

The instrument was applied to 40 students at the end of the implementation of the instructional design. The selected sampling was for convenience, because the youngsters had to include the consent and participation permission of their guardians and them. In order to safeguard the confidentiality of the participants, they were assigned a code and number, starting with A1 up to A40. They were informed that if they wanted to abandon the test, they were free to do so at any time they wished and that the results they presented during the completion of the document would be omitted.

The application presented no incidents and the participants honestly answered the questions that were indicated to them. The test lasted two hours and none of the members required additional time. They were asked to write down the procedures used and, if possible, not to delete the incorrect methods. The questionnaire included a first section where the procedural skills of the students were analyzed when solving linear function exercises, of which it was reviewed if the graph, the domain and the range of this could be made (see figure 4). For the statistical analysis, the set of frequencies (relative and absolute) of each indicator was considered, as well as the average number of responses for each level of understanding.

On the other hand, the following section contained two problems: the participants had to build the linear function model that would provide a solution to the situation posed. In this case, the expected (correct) answers were taken into consideration, as well as the incorrect ones, which were subdivided into misunderstanding and inadequate interpretation. In the case of misunderstanding, those participants who had not understood the meaning of the statement and had not created a development based on it were grouped. On the other hand, in the inadequate interpretation, those who did manage to understand the problem were grouped, but had a wrong interpretation of the conditions or variables within the situation raised.

Figure 4. Questionnaire

Source: Own elaboration

Results

In the first part of the questionnaire, the students solved three functions where they had to obtain the domain, range, as well as the graph of the requested functions. In the first case, where the function was f(x) = 5, corresponding to a constant linear function with a low degree of difficulty, the youngsters obtained the results shown in Table 1:

Table 1. First linear function excercise

$f(x) = 5$	Graph	Domain	Range
Expected procedures	32 (80 %)	40 (100 %)	31 (77.5 %)
Incomplete procedures	8 (20 %)	0	9 (22.5 %)
Did not answer	0	0	0

Source: Own elaboration

In this case, the majority of the participants managed to reach the expected procedures, made the graphs and obtained the range and domain, the latter being where everyone managed to reach the expected answer. For the second exercise, corresponding to a linear function f(x) = -2x + 5, a similarity was found in terms of the previous values, since more than 60% of the young people obtained expected responses in each of the indicators. However, the data that stands out the most is the fact of finding unanswered items, that is, moments in which the young people did not make any attempt to reach the requested response (see table 2).

Table 2. Second linear function excercise

$f(x) = -2x + 5$	Graph	Domain	Range
Expected procedures	29 (72.5 %)	38 (95 %)	38 (95 %)
Incomplete procedures	6 (15 %)	0	0
Did not answer	5 (12.5 %)	2 (5 %)	2 (5 %)

Source: Own elaboration

Regarding the third exercise, fractional values were included for the slope ($f(x) = \frac{1}{4}x + 5$), and the results show that a small decrease was found with respect to the previous two. Here there were some errors on the part of the participants that prevented them from reaching the expected answers regarding the graphing process, but not so in the domain and range, where the same values were maintained as in the previous situations. As in the previous example, there were occasions where the participants did not answer the corresponding part of the exercise (see table 3).

Table 3. Third linear function excercise

$f(x) = \frac{1}{4}x + 5$	Graph	Domain	Range
Expected procedures	20 (50 %)	37 (92.5 %)	38 (95%)
Incomplete procedures	12 (30 %)	0	0
Did not answer	8 (20 %)	3 (7.5 %)	2 (5 %)

Source: Own elaboration

As for the next part of the questionnaire, where the performance of the participants was analyzed when solving an applied problem, situations similar to those previously obtained were found. For example, when analyzing the two problems, it is possible to identify agreement when reviewing the values of the mathematical model approach. In this case, the participants had a high incidence of expected responses and only three participants left the problem blank (see Table 4).

Table 4. Modeling of problems

	Problema 1 A parking garage charges $20 for its service and $5 per hour. Calculate its hourly pay model.	Problema 2 A video app pays its content creators $2000 for uploading new material and $3 for each play of their videos. Calculate its revenue model per video viewed
Expected model	38 (95 %)	34 (85 %)
Incomplete model	2 (5 %)	6 (15 %)
Did not answer/ Incomprehension	0	0

Source: Own elaboration

Regarding the questions to validate the function that provides an answer to the proposed problem, where they are asked to substitute and clear values so that the participants can verify their solution proposal and determine if the approaches were adequate, the results showed in the same way, a concordance with respect to what was obtained (see table 5).

Table 5. Model Validation

	Problema 1 Using your model, determine the payment that would be made by a car that stayed for five hours	Problema 2 With your model, determine the payment the content creator will receive if their last video had 1250 views
Expected response	36 (90 %)	33 (82.5 %)
Incomplete answer	4 (10 %)	7 (17.5 %)
Did not answer/ Incomprehension	0	0

Source: Own elaboration

When analyzing the restrictions of the function such as range and domain, a better understanding was identified within the answers; Furthermore, high rates of expected processes were found in both problems. In the case of domain, Table 6 shows the values obtained.

Table 6. Problem domain analysis

	Problema 1	Problema 2
Expected response	38 (95 %)	38 (95 %)
Incomplete answer	2 (5 %)	2(5 %)
Did not answer/ Incomprehension	0	0

Source: Own elaboration

In the case of the range, the values were similar to those presented in the domain. There were no young people without answering this section and almost all of them reached the expected answer (see table 7).

Table 7. Range analysis in problematics

	Problem 1	Problem 2
Expected response	36 (90 %)	35 (92.5 %)
Incomplete answer	2 (10 %)	2(7.5 %)
Did not answer/ Incomprehension	0	0

Source: Own elaboration

Finally, for the graphing, situations were found that allowed for similar results in both cases. The participants, in a percentage higher than 80%, managed to reach the expected answers, which consolidated what had previously been specified in the analysis of the function exercises. Another factor that stands out is not finding participants who left the problems unanswered, which shows a degree of understanding of the situation raised (see table 8).

Table 8. Graphing analysis in problematics

	Problem 1	Problem 2
Expected graph	38 (95 %)	32 (80 %)
Unexpected graph	2 (5 %)	8 (20 %)
Did not answer /Incomprehension	0	0

Source: Own elaboration

Discussion

Based on the results obtained, the importance of the use of PBL is established, which is considered a methodology focused on learning, research and reflection that students follow to reach the solution of the problem raised (Espinoza and Sánchez, 2014). The PBL maintains a multi-methodological and multididactic pedagogical approach aimed at facilitating the teaching-learning process (Dueñas, 2001). Under this strategy, the student must maintain self-learning and constant knowledge management with an orientation towards constructivism. In this aspect, the PBL takes up each one of the requirements established in the study program, since it allows the inclusion of mathematical models for the solution of problems.

To consolidate PBL in the classroom, it is important to include the new technological tools that have been developed in recent years. Teaching through digital media has created a new paradigm within teaching strategies, which have improved student performance, as indicated by research such as Fornari et al (2017), testimonials in which, Through virtual education, it has been possible to reduce failure rates in complex subjects such as differential calculus. Similarly, Molina and Romero (2010) created a mobile learning environment based on microlearning in a course at the Tecnológico de Monterrey in which they took advantage of the advantages offered by new smartphones to promote teaching with short intervals, with greater productivity. and accessibility.

In turn, the results show that the PBL helps to meet the objectives proposed within the DGB (2018b) study plan, that is, to promote critical and reflective elements for the solution of problems typical of the context of young people, a better understanding of the contents is presented, this being the case of the linear function. The results of the present investigation show that a good performance was presented by the participants within their procedural skills to solve exercises, in addition to a good understanding and adequate procedures for solving the problems raised.

In the case of the procedural skills of the participants, an adequate development was identified on the part of the young people, who mostly obtained expected responses in the three proposed exercises. Although a PBL approach was maintained, which implies a methodology focused on learning, research, and reflection (Espinoza and Sánchez, 2014), during the development of the design, reinforcement channels were established through exercise repetition approaches that allowed students to consolidate and improve procedural development. This allows opening a new route where the methodology is not only focused on a single teaching approach, but, on the contrary, includes different methods according to the needs and contexts of the students to build better strategies for high school teachers.

When analyzing the problems raised, a relationship is found with what was proposed by Fornari et al. (2017), since an improvement in student performance was identified when implementing a virtual education, which must be well supported within the instructional design and the set of activities proposed in each module or unit. Similarly, there is a similarity with the vision of Molina and Romero (2020), due to the benefits obtained by including microlearning supported by mobile learning, which has created in this research a new paradigm where the mobile phone becomes a tool within the teaching-learning process.

On the other hand, the results support the methodology used, the PBL as a strategy for teaching the linear function in a microcourse through mobile devices, this being a contribution that differs from others where the PBL is only analyzed from a face-to-face environment. , or in some cases mediated by technology, but without considering mobile learning and the use of micro-courses to motivate learning. This creates a scenario to build new courses more adapted to the needs of students and the technological development in which society finds itself.

Conclusion

The current digital era has allowed that each year there are emerging technologies that incorporate a new horizon of possibilities to improve teaching strategies. In recent years, methodologies such as PBL have had a strong development within various proposals, but this one linked the use of problem-situations mediated by m-learning, which not only improved the perspective of young people towards mathematics, but also Rather, it incorporated a new, more up-to-date strategy with greater affinity for students.

The results showed that the participants had a better understanding of concepts such as range and domain, which, in normal situations, are complex to analyze. In the same way, the development achieved by the participants when solving the problems shows an adequate transition between procedural knowledge, between natural language towards a mathematical one.

At the beginning of the study, it was raised whether the present proposal would improve the performance of the students in their understanding of the linear function and the elements that surround it. The results show that this study fulfills this purpose, which allows expanding this type of methodologies to build learning objects with an orientation towards the development of technology and the promotion of emerging media.

Finally, it is established that the use of mobile devices are not an enemy in the classroom, on the contrary, they can emerge as an important ally for the teaching process. Thanks to the construction of new learning objects and proposals such as this one, the teaching of mathematics at the high school level is increasingly in line with the century in which it is being developed.

Future lines of research

According to the results obtained, two important perspectives were obtained. The first consists of the creation of more units and designs that expand the proposed methodology for the future construction of a Mathematics IV course with the same approach that has been used in the module. Thus, the use of technological resources such as mobile devices that promote m-learning in conjunction with more interactive elements that are more enjoyable for students will be prioritized. Considering that the baccalaureate is the educational level where there is the highest failure rate within the Mexican educational system (Inegi, 2020), it is important to update and promote the construction of courses with more dynamic content and adapted to the use of emerging technologies in conjunction with methodologies such as m-learning.

The second aspect consists of the attitudinal development of the participants. It is about identifying mathematics as a discipline where they can promote skills for critical and reflective thinking through the use of resources more adapted to the new needs and requirements of the current century, with updated and relevant approaches to the digital age in which it is applied. Find the educational process.

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