

Educational computing to assess decision-making learning in university students

Tecnología educativa para evaluar aprendizaje de toma de decisiones en estudiantes universitarios

<https://doi.org/10.32870/Ap.v15n2.2363>

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ABSTRACT

Keywords

Virtual learning environment; educational computing; m-learning; engineering

This paper describes a study related to the learning of decision-making heuristics such as preference matrix, break-even point and decision tree from the perspective of using a computational tool. With their respective algorithms, a virtual learning environment through a mobile application (app) aimed at Engineering students was developed. To answer the research questions posed in this report, an empirical study was conducted to assess the effectiveness, efficiency and cost in solving decision-making problems with and without the use of the app. The results in this study suggest that the use of the app in learning decision-making skills facilitates the mathematical process for students, and that by using critical thinking competence, they can make assertive and accurate decisions considering different alternatives.

RESUMEN

Palabras clave

Ambiente virtual de aprendizaje; tecnología educativa; aprendizaje móvil; ingeniería

En este artículo se describe un estudio relacionado con el aprendizaje de las heurísticas para la toma de decisiones como son matriz de preferencias, punto de equilibrio y árbol de decisiones desde la perspectiva del uso de una herramienta computacional. Con sus respectivos algoritmos se desarrolló un ambiente virtual de aprendizaje a través de una aplicación móvil (app) dirigida a estudiantes de ingeniería. Para responder a las preguntas de investigación planteadas en este reporte, se realizó un estudio empírico para evaluar la efectividad, eficiencia y costo en la resolución de problemas para toma de decisiones con y sin el uso de la app. Los resultados en este estudio sugieren que el uso de la app en el aprendizaje de las habilidades en la toma de decisiones facilita a los estudiantes el proceso matemático, y que al utilizar la competencia de pensamiento crítico pueden tomar una decisión de manera asertiva y correcta, considerando diferentes alternativas.

Received: December 16, 2022
Accepted: July 14, 2023
Online Published:
September 30, 2023

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INTRODUCTION

The industrial sector in Mexico has undergone significant development through the incorporation of new technologies that have enabled the growth of the industry. In order to guarantee an adequate administrative management and avoid operational losses, it is essential to implement the tool known as break-even point, which shows the interrelation of changes in costs, volume and profits over time, making it a useful tool for planning, control and, above all, decision making.

Likewise, there is research concerning the use of the decision tree tool, such as the work of Contreras *et al.* (2020) where they calculate academic performance as an indicator of success or failure of engineering students by means of machine learning. On the other hand, Luan *et al.* (2019) mention that people can make better decisions by employing fast heuristics under common uncertainty conditions.

Although abundant and accessible information is available from databases in the field of decision making, concepts such as formal training and day-to-day experience are also considered as alternative options in the evaluation and development of decision making tools. Hutchinson *et al.* (2010) indicate that belief-based information can be contrasted with data-driven information, which flows routinely in most organizations to interpret numerical data that are sometimes heavily biased by the cognitive heuristics used to analyze them.

On the other hand, the use of information and communication technologies (ICT), understood and used as support tools, allows the teacher to create an enthusiastic and motivated environment, which improves the teaching-learning process. Educational technology enables the development of new integration models (teacher-student) and the use of technological devices to access information and resources that complement classroom learning. Currently, education is a variable that incorporates diverse communities, and ICTs are one of the main links for learning.

The purpose of this article is to describe a research project based on heuristics for decision making, which resulted in a mobile application that can be used in mixed educational modalities. This application has been used in an exploratory way by the researchers, obtaining positive results in its first empirical evaluation.

DECISION MAKING FOR PROBLEM SOLVING

In Industrial Engineering and Mechatronics Engineering, it is essential to teach students the appropriate procedures to develop the ability to make

appropriate and accurate decisions, which includes achieving the greatest benefit at the lowest possible cost. In this way, when students are faced with the work environment they will be able to resolve any inconsistencies that may arise and will be able to make decisions objectively and efficiently. Decision-making is a process that is carried out consistently whenever options are presented and consists of several stages.

There are three conditions when making decisions: certainty, risk and uncertainty. Certainty occurs in a situation where precise decisions can be made because the outcome of each alternative is known. Risk is the condition where the decision maker can estimate the probability of certain outcomes. Finally, uncertainty is when the outcome is uncertain and reasonable probabilistic estimates cannot be made.

Four main methods of evaluating alternatives are used for objective decision making: factor scoring (preference matrix), break-even analysis, decision theory and the decision tree. Although there are a large number of qualitative and quantitative factors, factor scoring can encompass more items to consider, such as expenses for rent, airfare, meals, or education; even trends, risks, and ethical issues, as well as costs related to recreation and job skills, among other examples (Heizer, 2009).

The preference matrix helps the evaluator to handle multiple criteria that cannot be evaluated with a single measurement of concepts, such as cost or utility. The break-even analysis allows determining the magnitude of change, either in volume or demand, that is required to consider one alternative as better than another. Decision theory evaluates the best alternative when outcomes are uncertain, and finally, the decision tree is considered when decisions are made sequentially, i.e., when the best present decision depends on future events.

EDUCATIONAL TECHNOLOGY

Educational technology has evolved and there has been a preference for audiovisual media and the use of digital applications that have an impact on technological influence. Although it is a new discipline -with several ways to express and apply it-, it is also considered a significant, integrative and living discipline, because changes happen according to the environment in which it is immersed (several disciplines, new problems and new solutions) (Cabero and Barroso, 2015).

According to De Pablos (2009), educational technology has a close relationship with the alignment, application and, undoubtedly, the relationship of experiences in the teaching-learning context. Like any product, as educational technology evolves, it shows improvements in formal and informal educational content due to the widespread use of

social networks and the web. This is manifested through virtual meetings, real-time and ubiquitous communication.

De Pablos (2018) further mentions that nowadays it is imperative for the teacher to be a person with initiative and ability to anticipate future problems or needs. These needs include everything related to the teaching-learning process in constant transformation due to the daily use of ICT and its media influence. The ways of teaching change with the use of digital tools, platforms, computers and, in general, new infrastructure in university education, considerations that should be taken with special attention.

Within the possibilities offered by ICTs, virtual learning environments with updated information must be created; however, it is necessary to emphasize that information and knowledge are not interchangeable terms, while the selection, interpretation and evaluation of information is identified as a problem. The use of ICT in the classroom will allow innovation in the way of having and transmitting information and knowledge, and also, based on the above assumptions, with its application there will be greater adaptability to educate, it will be possible to use different communication tools, strategies and techniques for training and there will be greater flexibility in the teacher-learner figure.

Some of the advantages offered by virtual learning environments is that they allow access to education at times suitable for the student, in specific contexts and at his or her own pace. Escarbajal (2010) details that knowledge adapts to networks or communities, it is built by working together with other individuals with support in the use of web tools or resources.

Similarly, when exploring the main works related to virtual environments, specifically with mobile technology (m-learning) for university learning (Romero *et al.*, 2021; and Tejada and Barrutia, 2021), there is a broad spectrum of educational institutions that have implemented applications to make classes more dynamic and more motivating to provide students with better cognitive bases, which in the long term will be useful in their working life.

Proposed innovation

In recent years, the acceptance of the use of mobile devices during the teaching process in higher education is becoming more accepted (Al-Rahmi *et al.*, 2022) and, in this sense, the interest of several researchers to experiment in this area has increased, specifically related to mobile learning or m-learning. According to Fernández-Arias *et al.* (2021), m-learning is "a teaching-learning process in which students use mobile devices for their development".

In this research, an application was developed for use on mobile devices (laptop or cell phone) to turn it into a tool with great educational potential. Alarcón (2018) also proposes a related work, however, what is innovative about our application is that the tools contained will provide a solution to systematic calculations and that the results can be visualized in different ways.

One of the most significant characteristics of the proposed tool consists of the integration of three heuristics together, such as the preference matrix, the equilibrium point, and the decision tree, which together allow the resolution of problems for decision making in process engineering. In general, this proposal can be identified as a computational tool that allows the user to identify solutions more easily, as well as to perform a more efficient analysis, evaluate, classify and interpret the data obtained for better planning and management.

An example of the user interface of the break-even module is shown in Figure 1. In the application, the options of the alternatives, their respective fixed and variable costs, and the initial and incremental production volumes (to be plotted according to the scale required by the user) are entered. Once the results are generated, the total costs obtained for each of the estimated options and the break-even point are shown in the graph (Figure 2 interface).

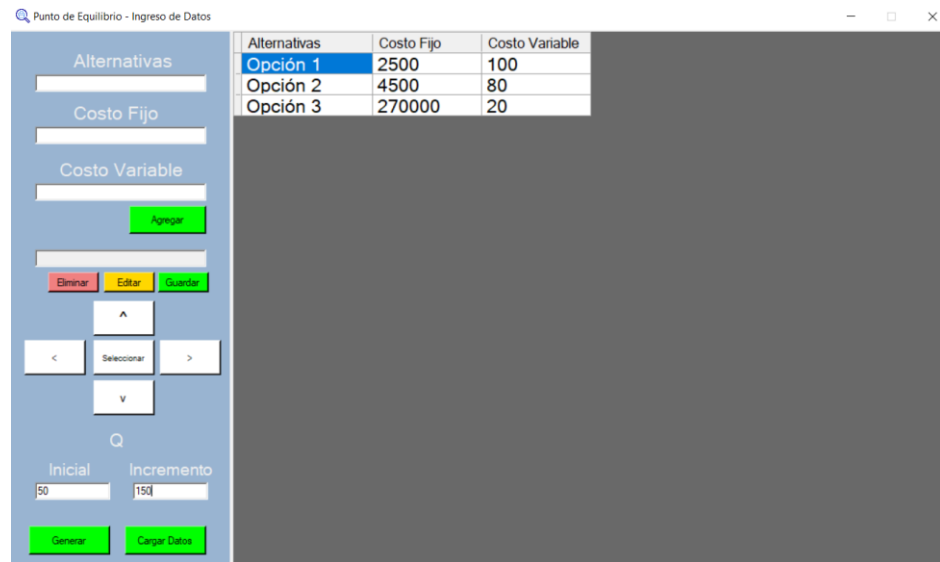


Figure 1. Breakeven point: input data.

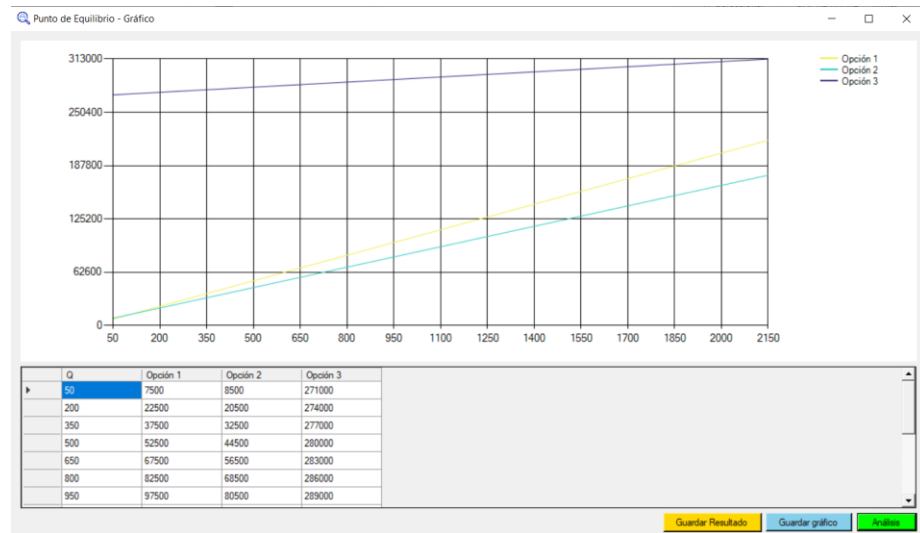


Figure 2. Breakeven point: output data

METHODOLOGY

The work reported corresponds to the research and development study of Gall *et al.* (2003) whose tasks performed, as part of the research project, are listed below:

- Literature review. This first task aimed to conduct a comprehensive literature review to determine whether there is research related to the use of decision making applications with the three heuristics together (preference matrix, equilibrium point and decision tree), in conjunction with problem solving.
- Educational technology development. Derived from the literature review, the purpose of this second task was to apply a disciplined and quantifiable systematic approach to software development, i.e., the software engineering process was applied to the development of a prototype (app) identified as decision making (DM).
- Design of learning scenarios. Based on the selected learning domain (decision-making skills), learning scenarios were designed to explore the feasibility of educational interventions to enhance student learning.
- Empirical evaluation. The purpose of this task was to plan and execute a series of pilot tests with students, which were oriented to

evaluate the proposal, as well as to collect feedback from real users and contrast different alternatives; this was carried out in the context of the Industrial Engineering and Mechatronics Engineering careers.

- Introspection and assessment. Based on the empirical evaluation reports obtained, the results were analyzed and the researchers reflected on the lessons learned from using the proposed prototype.

EMPIRICAL ASSESSMENT

In order to evaluate the efficiency, effectiveness and cost of the proposed virtual learning environment, that is, to evaluate the DM, a first empirical study was conducted with the participation of students, who worked with and without the DM in the task of using the heuristics: preference matrix (with uncertainty and without uncertainty), equilibrium point and decision tree.

Definition

The following research questions were posed for this study:

PI1 Does the use of information technologies influence the resolution of three different heuristics together in decision making as part of learning the subject of Production Planning and Control?

PI2 Does effectiveness, efficiency and cost impact the use of DM?

The above research questions translate into the following working hypotheses:

H1 Effectiveness measured as the percentage of the rating of responses per heuristic obtained by subjects is higher for participants who employed the DM than for participants who worked without the DM.

H2 Efficiency measured as the percentage of the score of answers per heuristic obtained per hour is higher for participants who employed the DM than for participants who worked without the DM.

H3 The cost measured as the duration involved in obtaining the answers per heuristic is lower for participants who employed the DM than for participants who worked without the DM.

The hypotheses described above are verified with the measurements obtained from the empirical evaluation, which pertain to two groups of participants who obtained the answers by heuristics of a set of problems, using the DM and those who did not use it.

Design

In this first empirical study, a completely randomized design was used to compare two treatments (subjects without using the DM [STD], and subjects with the use of the DM [CTD]), in two different periods. In this structure, in the first period a group of subjects receive the STD treatment and in a different session they receive the CTD treatment. The two periods mentioned in this research were also identified as pre-test and post-test. Table 1 shows the study structure used.

Table 1. Design used in the study

	Treatment
Period 1 or pretest (solving three problems)	STD
Period 2 or posttest (solving three problems)	CTD

Execution

The study was conducted in the months of April and May 2022 at Universidad Madero, located at Camino Real a Cholula 4212, Colonia Ex hacienda La Concepción Buenavista, San Andrés Cholula, Puebla, Mexico. The participants were seventh semester students of Industrial Engineering and Business Profitability, and ninth semester students of Mechatronics Engineering, corresponding to the January-May 2022 semester; the scenarios used were specifically with the subject of Production Planning and Control.

In this implementation phase, prior to conducting the empirical study, the selected students received training on the operation and use of the mobile application identified as DM in a two and a half hour session. It is worth mentioning that it was explained to them in a general way that both the practice session and the rest of the sessions would be part of a research project with the objective of validating the use of DM, and their verbal consent to voluntarily participate in the research was obtained.

In this study, 43 students participated in the pre-test, but due to the covid-19 pandemic, only 33 students participated in the post-test.

Once the training was completed, in two independent sessions of three hours each, the experiment was conducted in two computer classrooms at Universidad Madero. Both the first and the second session of the experiment started at the planned time, the students were provided with a link to a questionnaire made in Google Forms. This, in order to evaluate decision making, integrates the description of three problems where students must implement three heuristics together (preference matrix, equilibrium point and decision tree) to obtain the answer to each of the problems posed.

As mentioned above, in the first session the students solved the three problems described in the questionnaire identified as pre-test and obtained the answers by solving the problems in a traditional way; in the second session, on a different date from the first, the students obtained the answers to other problems in the post-test questionnaire, which they solved with the use of the DM. As part of the empirical study, to complement the evaluation of the DM, in addition to the problems provided, the students answered other items within the instrument, with the objective of making an analysis of opinions about the proposed computational tool (DM).

Analysis

Based on the metrics obtained, this section presents an exploratory analysis. Tables 2, 3 and 4 show the summary statistics of effectiveness, efficiency and cost with respect to the two treatments studied.

Table 2 shows an evident improvement in the post-test responses due to the fact that in the three heuristics the results are higher with the same resources.

Similarly, Table 3 shows an improvement in the post-test responses, since the results in the three heuristics are higher. This achieves the desired effect in the shortest possible time and, in this case, using the same resources, which complies with the planned and established objectives.

Table 4 shows that the cost in the heuristics solved with the application, i.e., those of the post-test, are much lower than those of the pre-test, indicating that students spent less time solving the problems using the application.

Table 2. Statistical summary of effectiveness by treatment

Treatment	Effectiveness		
	Preferences matrix	Breakeven	Decisions Tree
STD (pretest)	9.2	7.82	8.30
CTD (posttest)	10	9.76	10

Table 3. Statistical summary of efficiency by treatment

Treatment	Efficiency		
	Preferences matrix	Breakeven	Decisions Tree
STD (pretest)	4.76	3.91	4.15
CTD (posttest)	5	4.88	5

Table 4. Statistical summary of the cost per treatment

Treatment	Cost		
	Preferences matrix	Breakeven	Decisions Tree
STD (pretest)	0.07	0.24	0.12
CTD (posttest)	0.036	0.026	0.026

Regarding the metrics, in general it is observed that effectiveness and efficiency suggest better results when using the DM than without it; additionally, in cost, better results are identified with the use of DM than without it.

Once the measurements have been collected and processed, it is possible to perform an initial statistical analysis to identify potential differences between the two scenarios presented in this study. For the variable identified as the average of the results obtained, a pair of statistical hypotheses are posed:

Ho: $\mu_{pre} \geq \mu_{post}$; Ha: $\mu_{pre} < \mu_{post}$.

To test these hypotheses, a Student's t-test is used, which is carried out for the purpose of determining whether there is a significant difference between the means of two groups and to test whether or not the mean between pairs of measurements is equal to zero. The dependent variables are assumed to have a normal distribution. The paired t-test was done because it is designed to compare the means of the same group in two separate scenarios (pre-test and post-test).

In order to use the paired t-test, the following was considered: the test subjects are independent, that is, the responses of one subject do not affect those of any other; each pair of responses was obtained from the same student and the differences in measurements have a normal distribution. The summary is shown in Table 5. Being a statistical test that handles independent samples, the objective of randomization is met and, in turn, greater efficiency of the statistical contrast is achieved by reducing variability.

Table 5. Average responses to pretest and posttest problems.

Test subjects	Pretest	Posttest
SP-1	3.67	5
SP-3	5	5
SP-5	3.67	5

SP-6	3.67	5
SP-7	3.67	5
SP-8	2.33	5
SP-9	1	3.67
SP-10	5	5
SP-13	5	5
SP-14	5	5
SP-16	5	5
SP-17	3.67	5
SP-18	3.67	5
SP-20	5	5
SP-21	3.67	5
SP-22	3.67	5
SP-23	3.67	5

SP-24	5	5
SP-25	5	5
SP-27	5	5
SP-29	3.67	5
SP-30	5	5
SP-31	5	5
SP-32	3.67	5
SP-33	5	5
SP-35	5	5
SP-36	5	5
SP-37	5	5
SP-38	5	5
SP-39	5	5
SP-40	5	5

SP-42	3.67	5
SP-43	3.67	5

The averages of the students' responses in the pre-test and post-test were used to perform a paired two-sample t-test. A histogram was used as an analysis tool, since it should show the range of values of a measurement and the frequency with which each value occurs, in addition to indicating the readings that occur most frequently, and the variations in the measurements. Plotting the histogram (see Figure 3) shows that there are no strange points or outliers. The data show an approximate bell shape, so the assumption of a normal distribution is reasonable.

Dato	Frecuencia	% Acumulado
-2.6666667	2	6.25
-2.1333333	0	6.25
-1.6	0	6.25
-1.0666667	12	43.75
-0.5333333	0	43.75
más	18	100

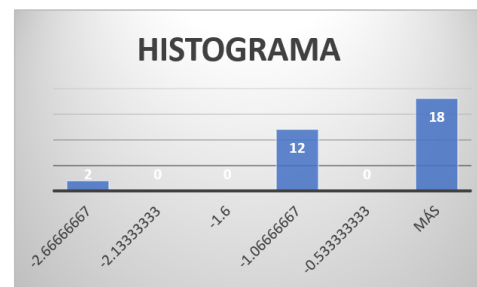


Figure 3. Histogram for the differences between student responses in the pretest and posttest

Table 6 presents the results of the t-test for means with paired data (i.e., students are scored the same, before and after) and was set as the level of significance, represented by $\alpha = 0.05$. It is considered good practice to make this decision before collecting the data and calculating the test statistics. The paired design gives greater validity to the inferences obtained and controls or eliminates the influence of extraneous variables that may intervene with a negative effect or mask the effect of the treatment or of the variable we are interested in evaluating. It is observed that in the results the mean in the pre-test is 4.27, and in the post-test it is 4.95. The variance shows a significant difference, since in the pre-test it is

0.89, while the post-test shows 0.05; that is, it is observed that, with the use of the app, the students' answers in the heuristic problems improve.

Table 6. Strong test, t-tes with two paired samples

T-tes: Sample mean of paired data		
	<i>Pretest</i>	<i>Posttest</i>
Half	4.27	4.96
Variance	0.89	0.05
Observations	33	33
Correlación de Pearson correlation	0.61	
Hypothetical mean difference	0	
Df	32	
t Stat	-4.78	
P(T<=t) one tail	1.85-05	
t critique one tail	1.69	

According to the analysis of the data, and after obtaining the result through the hypothesis testing performed, there is sufficient evidence to accept the alternative hypothesis that the use of the tool, on average, improves the students' responses.

DISCUSSION

In the last two years, various constraints have been experienced worldwide due to the period of confinement caused by the covid-19 pandemic, and the field of education was no exception; however, thanks to the use of ICT in the educational context (e.g., virtual education), the teaching-learning process was able to continue during the confinement.

As mentioned earlier in the empirical evaluation section, this research also faced a minor limitation due to the pandemic, related to the selection of the sample of participants, but fortunately this situation did not have a significant impact.

Initially, as Amendaño-Guarquila and Guevara-Vizcaíno (2021) comment, a large number of teachers had to innovate their teaching practice with the use of social networks, platforms and mobile devices or m-learning. As a result, the interest of several researchers in experimenting with m-learning and the development of mobile applications continues to grow, and this article reinforces this area of research with its contribution.

During this study, it is mentioned that m-learning offers several advantages to students, for example: the learning environment can be available anytime and anywhere (Althunibat, 2015), it fosters student motivation (Fernández-Arias *et al.*, 2021), and it allows immediate feedback and evaluation (Osorio *et al.*, 2021), among others.

Thus, with the use of m-learning, students can review their topics not only during scheduled class hours, but in days or weeks after teachers have addressed them. In addition, as noted earlier, the availability of knowledge at any time and in any place favors flexibility and ease of access to information, as long as students have internet connection and the necessary technological resources (Pineda, 2022).

In this sense, this research describes quantitatively, and in a first study, that the proposed tool based on a virtual learning environment through a mobile application or m-learning, on average, improves learning in decision making of students studying engineering.

CONCLUSIONS

This work arises from the need to reduce the response time in the choice of different alternatives in a given process and to reinforce the critical thinking of engineering students.

The main problem lies in the process of solving the heuristics used for decision making. Although the calculations are made in Excel, the students do not manage to define their selection assertively.

The implementation of ICT establishes learning processes and transmits new and lasting knowledge to people, generating high quality educational results that can be applied both in the workplace and in everyday life. The investment required to carry out the application is not high, so the cost as a limitation can be overcome.

In this work we have presented the proposal of a prototype of a mobile application for learning decision making, which was developed with three heuristics: preference matrix (with and without uncertainty), equilibrium point and decision tree. The application provides the resolution of the problem posed according to the selected heuristic and performs a detailed analysis of the best alternative, including diagrams and graphs.

By using the app, students were provided with a tool that allows them to do all mathematical calculations in a simple and fast way, which makes it easier for them to focus their attention and skills in the analysis-synthesis of the alternatives presented to them, evaluate them, reflect and, in this way, make a decision efficiently. Students are digital natives and the use of ICTs favors their concentration on high-level tasks, which will serve them in their working life. In this way, it is demonstrated that they have the adequate capacity to understand the heuristics proposed.

Finally, it is important to mention that, at the time of writing this article, the exploratory analysis of the opinions collected regarding the proposed computational tool is being carried out, with the aim of implementing the improvements suggested by the students in the computational tool. As future work, more experiments with the proposed computational tool have been considered, both within Madero University and in other universities, specifically with engineering students.

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HOW TO CITE

Maldonado Vargas, Martha Angélica y Ucán Pech, Juan Pablo. (2023). Tecnología educativa para evaluar aprendizaje de toma de decisiones en estudiantes universitarios. *Apertura*, 15(2), 6-19. <https://dx.doi.org/10.32870/Ap.v15n2.2363>

