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Evaluation Model of Virtual Learning Environments: A Pilot Study

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Abstract

Virtual learning environments (VLE) have frequently been used in educational practices, and the evaluation of their effectiveness as instruments to support learning gains must consider several dimensions. This paper presents an evaluation model for VLE, called MA-AVA (Model for the Evaluation of VLE), built after a review of the literature and focused on verifying students' learning gains. The MA-AVA evaluation model was applied in a pilot study to an undergraduate engineering class, using a VLE, Educ-MAS-GA, in the discipline of Analytical Geometry. The results indicate that, although students' perception of learning in VLE is relevant, the knowledge acquired is more subtle and difficult to assess. Therefore, a VLE learning evaluation model should include different dimensions of learning, such as the students' perceptions and their measures of learning gain.

Keywords: Evaluation Models**;** Learning**;** Learning Environments.

1. Introduction

The dissemination of computing in education evolves the possibilities of theoretical-practical investigative analysis, considering the use of virtual environments in different models of teaching-learning processes. Currently, virtual learning environments (VLE) have been used not only in distance education situations but also in hybrid classroom education processes (Nepomuceno, 2019).

Although some studies (Rahimi, 2015, Gustafsson, 2017) present the use of the virtual learning environment to improve the educational process, there are few analyses of the benefits acquired applying this resource. Most works on VLE evaluation focus on the development process of the virtual environment, or the interface and usability evaluation, not considering the gains in learning (Sandars, 2010, Sternig, 2017, Agredo-Delgado, 2019).

Some evaluation models for VLE have been developed. However, the learning dimension still needs improvement, as in many cases, it consists only in obtaining the user's opinion concerning their knowledge gain after using the environment (Lin et al., 2013, Sabourin et al., 2013, Pastushenko, 2018).

Aiming to expand the possibilities of evaluating the learning of the students who use a virtual environment in learning processes, this work presents the MA-AVA (Model for the Evaluation in VLE), which is an evaluation model focused on learning in VLE. In this context, the learning evaluation considers the combination of a value obtained from the knowledge measure with student´s perception of learning. A pilot study was carried out with two engineering undergraduate classes, using software to support the learning of Analytical Geometry, Educ-MAS-GA, to consolidate the MA-AVA activities defined in its modules.

This paper is organized into six sections, this introduction, followed by section 2, which presents an overview of Virtual Educational Environments evaluations. Section 3 describes the proposal learning evaluation model, its definition, measurement instruments, and steps to be adopted for its practical application. Section 4 details the use of the MA-AVA evaluation model in the context of an Analytical Geometry discipline, and section 5 discusses the results. Section 6 presents the conclusion of the work and future works.

2. Related Works Review

There are several approaches for the evaluation of virtual environment regarding its interface or functionalities (Sandars, 2010, Sternig, 2017, Agredo-Delgado, 2019). Few approaches, however, focus on the learning process evaluation. To expand knowledge about the evaluation of VLE, several studies present how the evaluation methods can be improved (Rahimi, 2015, Anonymous, 2016, Gustafsson, 2017).

Keller (2009) designed the ARCS model (Attention, Relevance, Confidence, Satisfaction), which aims at employing motivational strategies in the design of educational materials. This model can be used to evaluate students' motivation when using educational materials.

Kirkpatrick (1996) developed a training model composed of four levels: Reaction, Learning, Behavior, and Results. Level 1 evaluates students' reaction to educational content; Level 2 establishes the evaluation of learning gain obtained during a training program, using test methods before training (pre-test) and after training (post-test); Level 3 determines an evaluation of the behavior considering the effect of learning acquired during a training program; The last level aims to evaluate the practical effectiveness of the training, and it is necessary to use methods that can capture such change. Thus, it must make an individual evaluation to check if the effect has been achieved.

Savi (2011) used aspects of the two previous works and proposed a model for evaluating educational games based on level 1 of the Kirkpatrick training evaluation model (1996), in the motivational strategies of Keller's ARCS model (2009), in the user experience and the Bloom taxonomy (Bloom, 1956). The ARCS model was developed with a proposal to evaluate students' motivation. In this case, aspects related to fun and pleasure influence students' motivation and, therefore, facilitate the learning process. Savi (2011) added Bloom's concept of taxonomy to the strategy of Moddy and Sindre (2003), intending to evaluate the learning effectiveness using Bloom's first three levels of taxonomy: knowledge, use, and application. Although quite comprehensive, the Savi model has many dimensions and questions that the user must answer, which can cause impatience and weariness.

A systematic literature review (SLR) on VLE evaluation was performed in November 2016, looking for papers from 2010 to 2016 (in the relevant libraries in education information technology area) (Anonymous, 2016). Initially, the search returned 302 papers and 46 papers remained in the final selection. Most of the works (48%) have virtual environments for higher education students from different areas, followed by VLE for elementary school students (28%) and VLE for high school students (15%). The results identified in this study indicate that the evaluations have been positive considering the use of virtual environments as a tool in the teaching and learning processes. The perception of the effectiveness of learning process using these environments was pointed out in 41% of the papers. Different models of learning evaluation have been proposed, using questionnaires and pre/post tests. Therefore, most studies used questionnaires to obtain information about the personal characteristics of each student and their opinion regarding the VLE activity (Bruso,2016).

From the study of these different works, the MA-AVA evaluation model was developed, combining characteristics of these works.

3. MA-AVA Model

MA-AVA aims to analyze student performance in virtual learning environments, to measure knowledge gain about motivation, user experience, and learning, from the perspective of students' profile, perception (Kirkpatrick level 1) and learn (Kirkpatrick level 2) (Kirkpatrick, 1996). Savi's model (2011) was chosen as the basis, because this model emphasizes on learning, considering the perception of increased knowledge.

To support the measurement of motivation (Kirkpatrick level 1), the model relies on the structure already used by Savi (2011), but with simplifications, since this author's questionnaire is quite exhaustive. The model includes a pre and post-test to support the measurement of learning (Kirkpatrick level 2), and, with that, MA-AVA verifies if its use allows a significant learning gain.

The dimensions Motivation, User Experience and Learning Reaction are evaluated through adaptations of the dimensions of the ARCS model (Savi, 2011). Based on the integration of parts of models proposed in the literature and specific changes, the MA-AVA model has the structure shown in Figure 1.

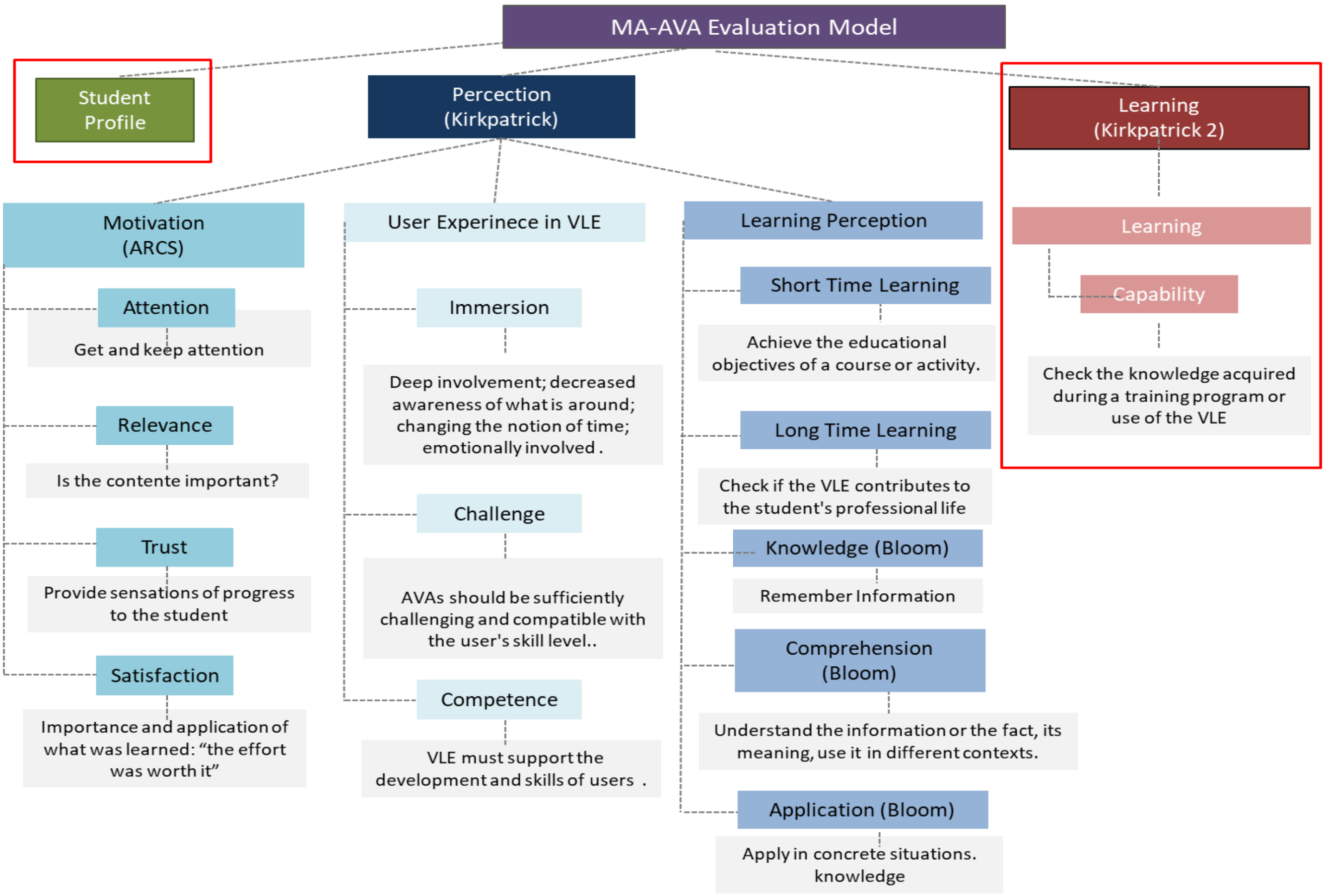


Figure1. Characteristics of the MA-AVA Evaluation Model

Savi (2011) used a questionnaire, that has a specific answer format that corresponds to the indication of the agreement or not of each the educational objectives perceptions. In the MA-AVA model, the scale was adapted to better understand the students, and the variation was between 0 and 4, which 0 means that the student strongly disagrees, and 4 that the student strongly agrees. Thus, according to the chosen value, the student can indicate the intensity of a certain aspect such as the example shown in Table 1.

Table 1. Questionnaire Model

The VLE contributed to my learning in the discipline						
Strongly disagree	0	1	2	3	4	Strongly agree

Source: Adapted from Savi (2011).

3.1. Motivation

Motivation for learning are related to student engagement and autonomy. For the motivation evaluation, it was used an adaptation of the questionnaire developed by Savi (2011), described in Table 2.

Table 2. Motivation

#	Objective	Dimension
1	The variation (form, content, or activities) helped me to keep an eye on the VLE.	Attention
2	The AVA content is relevant to my interests.	Relevance
3	It was easy to understand the VLE and start using it as study material.	Trust
4	I am satisfied because I know that I will have opportunities to use in practice things I have learned from VLE.	Satisfaction

Source: Adapted from Savi (2011).

3.2. User Experience

The User Experience dimension focuses on making it clear whether VLE provides a good user experience, which is essential to stimulate the learning process (Savi, 2011). The evaluation of the user experience uses only four items from the original 16 of the Savi model considered the most relevant for the work (Table 3).

Table 3. Questionnaire to evaluate User Experience

#	Objective	Dimension
5	I felt more in the VLE environment than in the real world, forgetting what was around me.	Immersion
6	The VLE evolves at an appropriate pace and is not monotonous - it offers new obstacles, situations, or variations in activities.	Challenge
7	I managed to achieve the goals of the VLE through my skills.	Competence
8	I had positive feelings of efficiency in the VLE.	Competence

Source: Adapted from Savi (2011).

3.3. Learning Perception

The Learning Perception dimension is evaluated in two ways. The first is regarding short and long-term learning, and tree items from Savi's original questionnaire were used (Table 4).

Table 4. Questionnaire to evaluate Learning Perception

#	Objective	Dimension
9	The VLE contributed to my learning in the discipline	short-term learning
10	The VLE was efficient for my learning, in comparison with other activities of the discipline.	short-term learning
11	The experience with VLE will contribute to my performance in my professional life.	long-term learning

Source: Adapted from Savi (2011).

The second way is to evaluate learning through the educational objectives. Savi (2011) uses Bloom's taxonomy and presents a questionnaire with these objectives (Knowledge, Comprehension, Application). The student only assigns a grade that corresponds to his level of learning before and after using the VLE.

Thus, the grade can vary on a 5-point scale depending on his/her level of knowledge. In the MA-AVA, the scale was adapted to the variation was between 0 and 4 as presented in Table 5. This part of learning evaluation is more associated with retaining the content worked on in a learning situation. In this case, the results of evaluations before and after using the environment are considered.

Table 5. Questionnaire to Evaluate Learning Perception of the Concepts

– Assign your level of knowledge before and after AVA to the concepts listed in the table below:

0	None
1	Weak
2	Regular
3	Good
4	Very Good

Concepts	**Remember what it is**		**Understand how it works**		**Apply in practice**	
	Before	**After**	**Before**	**After**	**Before**	**After**
My understanding of Conics						
Notion of Parabola						
Graphical representation of the Parabola and its variations						

3.4. Evaluation Process with MA-AVA

The MA-AVA model consists of five evaluation instruments: (i) the user profile questionnaire which the student describes his/her characteristics through pre-defined questions, such as sex, age, frequency of computer use, the possibility of accessing the internet and the level of knowledge in the theme to be studied; (ii) the perception questionnaires that capture the user's opinion with the union of the dimensions of motivation, user experience and learning perception (short and long-term), (iii) the learning questionnaire of the students' knowledge, comprehension, and application concepts before and after using the VLE; and (iv and v) to measure the gain of learning in pre-test and post-test with questions that address the content worked on in the VLE.

To use the MA-AVA, it is necessary to perform three steps: (i) planning the evaluation, (ii) using the VLE and the five evaluation instruments and (iii) analyzing the results.

This stage includes knowing all the VLE contents to be evaluated, customizing the user characterization profile, adjusting the questionnaire on the perception of motivation, user experience, and learning, and preparing the pre-test and post-test. Both tests must have the same level of knowledge and equivalence in the questions and not be identical. Besides, a schedule of activities for the use of VLE and the application of the MA-AVA evaluation should be proposed.

The stage of using the VLE and evaluation using the MA-AVA begins with the application of the user characterization questionnaire, which must be built taking into account the VLE to be evaluated and the performance of the pre-test to verify the level from the students. After this activity, it is necessary to explain to the students the functionalities of the virtual environment, and how the class will be with this VLE. After use, the post-test must be applied.

4. Model Application

The first step in applying the MA-AVA model was the choices of educational software and a theme. In this case, the researcher and the teacher chose the Educ-MAS-GA environment and the discipline of Analytical Geometry.

The second stage defined the hypotheses of the study, which will be proven or refused from the pilot test: the virtual environment promotes learning, motivating students, and offering a pleasant experience.

The Educ-MAS-GA environment (Sousa, 2012) offers contents for learning analytical geometry and addresses contents related to conics. The VLE offers didactic materials available with four levels of a Circumference Module and four levels of a Parabola Module. The key aspect of choosing the Educ-MAS-GA was the possibility of providing feedback to the user on its performance.

4.1. Planning the pilot test

Two meetings were held with the discipline's teacher to adjust the timing of the pilot test, set dates, and identify how many classes would participate.

The study would be carried out in three meetings of 2, 3, and 2 hours, respectively. The first would apply the characterization questionnaire, the pre-test, and a quick explanation of Educ-MAS-GA. In the second, students would use Educ-MAS-GA and, in the third, the post-test. The theme of this study is the Parabola that has a complete module in the Educ-MAS-GA environment. All the test questionnaires (pre and post) were defined for the study.

Each test had ten questions on the Parabola theme, which were classified by difficulty levels. The score of the questions varied from 1, for the first 8, which had a lower level of difficulty, and 4 points for the last two questions, subdivided into interdependent items.

4.2. Applying the pilot test

The professor used the software and the evaluation model in his teaching practice, with two classes of Engineering undergraduate course of a Public University in Rio de Janeiro. At the first meeting, the students who were willing to participate in the research signed a free consent, reinforcing the confidentiality of the data. After completing the consent form, students received the characterization questionnaire. The students had questions concerning/about the specific of VLE. The term VLE is not familiar to the students, and most of them did not know its meaning. However, all doubts were answered, and we reinforced that the most relevant issue was that they must fill the questionnaire with their real opinion. The first class (Class A) was composed of 16 students, and the second (Class B) had 15 students.

At the end of the characterization questionnaire, the pre-test was applied, making it clear that if they did not know how to solve a question, it could be left blank. The pre-test contained basic questions, fundamental for learning the topic about Parabola.

Both classes used Educ-MAS-GA in the second meeting, which took place in a Computer Laboratory.

Students were individually on a computer and had about 3 hours to use Educ-MAS-GA. The students used all the time available to complete the Parabola module. In the third meeting, the post-test was applied, and the students also answered the questionnaire on the perception of the use of Educ-MAS-GA. Only 15 students attended this last step.

5. Results and Discussions

This section presents the pilot test with Educ-MAS-GA in two parts. The first describes the learning evaluation results in the pre and post-tests; and the second considers student's perceptions about motivation, user experience, and learning perception, as defined in MA-AVA.

5.1. Learning Evaluation

From analyzing the percentage of correct answers in the pre and post-test, an improvement in the post-test performance of students is observed, with an increase of correct answers in the questions of higher levels of difficulty, as shown in Figure 2.

For validating this dimension, we applied the Student's t-test (Wholin et al., 2012) for paired samples. Figure 3 shows the means, standard deviation, variance, and sample size (N) for each group. From using the t-test with a 95% confidence interval, the result obtained determines that it is possible to reject the hypothesis that the averages of the pre and post-tests are equal since t = 3.407 and the t interval for hypothesis accepting would be 0,5822 to 2,649. The result of the post-test showed a mean and standard deviation slightly higher than the pre-test, proving the progress of the evaluated students.

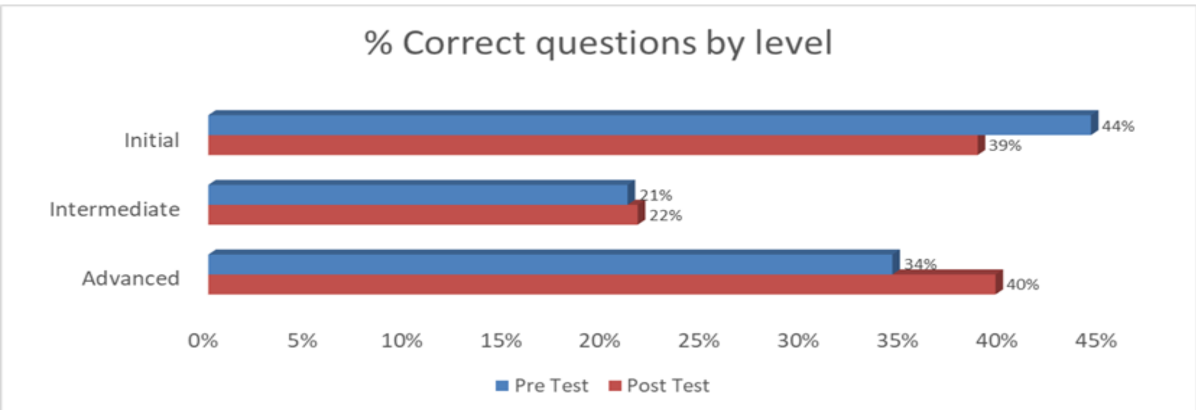


Figure 2. Percentage of correct answers by levels of difficulty of the questions in the Pre and Post Test

Type	*N*	*Mean*	*Standard Deviation*	*p-value*
Pre-test	13	6,92	1,85	< 0,005
Post-Test	13	8,54	2,37	< 0,005
Diference Pre-Post		1,62	1,71	

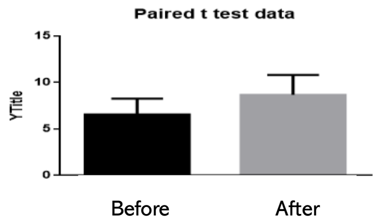


Figure 3. t-test results for classes A and B

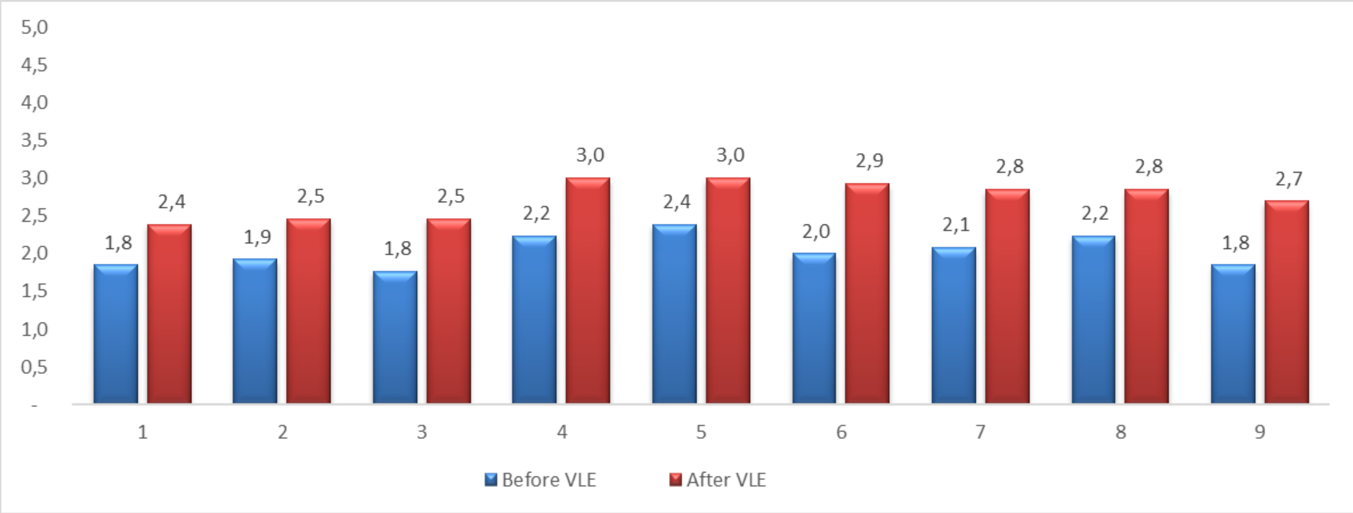
5.2 Evaluation of Student Perception

Table 4 summarizes the Tables 1, 2, and 3 from the students' answers to the questions that are related to the perception of motivation, user experience, and learning in the use of VLE.

Table 4. Summary of students' perceptions of Educ-MAS-GA

Perception of the VLE experience	Motivation	The students considered Educ-MAS-GA as a learning motivator. The presentation strategy was considered quite relevant and varied (form, content, and activities). The opportunity to apply the learned subject matter in practice, as well as its understanding, had a lower evaluation than the other dimensions of the motivation subscale.
	User experience	In general, Educ-MAS GA provided a regular experience, with emphasis on the challenge and competence dimensions, which had a more significant evaluation. The challenge item was the best evaluated by the students, showing that Educ-MAS GA opens perspectives to make traditional classes less monotonous.
	Learning	The perception is that Educ-MAS GA contributed to learning in the discipline. All items were well evaluated and showed that the learning did occur.

In addition to the components of attention, motivation and user experience, the learning objectives were also assessed through a self-evaluation of students. The results of the students learning objectives means were checked using the Student's t test for paired samples and presented a p-value less than 0.001. All nine objectives had an increase when compared to the average grades before and after using Educ-MAS GA (Figure 4).



Legend: Learning Objectives

1 *Remember:* My understanding of Conics
2 *Understand* : My understanding of Conics
3 *Apply:* My understanding of Conics

4 *Remember:* Notion of Parabola
5 *Understand:* Notion of Parabola
6 *Apply:* Notion of Parabola

7 *Remember:* Graphical representation of the Parabola and its variations
8 *Understand:* Graphical representation of the Parabola and its variations
9 *Apply:* Graphical representation of the Parabola and its variations

Figure 4. Results from Learning Objective evaluation in the VLE

Figure 5 shows the results of the 13 students who participated in all stages of the study. The pre and post-test scores were normalized to be between 0 and 5.

When analyzing the results of the students' perception combined with the grades from the pre and post-tests, it is possible to notice that some results of learning perception dimension do not match the gain from the tests, with emphasis on the students 4, 6 and 9.

When analyzing case by case, some divergences between the result obtained and the given answers are evident. For example, the student represented in the graph in Figure 5 as number 8 had the value of learning perception of 3, which means that he felt he had learned the content. However, the results of his pre- and post-tests showed no gains. The opposite also occurs, as can be seen in student number 3, who has an average of 2 in relation to the perception of learning but has an excellent result in the post-test. This indicates that student's perception does not always correspond to the results of the evaluation tests.

As analyzed in section 5.1, in statistical terms, the average increases in grades in the post-test concerning the pre-test was expressive, and this can be observed in Figure 5.

The analysis of the results and comments from the participants generated some relevant observations. At the end of the second meeting, some students provided feedback on Educ-MAS-GA, and they pointed out that the completion of the Parabola module was exhaustive. This issue is related to the strategies for presenting the content. In this sense, according to Markova, Glazkova & Zaborova (2016) the faculty members need to recognize that e-learning and virtual learning environments require design expertise, considering the skills stimulated in each interaction. Thus, as the content of Educ-MAS-GA is in initial tests with end-users, the question of pedagogical strategies needs to be further explored.

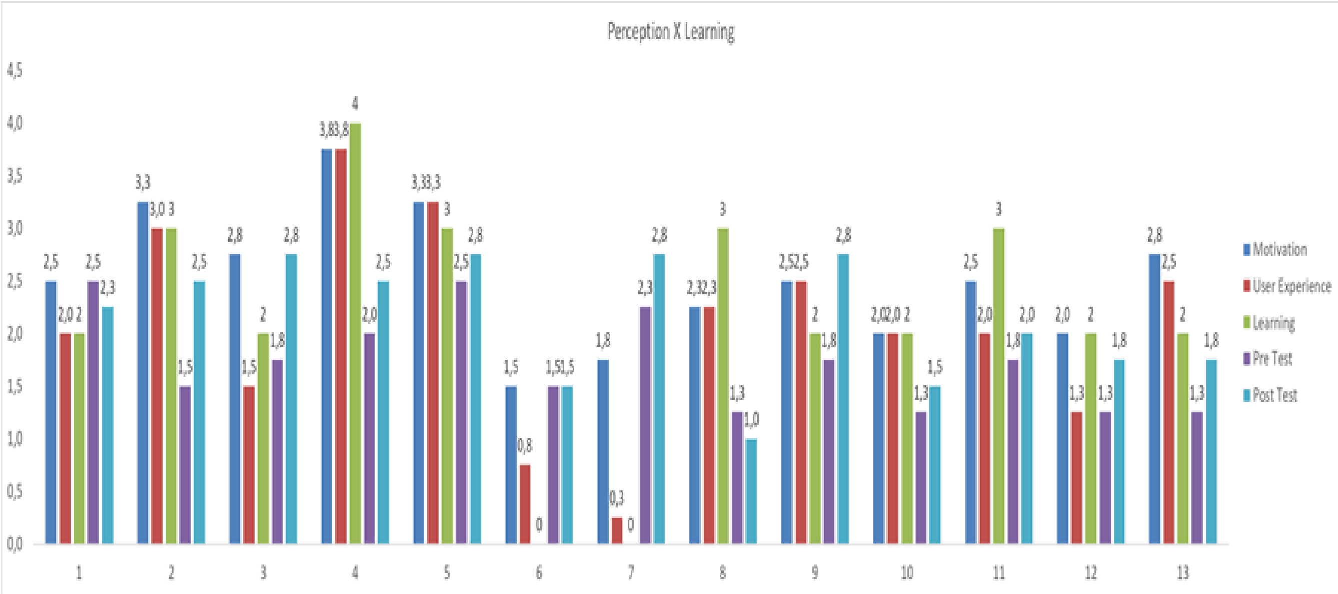


Figure 5. Perception and Learning Evaluation

An aspect noticed in this experiment was the low participation of students. However, because the experiment result would not add grades to the discipline of Analytical Geometry, many students were not motivated to participate.

6. CONCLUSION

Virtual learning environments can turn the teaching and learning process more attractive, allowing the integration of theory and practice of different disciplines. Therefore, it is necessary to evaluate such environments to understand whether there are gains in terms of knowledge, especially for the student. On the other hand, several papers discuss student engagement in the use of virtual learning systems and on the quality of activities available in AVA's (Agredo-Delgado, 2019, Aldredge, 2019), which are fundamental aspects to maintain students engaged in activities proposed by the environment. In this context, this paper presented the development of an evaluation model of learning in virtual environments, the MA-AVA, and developed a pilot test to identify positive points and weaknesses of the proposed model. The evaluation instrument considered two approaches, one based on students' perception of learning process and the other that explores the increase in students' knowledge, captured by pre and post-tests.

The first module assesses the students' perception considering three subcomponents: student motivation, user experience in the environment, and learning perception. This model was inspired by Savi's proposal (2011), which integrates aspects proposed by Kirkpatrick (1996), Keller's ARCS model (2009), and the Bloom taxonomy (Bloom, 1956, Moddy and Sindre, 2003). As Savi's model is quite long, with the evaluation of many dimensions, we tried to simplify the list of items to be evaluated to eliminate some questions and stimulate the users' commitment to the evaluation instrument. We also introduced the Kirkpatrick Level 2 (1996) that establishes the learning gain evaluation of training.

The student information was included in the model to determine the profile of classes or students, such as average age, levels of knowledge of the themes, and years of study. This information can be relevant for the teacher to analyze the performance of the class, making some interrelation to these characteristics.

To evaluate the model, a pilot test was developed with two undergraduate classes from a public university in the discipline of Analytical Geometry. The teacher used the Educ-MAS-GA virtual environment to work on the Parabola concept in a laboratory class. The environment already contains some geometry courses ready to be used (Sousa, 2012). The professor participated in the structure of the experiment and the construction of the pre and post-test instruments. This was essential for the proposed questions to be aligned to the content worked on.

The evaluation process was structured and defined according to the model. There were 3 stages, one of which was a pre-test, the other used the Educ-MAS-GA environment, followed by one that was applied to the post-test and filling in the instruments of learning perception. From the data collection, it was possible to evaluate the MA-AVA model concerning its objectives and the hypothesis that based this study.

The experiment results suggest that students were motivated to use VLE, especially to diversify traditional learning methods. The number of correct answers in the post-test is statistically higher than the correct answers in the pre-test, indicating some level of improvement in learning.

Although the sample is small, the results of the two evaluated dimensions indicate the confirmation of the hypothesis: the virtual environment contributes to learning, motivating students, and being able to provide a pleasant experience.

However, as threats to the validity of the research, we highlight the low number of students who participated in the pilot tests, and the limited number of classes. As future works, we expect to develop other experiments, with more days of classes, more content to be worked on, and more students.

We would also like to highlight that virtual environments such as Educ-MAS-GA need to be further studied and filled with content, especially at this time of pandemic, when students of different educational levels in Brazil have little access to communication networks. This system can be used locally, providing support for the learning of various topics.

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