

Teaching Sciences in Virtual Worlds with Mastery Learning: A Case of Study in Elementary School

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Abstract— Virtual worlds are 3D environments that provide a feeling of immersion and a high degree of interaction, collaboration, communication between users. Its applicability can be focused on the educational scope, in which theories can be integrated as the basis to didactic activities carried out in the 3D environment, being its area of interdisciplinary comprehension. In this context, this article presents the use of a Virtual World built to assist in the teaching of Science for students of the middle school, whose articulation of the activities performed in the course are based on the precepts of the educational theory Mastery Learning. Tests were carried out in the subject of science, being divided into two periods with different groups for comparative purposes and realized evaluations during the period of the experiments. Kruskal-Wallis and Wilcoxon-Mann-Whitney non-parametric test were applied to the results of the assessments to ascertain the performance of each group. It was verified in the general analysis that the participants who used the Virtual World had a growing performance, with high medians and adequate distribution of the results, being predominant of a smaller variability and amplitude. Thus, was possible to conclude that the results obtained with the approach were positive, which led to the validation of this research and presented a clear contribution to the academic environment.

Keywords— Virtual Worlds; Mastery Learning; Science; Educational Theory; 3D environment.

I. INTRODUCTION

Increasing technological evolution of tridimensional virtual environments (3D) and techniques for virtualization of real-life elements provided a significant advance in the use of these environments for leisure, education, and entertainment. Especially in the educational context, challenges are concentrated in the

creation of alternatives and adaptation of methods and environments already existent in the attempt to improve the teaching and learning processes.

The use of 3D has become increasingly widespread recently, with attention paid to their features, like the interaction with objects, simulations, use of educational resources, among others [1]. That resulted in the development of researches involving different fields of domain inside the educational area, as it can be seen in the works of Soliman & Guel [2], Troetst, Molina & Garita [3], Silva, Morgado and Cruz [4] and Sgobbi, Tarouco and Reategui [5].

Such environments have the objective to provide 3D spaces where the student can walk and live experiences in a highly interactive environment [6] [7]. This type of approach has many characteristics and advantages to be explored, some of them are listed by Kotsilieris and Dimopoulou [8]: synchronous operation in real time; representation of a real world; persistence of data; network of people and support to communication through chat channels; use of avatars to represent individuals; immersion sensation; interactivity with the use of objects that have scripts; and, support to the use of a varied range of multimedia features.

As recognized by researchers previously mentioned, virtual worlds can be seen as a stimulating pedagogical alternative to be used in an integrated mode to teach in classrooms or distance activities. Despite the highlighted potential advantage in the educational context, Gregory et al. [9] believes that there is some common sense that virtual worlds are in a construction process, and there is a lot yet to be done before teachers, students and managers fully adopt virtual worlds as a learning space. Is important to observe that exists some problems in this type of approach, since this type of environment has not been created to this kind of use (education) and a training is

necessary for the users, besides the requests that are imposed to computer resources: dynamic modeling of 3D CAD objects may be rather complex and demanding [10]. Despite some difficulties, Chang e Law [11] highlight that the creation of virtual laboratories and use of simulations with virtual worlds in the field of sciences, chemistry, and physics have special characteristics to be explored, such as visualization of microscopic phenomena with interactive simulations. Pellas [12] highlights that the interactive simulations supply a plausible illusion and allow that the users have an experience that reflects realistic situations using this type of environment.

Christensen, Maraunchak & Stefanelli [13] reinforce that in parallel to the use of computational resources available in this type of environment, the didactic planning of the activities to be defined by the teacher is also characterized as essential and must be carefully established and organized. The interaction in virtual worlds provides a motivation for students and generally attracts the interest and enthusiasm; however, it is necessary to notice that these environments cannot effectively substitute all the other existing approaches of learning [14].

Virtual worlds have been used in various paradigms as they provide fertile ground for the implementation of different learning styles, e.g. problem-based learning, exploratory learning and distance learning [15]. The didactic planning made by the teacher in a discipline, having as base a well-defined educational approach, can guide the objectives of the activities and assist the students to perform their tasks in a more adequate and consistent way in this type of environment.

Upon the huge research field to be explored with the use of educational theories and approaches, some initiatives have been applied in the scope of Virtual Worlds. Works as Devlin, Lally, Canavan & Magill [16] and Sajjanhar and Faulkner [17] correlate the concepts of the Experimental Learning of Kolb [18], aiming to show the four steps of the proposed cycle in the didactic activities realized in the Virtual World. In the work of Gamage, Tretiakov & Crump [19], concepts based in the Constructivism of Vygotsky [20] were related to the experiment carried out, while the research of Nunes, Herpich, Amaral, Voss, Zunguze, Medina, and Tarouco [21] correlated the theory of Meaningful Learning with the learning of algorithms. In the research of Sgobbi, Tarouco and Reategui [5] presented a proposal of use of intelligent agents in the Virtual Worlds to act as virtual tutors during the realization of educational activities, correlating the denominated study by 2 Sigma Problem of Bloom [22], where the individuals that have a support of a tutor in an individual way, obtained an improvement in the evaluation of two sigma's in relation to the control group.

In order to narrow the interconnection of Virtual Worlds with the application of educational approaches to conduct didactic activities, for the scope of this research, the educational theory Mastery Learning (ML) was selected. This educational theory is an idea intended to plan instruction sequences with the objective that all students can reach a level of reasonable performance in a determined content [23]. Students that show more difficulties to reach the percentage of necessary success to advance the units can receive reinforcement activities through tutorials, discussions and complementary materials. This way, the theory of Mastery Learning can be resumed as a learning model that puts emphasis in the characteristics of the students, tolerating the individual differences and having as a requirement that the students complete one unit before passing to the next unit [24].

Brito, Silva, Barbosa, Vasconcelos, Figueiredo, Soares, and Gaspar [25] explain that Mastery Learning becomes more accessible to implement through the use of Information and Communication Technologies (ICT), where, in a learning environment, students individualize this process and progress at their own pace. This makes possible the development of activities, the elaboration of tasks, with the permanent control of the teacher and self-regulation of the student.

The possibility of insertion of different types of learning materials (videos, slides and animations) and the formulation of evaluations during a course, makes the learning environments become exemplary tools, in what concerns the aggregation of Mastery Learning with the use of ICT. In this context, it is possible to adopt Virtual Worlds, by virtue of allowing the insertion of multimedia resources and the accomplishment of tasks in the distance format, according to the preference and availability of the student.

In this sense, the main purposes of this study were: (1) present a new methodological proposal that integrates the educational and technological bias and presents itself with originality in the academic environment, whose innovation is centered on the proposition of a teaching method that assists in the teaching of Sciences in elementary school with the use of Virtual Worlds as complementary activities and having all of their educational planning based on the educational theory of Mastery Learning, and, (2) identify the potential benefits and the difficulties in this approach in the performance of the associated students in the subject of Sciences.

The use of this theory in the research arises as an exciting challenge to be explored, because it is necessary to integrate its application to the didactic planning of a discipline, and, concurrently, to adopt the Virtual Worlds as a complementary environment during this process. Other aspects that motivated the development of this project is related to the diversity of resources and

beneficial potentials that the Virtual Worlds can proportionate to the users in the educational context. Characteristics as the facility of use, collaborative character and the attractive present in the 3D resources, that provide a sensation of immersion to the user, are responsible for the transformation of these environments in an interesting alternative in different areas [26].

The authors of this paper chose the field of sciences because it comprises a large number of contents that offers the opportunity of developing simulations to be presented to students. Chiu [27] explains that physical laboratory experiments in Science enable students to interact with observable scientific phenomena, but students often fail to make connections with underlying molecular-level behaviors. Virtual laboratory experiments and computer-based visualizations enable students to interact with unobservable scientific concepts [28].

The possibility of building laboratories in Virtual Worlds was configured as an alternative to be explored in the tests carried out, which reinforced the choice for the subject of Sciences. As previously emphasized, the conduction of the activities in the course and at the Virtual World created was guided by the precepts of Mastery Learning. Marteleira [23] points out that the use of environments of this type has, in terms of the operationalization of Mastery Learning, a great potential for the elaboration of interactive activities of remediation and enrichment, thus facilitating teachers to develop learning units following the principles of this theory.

II. VIRTUAL WORLDS IN EDUCATION

A Virtual Worlds can be defined as persistent online environments generated by a computer where people can interact, whether for work or leisure, in a comparative way to the real world [29]. Xenos et al. [30] consider Virtual Worlds as immersive three-dimensional interactive and graphical environments, which may be a replica of an existing physical place or an imaginary place, or even places that are impossible to visit in real life due to constraints such as high cost and/or security issues.

As an example of Virtual Worlds that have been used by different researches, are Active Worlds, Open Simulator, Second Life and Open Wonderland. Usually, users can navigate the entire environment scene, interact with objects (touch, save, push items, etc.), or talk to other Virtual World users [31].

The creation of Virtual Worlds aimed to education requires that many factors are considered, for example, pedagogical objectives and well-defined teaching strategies based in learning theories, friendly design and objects capable to encourage the interaction and collaboration between the users [21]. Such points must be analyzed in a detailed way, with the objective to

beneficially explore the existent potential in this kind of environment in the educational context.

It is important to highlight that genuinely this kind of environment was not developed for educational use, differently from other types of software as Moodle that is a learning virtual environment. However, the characteristics present in this environment, like immersion, collaboration, communication, and interaction can create possibilities so that the students in the moment of the realization of educational activities are more active and explore new opportunities of learning in the virtual world. Such conclusions are confirmed by Fernández-Gallego, Lama, Vidal & Mucientes [32], that understand that the students overpass an observation state and receipt of information to be more important in the learning process, in a more autonomous and active way.

A wide variety of teaching areas have been approached for the construction of didactic activities in Virtual Worlds, such as:

Algorithms and Programming Logics: in the analyzed works, the main focus is in the use of programming resources provided by the Virtual World with the use of scripts to teach students the basic concepts of logic and algorithms. The software Scratch and Scratch4OS are used as support tools since the students can construct codes using visual blocks and insert these in the 3D objects of the environment [12]. Educational theories, as the Significant Learning [33] and Mastery Learning [34], are used to substantiate the researches realized. The results were considered positive since the students have a vision in a real time of the function performed by the code in the object.

Mathematics: the studies presented in this scope approaches the Virtual Worlds in a different way, the objects referred in the environment are subject to the X, Y and Z positions. Such factor stimulates the exploration of research in the Geometry topics [35] and Calculation [36], due to the possibility to teach concepts referring to the tridimensional localization of objects, distance calculations and resolution of challenges involving these topics.

Health: the Virtual Worlds allow different types of movement to the users, like flying, running, walking, in addition to resources for communication (textual or through voice). Such resources can be explored in the context of health, mainly in topics as obesity of patients, whether infantile [37], as in the part of psychological treatments [38]. The use of videos and virtual agents to demonstrate practical exercises and instigate the participants to realize in the real world, as the communication between groups for the therapy of patients inside the Virtual World, were some of the used solutions in the highlighted researches, highlighting the results of

good performance of the participants and the positive feedback supplied to them.

Aviation: the training with Virtual Worlds are being explored in the academic area, mainly in the scope of aviation. Works as Pinheiro, Fernandes & Maia [39] that involve the construction of a virtual platform for the training of maintenance of hunts, and Lee, Park, Park, Kim & Oh [40], that approaches a more centralized scope in the mechanical part and of ammunition equipment, can be seen as pioneers in the use of Virtual Worlds with this purpose.

Foreign Language: can be considered a common practice in environments that provide the use of chats, the sharing of experiences and the practice of new foreign languages. With this in mind, the Virtual World has been explored as a complementary alternative for the teaching of this topic. Researches that involve the practice of the vocabulary [41], anxiety assistance by means of conversation in the environment [42] and practices involving the thematic of games to auxiliary in the language learning [43], are some of the explored alternatives in the academic area. The results are positive, where the practice with people from other places in the environment, it is an important experience and assists to aggregate new knowledge about the studied language.

In the scope of this article, the sciences area presents an instigator character to be explored by virtue of the types of contents present, for example, water cycle, atoms, physical and chemical phenomena, where many practical activities can be developed in a virtual way in this type of environment. The virtual worlds also open the possibility of multimedia resources insertion like texts, videos, slides, links, sounds, and quizzes to complement the educational activities that can be articulated [1]. Such resources can instigate the users to engage in a higher degree of interaction in the environment [44] and [1]. By providing learners with the freedom to choose the type of learning materials to explore, it makes learners create and design in the learning process, thus develop ownership on the process and environment of learning [45].

In addition to the multimedia resources, the Virtual Worlds allow, by means of 3D modeling of objects and programming resources, to create simulations of physical and chemical phenomena of a determined research area. These types of simulations do not consume natural and human resources to support experiences and, finally yet importantly, reduce risks of human or environmental accidents from eventual problems during experiences.

Despite these advantages discussed, it is important to highlight that the creation of a new Virtual World composed of multimedia and simulation resources needs a learning curve by the development team responsible. The Virtual World may need updating and therefore can be unreliable or in need of significant amounts of

maintenance, besides others reasons suggested for the disinterest as the lack of support to educators in terms of technical and pedagogical support or provision of additional time to develop virtual world lessons [46]. Insufficient bandwidth, data traffic, download and streaming during the user's interaction can be problematic, especially if several computers are sharing a network [46], [47], [48]. It is important to consider these problems when this kind of environment is adopted. The lack of support for access using mobile devices can also be considered as one of the main problems currently faced in the research developed with Virtual Worlds, as can be seen in the research of Herpich et. al [21]. Such support can already be considered as one of the main requirements to be explored in the future, in which only a more robust solution, known as Lumiya, is currently available to access a Virtual World.

Despite these disadvantages discussed, the benefits provided by Virtual Worlds have been shown as stimulating to continue the development of scenarios and simulations with educational character. Science, technology, engineering, and mathematics (STEM) classrooms are often environments where new technologies are implemented due to the nature of the content addressed [29]. In science classrooms specifically, the implementation of computer-based science teaching methods has been regarded as an important strategy because "it adapts to today's students who grew up in an increasingly digital world and are more accustomed to visual learning" [49]. In other words, an appropriated technological infrastructure with a well-structured instructional design method combined with learning theories or models can assist instructors to clarify the appropriate conditions on how students can learn in this type of environment.

III. MASTERY LEARNING AND THEIR INTEGRATION WITH VIRTUAL WORLDS

In 1968, Bloom proposed a model in his article "Learning for Mastery", where he believed that if the students received the opportunity to learn a proportional quality of instruction to the personal need, more than 90% of them could reach the aimed competence level [50]. Bloom defends the belief that all students at one class can reach an elevated level of performance in the academic activities and minimize the differences of learning among them.

There are alternatives that can be embraced to narrow these differences among the students that reach high and low percentages and assist the individuals that obtained an inferior performance of what is desired, through reinforcement activities that take in consideration the individual characteristics of each one [51] and [52]. John and Barchok [53] and Ozdemir and Erdemci [54]

understand that the motivational level of the student about the course is important in his / her learning, therefore, it becomes crucial that the topics addressed are clarified and assimilated by the students.

The schematic of the operation of the Mastery Learning can be seen in Figure 1 [55], where the contents are divided into small units ordered by a logic sequence with specific predetermined objectives, that are followed until being reached. Based on the illustration, it becomes possible to identify the basic principles that guide Mastery Learning [56]:

- Clearly define the objectives that represent the purposes of the course;
- Divide the curriculum into relatively small learning units, each with its own objectives and assessments;
- Identify learning materials and strategies: teaching, modeling, training, assessment, tutoring, and reinforcement should be included;
- Each unit is preceded by brief diagnostic tests (pre-test) or formative assessments;
- The results of the formative tests should be used to provide supplemental instruction or corrective activities to help the student overcome the problems.

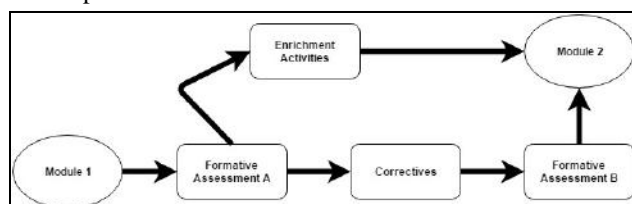


Fig.1: The process of Mastery Learning

Source: Zimmerman & Dibeneditto [55]

Tests in small questionnaires, written works, oral presentations, demonstrations of abilities and performances can be applied [57]. The objective of these evaluations is to measure if the student has the necessary knowledge so that he/she can advance to the next module or reinforcement activities that must be applied. Also, for Guskey [58], the use of these procedures (brief questionnaires, oral presentations, written papers, for example) allows for the systematic monitoring of students' progress and leads to feedback, as it assesses the extent to which the most important objectives of the unit are being achieved by students and clarifies what they need to improve.

The students that do not reach the domain level stipulated by the teacher must receive an immediate feedback with the application of reinforcement activities (complimentary classes or group works) and do a new evaluation to measure the level of evolution, while the others that already have a knowledge over the required can be fitted in enrichment activities [50]. If reinforcement is

successful in helping students remediating their learning difficulties, then almost all the students will demonstrate readiness to take the remedial examination [59].

The learning materials used in the classes can be presented in different formats, whether by readings, demonstrations/simulations, discussions, videos or any approach that the teacher understands to be the most appropriated [60]. This diversity of material types to be used by the teacher can be integrated to the present approach in the Virtual Worlds, where the use of videos, slides, texts, and simulations can be explored in the didactic activities performed by the students in the environment for the learning of sciences. From the point of view defended by Purbohadi, Nugroho, Santosa & Kumara [61], this theory can be easily introduced both in the present format and in the distance format, if the technological support is appropriated.

Mastery learning is relevant to competency-based education, given the shared emphasis on defined objectives rather than defined learning time or number of procedures [62]. It is in this context that the research developed in this article is fitted, where the possibility to make an integration of the realized activities is opened in the classroom, with the use of a 3D virtual environment to make the reinforcement works or specialization in the distance modality, as the diversification of multimedia resources proportionate in the Virtual Worlds. Although this proposal has potential to be explored, it is important to highlight some problems acknowledged in the academic area towards the use of the educational theory of the Mastery Learning.

Some main criticized points are the high level of performance for the approval (90%) originally stipulated by the theory and the cost of time that this approach involves to be applied, where Arlin and Webster [63] explain that many critics treat as inconvenient the additional time that needs to be supplied to the students that have the most difficulties to learn, due to the schedule grid and formulation of additional activities and materials. Bloom [50] defend these critics clarifying that the necessary additional time for the students with bigger difficulties is not permanent, seen that this learning will be better concretized in this initial step and in the posterior contents, their difficulties will be naturally minimized.

According to Šimić, Gasevic, and Devedzic [64], Virtual Learning Environments play an important role in the development of distance activities, which can be used to manage and monitor learning activities outside the classroom, as well as to record students' learning activities and progressions. This finding is fundamental for the application of a course, which is based on the precepts established by Mastery Learning. Nowadays,

Mastery Learning is used on large scale in dynamic, adaptive educational systems [65] [66].

In the scope of this article, where the integration among realized activities in the classroom with complementary reinforcements realized in the virtual world follow the precepts of the Mastery Learning, some adaptations had to be made to avoid the problems previously mentioned. The adaptations realized and the conduction form embraced by this project are presented in section 2.

IV. RELATED STUDIES

The analysis of the literature made for the development of this section aimed to evidence some important points related to the use of Virtual Worlds in areas of general sciences, as physics, chemistry, and biology. In compliance with this analysis, some main educational approaches and analysis involving motivational and usability aspects that were executed in some of the works found in the literature were also highlighted.

One of the main identified points is related to the intense use of 3D simulations in virtual worlds, which objective is to show phenomena of the real life in an accurate and detailed way. Due to the fact that the scope of this article is centralized in the area of sciences, some comparisons with other related areas, as physics and chemistry, are possible to be done, where both also have a great number of possible phenomena to be referenced in a virtual way in this kind of environment. Topics related to acceleration, free fall, capacitors, polarity, and electromagnetism, which representation and visualization by means of simulations become one of the main stimulations for the students in the Virtual World, were approached in the work done by Peachey, Withnail & Braithwaite [67]. The results of these works are instigative, seen that the topics are mainly visual and interactive, in which the Virtual World is a positive alternative to complement the processes of teaching and learning.

In the scope of these works, the realization of the executed didactic activities involving the physical area was rooted in different theories and educational practices, with the theory of cognitive load and constructivism concepts. The visualization and interaction with the simulations in the Virtual World can have a great number of visual elements to be processed by the students, what, according to Sweller [68] can produce a abnormal cognitive load if the instruction material is presented in a complex way, inconsistent or with a big quantity of visual grouped elements.

Chemistry is also related to the scope of this article, where was identified in this area a tendency to the use of simulations and multimedia resources as slides, texts and videos [69], as well as the use of Gamification techniques in the learning of these topics is represented in the work

of Shudayfat, Moldoveanu, Moldoveanu, Gradinaru and Dascalu [70]. Aspects related to the motivation of the students in using the Virtual World to teach chemistry, the usability of the environment and its potential for the learning process are the main approached points in the analyzed works. As it was verified in Physics, by being of a more interactive and visual area, where phenomena in micro and macro scales can be represented, this type of approach is being effective in the learning process of the students.

With the areas mentioned before, it is essential to highlight the relevant works in the study area realized in this research. The research did by Kennedy-Clark [71] presents a perspective on the usage of Virtual Worlds by teachers in training in the Sciences area. 28 participants were selected for the research, a questionnaire is answered at the end of the experiment about the interaction in the Virtual World that was aimed to teach Sciences. The results showed that the teachers were able to see the benefits related to the visualization form and interaction with the 3D objectives, as the motivational aspect in using the environment, being aware of the difficulties existent in implementing an environment of this size.

In the work developed by Rutten et al. [72] has as main focus the investigation of the impact of the use of simulations in teaching Sciences, a systematic review being realized in the literature of this scope of research. 51 publications were selected, where the results of the analysis showed the viability of the use of simulations in Sciences to complement the learning method considered traditional, emphasizing that this type of resource supports the improvement of a comprehension of the experiment seen in the real laboratories.

Jacobson, Taylor, and Richards [73] present a research that approaches the use of Virtual Worlds aimed to teach Sciences, having as a characteristic the realization of works with a more playful character. Two groups of the eighth grade, in one period of two weeks, used the proposed environment. As results, it was possible to see significant gains in the evaluations made and positive progress in the learning of the students is considered an environment apt for the use in this teaching area.

In relation to Mastery Learning, hundreds of works that use this theory in the last 60 years can be found. Leonard, Holot, and Gerace [74] identified at least five large-scale surveys that were conducted by different researchers in this period, and four of them concluded that most of the studies analyzed had positive effects in schools, while the fifth presented positive and negative views on the use of this approach.

The area of physics is also used with Mastery Learning, in which the studies analyzed involved the use of Virtual Learning Environments, both in the distance modality,

addressed in the work of Gladding, Gutmann, Schroeder, and Stelzer [75], and in face-to-face, seen in the works of Wongwatkit and Hwang [76] and Wongwatkit, Panjaburee and Srisawasdi [77]. The focus was on monitoring students' progress and performance in a more active way, seeking to understand the conceptual problems of learning, their preferences for learning styles and to propose teaching and reinforcement activities that could aid in the learning process. The experimental results showed that the students had evidence of improvement in their attitude of learning, better understanding and greater perception in the resolution of the activities proposed for the area of Physics.

As for the area of this research, there are several works to be explored. Özden [78] highlights the possibility of using technology to assist in the teaching of science in the fundamental series. In addition, the integration of Mastery Learning to this type of approach is also emphasized, and the proposal of the article is centered on explaining this integration, its benefits, and disadvantages. Thus, the author highlights the need for the teacher to be aware of the way of applying this theory using a Virtual Learning Environment focused on teaching science, how the processes should be carefully conducted, providing the appropriate didactic materials, individualized instruction or in groups, besides the application of formative evaluations.

Agboghoro's research [79] sought to investigate the effects of the application of Mastery Learning in Science teaching, establishing an experiment of the Near-Experimental type, with pre-test and post-test. A control and experimental group were defined, totaling 120 elementary students in a science course, whose topic was Metabolism of the human body. The experiment group received instructions and activities based on Mastery Learning, while the control group continued to learn based on the traditional method of teaching. The experiment demonstrated that the use of Mastery Learning helped students to improve their evaluation performance, and it is recommended to use this approach to teaching science.

The assertions discussed in the detailed works, reinforce the importance of the multimedia and technological resources exploration that allow the representation of contents and simulations in the Sciences area, inside the Virtual Worlds. Allied to this, is the use of educational approaches and theories to articulate activities in the environment, in which this analysis consisted in an important know-how for the development of this work.

Based on what was mentioned before, it is possible to see that the proposal of using Virtual Worlds, more specifically OpenSim, has the potential to remit an aperture of the application possibilities in the Sciences area. The identification of the use of Virtual Worlds with

an educational base guiding the activities carried out helped to reinforce the need for this type of planning for the use of environments of this size, which was considered as an extra motivation for the adoption of Mastery Learning as a strategy to be followed during this work. The main difference identified in this work is centered on the proposition of an approach based on the educational theory Mastery Learning, which consists of an approach widely diffused in the academic environment and with a character of interdisciplinary application. Attached to this proposal, is the insertion of technological resources, which can be considered as an emerging practice, which has been revalorizing the Mastery Learning in the midst of academic research.

In this context, the technological resource adopted was the Virtual Worlds, which consist of a solution widely diffused in the academic environment and of an interdisciplinary nature. It is important to emphasize that, for the most part, the papers analyzed do not aim to propose a clear and definite method but to carry out researches using Virtual Worlds based on some educational theory, in order to ascertain their impact on learning, however, without defining a new approach.

Therefore, it was possible to plan the development of a virtual laboratory composed by multimedia and simulation resources that present many contents of sciences in the Virtual World, which identified works were in a differentiated scope of this project. The use of the Mastery Learning theory to organize the didactic activities with the students in the virtual world can be seen as an important differential in this research in relation to the other analyzed works, highlighting the conduction form of the activities, articulated as a permanent reinforcement during the subject.

V. METHODS

The research question of this study was the following: Does the introduction of an approach to assist in Science teaching with the application of activities in Virtual Worlds and the planning of activities guided by the precepts of Mastery Learning can improve student's learning? In order to answer this research question, several tests were carried out with participants in the subject of Science with the use of a developed Virtual World and activities with Mastery Learning theory. This research and the results obtained are described in the following sections.

The planning used for the development of this project was based in the case study, that had the objective to implement an approach with the use of the virtual worlds and the articulation of the didactic activities based in the Mastery Learning theory, changing the traditional method that was being applied with the participants of this project. The case study investigated contemporaneous

phenomena inside the context of real life, in situations where the frontiers among the phenomenon and context are not clearly established, where many sources of evidence are used [80]. Added to this, an analysis was realized about the quantitative type, based in the measure (generally numerical) of few objective variables, in the emphasis of comparison of the results and in the intensive use of technical statistics [81]. The results obtained are coming from the evaluations did by the participants during the experiment periods, where the analyzes of the performance of the students required the application of statistical techniques that can prove the significance of the results.

The theoretic research and the analysis of the related works provide the creation of a base of initial knowledge for the construction of this research. The necessary technological infrastructure to implement the virtual world was selected based on the experiments realized by the authors of the work. The platform selected to develop and implement the 3D virtual world was OpenSim. The virtual world was hosted on the WAMP web server. The viewer used to visualize the virtual world by the students was Singularity. Established the necessary technological infrastructure, the experiment was delineated following the molds of the educational theory of the integrated Mastery Learning, some necessary adaptations being made to adequate the context where the tests were made. The research described in this article covers 2 periods of testing with different groups of users in each of these periods. The procedures of the study were strictly the same for the 2 periods, followed by a protocol of execution of activities exactly the same for the two stages of testing, only changing the groups of participants in each. In this way, the study procedures described in this section occurred in exactly the same way for both test periods. The first phase of the experiment occurred in 2016 during all the trimester that had a total duration of 4 months, while the second phase of the experiment occurred in 2017 also during all the trimester with a total duration of 4 months. The procedures described below are exactly the same for the two test periods that were performed.

Firstly, the objectives of the subject were previously clarified to the students so that they could know the contents that were about to be taught. The content of the subject was divided into 3 units, following the established precepts of the Mastery Learning:

1. Constitution of the subject - atoms and molecules
2. Physical and chemical phenomena and Energy sources;
3. Ground and health: Pollution and diseases;

The theory of Mastery Learning defends that the initial and intermediary evaluations for each subject are made for each unit of the subject, as complementary activities

are made to reinforce the students that had a performance over the required or to improve the knowledge of the students that obtained the required grade, a new step being made of evaluations to analyze the performance of the students.

As mentioned before in section 1.2, this procedure requires an elevated workload for the teacher in the creation of materials and activities, in addition, to expend a significant quantity of time so that all process is executed, as it was originally defined by theory. Based on this problem the adaptations were made in the application form of this approach with the objective to make it less instructional.

This way, the students had a weekly class with the duration of 40 minutes in the morning period, where the content was exposed in the oral form by the teacher, using the blackboard to present slides. The complementary activities were stipulated in the distance modality during all the semester and not only after the realization of the tests, being that the students should realize the virtual world and the Moodle to perform the activities required by the teacher to complement the knowledge acquired in the classroom. This adaptation had the objective to realize the attempt to diminish the elevated time load originally required by the original process of the application of the theory Mastery Learning, in addition to supplying constant reinforcement activities and not only after the realization of the tests.

The virtual world used by the students was composed by a virtual laboratory divided in five different types of rooms: videos, texts, slides, questions, and simulations. The room of texts and slides had theoretical contents related to the units of the subject.

The questions room allowed the students to answer questions of multiple choices in a panel that was shown on the screen, where the feedback was immediately given. About the video room, they were directly taken from YouTube and had explanations about the contents.

The simulation room had many 3D animated representations and experiments related to the contents approached in the subject, being 34 simulations constructed in the Virtual World for the students to interact. Figure 2 presents the representation of molecules and atoms in the environment, while Figure 3 shows some cases of energy and pollution sources.

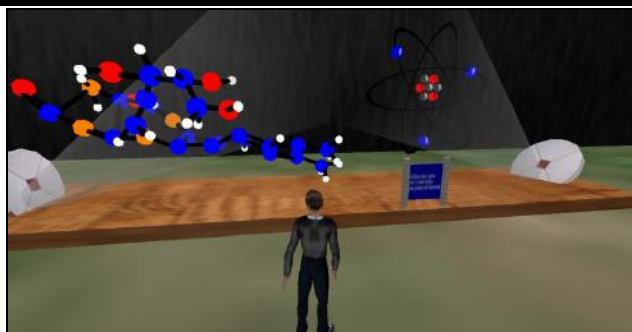


Fig.2: Simulations of atoms and molecules



Fig.3: Simulations on Energy Sources and Pollution

The place where the experiment occurred did not have an informatics laboratory, because of this, the complementary activities had to be carried out by the students distance-based, with the support of their families. It is important to highlight that for the students that used the Virtual World, an exposing class happened at the beginning of the experiment in each phase, where the basic commands of the movement were presented and the process necessary to install and the configuration of the viewer were also explained. Furthermore, tutorials in the format of texts and videos were released to the students to facilitate the access to the Virtual World in their homes. As explained in the previous section, the tests were performed in two different periods with different groups of users, but following exactly the same procedures. The description was made in the way as the experiment was conducted, as the laboratory created in the Virtual World, the next section presents details referring to the participants of this research.

a. FIRST PERIOD OF TESTS

Details about the first period of tests involving the participants, data collection instruments and the procedure adopted for the analysis of the results are described below.

Participants

3 classes of the sixth grade of the elementary school enrolled in a subject of Sciences were selected to participate in the experiment. Each class had 25 students, total of 75 students.

Among the 75 students of this sample, 38 (50.66%) were girls and 37 (49.34%) were boys, which age range was

between 15 and 11 years. The students were divided into 3 different groups, including the three classes. The groups were arranged as follows:

- Group 1: 13 students chose to only participate in face-to-face classes, they didn't access Moodle or the Virtual World;
- Group 2: 49 students chose to participate in face-to-face classes and to carry out complementary activities in distance way using the Moodle environment;
- Group 3: 13 students chose to participate in face-to-face classes and carry out complementary activities in distance way using the Virtual World;

It is important to highlight that no student of group 3 had previously interacted with a platform of Virtual Worlds. However, in relation to the Moodle environment, all had used it in the previous year on other subjects. Because the school does not have an informatics laboratory and the access to the Virtual World was done distance based by the students, the number of participant in this group considerably decreased in relation to the size of the available sample. The positive point to be highlighted is that the 13 students of this group used the virtual world during all the semester and interacted with all resources and simulations available in the environment.

Instrument of research

Students of the first period of testing did 5 types of evaluations, applied in printed format in the classroom by the teacher of the subject. The first evaluation was a pre-test applied on the first day of class of each period, about all the contents of the 3 units defined in the subject, having 8 questions of multiple choice. It is important to clarify that all students had not had previous classes about the contents of this experiment.

The content of the subject was divided into 3 units, where at the end of each one was applied an intermediate test composed of questions of multiple choice about the contents of that specific unit. In the end, a post-test including all content of the subject was applied having 21 mixed questions among multiple and written choices, being different from the pre-test applied at the beginning of the trimester of each period. Interviews were conducted with participants to evaluate the approach implemented and identify the strengths, weakness, and modifications needed.

Data Analysis

The tabulation of the results obtained with the five evaluations applied in the three groups needed a statistical analysis, which objective was to compare the groups and to analyze the existence of significant results referring to the application of this proposal. For this, it was necessary to formulate the hypothesis, which in the scope of this

article, the non-parametric approach was selected with the test of Kruskal-Wallis, being possible to compare three population.

Furthermore, the test Kruskal-Wallis was used to test the null hypothesis that all populations have equal functions of distribution against the alternative hypothesis that at least two of the populations have different distribution functions. For that, two hypotheses were created:

- H0: the groups have the same distribution of values in the grades.
- H1: The groups do not have the same distribution of values in the grades.

In this way, the final goal was to compare the hypotheses to verify whether there were significant differences in the averages of the 3 groups belonging to this experiment, noting that the group that used the Virtual World got a performance which was significant in relation to the others. To complement the statistical analysis performed and provide a clearer view of the opinion of the students, interviews were conducted with participants to evaluate the approach implemented.

b. SECOND PERIOD OF TESTS

Details about the second period of tests involving the participants, data collection instruments and the procedure adopted for the analysis of the results are described below.

Participants

Although the implementation protocol was the same as in the first period, the participants were different, being 3 new classes of the sixth year in the same subject, a total of 74 students, divided into 2 different groups:

- Group 2: 46 students who chose to attend the classes and carry out complementary activities distance based, using the Moodle environment;
- Group 3: 28 students who chose to attend the classes and carry out complementary activities distance based, using the Virtual World;

The names of the groups were kept equal to the previous phase to avoid distortion in the reading of the analyzes. In this phase of experimentation, no student chose not to use any of the available environments, in this way, a third group did not need to be created. The 28 students who were using the Virtual World in this phase had an introductory class to the environment, for familiarization with the way of interaction and how to perform the necessary procedures so that they could access the environment distance based. It is important to highlight that the participants also used the environment freely and on their own will and motivation, using it constantly and carrying out the proposed activities.

Instrument of research

Students of the second period of testing also did 5 types of evaluations, applied in printed format in the classroom by the teacher of the subject. The tests were exactly the

same as those applied in the first test period, without any changes. Interviews were conducted with participants aimed to present pertinent information about the resources that were used in the environment if the proposal was approved by the students and other relevant factors, as possible difficulties and benefits identified by the participants.

Data Analysis

The procedures adopted for this second test period are exactly the same as those described and applied in the first phase of experimentation, except for the type of applied statistical technique. Thus, the non-parametric hypothesis test selected for this phase was the Wilcoxon-Mann-Whitney test, being used in this case because there were two samples (Group 2 and Group 3). This test verifies whether the two groups come from the same population, that is, test whether the two independent groups are homogeneous and have the same distribution [82]. Also, two hypotheses were created as in the first test period. In order to complement the statistical analysis carried out and provide a clearer view of the opinion of the students, interviews were conducted with participants.

VI RESULTS

For the analysis of the results in each period, statistical non-parametric methods were used, considering that the data are not continuous, non-normal and small sample size. The non-parametric Kruskal-Wallis test was selected in the first period to compare more than two samples (K samples), while Wilcoxon-Mann-Whitney test was used in the second period to compare two samples, considering that the data generated during the research were ordinals. A critical level of significance of 5% was considered ($\alpha = 0.05$) for both period of tests, whenever the p-value is less than 0.05 ($p < 0.05$), the result is considered statistically significant. Results of each test period are presented in the following subsections.

Results of the First Period

The first test was carried out in order to identify if the three classes had homogeneous performances in the assessments performed, ascertaining whether it was necessary to perform separate analyzes for classes. 5 evaluations were realized in total, and they were the pre-test, an assessment for each of the three modules and the post-test. Table 1 presents the results obtained with the analysis of Kruskal-Wallis.

As it can be seen in Table 1, all p-values are above 0.05, this way we can assume that all classes were homogeneous in terms of their performances in assessments. This allows the analysis to be performed jointly with the students of the three classes, separating only participants in the three groups previously described. From this observation, a comparison of the medians of the evaluations of the students was made in relation to the

three groups created to check if there was a statistically significant difference between the groups if the p-value has a value less than Alpha. Table 2 presents the results of analyzes performed with the Kruskal-Wallis test.

Table.1: Comparison of the results of the three classes

Class	Pre-test	Eval 1	Eval 2	Eval 3	Post-test
601	36.64	34.84	36.38	31.00	36.68
602	37.78	37.52	38.54	39.84	38.36
603	39.58	41.64	39.08	43.16	38.96
p-value	0.8881	0.5350	0.89631	0.11996	0.92856
	63	1	6	4	5

Table.2: Comparison of the medians in the three groups

Platform	Pre-test	Eval 1	Eval 2	Eval 3	Post-test
1	29.42	27.88	25.81	33.00	26.08
2	38.04	38.50	39.71	39.15	38.46
3	46.42	46.23	43.73	38.65	48.19
p-value	0.132	0.093	0.068	0.654	0.033

As seen in Table 2, the pre-test and the three intermediary assessments conducted showed no significant differences, which can be regarded as an expected result, since the pre-test students had not yet studied the content covered in the evidence and intermediary tests, the contents were smaller and more specific, which ultimately resulted in this balance of grades. It is important to see that this type of monitoring of the group of students can be considered positive; in virtue of the Mastery Learning theory adopts the application of initial and intermediary evaluations for each module.

It was evidenced by the statistical analysis that at least two groups differed from the medians of the scores in the post-test evaluation since the p-value (0.033) was less than 0.05. In the other ratings, there was a statistical significance, which means that there is no difference in the population or if there is, was not possible to see it, due to sample size. Figure 4 represents the Pairwise Comparisons of the groups.

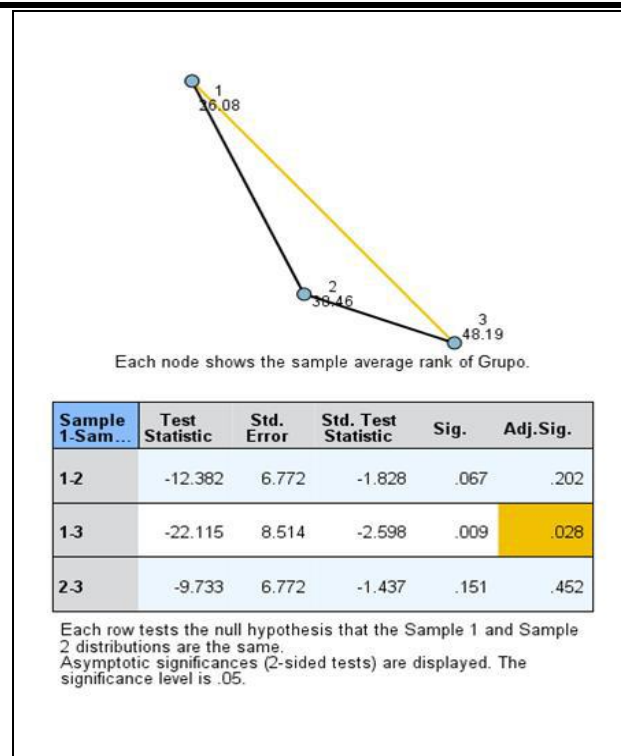


Fig.4: Pairwise Comparisons of Groups

To compare the medians of the groups regarding the assessment of the post-test, there was a difference only between groups 1 and 3. In this way, the statistical analysis found that the participants who used the virtual world (Group 3) were significantly better than the participants who did not use any type of environment (Group 1). In the comparison made between group 1 and group 2 (participants who have used Moodle) the statistically significant difference was not observed.

The use of Moodle environment for supplementary studies was an approach already adopted previously by the teacher of the subject, and this factor can be one of the reasons for not having a significant difference between the group using Moodle and the students who have chosen to only study during the period in person in the classroom and at home with their grades. The observation of a significant difference in the post-test between Group 1 and Group 3 can be considered positive, being justified by the use of the virtual world as a complementary activity, with characteristics such as interactivity and visualization of 3D animated objects can be considered as final in the learning process of these students. For a better visualization and comparison of the scores obtained with the post-test, Figure 5 represents the results of the analysis performed by means of Box Plots.

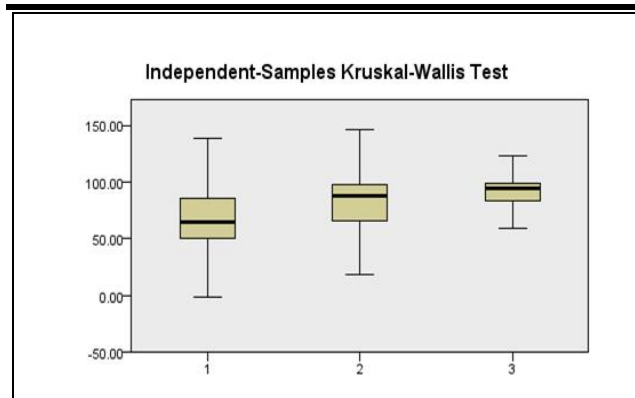


Fig.5: Box Plots of the Kruskal-Wallis Test

Regarding the comparison of Group 2 and Group 3, the analysis showed that it was possible to observe a significant difference between the grades of the post-test, as one of the plausible causes from a statistical point of view is due to the low number of participants who used the virtual world, a factor that makes it difficult to understand with greater accuracy, the significant changes in the analysis. Although this result was found, in the analysis of medians it was possible to see that although not significant, the grades obtained by Group 3 were equivalent to the grades of Group 2 at the post-test. This allows us to infer, based on the medians of groups and statistical analysis performed, that despite the non-significant evidence of improvement in results, the Group 3 that used the virtual world can be considered equivalent to Group 2 who used the Moodle.

Results of the Second Period

As in the first test period, it was necessary to check if these three new classes had homogeneous performances in the evaluations carried out, checking if it was necessary to perform analyzes separated by classes. Table 3 presents the results obtained in the analysis, in which we have the three classes that participated in the experiment and the five evaluations carried out.

Table.3: Comparison of the results of the three classes

Class	Pre-test	Eval 1	Eval 2	Eval 3	Post-test
601	60.00	84.00	90.00	100.00	83.00
602	50.00	88.00	87.50	87.50	83.00
603	60.00	92.00	90.00	85.00	83.00
P-value	0.085	0.658	0.55	0.108	0.745

The p-value obtained for each of the evaluations performed by the classes is above the established level of significance of 0.05, in this way, it is possible to assume that all the classes were homogeneous regarding their performance in the evaluations. This allows the analysis to be done jointly with the students of the three groups,

separating only the participants in the two groups previously described.

A comparison of the medians of the student's evaluations regarding the two groups was carried out to verify if there was a statistically significant difference between the groups if the p-value presented a value lower than 0.05. Table 4 presents the results of the analysis carried out, in which Group 2 concentrates the students who used Moodle and Group 3 has the students who used the Virtual World. The pre-test performed did not show significant differences, so the null hypothesis for this case was maintained. In this evaluation, the median of Group 3 (60.00) had a higher value in relation to Group 2 (50.00).

Table.5: Comparison of the medians in the two groups

Platform	Pre-test	Eval 1	Eval 2	Eval 3	Post-test
2	50.00	84.00	85.00	90.00	83.00
3	60.00	94.00	90.00	90.00	84.50
p-value	0.265	0.044	0.297	0.347	0.309

In the first intermediate test, it was possible to verify significant differences in the observed medians, thus rejecting the null hypothesis in this case. The median of Group 3 (94.00) was higher than the Group 2 median (84.00). In addition to this observation, the concentration of the scores in Group 3 is better distributed, as well as a smaller amplitude, which reinforces the lower variability of the data, to the point of becoming significant when compared with the results of Group 2.

Regarding the second intermediate test, the median value of Group 3 was 90.00, which was higher than the median of Group 2 (85.00), but no significant difference was found. Despite this, the distribution of the grades is similarly concentrated in both groups, as well as their amplitude, which indicates that both had similar variations. Therefore, the advantage in Group 3 is not significant, being centered on the superiority of the median value, which slightly leads to a better performance of the participants in this group.

Box Plot of the third intermediate evaluation showed the equality of the medians of the two groups (90.00), with no significant difference. However, the differential is centered on the distribution more concentrated in Group 3, as well as in the lower amplitude, which results in a lower variability and shows that the scores were more constant in this median range.

Finally, the post-test performed in this third phase presented a slightly higher median of Group 3 (84.50), compared to Group 2 (83), as seen in Figure 8. As well, the distribution of the data is better concentrated in the group that used the Virtual World, presenting smaller amplitude and consequently a smaller variance of the grades, in relation to the group that used the Moodle

environment. This implies in observing a performance improvement of Group 3 in relation to Group 2, noting that this observation did not present significant differences in the post-test.

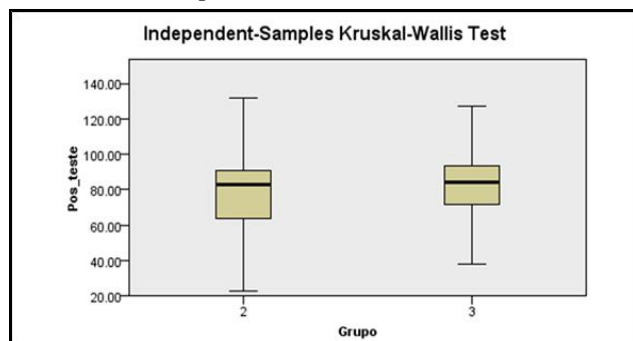


Fig.6: Box Plots of the Kruskal-Wallis Post-Test

In this way, analysis of this second period of tests reinforced the previously presented scenario, in which it was possible to infer an equal or better performance of the group that used the Virtual World in relation to the group that used Moodle, although not in a significant way. In this phase, the performance in the intermediate tests was superior for the participants who were interacting with the Virtual World, being in the first evaluation verified a superiority in a significant way, just as the post-test presented signs of equality or superiority for this group. Distributions of the grades were shown to be better concentrated in the Virtual World group, as well as smaller amplitudes and less variability in the intermediate and post-test evaluations. In this way, it was again possible to verify results of the application of the method that could be considered positive and satisfactory, highlighting the potential to be explored as a complementary alternative in the teaching and learning process.

Interconnection of the Results

The analysis of the results in the two periods of the experimentation process was completed, and the statistical analyzes performed were described. It is important to see that the groups in the two periods were formed naturally, based on the personal choices of each student in relation to the type of environment that would use or none of them. The grades had high and low variations in all groups in both phases, and varied performances were verified, which can be considered positive since there was no predominance of a group with students with better grades or who only had students with greater difficulties of learning. Therefore, in order to finalize the process of analysis of the results from this study, it was necessary to make a comparative evaluation from the evaluation point of view, between the results obtained in the two test periods.

The non-parametric Kruskal-Wallis test was applied in order to determine if the comparison of the performance

of the groups presented significant differences in the medians analyzed in each of the five evaluations. Group 1 was formed only by participants in the first test period who did not use any environment. Group 2 was formed by participants who used Moodle in both periods, as well as Group 3 that was formed by participants who used the Virtual World in both phases. The objective was to ascertain the overall performance of the groups and provide an overview of the evaluation of the approach performed, considering participants from different years, but who were being tested under the same conditions, with the exception of Group 1 that was only in 2016.

Table 5 presents the results of the analysis performed, in which the medians of groups 2 and 3 cover the values of the two test periods, while the median of Group 1 only addresses the first period. As observed in previous analyzes, Group 3 that used the Virtual World obtained higher scores in the medians in this analysis.

Table.5: Comparison of the medians in the groups

Platform	Pre-test	Eval 1	Eval 2	Eval 3	Post-test
1	40.00	64.00	70.00	75.00	65.00
2	50.00	84.00	85.00	85.00	83.00
3	60.00	92.00	90.00	90.00	88.00
p-value	0.041	0.007	0.027	0.101	0.059

In this case, there was a significant difference in performance between Group 3 and Group 1, which did not use any platform. Participants in Group 1 were not willing to interact with any environment and obtained inferior performances from the pre-test to the post-test, which could indicate even a lack of commitment of these in the contents covered in the discipline, besides the lack of support provided by the resources present in both environments at the time of the study.

In the case of the first intermediate evaluation, in both periods of tests, the medians of Group 3 were superior to the other groups, being significant the difference in the second period. In this analysis, it becomes possible to identify that there was a significant difference (p-value of 0.041 less than 0.05), which refers to rejection of the null hypothesis and presents a superior performance of Group 3 in relation to Group 1. In the comparison between the groups by the Box Plot, it is possible to visualize that Group 3 presents a more concentrated distribution of the grades with smaller amplitude and higher median, which leads to a lower variability. This allows inferring that the performance of Group 3 showed signs of superiority in all analyzes when compared to Group 1 and was equally or better in this evaluation when compared to Group 2.

In the second evaluation, the medians of Group 3 were superior to the other groups in the two periods analyzed previously, but there was no significant difference. In this

analysis, it was possible to identify that there was a significant difference (p-value of 0.007 less than 0.05), which refers to the rejection of the null hypothesis and presents a superior performance of Group 3 in relation to Group 1. In the comparison between the groups by the Box Plot, as previously occurred in these two phases, again it was possible to identify that Group 3 presents a more concentrated distribution of the grades, with smaller amplitude and higher median, which leads to a lower variability. As in the first evaluation, this analysis allows to infer that the performance of Group 3 showed signs of superiority in all analyzes when compared to Group 1, and was equally well or better in this evaluation when compared to Group 2.

In the third evaluation, the medians of Group 3 were equal to the medians of Group 2 in both periods, while the medians in Group 3 were higher in the first period when compared to the medians in Group 1. In this analysis, the lack of significant difference was identified, which maintain the null hypothesis, but the median of Group 3 was superior to the others. In the comparison between the groups by Box Plot, it was possible to observe that Group 3 when compared to Group 1, presents a more concentrated distribution of the grades with a smaller amplitude, which leads to a lower variability. In the comparison between groups 2 and 3, it was possible to observe a similarity in the distribution of grades and amplitude, in spite of the fact that the median was higher in Group 3 in this analysis, it shows the performance equalization of these two groups in this evaluation in both periods of tests.

Finally, the analysis of the post-test in the first period returned to a superiority of the Group 3 median in relation to the others, being significant the difference when compared to Group 1. In the case of the second test period, there was no significant difference, but Group 3 had a median higher than Group 2. In this analysis performed between the two phases, as seen in Figure 9, it is possible to verify in the Box Plot that the Group 3 median was higher than the other medians, with p-value 0.059, close to 0.05, which would result in a significant difference in relation to Group 1.

It was also possible to verify that the concentration of the grades is better distributed in Group 3, with a smaller amplitude, which results in a lower variability of the grades. This refers to a superior performance of Group 3 when compared to Group 1, as well as results in an equal or superior performance of this group in relation to Group 2, in the two phases.

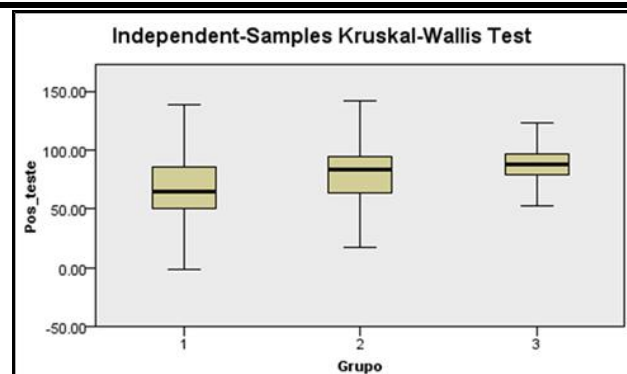


Fig.7: Box Plot of the comparison between groups in the third intermediate evaluation

This analysis reinforced the tendency observed in the interpretation of the results, in which it was verified that the performance of the group that used the Virtual World, in relation to the group that did not use any environment, was always superior, being of significant form or not. The medians, the way of distribution of the grades, amplitude and variability in the evaluations were better in Group 3 than in Group 1, which clearly demonstrates the superior performance of the participants who had the activities of reinforcement in the Virtual World in their process of learning, when compared with those who only studied with their notes.

In the comparison between the group that used the Virtual World and the group that used the Moodle environment, the analyzes did not show significant differences in the statistical verification performed, except for the first intermediate evaluation in the second period, in which Group 3 was better than Group 2. In spite of this only significant difference in performance, in all evaluations the performance of the group that used the Virtual World was equal to or greater than the performance of the group that used Moodle, in the questions of values of the medians, of the form of distribution data, scale and variability of data, with more cases of Group 3 superiority being identified than of equality in the evaluation analyzes.

VII. DISCUSSION

The findings of the analyzes carried out on the research related to the scope of this research demonstrated the lack of research involving both areas in an integrated way, which was motivating for the development of this work. In order to explore the potentialities of each of these areas and to solve their limitations, this integrated approach was proposed with a focus on the teaching of Sciences for elementary school, with two periods of tests being carried out.

The results of the first experiment period could be considered positive, in which the group of students who used the Virtual World performed better than the group

that chose not to use any environment. Regarding the group that used Moodle, the results were also positive in relation to the group that chose not to test any of the environments but did not have significant differences.

In the comparison between the Virtual World and Moodle groups, it was not possible to identify significant differences, however, the medians were larger for the participants who used the Virtual World, as well as, there was a better distribution of the grades in the evaluations and their amplitudes were smaller, causing less variability.

In the second period of the tests, only two groups were established, being formed by students who used the Virtual World and Moodle. The groups had similar performances regarding their medians in the evaluations, however, the distribution of grades was better concentrated in the Virtual World group, resulting in a smaller amplitude and variability. These results showed that this group was similar or even better than the participants who used Moodle, again being a positive result to be considered, and essential for the consolidation of the proposed approach.

By comparing the three groups, without dividing periods, it was possible to observe significant differences in three of the five evaluations performed, as well as in the others, the medians were superior. This resulted in significant differences in the performance of the Virtual World group compared to the group that did not use any approach. In comparison to the Moodle environment, Virtual World users had higher medians, with better distribution of grades, lower amplitude, and variation, but without significance.

In relation to the interviews carried out with the students, in which different students of the two test periods were selected, the pattern of the responses was positive, which indicates that the students unanimously approved the adoption of this type of proposal and they indicated that they would like to continue to perform complementary activities in the Virtual World in the coming semesters and the adoption of Mastery Learning approach.

Experimentation with these spaces and tools for simulation could facilitate the students' acquisition of competences and construction of knowledge [83]. The use of Virtual World with a focus on science education can be regarded as a valid alternative and beneficial when compared with most traditional teaching method, in that the teacher ministers the class in person and only with the blackboard and slide presentations. It was emphasized the use of simulations and questionnaires as something positive at the time of the study for evaluations, as well as they described to have liked to use this type of environment and expressed the desire to continue to use it in the coming semesters. The problems mentioned above

were also highlighted by them, such as the slowness and the requirement of a good internet connection and improvements planned for future steps.

The analysis carried out in this article with the description of the theoretical reference highlighted the way of conducting the educational theory of Mastery Learning, its advantages and disadvantages, as well as related works built in different areas of teaching. The exposition of the way of applying this theory, through its integration with Information and Communication Technologies, from which new research possibilities emerged, have also become important points for the academic environment. Mastery learning brings about behavioral advantages that include positive change in attitude, nature of approach to a problem, spirit to achieve one's best and beyond, and sense of rising to the challenge [84].

In terms of pedagogical resources, ICTs have been identified as innovative solutions that allow the elaboration of educational proposals that are more dynamic, interactive and integrated to the current conjuncture [85]. The study carried out in this research allowed the integration of Mastery Learning with a learning environment created in Virtual World, which is outside the context that had been applied in previous research, that approached the use of Moodle. Tüzün and Özding [86] explain that Virtual Worlds have the potential to provide individuals with more meaningful and long-term data compared to traditional or interactive multimedia environments. Using simulations in technological environments allows students to access data and information from remote sites, to relate visible and invisible data, to manipulate environments and variables, to influence changes or processes and to practice skills that would be difficult to develop in real life [83]. This factor has led to new exploration fronts, culminating in the creation and validation of the approach described in this article for science education.

Limitations

The process of implementation (development and deployment) of the Virtual World may be one of the most complicated issues of the solution proposed here for a school environment [85]. This finding was based on the essential work carried out by the teacher of the discipline, who together with the authors of this research, sought to articulate the complementary activities to be proposed with Mastery Learning, to assist in the creation of simulations in the Virtual World and to review the process. These activities have become valuable for the correct and proper functioning of the proposed method.

The process of developing the Virtual World requires more advanced technological knowledge in information technology and education, which in most cases is not

possible to be carried out by teachers who do not have knowledge of these areas. This reinforces the fact that an interdisciplinary team is essential for the development of this proposal and adds quality to the work developed.

Regarding the resources of the school environment that adopts the proposed Virtual World solution, the main problems identified were centered on the limitations involving infrastructures such as Internet connection speed and hardware resources. Because it is a three-dimensional environment, which consumes hardware and Internet connection resources, due to the data rendering and storage process, this type of problem ends up being a limitation, considering that it somehow escapes from the control of the teacher, being considered as an external factor that may occur and jeopardize the interaction of the students with the teaching materials available.

The installation and configuration of the viewer were also considered a challenge, since the students were children, with the help of their parents, who were supposed to carry out this process in their homes. In this context, there is the fact that Virtual World does not provide adequate support for use on mobile devices or on a page in a browser (like Moodle), requiring the installation of software on the user's computer, which causes difficulties to users as described above.

This point should be taken into account, identifying its target audience when applying this type of approach, as well as ways to facilitate this process. It is important to emphasize that despite the limitations identified, the process was able to be conducted properly and validation of the approach occurred correctly.

VIII. CONCLUSIONS

In this study, the virtual worlds were presented as an environment that allows the creation of 3D static and interactive objects, containing resources for communication between individuals, as well as to establish a high degree of interactivity and sense of immersion to the participants. The educational focus that was developed in the Virtual World to assist the teaching of science aimed to cover the elements mentioned above. The experiment adopted enabled the demonstration that this type of approach can be created with a focus on science teaching, in which the multimedia resources such as slides, texts, questions, and videos could be inserted into the environment, beyond the creation of interactive 3D simulations through the use of script programming. The evaluation of the participants made it clear that the resources used were considered important in the learning process and helped in the study period for the evaluations, noting that problems involving the internet connection speed and the ability of the computer hardware were identified as the main obstacles during the experiment.

The adoption of precepts of Mastery Learning as the basis for the formulation of activities and assessments encompassed the groups established during the experiment, in which both the students and the teacher who gave the activities considered positive this type of approach. The application of initial evaluations, at the end of each module and at the end of the semester allows the teacher to have a clearer vision and detailed status of each student, allowing the adoption of corrective measures during the semester, if he considers it necessary. It is important to emphasize that with the use of virtual worlds and Moodle as complementary activities, students had a satisfactory performance in all evaluations, which did not require that the teacher had to perform the recovery measures of activities during the experiment.

This factor can be considered as a positive outcome of the adopted approach, in which the group of students who did not use any of the environments got enough grades for approval, but at no time the group was with the median of grades above other groups. This demonstrates that the use of Mastery Learning for the planning of teaching activities during the semester, adopting Moodle and Virtual Worlds as places where students could perform reinforcement activities can be considered positive and beneficial.

The study made it possible to identify limitations highlighted by different researchers, who criticized the time required to conduct the activities and the excessive workload of teachers, as originally proposed by the Mastery Learning theory. However, this study allowed us to envisage new possibilities of adapting the adopted procedures, seeking to make the temporal issue more flexible and concomitantly reducing the workload of the teacher, whose main support was centralized in the use of technological resources, more specifically with the application of Virtual Worlds integrated to this theory. It was precisely at this point, taking into account its limitations and advantages, together with the exploration of computational resources in this environment, that the initiatives for the construction of this research emerged. The modification of the original method proposed, altering its way of conducting and proposing its integration to an environment of learning outside the context that had been applied in previous researches, that approached the use of Moodle, sent new exploration fronts, that culminated in the creation and validation of this approach.

This way of planning and adoption is not exclusively linked to the area of sciences but can serve as an approach to be adopted by teachers in different areas, this being one of the main contributions of this study. As subsequent stages of this project, new experiments are already being applied in the field of Geography and Algorithms,

showing that this approach is already being replicated to other areas of teaching.

One of the main aspects to be explored is related to the use of the mobile devices to have access to the Virtual World. This access, although it can be realized through an Internet browser, can also be through a specific program that personalizes and facilitates to explore all the didactic resources of the Virtual World. This problematic includes an instigating field of research to be explored in the future, from which important solutions can emerge for the academic and professional environment, which have helped in a significant way the diffusion of Virtual Worlds. The integration of this type of environment with Moodle can also be considered an interesting research area, for example, the Sloodle tool already does the mentioned integration. Although this type of initiative has lost momentum over the last few years, since there has been considerable time involved in creating and maintaining a resource in a Virtual World, as in "real worlds" where it is necessary periodic maintenance [86]. The creation of didactic content authoring tools that facilitate the availability of Virtual Worlds is a promising future work. It is now considered a complex process by [87]. Therefore, this is characterized as a still active need, which would significantly facilitate the difficulty of development for teachers in non-technological areas, allowing the inclusion of didactic materials such as videos, slides, and questions.

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