International Journal of Innovation Education and Research

ONLINE ISSN: 2411-2933 PRINT - ISSN: 2411-3123

Experience in Teaching Science in Virtual Environment

Leandro Rosniak Tibola;Fabrício Herpich;Patricia Fernanda da Silva;Liane Margarida Rockenbach Tarouco

Abstract

Labs are needed in science education, and schools usually lack appropriate conditions to provide active learning activities with experience. In schools, the lack of labs for science education is usual. The new technologies of 3D virtual worlds allow the user, through immersive virtual worlds, or metaverses, to experience situations similar to those possible in a real environment. A solution to the lack of labs is the virtual labs, which consist of virtual representations that reproduce the environment of a real lab. These are applications based on simulations, offering computational representations of reality. The simulation of concrete and real situations gives the student the opportunity to experiment, actively participating in the learning process by performing experiments that would otherwise not be possible due to safety issues (possible damage to students or the environment) or economy (cost of components involved and derived from the creation and operation of the lab). These virtual labs can be implemented on personal computers that exist in schools or even in the student's home. Users can work in the virtual lab, through their avatars, using experiments provided there, as well as acting collaboratively.

Keyword: Experience; Science Teaching; Real Labs; Virtual Worlds; Virtual Labs;

Published Date: 4/30/2019 **Page.23-43** **Vol 7 No 4 2019**

DOI: https://doi.org/10.31686/ijier.Vol7.Iss4.1375

Experience in Teaching Science in Virtual Environment

Leandro Rosniak Tibola, Fabrício Herpich, Patricia Fernanda da Silva, Liane Margarida Rockenbach Tarouco

Abstract

Labs are needed in science education, and schools usually lack appropriate conditions to provide active learning activities with experience. In schools, the lack of labs for science education is usual. The new technologies of 3D virtual worlds allow the user, through immersive virtual worlds, or metaverses, to experience situations similar to those possible in a real environment. A solution to the lack of labs is the virtual labs, which consist of virtual representations that reproduce the environment of a real lab. These are applications based on simulations, offering computational representations of reality. The simulation of concrete and real situations gives the student the opportunity to experiment, actively participating in the learning process by performing experiments that would otherwise not be possible due to safety issues (possible damage to students or the environment) or economy (cost of components involved and derived from the creation and operation of the lab). These virtual labs can be implemented on personal computers that exist in schools or even in the student's home. Users can work in the virtual lab, through their avatars, using experiments provided there, as well as acting collaboratively.

Keywords: Experience; Science Teaching; Real Labs; Virtual Worlds; Virtual Labs;

1. Teaching Sciences

As we investigate the teaching of science in schools, we can see that there are still tendencies of teaching based on an exposition of programmatic contents, in a fragmented and decontextualized way. Although the National Curricular Common Base (BRASIL, 2017) prioritizes the teaching of science through an articulated view of the various fields of knowledge, allowing students access to diverse knowledge, practices, and procedures of scientific research.

On the other hand, there is consensus about the importance of experimentation in science teaching and its presence in natural science classes, for teachers and even students. In this context, Kapici et al. (2019) states that the use of laboratories is essential for scientific education, since it enables science to be taught by students, based on the practical experiences that can be realized.

Research related to this teaching has been growing in recent years, discussing the most diverse methodologies and pedagogical practices, among them the use of experimental activities as a teaching strategy for the construction and understanding of concepts in science (Moreira, 2018). Gonzáles et al. (2018) the literature has presented different ideas for the teaching of Science, so that an advanced way with the use of different dynamics for the education in this discipline is traced.

The National Curriculum Parameters state that learning Biology in basic school allows broadening the understanding of the living world. Playful teaching, marked by direct interaction with phenomena, facts, and objects favors learning in a general way by developing skills and competences (BRASIL, 2000).

To achieve these objectives, experimentation can be an interesting tool, since it promotes and favors student interaction, teamwork, raises questions, generates hypotheses and allows abstract explanations. Experimental activities allow students to exercise their skills, concentration, organization, and experience the steps of the hypothetical-deductive method. Through such experiences it may be possible for the student to re-sign theoretical concepts and learn how to develop solutions to complex problems, and to be able to control and manipulate different variables to test possible hypotheses.

In addition, students have the opportunity to build their knowledge by experimenting, which is not an easy task, since it requires time and also adequate facilities (Kapici et al., 2019). In results already acquired, it was possible to perceive that the students when they have the opportunity to explore experimental activities are able to obtain more success in the development of concepts, develop investigative attitudes and have a better engagement in carrying out these activities (Deboer et al., 2017). The authors also noted that the conceptual understanding of the students was supported in view of the possibility of manipulating the materials and of learning actively.

Mikeska et al. (2018) observed that investigating makes students have access to high-quality science teaching because they can make sense of real-world phenomena by engaging in activities that need to be investigated, analyze and interpret data while also building their knowledge and understanding. During the experimental activities, students have the opportunity to answer questions that can be tested. These can start from data collection, analysis of secondary data or even from research (Mikeska et al., 2018).

In general, it is perceived that providing students with their previous knowledge, concrete materials and that can perceive the occurrence of certain phenomena, can favor the process of knowledge construction and understanding about concepts that are often abstract in relation to the level of understanding of the students.

The teaching of science has been worked in different ways and with the most varied methodologies, such as: experimentation activities, videos, lectures, reading science books, however, it is proven that activities in which students can "put the hand in the mass" also allow teachers to interact with students and to incorporate themselves into the context in which activities take place (Mikeska et al., 2018).

Although experimental activities have an excellent methodological strategy, it is still little used in teaching, with a large number of variables as obstacles to its use. Experimenting requires time for students to engage in experimental activities, which have now been seen as a hindrance, as well as having adequate space, materials, products, and the responsibility of using this equipment during classes in one laboratory.

Kapici et al. (2019) point out that chemicals pose susceptible and costly hazards, as well as the lab equipment and materials required to carry out the activities. The number of students in the class usually constitutes an important factor that makes difficult the use of experimentation due to the lack of conditions to provide the opportunity of each student's individual performance in the experiment.

As highlighted by Moreira (2018) several situations are perceived:

- The teaching of Sciences must have the experimentation so that there is an understanding of what happens in the sciences;
- Expand the horizons of the student in such a way, that the experiment refers to future classes;
- In experimental teaching, both correctness and error contribute to the process of knowledge construction;
- The practice in teaching science is fundamental in the structuring of learning;
- The short time and sometimes a large number of students in the class makes it difficult to carry out many activities.

However, despite these difficulties, it is agreed that the experimental activity, influences the teaching-learning process since it modifies the action and reflection of those involved.

2. Science Labs

Science labs have a central role in teaching because in order for students to actually understand certain activities it is necessary that they can experiment, visualize, understand and reflect on the experimentation activities carried out. Kapici et al. (2019) support this argues that to learn science through research and the use of labs is still one of the most effective ways of learning since it allows the student to build his/her knowledge by experimenting.

The use of labs allows learning to occur through experimentation and research so that scientific knowledge is delineated. To develop activities in the lab is not trivial, because it requires that both teacher and student are engaged and that they can develop strategies for the activities to generate the hypothesis, the interpretation of data, reflections and also conclusions from the results obtained.

In addition, the previous knowledge presented and the collaborative work developed by the students can also favor the development of these activities since they imply directly in the discoveries and the creative thinking of them (Grobmann & Wilde, 2018).

Although experimental activities are of great relevance for the construction of learning, the lab (hands-on or virtual) environments still present some disagreements regarding the use in the school context. On the other hand, real labs (hands-on) allow students to observe events during activities, as well as understand certain concepts that for students can be abstract.

In the same way, these experiments do not always bring clear and objective answers to the students, which in turn can generate more doubts or confuse them in relation to the observed situation, making it difficult to generate a hypothesis, to extract data and to obtain conclusions from the results obtained during the experimentation (Kapici et al., 2019).

Other factors that may be responsible for restricting the use of labs in schools refer to costs, time, expensive equipment and the need to apply activities to small groups (Estriegana et al., 2019), which causes difficulties in the planning of classes and the development of activities by the teacher.

Expanding ideas about the use of laboratory experimentation, Kapici et al. (2019) report that the use of virtual labs also begin to be part of schools, either by using them from their capacities and individually or even for the development of sequenced activities where the use of real and virtual labs are used in combination.

Gunawan et al. (2018), the use of virtual labs can solve the problem of students' conceptual understanding and increase the interest in learning in the classroom, providing better learning outcomes. The authors also point out that the use of virtual labs is essential for learning, especially physics because, through experimental activities, students can become more curious and practice their scientific attitudes, as well as observing concepts about the content studied and so understand it easily.

The use of virtual labs can also be used by the student remotely through the access of an experiment interface and thus has the opportunity to experiment and contemplate the expected educational objectives (Sypsas & Dimitris, 2018).

2.1 Experiment activity

Developing activities aimed at the use of experimentation can help students to build their knowledge since the process starts with an experiment and then examines what happened. Kolb (2015) argues that the activities of experimentation allow learning also with the life experience since the student is in direct contact with the reality of study. For this, the emphasis is on direct experience, along with the senses and also actions in the context.

Although there are opposing ideas to experimentation activities, Metcalf et al. (2018) affirm that in experimental activities students can generate a large number of evidences, allowing to construct concepts so that they can better promote learning. In addition, the authors emphasize that the involvement of students in scientific activities contributes to the construction of explanations, phenomena, as well as the development of cooperative work.

Enable students to develop activities with experiments, allow them to seek evidence for the explanation of phenomena, analyze, reflect, verify the concepts involved and then take advantage of them partially, totally or even have subsidies to create and develop a new experience.

In experiencing and realizing an experience, you can act to develop it because it refers to a particular situation. Aiming to achieve this, it is necessary to evolve perceptual acts and anticipate concepts, which by the way involves both knowledge and evaluation of objects used, the steps that will be developed and also the situation itself.

During a trial activity, all modes of the Kolb Learning Cycle (2015) are present, from the Concrete Experimentation to the Active Experimentation and for this reason, it is important for the process of knowledge construction by the student.

2.2 Kolb Learning Cycle

In Kolb's view (2015), learning happens in an experiential way, that is, from experimentation to the context of learning and is defined by a transformation that occurs in an experience, and from which knowledge is created.

> Experiential learning theory offers a fundamentally different view of the learning process from that of the behavioral theories of learning based on an empirical epistemology or the more implicit theories of learning that underlie traditional educational methods, methods that for the most part are based on a rational, idealist epistemology. From this different perspective emerge some very different

> prescriptions for the conduct of education; the proper relationships among learning, work, and other life activities; and the creation of knowledge itself.
>
> This perspective on learning is called "experiential" for two reasons. The first is to tie it clearly to its intellectual origins in the work of Dewey, Lewin, and Piaget. The second reason is to emphasize the central role that experience plays in the learning process. This differentiates experiential learning theory from rationalist and other cognitive theories of learning that tend to give primary emphasis to acquisition, manipulation, and recall of abstract symbols, and from behavioral learning theories that deny any role for consciousness and subjective experience in the learning process. It should be emphasized, however, that the aim of this work is not to pose experiential learning theory as a third alternative to behavioral and cognitive learning theories, but rather to suggest through experiential learning theory a holistic integrative perspective on learning that combines experience, perception, cognition, and behavior (Kolb, 2015, p. 31).

In this model of learning, Kolb highlights the importance of "concrete experience". Learning is described as a process whereby concepts are derived from and continuously modified by experience. The fact that learning is a continuous process grounded in experience has important educational implications.

New knowledge, skills, or attitudes are achieved through confrontation among four modes of experiential learning. Learners, if they are to be effective, need lour different kinds of abilities concrete experience abilities (CE), reflective observation abilities (RO), abstract conceptualization abilities (AC), and active experimentation (AE) abilities. In experiential learning theory, there is a transactional relationship between the person and the environment. Learning is the process whereby knowledge is created through the transformation of experience.

3. Virtual Labs

Currently, computer and communication technology allows the creation of digital educational material using interactive multimedia that makes teaching-learning environments more effective in Information and Communication Technology (ICT).

The increasing availability of computer labs in schools contrasts with the lack of labs to support teaching-learning activities in Science and Mathematics in schools. According to the latest School Census in Brazil, only 11.5% of schools have a science lab and in secondary education, 44% of schools have this type of resource. The availability of IT labs is higher: 44.1% in elementary education and 78.1% in secondary education (INEP 2019). These data show that developing and deploying virtual labs that can be used to simulate real labs is an alternative solution to alleviate the much needed real lab lability in science teaching.

Virtual labs using immersive environments and mobile devices begin to emerge and ready-made solutions or authoring tools for creating virtual labs, using both commercial software and free software become available both internationally and nationally.

The development of solutions in terms of virtual labs, focused on the context of education in the country needs to take advantage of existing strategies using them as a leverage element for the design and construction of new solutions that allow to make available not only a new set of solutions in terms of virtual labs, as well as to promote training for the development of virtual labs focused on science education.

These labs should be able to be created by teachers and by the students themselves using authoring tools that do not imply extensive knowledge of computer languages. A path currently used involves the use of visual block-based programming languages such as Scratch and App Inventor developed by MIT.

In addition, it should be noted that the construction project of virtual labs should aim to use laboratory activity not only as an element of demonstration of concepts and theories as it is usually done in real labs. It is necessary to plan and provide learning interactions to be carried out in the virtual lab capable of promoting the development of high-level thinking because as the young people reach the teenage age they become able and able to use structures of formal thought.

Figure 1 illustrates the relevant elements of a virtual lab where the student represented by an avatar traverses the environment and has the opportunity to observe and interact with interactive multimedia resources (panels with static images, animations, videos, tests) as well as artificial characters that are included in the virtual world and are controlled by specific scripts that govern their interaction with users.

In this sense, virtual labs should offer a context in which challenges are presented and lead to experimentation activities aimed at testing hypotheses and that are capable of promoting the necessary reflection, capable of exercising and instigating high-level thinking activities. Implementing a virtual lab in an immersive virtual world can take advantage of important and relevant features that favor learning. Figure 1 shows the relevant aspects of an immersive virtual world with 3D elements in the context of virtual lab deployment.

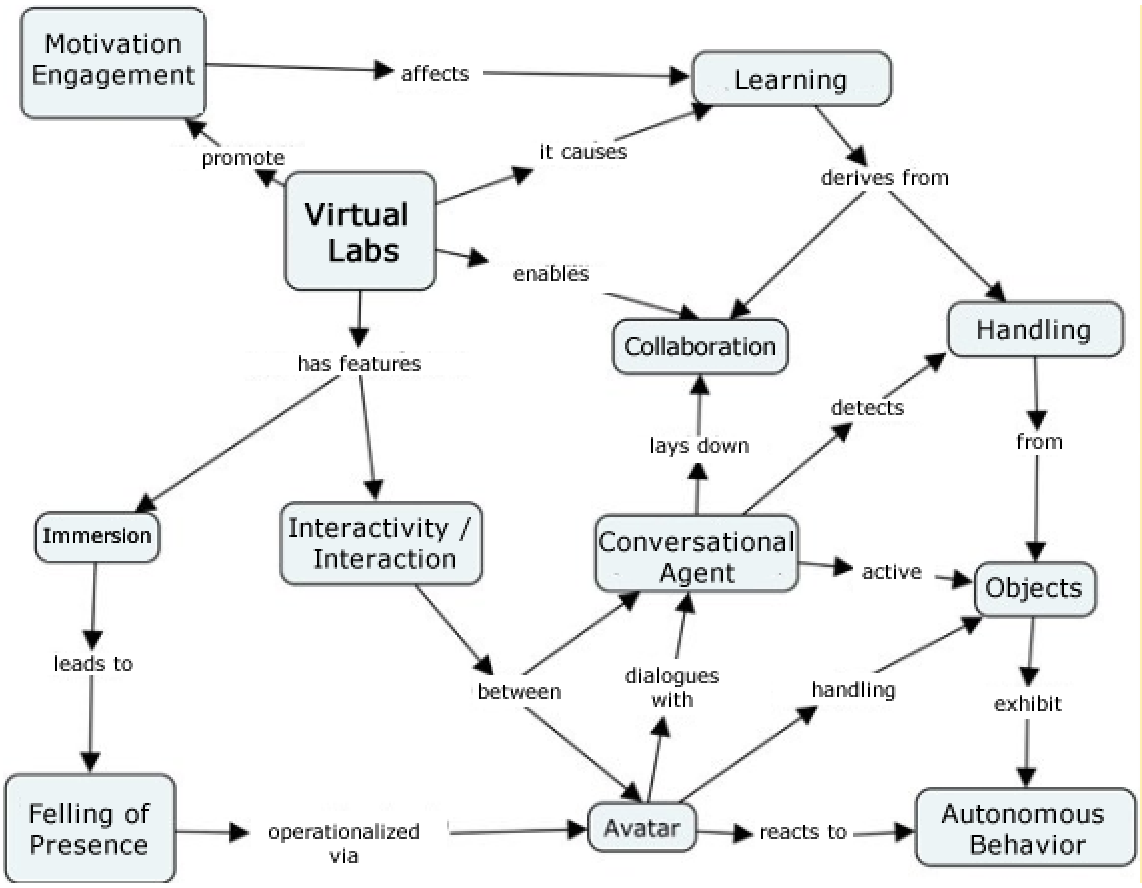

Figure 1. Conceptual map with relevant elements of a Virtual Lab.

An Immersive Virtual World (IVW) environment such as OpenSim offers numerous possibilities for adding multimedia features such as still and animated images, videos, and audio. Multimedia resources are 3D objects that can be embedded in the immersive virtual world and therefore be present in a virtual lab offering various forms of manipulation:

- Visualization without interaction - the user watches videos, animations and observes images and panels with text;
- Visualization with control - the user can use commands that approximate the 3D virtual object to be observed, also allowing diverse points of view for its inspection;
- Provide data that controls the behavior of certain objects in the environment (position, speed, etc);
- Ask questions about the concepts involved in the experiment, which will be answered by a chatbot that uses a knowledge base specifically built for the area in question;
- Modifications and construction of new objects with a view to modifying or expanding the experiment;
- Demonstrate to other students the outcome of such activities.

Each 3D object included in the immersive virtual world can have a behavior, controlled by scripts associated with them and that are triggered from user actions like clicking on the object or from a mere approximation of it. The objects have the possibility of communication with each other so that a manipulation of a given object by the user can result in sending a signaling to another object and trigger behavior that modifies the environment or that sends messages to other systems that will result in recording actions of users (activity log) or query to external systems, such as chatbots, that will return information relevant to the experience activity being performed by the user. This information can be of the announcement of possible interactions with the experiment, orientation on how to proceed, answer to questions received from users, instigation to reflection from the activities carried out by the user, through his avatar.

4. Strategy for the creation of Virtual Educational Lab using IVW

The creation of a virtual lab set in the Immersive Virtual World is based on the understanding of the desired lab model. In this text, the Virtual Educational Labs (VEL) are understood as educational labs, which aim to perform practical activities to fix theoretical contents of Science, Mathematics, Physics and other subjects, and are made available in a virtual way, where presentation and behavior of digital objects is similar to objects in the physical world, as well as allowing the representation of situations or conditions that are impossible to be experienced in a physical lab, such as manipulating an atom in large proportions, compared to their actual size (Tibola, 2018).

In order to investigate the effectiveness of the use of virtual labs, in substitution of real labs, a project was developed called AVATAR (Virtual Environment of Learning and Remote Academic Work - acronym in Portuguese), which contemplated the implantation and configuration of an immersive virtual worlds service based in free software, that allows to create an immersive virtual environment capable of giving the realization of virtual experiments. In the immersive virtual environment created, students / users find areas or rooms where they have the opportunity to manipulate virtual artifacts and experiments, triggering experiments simulating real experiments. They can observe, annotate and intervene, changing settings that govern the behavior of the experiment and interact with other users, also represented by avatars, to discuss the experience and collaborative reflection.

The AVATAR project has an OpenSimulator server, composed of several regions, in which the virtual educational labs are made available. These labs can be accessed remotely through compatible viewers. Furthermore, WWW and database servers are part of the structure of the AVATAR project, so that the data of the student movement in the regions and their interaction with the objects that are part of the scenario of the virtual world and, especially, those objects about which were built the virtual educational labs, can be stored and analyzed later.

In addition to providing remote access, the AVATAR project contemplated the creation of a structure that could receive virtual educational labs without the need for online access to the Internet. A Standalone version was made available, with a structure composed of the servers: Sim-on-a-Stick - portable version of OpenSim (Simona, 2017), WWW, databases, and PHP interpreter. This structure also allows the collection of information regarding the movement and interaction of the student in the virtual world and in the virtual educational lab. The creation and availability of the Standalone version of the labs are justified by the existence of schools that do not have access to the Internet or the access speed is insufficient for the execution of the remote structure.

The AVATAR project is a multidisciplinary and comprehensive domain, using various resources to achieve its objectives: immersion, realism, and interaction - present in immersive virtual worlds; virtual tutors - through Non Players Characters (NPC) and chatterbots resources; augmented reality - through markers and reading devices; ontology - for the representation of students' interactions in immersive virtual worlds.

Also, they are used of diverse approaches for the construction of environments with educative and motivating educational labs, that allow to register the actions of the students in their experiences, allowing to identify if the experiences proposed and the activities realized by the student propitiated the acquisition of knowledge and of this one validation of the proposal of the virtual educational labs. For this, the creation of labs can use strategies such as gamification, Flow State, Learning Paths, Mastery Learning, digital conversational support, among others. These strategies can be used according to the purpose of the lab; the decisions of the programmer and the graphic designer; of the public to be reached, of the multidisciplinary team involved in the construction of the lab and directing the research itself.

Figure 2 exemplifies a scenario found in the immersive virtual world that implements the relevant elements. In this environment is the avatar of the user accompanied by a conversational agent with which dialogue (textual) can be established.

Figure 2. User avatar (left) and a conversational agent (right).

The pedagogical approach used in the implementation of the labs is supported by the Kolb Cycle (1984) which proposes to be the experience the motto for a process of reflection that should lead to the consolidation of abstract learning and conceptualization, which will create conditions for the student to make the transfer (translation of knowledge) to other contexts becoming able to realize new experiences.

5. Analysis of results achieved with the use of Virtual Educational Lab

5.1 Virtual Educational Lab description

This work presents an experiment carried out in a virtual educational lab in the immersive virtual world, delivered in Standalone mode. The equipment used for the experiment had the following configurations: Intel Core i5, 6 Gb RAM, 500 Gb hard disk, GeForce GT430 2GB video card, 22-inch LCD monitor and Windows 7 Professional 64-bit.

Due to the Windows permissions, some firewall and proxy security parameters were initially reconfigured from the computers in the computer lab where the virtual educational lab was installed. On all the computers were installed portable versions of OpenSim, from a WWW server, from a database server. Figure 3 shows the contact electrification experiment (A) and the induction experiment in the VEL used by the students.

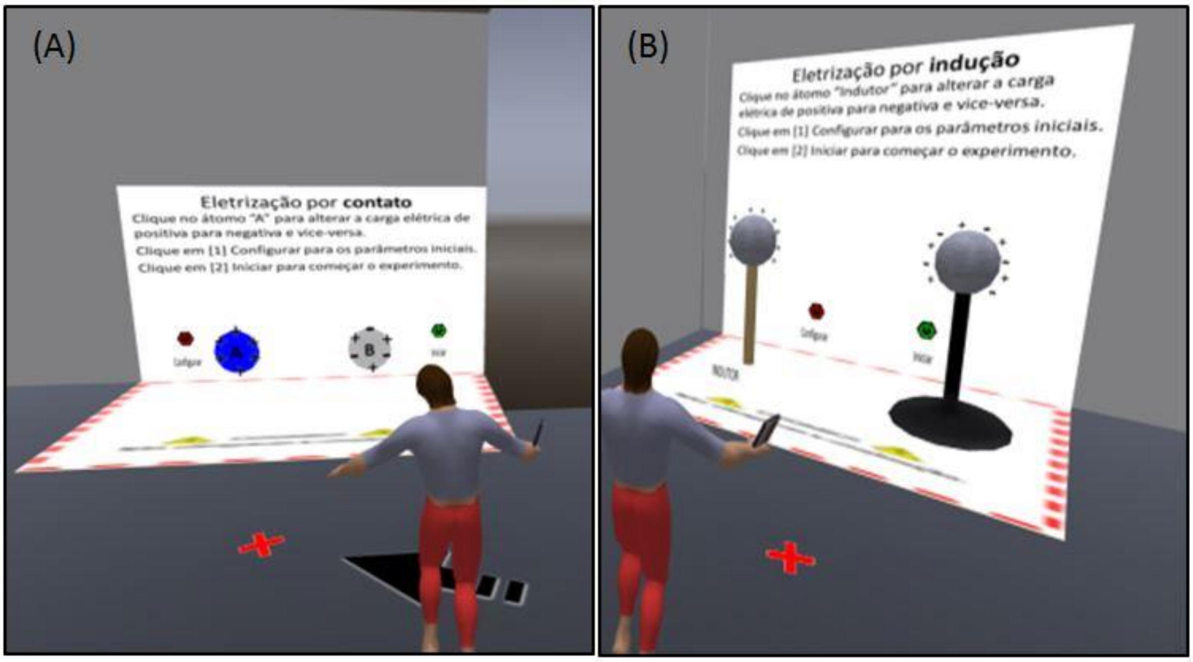

Figure 3. Virtual Educational Lab experiment

5.2 Demographic description of the population

The students participating in the study studied in the 1st Year of High School (1AEM), 2nd Year of High School (2AEM) and 2nd Semester of the course of Computer Science (2SCC) of a university in the Rio Grande do Sul - Brazil. The students' participation was voluntary and without reward or financial, academic or other remuneration. All the legal authorizations of the participants and/or those responsible for conducting the research were collected and the research was approved by the Research Ethics Committee. The choice of these classes is due to the reason that the professors of the subjects of Mathematics and Physics in High School and in the course of Computer Science were the same and they observed that the students of the High School were not yet familiar with the contents in your classes. Already for the students of Computer Science, there was interest in identifying the level of knowledge of these students on the content.

In the 1AEM class, all 24 students accepted to participate. The class had 11 men and 13 women with ages ranging from 15 to 17 years, with an average of 15.5 years. In the 2AEM class, 12 of the 12 students took part in the activity, being 3 men and 9 women, aged 16 and 17 years, in an average of 16.1 years.

Finally, 13 of the 17 students from the 2SCC committed to participate in the experiment, all of whom were men ranging in age from 17 to 20 years, with a mean of 18.4 years. Thus, 49 individuals, 27 men, and 12 women, with an average age of 16.4 years, accepted to participate in the evaluation of the Virtual Educational Lab.

5.3 Methodology

The present article reports a case study that addressed the construction of an educational lab in the immersive virtual world OpenSim, offering practical experiences in the field of Physics, specifically the

Electrostatic area, for the following contents: Introduction to Electricity, Electric Charge, Conductors and Insulators, Body electrification and Experiments with electrification.

The use of the immersive virtual world was done as follows: (1) reception of the students (1AEM at 08:00 AM, 2AM to 3:00 PM and 2:00 PM to 7:00 PM); (2) presentation and explanation of the use of the immersive virtual world upon receipt; (3) delivery of the card with the avatar and password for each student, after choosing a computer by the student; (4) completion of the Student Profile, after the explanations and confirmation that everyone had understood the procedures; (5) completion of the Pre-Test, after delivery of the Student Profile; (6) use of the Virtual Educational Lab, after all the students delivered the Student Profile and the Pre-Test; (7) the Flow Questionnaire was signed, as the student finished using the Virtual Educational Lab, he would raise his hand and receive the questionnaire; (8) completion of the Post-Test, after delivery of the Flow Questionnaire; (9) completion of the Evaluation of the Experience, after delivery of the Post-Test; (10) release, upon delivery of the Experience Assessment; (11) preparation of the lab, before each session of the experiment.

After each hour of use of the VEL, the questionnaires, unidentified, were gathered by class and by type. Subsequently, the questionnaires were tabulated and analyzed. Several variables should be considered in order to identify the advantages and disadvantages of using a virtual educational lab. This study focused on the Virtual Educational Lab Assessment Questionnaire. The analysis of this questionnaire is presented in the following sections.

5.4 Assessment tool used

The VEL Assessment Questionnaire aimed to identify students' opinions about the use of the environment. Ten objective questions and two descriptive questions were elaborated, which the student was free to complete or not. Objective issues followed the Likert Scale, scoring from 1 to 5 for the "Strongly Disagree", "Disagree", "Neutral", "Strongly Agree" and "Strongly Agree" options respectively. Following the text shows the values tabulated based on the answers provided by the students and in the next section will be presented the results of the questionnaire Evaluation of the Virtual Educational Labs.

5.5 Discussion of the results

From the tabulation and analysis of the LEV Assessment Questionnaires, the following interpretations were obtained, reported by the question:

1. Was the information I received prior to using the environment sufficient to enable me to accomplish all the activities in the Virtual Educational Lab?

Before the interaction of the students with the Virtual Educational Lab, all the aspects related to the VEL were clarified, as well as the students' instruction on the operation of OpenSim (eg construction, movement, characteristics) and on the day of the experiments. of the Virtual Educational Lab environment (eg beginning and end of the course, intermediate activities, interaction). The "Agree" (45%) and "Strongly Agree" (43%) indices for the total number of students show that the students received the necessary information about the VEL to carry out the activities foreseen in the Virtual Educational Lab and to interact with the experiments education. The students' opinions about the information received to carry out activities in the VEL can be seen in Table 1.

Table 1. Students' perception of the information received about the VEL.

Class / Answers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1AEM	0%	8%	13%	38%	42%
2AEM	0%	0%	10%	70%	20%
2ACC	0%	0%	0%	38%	62%
Total	0%	4%	9%	45%	43%

2. In the Virtual Educational Lab, were the task indications clear?

The objective of this question was to verify if the virtual world had instructions of any format (text, image, video, etc.), indicating how the student should proceed in the activities. In addition to instructions, the very construction of the scenario and 3D objects could be intuitive to the point where the student can perform the task without problems. Table 2 demonstrates the answers to this question. In all, the 45% markup for "Agree" and 36% for "Strongly Agree" demonstrates that students received enough information to perform the activities proposed in the experiment.

Table 2. Students' perception about the clarity of the indications about the tasks in the VEL.

Class / Answers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1AEM	0%	4%	17%	46%	33%
2AEM	0%	0%	0%	50%	50%
2SCC	0%	0%	31%	38%	31%
Total	0%	2%	17%	45%	36%

3. In Virtual Educational Lab, was there feedback for the tasks performed?

According to Zichermann & Cunningham (2011) immediate feedback is one of the principles of gamification, so it was important to know if the student had received the feedback information soon after performing a task. For all respondents, 51% "Agree" and 30% "Agree strongly", that there was enough feedback when doing the tasks. Table 3 presents the selection of students' options for this questioning.

Table 3. Students' perception about the availability of feedback in tasks in the VEL.

Class / Answers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1AEM	0%	4%	25%	46%	25%
2AEM	0%	0%	0%	60%	40%
2SCC	0%	8%	8%	54%	31%
Total	0%	4%	15%	51%	30%

4. Did experiments, such as Attraction and Repulsion, have sufficient information for their correct execution?

This question sought to identify if the interactions with the objects in the practical activities had information or its construction allowed the correct execution of that activity. Figure 8 shows student responses. It can be observed that the students indicated "Agree" (60%) and "Strongly agree" (26%) with the presence of sufficient information in the experiments for their correct execution.

Table 4. Students' perception about the experiments and if they had sufficient information for their correct execution.

Class / Answers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1AEM	0%	4%	21%	50%	25%
2AEM	0%	0%	0%	70%	30%
2SCC	0%	0%	8%	69%	23%
Total	0%	2%	13%	60%	26%

5. Were the objects present in the experiments, such as Attraction and Repulsion, are easy to operate?

Interaction is an important feature in the construction of environments involving gamification and are educational (Zichermann & Cunningham, 2011; Yilmaz et al., 2015, Tibola & Tarouco, 2015). As the interaction was one of the principles sought with great intensity in the development of the Virtual Educational Lab, its measurement is important to analyze its presence. Table 5 reports student responses.

Table 5. Students' perception about the ease of operation of experiments.

Class / Answers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1AEM	0%	13%	33%	42%	8%
2AEM	0%	0%	10%	60%	30%
2SCC	0%	8%	23%	46%	23%
Total	0%	9%	26%	47%	17%

Regarding the ease of operation of the experiments, most students demonstrated that they were easy to operate (47% agree and 17% strongly agree - 64% of the total). On the other hand, 26% of the students did not agree or disagree, which suggests that the first group (they Agreed and Strongly Agreed) perceived the experiments as easy to operate and the second group (did not agree or disagree) understood the experiments are sufficient easy to operate, as is commonly expressed when there is no understanding that the activity is not considered easy, but it was possible to do so. From the indications of the students described above and since only 9% of the students declare that the operation of the experiments was not easy, it is believed that the experiments are generally easy to operate but can still be improved.

6. Starting the experiments, such as Attraction and Repulsion, did the objects perform what was expected of them?

The objects present in the Virtual Educational Lab were developed to perform certain operations on themselves and/or other objects (move, appear/disappear, change color, etc.), when the student performed an action (touch, or collide with an object, for example). Here we consider the three-dimensional object, for example, a cube in yellow that, when detecting the student's presence, changed to green or a start button, which when touched approaches or distances two other objects. This question wants to check if the objects started the actions as caused by the avatar. Table 6 demonstrates students' understanding of this question.

Table 6. Students' perception about the experiments and whether they were executed as expected.

Class / Answers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1AEM	4%	4%	21%	46%	25%
2AEM	0%	0%	20%	40%	40%
2SCC	0%	8%	0%	62%	31%
Total	2%	4%	15%	49%	30%

In this question, we can see that, in general, most of the students "Agree" (49%) or "Strongly Agree" (30%), while 15% "Did not Agree or Disagree". However, 4% of students "Disagree" and 2% "Strongly Disagree". These opinions lead to the understanding that for 79% of the students the objects presented the correct execution of the activities, which students who "did not agree or disagree" may have faced some unexpected situations, but the execution of the actions of the object was close to that of the was previewed. Students who "Disagreed" or "Strongly Disagreed" the objects did not perform the expected actions, which may have been caused by: (A) misuse by the user, since the student could press a button and due to processing, the student did not notice the action; pressing one or more times a button, causing the action to be repeated or even stopped; (B) with the dependence on the local computational capacity and connections with external servers, the environment could slow down in a few moments, leading the student to believe that it was no longer working; (C) still, exception handling in object programming, since unexpected situations can happen and object programming script was not prepared to treat this condition.

Observing these considerations, in general, the students realized that the objects executed as they were expected to do (79%), and for 6% the actions of the objects do not occur correctly. It is noted that, through the students' responses, the objects functioned properly; but there is a need to improve the programming of objects in relation to the state of execution of the object and the clear visualization of this object for the user, as well as to review and reinforce the repetitive pushing of buttons or out of order.

7. At the end of their execution, such as Attraction and Repulsion, did the experiments "as a whole" accomplish what was expected of them?

In the Virtual Educational Lab, the equipment or devices can be constructed with single objects or with the grouping of two or more objects. For example: three circles, in the colors green, yellow and red, plus a three-dimensional square can be joined to form a semaphore; so when the avatar approached the traffic light and the light was red, a danger message was displayed, if the signal was yellow, it would send a warning message and if the signal was green, the message would be to proceed. In a simple way, the semaphore process comprises the establishment of constant times for the signals and with the detection of the avatar, the message visualization corresponding to the color of the signal. Failure to view the message or display an incorrect message is the unsuccessful completion. Thus, in addition to the individual behavior of the object, it was sought to verify the integration of objects in the experiment "as a whole": the communication of the object with its parts and with other objects, the activation of objects and messages for the avatar, and reaction to user actions. This question wants to check if the objects started the actions as triggered by the avatar. Table 7 shows the student markings for this question.

Table 7. Students' perception about if the experiments performed what was expected of them "as a whole".

Class / Answers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1AEM	4%	4%	0%	71%	21%
2AEM	0%	0%	10%	50%	40%
2SCC	0%	0%	8%	85%	8%
Total	2%	2%	4%	70%	21%

Generally examining the 47 participants, 70% "Agree", 21% "Strongly agree" and 4% did not agree or disagree with the closure of executions according to what was expected of them. However, 2% of these students "Disagree" and another 2% "Strongly Disagree". Unlike when asked to "begin experiments, objects performed what was expected of them" in which 79% of the students responded positively, now 91% of the students confirmed the complete execution of the experiment and its correct functioning "as a whole". Based on the percentage of affirmative answers, it is understood that the objects that compose the experiments presented the expected result, having had a satisfactory execution to the presets of its creation.

8. What is your assessment of the Virtual Educational Lab presented here?

In this question, we wanted to discover how the student qualifies the VEL in general, evaluating the resources present in the environment. In Table 8 it is possible to visualize the students' choices. The indication that 94% of the students evaluated the positively Virtual Educational Lab is a confirmation that the construction of the environment presented resources, such as movement, information visualization, and experiments, interaction, challenge, and feedback, that met the students' expectations regarding the VEL.

Table 8. General students' perception of the VEL.

Class / Answers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1AEM	0%	0%	4%	50%	46%
2AEM	0%	0%	0%	30%	70%
2SCC	0%	0%	15%	46%	38%
Total	0%	0%	6%	45%	49%

9. How much did you enjoy using the Virtual Educational Lab?

Student satisfaction and approval in using the environment is one of the points of interest of this research. So it was asked how much the student had enjoyed the experience. Students' choices are tabulated in Table 9. This question is approved by 96% of the respondents ("Strongly Agree" with 36% and "Agree" with 60%) and is reinforced by the result of the "virtual world" question. It is confirmed that the environment provided satisfaction and pleasure in its use; certainly promoted by the interaction capacity, realism, and immersion provided by the 3D structure available in the Virtual Educational Lab and by the strategy of building and arranging the objects in the available activities.

Table 9. Students' perception of satisfaction in using the VEL..

Class / Answers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1AEM	0%	0%	0%	75%	25%
2AEM	0%	0%	0%	30%	70%
2SCC	0%	0%	15%	54%	31%
Total	0%	0%	4%	60%	36%

10. How much use Virtual Educational Lab was fun?

In addition to the correct operation of the objects, enough instructions and satisfaction with the Virtual Educational Lab, the student was also asked if the use of the 3D virtual world was fun. These responses are shown in Table 10.

Table 10. Opiniões sobre quanto a utilização do VEL foi divertida.

Class / Answers	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1AEM	0%	0%	4%	75%	21%
2AEM	0%	0%	0%	40%	60%
2SCC	0%	0%	0%	62%	38%
Total	0%	0%	2%	64%	34%

Taking into account the judgment of the students who completed the evaluation questionnaire, it is noticed that 98% of these students considered the Virtual Lab environment fun. This result indicates that the environment allows the student's involvement, attracts his attention and his dedication, necessary for the accomplishment of the activities. In harmony with the manifestation of the students, it can be said that this is a fun environment.

Another important result is related to attention levels achieved during the student interactions in Virtual Educational Lab resources. In order to ascertain the levels of attention achieved, three students were equipped with an encephalogram sensor capable of measuring the level of attention during the interaction of the students with the Virtual Educational Lab, a sensor called MindWave Mobile 2[1] by Neurosky. The Mindful Metrics app[2] was used to record the levels of attention achieved. Additionally, scripts in the OSSL language were developed in the VEL to record the types of interactions performed by the students, which were compared with the results recorded by the Mindful Metrics app and presented in categories for each multimedia resource (Table 11).

Table 11. Students attention level during interaction with VEL multimedia resources

	Texts	Videos	Web Pages	Quizzes	3D Objects	Simulations
Student 1	35	48	39	46	55	62
Student 2	47	63	51	55	69	77
Student 3	26	34	28	33	43	58
Average	36,0	48,3	39,3	44,7	55,7	65,7

Table 11 shows the average attendance recorded for each student during their interactions with the different types of multimedia resources available in LEV. Through the data provided by the encephalogram sensor and recorded by the Mindful Metrics app and the LEV scripts, it was possible to establish relationships between the levels of attention and the type of multimedia resource used by the student at a given time.

This result highlights the importance of interactivity in Virtual Educational Labs, since Table 11 demonstrates that the greater the perception of interactivity provided by the multimedia resource to students in the VEL, the higher their level of attention was achieved, observed observation based on the averages

[1] Official Neurosky web page: http://neurosky.com/2018/06/mindwave-mobile-2-available-now-improved-comfort/

[2] Official Mindful Metrics web page: blind-review.

of multimedia resources involving Simulations (average 65.7), 3D Objects (average 55.7), Videos (average 48.3), and Quizzes (average 44.7). Texts (average 36.0) and Web Pages (average 39.3) show lower focus than other multimedia resources because they do not offer so much interactivity to the student. For future research, the intention of the authors is to build an algorithm capable of identifying the elements that promote attention in multimedia resources in VEL, by crossing the data obtained by the EEG headset in conjunction with the logs captured by the scripts implemented in the VEL.

6. Conclusion

Teaching labs are essential for students to make concrete theoretical concepts received in the classroom. Because physical labs have some restrictions: limited usability, high cost, and danger to human life, Virtual Educational Labs offer an alternative to these limitations.

The Virtual Educational Labs, developed in immersive virtual worlds, allow to offer experiences that can be carried out by the student, so that he reflects on it and the results achieved, arriving at his own conclusions, which allows the student to look for new variations of these experiences and achieve the results that prove or refute their proposed assumptions.

This study presented a case study in which 49 students used a virtual educational lab in the field of physics and evaluated several aspects of the teaching-learning process and described the students' perceptions regarding the experiences proposed. The evaluation questionnaire of the virtual educational lab generally identified that the students received enough information to conduct the experiments, that the tasks were clear and there was feedback at the end of the experiments. Also, the virtual instruments and resources present in the experiments were easy to operate and when the experiment started, it ended in the way that was expected. Also, the evaluation of VEL as positive by the students, the level of appreciation and the degree of satisfaction demonstrate that the virtual lab and the experiments proposed to meet the expectations of the students of the Millennial generation.

It was observed that the virtual labs offered in immersive virtual environments increase the student's interest in the experience since these environments have technological characteristics similar to those used by young people in their day to day life. They also increase engagement, through the playfulness and the presence of challenges, common in the electronic games practiced by students. It also allows simulated practical experience, individual reflection and the exchange of results, conclusions and questions as colleagues, enabling teamwork, confrontation of ideas and the exchange of knowledge online. Therefore, it is concluded that the Virtual Educational Lab presents technological and educational resources that arouse the student’s interest and engagement in performing practical activities in the virtual lab.

As future perspectives, the recording of the student's movements and interactions with the objects of the experiment and with the immersive virtual world are stored in a database and can be analyzed using data analysis tools, allowing a better understanding of the preferences of the students. students and about which multimedia resources present greater efficiency in the teaching-learning process, as well as to investigate the relationship of these resources with the awakening of students’ attention.

8. References

Brasil. Base Nacional Comum Curricular (BNCC). Educação é a Base. Brasília, MEC/CONSED/UNDIME, 2017. Disponível em: <http://basenacionalcomum.mec.gov.br/images/BNCC_publicacao.pdf>. Acesso em: 02 jun. 2017.

Brasil, Parâmetros Curriculares Nacionais: Ensino Médio. Secretaria de Educação Fundamental. Brasília: MEC/SEF, 2000.

Estriegana, Rosa; Medina-Merodio, Jose Amelio; Barchino, Roberto. Student acceptance of virtual laboratory and practical work: An extension of the technology acceptance model. Computers and Education, Volume 135, July 2019, Pages 1-14. **DOI:** 10.1016/j.compedu.2019.02.010.

Gunawan, G., Nisrina, N., Y Suranti, N. M., Herayanti, L., & Rahmatiah, R. (2018). Virtual Laboratory to Improve Students' Conceptual Understanding in Physics Learning. Journal of Physics: Conference Series, 1108, 012049. doi:10.1088/1742- 6596/1108/1/012049.

Hickman, L., & Akdere, M. Exploring virtual reality for developing soft-skills in STEM education. Paper presented at the Proceedings - 2017 7th World Engineering Education Forum, WEEF 2017- in Conjunction with: 7th Regional Conference on Engineering Education and Research in Higher Education 2017, RCEE and RHEd 2017, 1st International STEAM Education Conference, STEAMEC 2017 and 4th Innovative Practices in Higher Education Expo 2017, I-PHEX 2017, 461-465. doi:10.1109/WEEF.2017.8467037.

Ibáñez, M. -., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. Computers and Education, 123, 109-123. doi:10.1016/j.compedu.2018.05.002.

Inep. Censo Escolar. Instituto Nacional de Estudos e Pesquisas Anisio Teixeira. Dsponível em http://inep.gov.br/censo-escolar. Acesso em março de 2019.

Jamie N. Mikeska, Steven Holtzman, Daniel F. McCaffrey, Shuangshuang Liu, Tamara Shattuck. Using classroom observations to evaluate science teaching: Implications of lesson sampling for measuring science teaching effectiveness across lesson types. 7 September 2018. DOI: 10.1002/sce.21482. SCIENCE EDUCATION POLICY. Science Education. 2019;103:123 – 144.

Jennifer DeBoer, Casey Haney, S. Zahra Atiq, Casey Smith & David Cox (2019) Hands-on engagement online: using a randomised control trial to estimate the impact of an at-home lab kit on student attitudes and achievement in a MOOC, European Journal of Engineering Education, 44:1-2, 234-252, DOI: 10.1080/03043797.2017.1378170.

J D González, J H Escobar, H Sa´nches, J De la Hoz, J R Beltra´n, S M Arciniegas and L S Mart´ıne. Advanced virtual laboratories of electromagnetism using a mobile game development ecosystem. International Conference on Mathematical Modelling in Physical Sciences. IOP Publishing, Conf. Series: Journal of Physics: Conf. Series 1141 (2018) 012011 doi:10.1088/1742-6596/1141/1/012011.

Kapici, H. O., Akcay, H., & de Jong, T. (2019). Using Hands-On and Virtual Laboratories Alone or Together—Which Works Better for Acquiring Knowledge and Skills? Journal of Science Education and Technology. 2019, doi:10.1007/s10956-018-9762-0.

Kolb, D. Experimental learning: Experience as the Source of Learning and Development.Second Edition. Pearson Education. New Jersey-US, 2015, p. 390.

Majid, N. A. A., & Majid, N. A. Augmented reality to promote guided discovery learning for STEM learning. International Journal on Advanced Science, Engineering and Information Technology, 8 (4-2), 1494-1500. Noureddine Elmqaddem. Augmented Reality and Virtual Reality in Education. Myth or Reality? International Journal of Emerging Technologies in Learning. 2018, Vol 14, No 03 (2019). p 234-241.

Markowitz, D. M., Laha Rob, Perone Brian P., Pea Roy D., Bailenson Jeremy N. Immersive Virtual Reality Field Trips Facilitate Learning About Climate Change . Frontiers in Psychology. V9 . p. p 2364 - (2018) . Available in https://www.frontiersin.org/article/10.3389/fpsyg.2018.02364.

Moreira, M., Pinhão, F. Representações discursivas sobre experimentação didática de mestrandos em ensino de ciências. Ensaio, Pesquisa em Educação em Ciências, 2018; 20: e2856.

Nadine Großmann & Matthias Wilde. Experimentation in biology lessons: guided discovery through incremental scaffolds. International Journal of Science Education, 2019, https://doi.org/10.1080/09500693.2019.1579392.

Shari J. Metcalf, Joseph M. Reilly, Amy M. Kamarainen, Jeffrey King, Tina A. Grotzer, Chris Dede, Supports for Deeper Learning of Inquiry-Based Ecosystem Science in Virtual Environments - Comparing Virtual and Physical Concept Mapping, Computers in Human Behavior, 2018, doi: 10.1016/j.chb.2018.03.018.

Simona. Sim-on-a-Stick 0.8. In: <http://simonastick.com/>. 2017.

Zichermann, Gabe e Cunningham, Christhoper. Gamification by Design. Sebastopol: O'Reilly Media, 2011.

Sypsas, A. and Kalles, D., Virtual Laboratories in Biology, Biotechnology and Chemistry education: A Literature Review. In Proceedings of PCI '18, November 29-December 1, 2018, Athens, Greece, 6 pages. https://doi.org/10.1145/3291533.3291560.

Tibola, Leandro R. e Tarouco, Liane, M.R. Rastreamento de Interações em Laboratórios Educacionais nos Mundos Virtuais 3D para Identificação de Engajamento. In: Revista Novas Tecnologias na Educação - RENOTE, v.13, n.2, 2015.

Tibola, Leandro Rosniak. Fatores ensejadores de engajamento em ambientes de mundos virtuais. Theses. Universidade Federal do Rio Grande do Sul. Centro de Estudos Interdisciplinares em Novas Tecnologias da Educação. Programa de Pós-Graduação em Informática na Educação. In: http://hdl.handle.net/10183/188247. 2018.

UFRGS. AVATAR Project. In: <http://www.ufrgs.br/avatar/>. 2019.

Yilmaz, Rabia M.; Baydas, Ozlem; Karaus, Turkan e Goktas, Yuksel. An examination of interactions in a three-dimensional virtual world. In: Computers & Education, Vol. 88, 2015, pp. 256–267.