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LONG PAPER

A framework to prepare the application of virtual worlds in distance education in developing countries

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Abstract
This paper presents a framework to help preparing the implementation of virtual worlds, emphasizing on the requirements that distance education students need to meet to have a successful learning experience. A virtual world was developed using the OpenSimulator platform, under the pedagogical perspective of the Experiential Learning model, in a role-play simulation approach. An exploratory study was carried out with 19 experts from three different domains, collecting specialized feedback around technical and pedagogical dimensions, considering the target audience peculiarities, especially focusing on developing countries. The results culminated with the proposal of eight guidelines to harness the potential of the technology of virtual worlds for distance education.

Keywords Framework · Distance education · Virtual worlds

1 Introduction

Virtual reality technology has been emerging in education, allowing the creation of immersive environments that simulate the real world. Learning activities that are too expensive, complex or even dangerous and impossible to perform in real life, are made possible through highly interactive and realistic simulations. Students, represented by their avatars, are free to move around and interact with objects by multiple perspectives, having a more active participation. In cases where poor judgment could lead to real harm, students can practice decision-making without real-life ethical implications.

According to Bredl et al. [4], this new paradigm of immersive education tends to be more engaging than text or video-based online communication, and the evidence points to a future in which it alters how, what, when and where we teach. In this sense, this potential can be more significant for the context of distance education, by allowing teachers and learners separated by distance to engage in the social activity of learning.

Virtual reality technology can be divided into two main strands: fully or partially immersive. It is considered fully immersive when it potentially excludes external stimuli, tracks and projects the user's physical movements in real time, providing the ability to perceive through natural sensorimotor contingencies [25]. This is usually achieved using Head-Mounted Displays (HMDs) devices or Cave Automatic Virtual Environments (CAVEs).

However, these sophisticated features are not yet readily available to educators, as they are expensive and difficult to handle [19] and can accommodate only one or a few people simultaneously [26]. Current HMDs are also primarily entertainment devices, not designed for classroom use, requiring a level of technical skills that challenge instructors. Although learners are generally very positive about such use, there are also still substantial barriers to the use, especially

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regarding cybersickness symptoms, lack of appropriate software and technical limitations of peripheral devices. Furthermore, realistic environments of fully immersive virtual reality are developed on complex engines such as Unity, which require technical staff and long development time, given the greater level of detail involved. Consequently, it also requires computers with a higher processing power for both development and use.

Virtual worlds, on the other hand, are a more accessible category of virtual reality, which do not require the use of specific devices, and can be accessed through personal computers [6]. Therefore, they are considered partially immersive environments. Despite not allowing the creation of high highly realistic environments, this format makes it technically feasible for a large cohort, presenting as good cost-effectiveness for educational purposes, by allowing researchers and students with just a conventional desktop easy access, either for development or use purposes. It provides options for multimodality communication (voice, chat, gestures) and access to a variety of content, which opens the possibility to combine it with traditional 2D didactic materials [14, 20].

Several virtual world platforms have been launched since the late 1990s, such as Active Worlds, Second Life, OpenSimulator (OpenSim) and Open Wonderland, being the last two free and open source, launched in the mid-2000s. However, in spite of the large community of developers exploring this medium for almost 20 years, virtual worlds are still a Pandora's box for educators: While offering a plethora of new teaching and learning possibilities, they also present a host of new challenges, mainly from technical and pedagogical points of view [27]. Besides that, even though virtual worlds do not require advanced computers configuration, like other graphic systems, they usually require an intermediate configuration and a good Internet connection bandwidth for optimal use. In this sense, another challenge is having students meet the minimum infrastructure requirements.

To fulfil the objective of democratizing and universalizing access to formal education, around the world, especially in developing countries like Brazil, it is common to observe a search for distance education from students of lower social classes and/or students who live distant from central municipalities, with digital inclusion limitations. People in remote areas can have access to courses to which they might not have had access otherwise [2]. Thus, the reality faced by them makes us question if, even nowadays, virtual worlds can be indiscriminately adopted toward this audience.

In addition, for the use of technological tools to have meaning in the formation of students, it needs to line up with solid pedagogical models that move away from passive teaching practices (teaching-as-transmission model). As virtual worlds allow recreations of our reality, they can accomplish different purposes and fit in distinct pedagogical theories, making this task especially difficult concerning more auto-didactic learning as it is in the scope of distance education. According to Lim [18], to the extent that the learner has some control over his time and place, instructional designers need to take extra care to ensure that the environment is not just defensible, but also provide opportunities for learners to invest meaning (and therefore time and effort) in it. Therefore, creating lessons in a virtual world requires skills that most educators lack, such as adapting to an intuitive free-form learning experience [16].

Seeking to contribute to clarifying these points, a virtual world was developed and submitted for the evaluation of a panel of experts, composed of professionals with educational experience, aiming to answer the following two research questions:

1. Technical dimension (TD)—Do experts believe that distance education students have the technical conditions to satisfactorily access virtual worlds?
2. Pedagogical dimension (PD)—Do experts believe the pedagogical modeling of the virtual world fits an application in distance education students?

The objective of this study is to prepare the application of virtual worlds in distance education, verifying the experts' vision regarding technical and pedagogical implications that must be considered to a successful application with the target audience. The recommendations were synthesized and organized in a framework, with guidelines to support educators and similar practitioners.

This remaining of the paper is organized as follows: In Sect. 2, we present the theoretical foundation of the study, pointing out the importance of the two dimensions analyzed, followed by Sect. 3 presenting related work. Details on the materials and methods of research are given in Sect. 4. In Sect. 5, the results are presented, followed by Sect. 6 with the discussion and the framework proposal. The paper ends with the conclusions and limitations in Sect. 7.

2 Theoretical foundation

Virtual worlds present great benefits for distance education, allowing to enhance interaction among students and between instructor and students, especially when compared to traditional methods used in this mode of instruction, bringing it closer to face-to-face education [14]. Bronack et al. [5] suggest that it supports deep learning and can help learners make meaning in ways similar to those offline, through features unavailable within traditional web-based learning environments. A practical example at distance education is seen in the West Virginia University (WVU), which has been making extensive use of virtual worlds in postgraduate programs [13].

Therefore, this is a field of research poised to take off [27]. Alenezi and Shahi [1], relatively recently, suggested that over 80% of universities in the UK were making use of such platforms. The National Aeronautics and Space Administration (NASA) sponsored one of the largest projects with OpenSim virtual world between 2014 and 2017, Virtual Missions and Exoplanets (vMAX), with the objective of engaging middle school students and educators in the search for worlds beyond Earth [10].

Notwithstanding these advantages and its long time of existence, the effective adoption of virtual worlds in formal education has not occurred widely, as predicted by specialists [12]. In 2007, Gartner's report even suggested that by the year 2011, 80% of Internet users would have a "Second Life" [3]. Few pieces of research with the aim of understanding the causes of this phenomena have been carried out. According to Holmberg and Huvila [14], the ultimate value of virtual worlds in education has not yet been fully discovered. Generally, studies focus on investigating the students' perceptions, creating a gap of experts' opinion, who could give their impressions considering their professional background.

In order to investigate the adoption of new technologies, it is always necessary to take into consideration the context where it is applied (in the technological and pedagogical levels), including the characteristics and peculiarities intrinsic to the target audience (in this case, distance education students). Thus, that is why this research analyzes two dimensions, technical and pedagogical, described as follows:

2.1 Technical dimension

The requirements to run a virtual world are not of advanced computers, but neither basic. Usually, the client-side software (the viewer), which renders the 3D graphical part, requires an intermediate configuration, such as a dual-core CPU with SSE2 support, graphics chip, 2 GB RAM and bandwidth of a minimum of 2 Mbps. Besides system requirements, users must have a level of familiarity with informatics to be able to access a virtual world from their home, having to install the viewer and configure it for use. Chow [7] adds that users must have some digital proficiency, like navigation, avatar manipulation and 3D visual grammar.

These technical issues can act differently on users, hindering the assumption of a consistent experience for everyone. Christopoulos et al. [8], for instance, discovered that the difficulty to understand the tool was the main source of frustration and disappointment from students. Jacka [15] identified that the factor of time was considered as a barrier by both teachers and students, due to their perceptions about the learning curve on how to use the virtual world, affirming that this time was not well spent.

According to Porto Bellini [24], digital effectiveness is a state of desirable digital Access, Behavior and Cognition (ABCs). Access limitations refer to one's social, material and contextual barriers to properly access and use the technology, manifested through levels of social exclusion, lack of Internet access or desirable bandwidth, obsolete hardware, etc. Behavior limitations refer to barriers in one's beliefs, attitudes and intentions that eventually result in negative behaviors, like technophobia or techno-addiction. Cognition limitations refer to barriers in one's neurological structure, educational background, information processing capabilities and hands-on experience, manifested through lack of digital literacy or interest, etc.

In this sense, although in the last years the fast technological evolution resulted in affordable powerful personal computers, with graphical resources able to efficiently provide users with quality 3D interfaces, the ABCs of digital effectiveness may be present in the target audience of distance education students. According to Alenezi and Shahi [1], the operation of virtual worlds can become difficult in developing countries, where there is a lack of infrastructure and high-speed broadband services are not readily available. In other words, this audience may not have the expected profile to satisfactorily receive the instruction using this innovative technology, and the institutions must deal with that accordingly.

Given the above mentioned, this research investigates if the perceptions and expectations of education experts are compatible with the knowledge available in the scientific field about the technical implications that involve the use of virtual worlds in distance education. To achieve this goal, we question them about the potential capability of the target audience to properly enjoy this tool and the aspects to be considered, confronting it with the ABCs of digital effectiveness.

2.2 Pedagogical dimension

Virtual worlds cannot be applied in education apart from pedagogical models, and the particular selection of learning theories can prefigure the type of learning outcomes [9]. Therefore, the didactic planning made by the teacher, based on a well-defined educational approach, is necessary to guide the activities and help students to perform them more clearly, adequately and consistently with this type of environment. However, it seems that so far, most educators have just transferred classical methods that are proven efficient in face-to-face education into the virtual worlds [14]. In this sense, as suggested by Dogan et al. [10], the lack of guidance on how to organize instructional design elements and pedagogical arrangements in virtual worlds is a major limitation for educators.

In accordance with Englund [11], teaching in virtual worlds requires the adoption of student-centered approaches and the use of problem-based activities, as its immersive and social nature facilitates the creation of autonomous and communicative activities. Corroborating with this perspective, Nunes et al. [22] conducted a systematic review of virtual worlds in education, resulting in the analysis of 58 articles in total, identifying within the most used educational theories as follows: Collaborative Learning (6), Experiential Learning (4) and Constructionism (4).

With the wide diversity of educational theories and possibilities for the application of virtual worlds in distance education, it becomes important to inquire experts under this point of view, after testing a specific environment. Thus, this research also aims to ascertain if the virtual world fits the pedagogical model projected for it and how it can be improved to meet its didactic purpose of promoting learning, especially considering the target audience for which it is intended.

3 Related work

To the best of our knowledge, the literature lacks an up-to-date framework for the design and implementation of virtual worlds in distance education, considering both technical and pedagogical dimensions. Other frameworks for virtual worlds have been proposed, which are synthesized in this section.

Bronack et al. [5] present a social constructivist framework for distance education using Active Worlds platform, called AET Zone. The scenarios include a library, an alumni center, a student services building, and a teleport for transiting to and from course areas. Available services include full-text articles from the university databases, book checkouts, and synchronous chats with university research librarians. It offers text and audio-based conversational tools, interactive elements, and metaphors not found in traditional web-based environments. Their contribution is limited to presenting the AET Zone and the implications of using a social constructivist framework for designing and delivering an online learning environment.

Lim [18] proposes "The Six Learnings framework" for the planning and design of curricular interventions in-world, "derived after careful consideration and relatively extensive and sustained in-world experience over sixteen months" (p. 06). It consists of six lenses, namely Learning by exploring; Learning by collaborating; Learning by being; Learning by building; Learning by championing; and Learning by expressing. Each lens is explained in detail in the paper, and the author recommends that each intervention be planned to target just one or two of the six learnings, selected based on how well they align with the mission and values of the school and the learning objectives, as decided upon by the curriculum designer/teacher.

The study of Minocha and Reeves [20] elicited educators', designers' and students' perceptions regarding the usability of learning spaces within the Second Life platform, culminating with a list of recommendations. The overall questions were related to factors affecting design, levels of realism, and learning activities, and the students' questions emphasized aspects that either supported or hindered their learning experiences. The themes and sub-themes that emerged in the results become guidelines, as, for example, "Design for storytelling," "Use real-world metaphors" and "Consider realism for familiarity and comfort." The authors conclude that the design of learning spaces may influence student learning and engagement, but there are several other contextual factors that may impact on student experiences, such as student's skills and the nature of course delivery (distance education, face-to-face, or blended).

De Freitas et al. [9] developed an evaluation methodology for immersive learning experiences in a Second Life virtual world, conducting a study with undergraduate students. The dimensions evaluated include the learner dimension, the pedagogic dimension, the representational dimension, and the contextual dimension. The study diagnosed that connectivity issues impeded full usability of the system, and users need to familiarize themselves with the software in advance of holding sessions to get used to the interface. The authors conclude that while the advantages were somehow outweighed by the technical issues that arose, the benefits for supporting and engaging learners were highlighted.

Williams [27] proposes a research framework for understanding the mapping principle across a range of theories and approaches of virtual worlds. This principle refers to the extent to which human behaviors occur in virtual spaces in the same way they occur in real spaces. His contribution consists of a five steps checklist for a research program. Step 1 is to begin with a theoretical orientation, regardless of the discipline. Step 2 is to simply enter the virtual space. Step 3 is to choose the level of analysis (individuals, small groups, whole cultures, etc.). Step 4 is for researchers interested in causal models (how the real impacts the virtual, or vice versa). Step 5 is where the theory is applied to the virtual world in question, the operationalization step, therefore the more complex one.

The article of Bredl et al. [4] suggests two sets of criteria to evaluate avatar-based virtual learning and teaching settings, through a theoretical approach for immersive knowledge-based virtual environments. They built up a prototype of an online training site within Second Life, simulating a cargo plane crash, where the individual player had to manage multiple spreading fires and perform triage. The set of criteria for immersive learning environments includes nine categories: 1. “Getting Started” and Support; 2. Content Design; 3. Didactic Design; 4. 3D Design; 5. Design of Tasks and Questions; 6. Immersive Dimension; 7. Motivation & Emotion; 8. Communication & Cooperation; 9. Results. The authors do not explain in detail each of the categories.

The difference of this study lies in proposing guidelines to prepare the application of virtual worlds in the context of distance education, especially in developing countries. Differently from Bronack et al. [5] and Lim [18], we are not restricted to the pedagogical dimension, adding the technical one, proposing a more generic framework, adaptable to several disciplines. As suggested by the work of Minocha and Reeves [20], we consider other contextual factors that may impact on the learning experience, such as student’s skills and the nature of course delivery (distance education).

Our study also differs from De Freitas et al. [9], as their methodology was designed for constructing learning activities in-world as well as for evaluating the efficacy of experiences. Williams [27], on the other hand, proposes a research agenda of virtual worlds, and we believe to contribute to Step 5 of his framework, which refers to the operationalization step. Finally, our study differs from Bredl et al. [4] as the authors do not make an in-depth analysis of each proposed category, focusing more on a theoretical perspective. In addition, all the mentioned studies, with the exception of Bronack et al. [5], did not focus on distance education specificities.

4 Materials and methods

This is an exploratory research with a non-probabilistic convenience sample composed of experts from three different domains and educational experience. Our institution’s ethics committee reviewed and approved the research materials prior to carrying out the study. In the following subsections, more details are given about the virtual world, subjects, instruments, and procedure.

4.1 The virtual world

The virtual world is part of the AVATAR Project of the Federal University of Rio Grande do Sul, located in Brazil. It was implemented using the OpenSim platform in grid mode (which allows external client–server access), with regions distributed in three identical configuration servers (Intel Core 2 Duo 2.66 GHz processor, 8 GB of RAM, 148 GB hard drive with Windows 7 Professional 64-bit). It supports a load of approximately 20 users simultaneously without losing any quality of rendering. The Singularity Viewer, also free, is the software that must be installed on the client side to render the graphical part, selected due to the compatibility with the Portuguese language.

The environment was designed following the pedagogic model of Experiential Learning [17], under the Active Learning umbrella. This choice was made in accordance with the study of Englund [11], which states that the design of virtual world activities should focus not on “learning about,” but on “learning by being.” This approach is also one of the six lenses of the framework proposed by Lim [18], which means that learning results from explorations of the self, involving the assumption of identities and dispositions through enculturation. Role-play is a common learning design in virtual worlds, as it is relatively easy to customize avatars and scenarios.

In this sense, the virtual world seeks to offer distance education students the opportunity to apply what they learn while experiencing a simulated real-world context. Based on a role-playing approach, a curricular activity was designed, aiming at two educational objectives: (a) to provide a differentiated fixing exercise, in which they will practice the knowledge acquired in the discipline; and (b) to provide the opportunity to engage and reflect on the sociocultural practices of the accountant profession, experiencing the real-world task of being admitted in a company.

Focusing on the discipline of Financial Mathematics, which is in the scope of various technical and superior courses, and covering the curricular topics of percentage, simple and compound interest, a building was constructed that simulates an accounting firm called C-Company, populated by automated avatars (Non-Playable Characters—NPCs). The 3D objects that compose the scenario were partly manually created directly in the environment and partly by importing files from free online repositories such as Zadaroo and Outworldz. The Linden Script Language was used for script programming.

As the student avatar walks by the building, the NPCs express themselves bodily, simulating tapping at the keyboard of their workstations, and verbally, by textually participating in the narrative, triggered by sensors of the avatar’s presence. The narrative revolves around the routine of the fictitious company; the student receives the role of a trainee on the first day of work, having to pass through the five offices that comprise it to be admitted: Human Resources Directory, Marketing Directory, Commercial Directory, Administrative Board and Presidency.

This way, 15 objective questions are proposed along the path (a quiz with three questions in each office). At each room, the student is received by the “chief” of the department, who briefly explains what their sector is responsible for and invites to seat in a chair to start the quiz, which was developed using the device Heads Up Display (HUD). By starting the quiz, the camera of the viewer is adjusted so the student has a frontal vision of the table that is, facing the chief, in a more photo-realistic view (Fig. 1 left).

The quizzes are presented at an increasing level of difficulty. Each question has five answer alternatives. If the answer is correct, the score is increased, and a message informs the partial result (one point for each hit). When responding incorrectly, the student is advised to touch the Help button, which rotates the avatar's chair to a screen with a short didactic video about the subject, or the Calculator button (Fig. 1 left). The student can see the video in the full-screen mode without leaving the virtual world, having to touch the "Back to Questionnaire" button to resume the quiz. The calculator disappears when an answer option is selected and can be reopened in the next question.

At the end of each quiz, the individual score is given, and the student receives instructions in the form of dialogue as if the NPCs were talking to him/her, guiding to the next room. This occurs regardless of the score obtained, maintaining the freedom of the user in an open environment, but consistently with the narrative of concatenated events. After going through the five offices, the student receives the news that he/she has been accepted into the C-Company and can start the internship. Then, he/she is instructed to sit in his/her workstation, placed in a larger room, like a corporate workspace (Fig. 1 right), containing several NPCs actively "working." By sitting there, the student is congratulated by the achievement and receives the total score in the activity.

The idea is that the environment can be individually accessed by the students from their own home, in a comfortable and convenient way, at any time of the day; and it can be revisited countless times, depending on their interest. However, a single access of approximately 40 min is estimated for a new user to get used to the controls and do the activity, going through all the rooms, reading the narrative, and answering the quizzes.

4.2 Subjects

The sample was composed of 12 (67%) female and 9 (33%) male participants, aged 19–46 years ($M = 29.4$, $SD = 8.9$), that were invited and filled a consent form. They were divided into three groups of expertise, according to the importance of their professional or academic background/profile for the research, described as follows.

Group 1 Eight undergraduate students in Nature Sciences from the Institutional Program for Teaching Initiation (PIBID, from the Brazilian Programa Institucional de Bolsas de Iniciação à Docência) (42%). These experts are pre-service teachers of basic education who, in addition to their educational background, currently work in an internship in public schools of a developing country, being, therefore, familiarized with the limited resource conditions of public schools and its students.

Group 2 Nine PhD. students of Informatics in Education (47%). These experts are researching an interdisciplinary area that directly relates to the tool and the proposed approach, being familiarized with new technology-enhanced pedagogical models.

Group 3 Two teachers of the Accounting Sciences area (11%)—graduation level. Professionals, who teach in the subject area of the environment.

To identify the sample's level of knowledge on virtual worlds, participants were asked about this aspect, with answers options on a 5-point Likert scale, ranging from "I am totally unaware" (1) to "I fully know" (5). To make them able to answer this question, they were previously explained the inherent characteristics of virtual worlds, such as open environments in which the user is projected through an avatar and can interact directly with the available objects (e.g., Second Life, The Sims, etc.).

Approximately, one-third of the participants ($n = 6$) considered that they did not have much knowledge about virtual

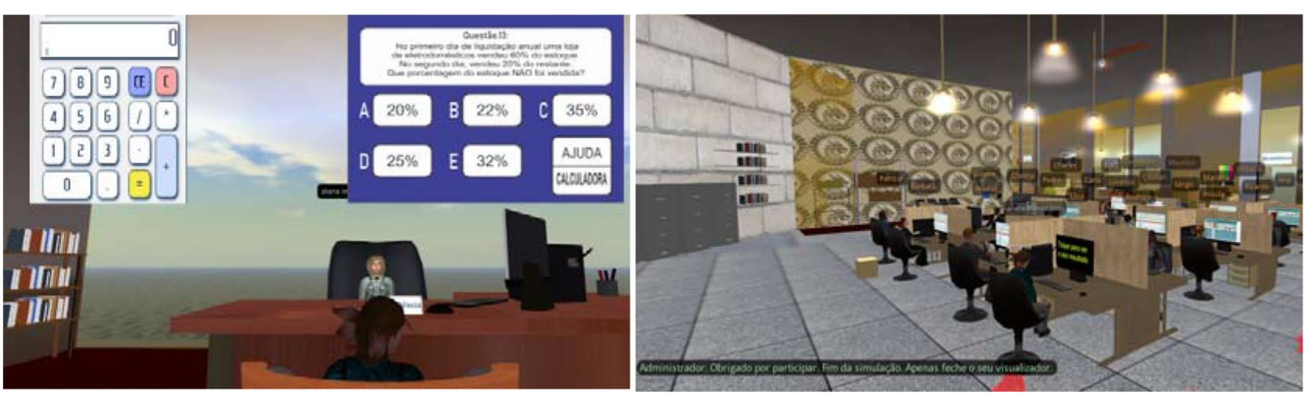

Fig. 1 Screenshots of the quiz and the calculator (left) and the corporate workspace (right)

worlds (31%), as they marked options 1 or 2, which agrees with the novelty factor of the employed technology. However, 27% ($n = 5$) reported knowing these environments well, and 42% ($n = 8$) positioned themselves at the middle point of the scale, showing an intermediate level of knowledge. Thus, it can be argued that the majority of the participants (69%) have at least a basic level of knowledge on virtual worlds. The data from the group who does not have this knowledge were not disregarded because the final user of the environment will probably be in the same position, giving more naturalness to the experience and the feedback.

Considering that participants are teachers under formation (Group 1 and Group 2, 89%) or in exercise (Group 3), although they are not experts in the area of the virtual worlds, we assume that there is an overall intention to future use this tool in the formal education, in line with the current trends of virtual reality technology and its growth for teaching purposes.

4.3 Instruments

An online form containing 12 questions, including open and closed ones, was applied individually immediately after the environment use. Closed questions had answer options on a 5-point Likert scale, with negative (1) and positive (5) extremes, and at each one, a blank space was added to receive comments, encouraging participants to provide explanations and reasons for the responses given. The content of the questions was elaborated by the researchers, who have experience in distance education of over 6 years, and is presented along with the results.

4.4 Procedure

Participants were previously informed on the purposes of the study, the functionalities of the environment, and received an individual login for testing purposes. It was emphasized that the content itself (Financial Mathematics) was not being evaluated and that the objective was to prepare the tool (virtual world) for the context of distance education. That is, they should focus on observing the environment operation, functionalities, and pedagogic design, thinking on the practical use by the target audience.

Initially, the eight undergraduate students in Nature Sciences from PIBID (Group 1) accessed the virtual world. They used computers from the laboratory of the public institution in which they were enrolled, in a schedule defined with a teacher of the course. The Singularity Viewer software was previously installed in the laboratory. In the following days, the other participants were individually invited to use one of the research group's workstations. Participation was supervised and observed by the researchers. The duration of each experience varied between 20 and 50 min. The questionnaire was answered in the same computer immediately after the experience. The participants were instructed to assign option (3) neutral in cases of doubt or of not knowing how to answer.

Table 1 Comparison of mean scores by research groups

Research group	*n*	Technical question		Pedagogical question	
		M	SD	M	SD
Group 1	8	3.53	0.73	4.26	0.46
Group 2	9	2.47	0.67	3.29	0.26
Group 3	2	3.00	0.70	3.78	0.35
p value	0.463		0.067		

Table 2 Comparison of mean scores by groups of knowledge on virtual worlds

Level of knowledge on virtual worlds	*n*	Technical question		Pedagogical question	
		M	SD	M	SD
Good knowledge	5	3.60	0.78	4.20	0.53
Medium knowledge	8	2.34	0.68	3.17	0.38
Low knowledge	6	3.60	0.83	4.17	0.29
p value	0.098		0.035		

5 Results

Although the sample sizes are very small, to perform a deeper analysis of the data we ran some statistical tests with a significance level of 95%. However, they are used just to provide some indications and should be interpreted cautiously.

Firstly, to verify if the analysis should be carried out by groups, a nonparametric Kruskal–Wallis test was performed, considering the Likert scale items from TD and PD (7 items). Table 1 shows the results, with the total mean and standard deviation values, pointing out that although Group 1 mean scores were higher in both TD and PD, the null hypothesis of equality was not rejected, supporting the decision of performing a homogeneous analysis of results.

In the same perspective, the difference in the scores was tested according to the subject's level of knowledge on virtual worlds. For this purpose, participants were grouped in categories according to the Likert scale option assigned in this question: 4 or 5—good knowledge, 3—medium knowledge, 1 or 2—low knowledge. Table 2 shows that although the mean scores were very proximal, the null hypothesis was rejected regarding the PD, with the higher values coming from the Good Knowledge group. However, due to the small sample size and the higher standard deviation in the mean score for this group, it can be assumed that this difference is not enough to support analysis by groups of knowledge on virtual worlds.

In the following subsections, the results are presented by dimension analyzed.

5.1 Technical dimension

The first part of the questionnaire was designed to investigate the technical dimension. Table 3 presents a summary with the percentage of responses received in each of the 5-point Likert scale items (Q1 to Q5), except for Q3 that is an open question.

Question 1 asked about the level of computer skills that a distance education student should have to properly enjoy the virtual world. Almost half of the participants (48%) assigned options 1 or 2, meaning some (few) specific skills. Another 42% assigned the neutral option (3), indicating that the virtual world does not require few nor many skills. Considering that only 10% assigned the other end of the scale (4 or 5), it can be inferred that the general perception is that the use of virtual worlds by distance education students does not require a lot of (or advanced) computer skills.

Similarly, in Question 2, participants were asked how much Information and Communication Technology (ICT) infrastructure the virtual world requires from the student's computer. According to the answers, it requires a basic-to-medium infrastructure (neither too much nor few), since 47% chose the neutral option (3), and 21% option 2. However, 32% assigned options 4 or 5, indicating that approximately one-third of participants believe that the virtual world requires a good amount of ICT infrastructure, a result that is corroborated by the fact that none opted for the other extreme score (1), referring to little infrastructure.

Alongside these questions, there was an open space for participants to answer if they could think of any other requirement that the distance education student must fulfill in order to properly enjoy the virtual world (Question 3). The most mentioned requirements are listed as follows:

- Time and patience to develop the work in the virtual world;
- Supervision, otherwise, the students will make it a "just for fun" activity;
- Experience in navigating virtual worlds or 3D games;
- Clear instructions on the configuration of the viewer.

Question 4 sought to identify how difficult it would be for a distance education student to learn how to use the virtual world. The perception identified was that this learning curve would be relatively easy, since 43% of participants chose options 1 or 2, and 37% positioned themselves in the middle point of the scale (option 3). Only 10% considered it to be somehow difficult (option 4), and none indicated that it would be very difficult (option 5). Thus, participants consider that it would be relatively easy for distance education students to learn how to operate the virtual world.

Linked to the previous question, Question 5 was designed to investigate the perceptions on how much guidance, instruction and/or tutorials are required for a student to use the virtual world at their home, from their own personal computer. Most participants (63%) indicated that much guidance is required, by assigning options 4 or 5. The neutral option (3) was indicated by 26%, and another 11% stated that such guidance is not that necessary, choosing option 2. However, no one indicated option 1, highlighting the need of a good amount of instructions to instrumentalize the distance education student so that he/she can use a virtual world from his/her own computer.

To complement the analysis, two items with "Yes," "Yes, but with reservations" and "No" answer options were inserted. The responses are summarized in Table 4.

Question 6 sought to investigate whether participants consider that after all their reflections, it is feasible for distance education students to use the virtual world from their own home, in which the majority (63%) indicated the option "Yes, but with reservations," while the remaining 37% indicated the option "Yes," and no participant denied this viability. Hereupon, their perception regarding this possibility is seen as feasible.

Table 3 Summary of responses to the technical dimension (Q1 to Q5)

Item	Description	Likert scale				
		1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Q1	What level of computer skills does the virtual world require from a distance education student?	11	37	42	5	5
Q2	How much ICT infrastructure (computer, Internet) does the virtual world require from a distance education student?	0	21	47	16	16
Q3	Any other requirements a distance education student must fulfill to properly enjoy the virtual world?	Open question				
Q4	How difficult is it for a distance education student to learn how to use the virtual world?	32	21	37	10	0
Q5	How much guidance/instruction/tutorials are needed for a distance education student to use the virtual world from home?	0	11	26	26	37

Table 4 Summary of responses to the technical dimension (Q6 and Q7)

Item	Description	Answer options		
		Yes (%)	Yes, but with reservations (%)	No (%)
Q6	Is it feasible for a distance education student to use the virtual world from their own home?	37	63	0
Q7	Is it feasible for a distance education student to use the virtual world from the distance education center?	74	21	5

In a variety of distance education courses, especially in developing countries like Brazil, students have access to a physical location with a laboratory to take face-to-face tests or to perform activities, where a tutor (a professional in the course area with pedagogical experience) is available to help. This is what we call a distance education center. In this sense, participants were asked if they consider feasible for a distance education student to use the virtual world from the distance education centers (Question 7). The majority said yes (74%), and another 21% chose "Yes, but with reservations," whereas only one assigned the option "No." Thus, there was a significant increase in positive responses compared to the previous item (11% more in the "Yes" option). Therefore, it can be inferred that participants consider it more feasible for a student to use virtual worlds from distance education centers than from home.

In addition to these questions, a blank space was provided for comments, so that participants could justify their answers and indicate the reservations to be considered. The recommendations were synthesized as follows:

- Students who are not familiarized to computers may have more difficulty using the platform;
- Computers must have "high-performance capabilities for gaming" or a "minimum of hardware," and the Internet connection must be "good," with adequate speed;
- The fact that many participants were simultaneously in the virtual world made the progress of activities difficult (in the case of Group 1);
- Videos with tutorials and instructions for the correction of possible technical problems must be available;
- The best approach is to enable students to have the first access with the tutor assistance in the distance education center, enabling them to follow up in-home use.

5.2 Pedagogical dimension

The second part of the instrument focused on the pedagogical dimension. Table 5 shows the answers for Questions 8–10, which had response options on a 5-point Likert scale.

In Question 8, participants were asked whether a distance education student would be motivated to use a virtual world as the one tested. The majority (79%) assigned options 4 or 5, agreeing with this hypothesis. Another 11% were neutral (option 3), and only 10% disagreed partially, choosing option 2. No one totally disagreed with the statement (option 1). Thus, it can be inferred that they believe that the virtual world has the potential to motivate distance education students.

Question 9 sought to identify whether experts consider that there is a correspondence between the virtual world and what is explained in distance education classes. Most participants indicated yes (58%), assigning options 4 or 5. However, 42% manifested themselves in the neutral point of the scale (option 3), demonstrating that they are not certain that this correspondence exists, or perhaps indicating it is weak or insufficient. Again, no participant fully disagreed with the assertion (options 1 or 2).

The last Likert scale item (Question 10) asked if participants understood that the virtual world is pedagogically adequate to be used by distance education students. Among the answers, 47% indicated partial or total agreement (options 4 or 5), and 32% were neutral (option 3). The further 21% positioned themselves negatively, by assigning options 1 or 2.

Table 5 Summary of responses to the pedagogical dimension (Q8–Q10)

Item	Description	Likert scale				
		1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Q8	Would a distance education student be motivated to use such a virtual world in the course?	0	10	11	32	47
Q9	In general terms, is there a correspondence between the virtual world and what is explained in distance education classes?	0	0	42	32	26
Q10	Does the virtual world is pedagogically adequate to be used by distance education students?	5	16	32	26	21

However, as only 21% of the respondents did not agree with the assertion, it is possible to infer that the virtual world was considered reasonably pedagogically suitable for the use by distance education students.

In a complementary way, participants were asked to indicate which pedagogical model they consider most adequate to support the application of virtual worlds in distance education (Question 11). It was not previously informed under which model the environment tested was idealized by the researchers (Active/Experiential Learning), leaving them free to conclude from their own perceptions. The question had five response options with renowned educational theories, but each participant could mark more than one. Experiential Learning was not one of the options.

As a result, "Problem-based Learning (PBL)" was chosen 42% of the time, followed by "Active Learning" with 38%. "Socio-constructivism" and "Meaningful Learning" received 23% of the choices each. The option "I do not know" was chosen fewer times (14%). The answers were well distributed among the available items of choice, perhaps due to resemblance and convergence of the listed pedagogical models. Since Experiential Learning resembles PBL, and both can be considered ramifications of the Active Learning model, it can be concluded that the experts agreed with the overall pedagogical design projected for the virtual world.

In Question 12, a blank space was opened to receive suggestions for the satisfactory didactic application of the virtual world with the target audience. The main recommendations are summarized as follows:

- Need for guidance, through the creation of video tutorials and handouts, with a previous explanation about virtual worlds;
- A moment of experience together with tutors and colleagues, for the student to understand the basics before properly starting to use the virtual world;
- The virtual world should be "lighter" and accessible in simple "PCs," with a "basic" Internet connection;
- Previous classes on the subject must be taught, allowing a connection of the virtual world activity with the content being studied;
- More interactive questions (not only question–answer sessions) should be elaborated, for example the solution of a more complex problem.

The next section presents the discussion on the practical implications of the study, with the proposal of a framework and guidelines extracted from the lessons learned.

6 Discussion

In this section, the results are contextualized and confronted with the knowledge available in the literature and the perspective of the researchers, who have been investigating virtual worlds in education for the past 7 years, culminating with the proposal of a framework for the design and implementation of virtual worlds in distance education.

The results of the study allow observing that the subjects agree with the importance of the ABCs of digital effectiveness [24]. First, for the efficient use of virtual worlds, the access of ICT resources should not only be granted but be of good quality as well. This aspect was highlighted as the strongest limitation for the lower social classes of students that usually attend distance education courses in developing countries (with limited ICTs). This finding corroborates with Jacka [15] study, which although applied in a developed country (Australia), noted that many students did not have computers with enough graphics capability to run the virtual world at a rate that would provide a satisfactory experience, leaving teachers and students less motivated about such use, as their experience of access became a problem. The study of De Freitas et al. [9], also conducted in a developed country (UK), reported that technical issues of broadband connectivity had a negative impact on learning.

Corroborating with this perspective, in the work of Holmberg and Huvila [14], carried out in Finland, some students had to even be excluded from the sample because they had technical difficulties that hindered the participation, most related to computer graphics cards that did not meet the technical requirements. However, the respondents did not feel that using the virtual world was too difficult. When compared to web-based platforms, it was considered to be neither easier nor more difficult, and when compared with face-to-face education, it was seen as somewhat more difficult, although more fun.

In accordance with the above mentioned, it was identified that the viability of virtual worlds' access from distance education centers is seen in a more positive way than from student home, emphasizing the help of the tutors and the availability of a consistent infrastructure. This finding goes in consonance with the study of Perera et al. [23], which showed that the right sort of support can substantially improve the competencies of the OpenSim user, thereby making such technology more amenable to adoption in mainstream educational practice. Although not encouraging, this result provides indications that the implementation of virtual worlds should go through a gradual transition, before its full implantation.

The Behavioral and Cognitive limitations, as they converge in some points, were identified regarding the lack of digital literacy and computer experience of students. The experts concluded that all students should benefit from the virtual worlds, but the ones who are "not familiarized to computers" may present more difficulties. This result contrasts the ideal profile for this mode of instruction, provided mainly online, through the use of ICTs, revealing a little contradiction and, at the same time, a reality faced by distance education, especially in developing countries. That is, the student, who should (ideally) naturally be accustomed to the use of computers, does not always have the time, the money or even the sufficient interest to get familiar with ICT resources. So, they end up being restricted to reading the materials and performing the activities when required. The experts even suggested that the virtual world should be "lighter," referring to the software used, something that is out of our control, as the requirements are basically the same for all graphic viewers. Nevertheless, in the study by Holmberg and Huvila [14], it was hypothesized that the use of virtual worlds would be more challenging for students without experience in digital games, and that assumption was incorrect.

The learning curve to use virtual worlds was understood by the experts as a feasible task, although much guidance is necessary, with a good amount of clear instructions. This recommendation is very important, because if students are struggling, they may actually believe that the system is too difficult to use and that the benefits of using it are outweighed by the effort required [7]. In the work of De Freitas et al. [9], similar issues were highlighted, with users arguing that they needed to have a good understanding of technology to gain the most of it. Chow [7], by its turn, demonstrated that students should be provided with long introductory sessions before the activity, and both online and offline support services should be enhanced to boost the self-confidence in using the system.

This process of acclimatization is generally referred to as orientation and is essential to avoid disruptive behaviors and/or appearance of issues at the moment of the learning activity. According to De Freitas et al. [9], p. 07), "orientation is important for new users of virtual worlds to induct them into using the platform, and for maximizing their engagement with virtual worlds as a whole." Nash et al. [21], alternatively, suggest that repeated exposure or a map of the environment allows the navigator to iteratively refine the knowledge about it.

Furthermore, corroborating with the research of Jacka [15], time and patience were pointed out by experts as important factors for the use of virtual worlds in distance education. Besides the time necessary for the user to get familiarized with the new platform, which will probably be used in parallel to the traditional web-based learning environment, this concern is associated with the fact that this audience is mostly composed of adults, who work part or full time and have home responsibilities. Christopoulos et al. [8], although not referring specifically to distance education, agree that the time limit seems to be a common obstacle to the involvement of the students in virtual worlds, as acclimatization processes are time-consuming.

The study of Jacka [15] also diagnosed that the use of virtual worlds was not perceived as time well spent, which alerts to the necessity of grounding the experience in solid instructional design, so students do not consider this investment of time more connected to leisure than to actual learning. Therefore, we also identified that the virtual world has to be meaningful and relevant to the student, presented as an extra or curricular activity in the context of a discipline, and as a complement of previous classes (not new content). The offering of curricular credit can be a differential in motivating student participation. The willingness of the individual to interact with the environment and the willingness to accept the environment are both important determinants of the user's motivation to participate [21].

On the other hand, Englund [11] highlights that while it initially takes time to gain the skills and knowledge to navigate and teach in virtual worlds, the benefits offered, especially to distance education students, overcome the obstacles. This potential was corroborated by the experts, who reported that it can increase motivation, providing a new way of interacting with the course material. They emphasized that the platform will be well accepted by most distance education students and that the role-play simulation is a very positive approach, especially in an educational modality that, in general, lacks educational practices, sticking to the theory and passive learning methods.

The recommendations collected in the study allowed us to propose a framework composed of guidelines to cooperate with the successful design and implementation of educational virtual worlds in distance education. Eight principles were ordered by the frequency they were mentioned, which suggests an importance order (Table 6). In this context, the importance of interdisciplinary collaboration must be highlighted, gathering close instructional designers, software engineers, and technical staff to help teachers and researchers in developing dynamic and innovative educational approaches.

7 Conclusions

The unique features of virtual worlds, such as immersion and high interactivity, have great potential for distance education, allowing the creation of different and practical learning experiences. However, the adoption of this tool by both this and other teaching modalities of formal education has not intensely occurred, and the causes of this phenomenon are still not very clear [12].

Table 6 Framework for the design and implementation of virtual worlds in Distance Education

Guideline	Principle	Description
1	ICT resources	Distance education students must have sufficient hardware, software, and infrastructure to participate in virtual world activities, which can be analyzed with a checklist of requirements
2	Time	Due to professional and familial responsibilities inherent to this audience, distance education students must have sufficient time to perform the activity in the virtual world, that is, it has to be offered with an extended deadline to allow them to prepare for it
3	Guidance	Distance education students must receive clear instructions on the configuration of the viewer and the solution of eventual technical problems, through video and text tutorials that also present frequently asked questions
4	Familiarization	Previously to the actual learning activity, distance education students must have a moment inside the virtual world, to recognize the controls, change the avatar, and get more comfortable with this new kind of interaction
5	Assistance	The activity in the virtual world should be conducted preferably in the distance education center, with the assistance of tutors prepared to help the students. However, remote support channels must be available (forum or e-mail) for students to solve doubts and report problems
6	Relevance	The virtual world must be presented as an activity in the context of a discipline, ideally worth curricular credit. The importance of participation must be brought explicitly to students' attention, highlighting the links with the course content
7	Background	Previous classes on topics dealt with in the virtual world must be offered, as this tool is adequate for complementing and practicing. That is, the subject addressed must not be new, in order to not overload the cognitive processing of students, as they will be also learning how to use the new tool
8	Interactivity	The level of interactivity provided by the virtual world must compensate for the time effort invested by the distance education student. That is, the interactivity potential must be well explored, but at the same time with a simple and clear interface to not overload ICT and cognitive processing demands

It is understandable that the adoption of new technologies always faces some resistance from all parts; however, we cannot avoid the introduction of ICTs in education, especially an emerging technology as the virtual reality. However, unlike video, books, or web-based environments, in which people are accustomed to using and navigating, virtual worlds reveal many gaps, and practitioners should be prepared for the reaction [27].

Aiming to contribute to the introduction of virtual worlds in formal distance education, an exploratory study was carried out with the participation of a panel of 19 experts, from three different areas and educational experience. Technical and pedagogical dimensions were analyzed to improve the environment focusing on the target audience. The results corroborate that the use of such platforms should not be imposed or mandatory, as not all students might meet the necessary requirements and may not be familiarized with 3D environments or even ICT resources. Thus, alternative activities in traditional web-based learning platforms must be offered.

The feedback collected in the study culminated with the proposal of a framework with eight guidelines. Although based on an environment created toward the discipline of Financial Mathematics, it is generic and adaptable to other fields. Specific criteria may apply to special contexts such as Health. The overall intention is to harness the potential of the technology of virtual worlds for distance education, helping policy-makers, school management, teachers, and researchers to make more informed choices as to the nature of curricular forays and potential technical obstacles.

The research, albeit not groundbreaking in concept, is quite significant to the field, as it contributes with some new insights to drive the refinement of the implementation of virtual worlds in real distance education contexts, with a framework to help teachers to explore this potential in full, and students to extract the best of this experience. The OpenSim project is still active, and researches all over the world are using this free open-source platform to benefit students. The outdated and rather clunky user experience is compensated by its relatively simple interface of development and access, being a first door for the adoption of more complex virtual reality systems of the future.

As a limitation of the study, in addition to the constraints of a small convenience sample, it was identified that the data collection instrument could have clearer statements, avoiding ambiguity and misinterpretation. Also, some questions might not have been adequate for all participants in the sample, given that only two of them were teachers of the content treated in the environment. Although none of them is expert in technical ITC infrastructure conditions worldwide, we believe this does not prejudice the overall evaluation, since they are all capable professionals of the educational area, with experience in technology-enhanced learning models and acting in a developing country.

Future work could focus on three main areas, as follows:

- Validating the framework with researches and experts of educational virtual worlds and distance education areas, aiming to test its feasibility and to improve it, accommodating eventual new aspects;

- Developing a protocol for the implementation of each guideline outlined in the framework, to describe a clear path to its satisfactory accomplishment;
- Testing the application of the framework to optimize a virtual worlds' approach with distance education students as a platform to complement the traditional web-based learning environment.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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