Development of the Software Engineering Education Virtual Classroom Prototype: An Experience Report

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Abstract. *COVID-19 pandemic forced educational institutions to reinvent themselves by using digital information and communication technologies to support the continuity of distance learning. Google Meet and Zoom were one of the tools adopted as solution. However, the learning process presented challenges, mainly related to the lack of engagement and growing demotivation of students. Immersive Learning (iL) is a research topic that has the potential to improve learning outcomes. Through immersive environments, students have access to new ways of viewing and interacting, providing more engagement in learning. Therefore, the objective of this work is to present the development of a Virtual Classroom prototype, a virtual environment to support Software Engineering Education (SEE). An initial evaluation with a specialist was carried out and it was found that the usability of the environment is satisfactory, but aspects of performance must be improved. As future work, apart from adjusting the indicated points for improvement, a user experience evaluation with 3 to 5 extended reality specialists and another evaluation with students in order to verify the influence of the Virtual Classrooms on learning outcomes will be carried out.*

1. Introduction

With the start of the COVID-19 pandemic in 2020, the uptake of web conferencing tools has grown exponentially [Simamora *et al.* 2020]. Educational institutions also needed to reinvent themselves. In-person courses were adapted to the distance modality in order to continue the teaching and learning process. However, the exhaustive use of web conferencing for learning can result in cognitive overload and complicate learning outcomes [Simamora *et al.* 2020]. In this sense, Immersive Learning (iL) can mitigate this problem by impacting on increasing student engagement and consequently improving learning outcomes [Dengel and Mägdefrau 2019]. iL is learning facilitated through eXtended Reality (XR) technology. The advantage of this technology in teaching and training is the possibility of creating immersive experiences that allow the student to experience situations in a controlled and safe environment, with the feeling of being present in the virtual environment [Fernandes and Werner 2019].

In this context, a virtual classroom prototype was developed by 2 master's students and 1 doctoral student, in the context of a course on special topics in Software Engineering (SE) at the Federal University of Rio de Janeiro, Brazil. The course aim was to develop immersive environments for SE teaching, using Augmented and Virtual Reality (AVR), as well as incorporate serious game techniques in the context of virtual environments for education. The design of the virtual classroom was carried out by a team of four people, each with expertise in a subject: the doctor professor of the discipline specialized in Software Engineering Education (SEE), a doctor specialized in AVR; a doctoral student specialized in iL and a doctoral student specialized in serious games. The main objective of this paper is to report the planning and development experience of a SEE virtual classroom prototype using the FRAME[1] tool. An initial usability evaluation with a specialist was carried out and positive and negative aspects, such as potential engagement, satisfactory experience, intuitive interface, performance problems, were found. We consider this initial evaluation a pilot test.

This paper is organized as follows: Section 2 presents the concepts of iL and Virtual Reality (VR) Spaces, which are the basis for this work; Section 3 describes the environment design and development, as well as provides an overview of the SEE Virtual Classroom prototype; Section 4 shows the design of an evaluation carried out with a specialist; the results, discussions and the threats to validity are discussed in Section 5 and, finally, Section 6 concludes the work and reports the future steps of the research.

2. Background

Immersive Learning is characterized by the use of immersive technologies for educational purposes. Immersive technologies are computer systems that enable human-computer interaction through up to the five human senses. By using these technologies it is possible to create immersive experiences in order to support the improvement of learning outcomes. iL enables immersion in virtual environments or even the creation of virtual objects that complement the perception of the real world, supporting the educational process through new ways of viewing inaccessible objects of study, such as the observation of galaxies; time travel; situations with a high degree of danger, such as firefighting training and flight simulations; opportunities to visualize geometric relationships in concepts or data that are difficult to interpret [LaValle 2016].

VR Spaces allow users to gather in a virtual and three-dimensional environment and interact with each other and with the environment itself through avatars [LaValle 2016]. In previous studies, this resource has been explored to support the teaching of Software Engineering. Among them, a virtual world proposed by [Ye *et al.* 2007] was used to enhance software engineering education by exploiting communication and collaboration tools to teach practices such as problem solving, plan formulation, interpretative analysis, and adaptation to rapid change, in a virtual office provided by Second Life (SL). Likewise [Ye *et al.* 2007], [Parsons and Stockdale 2010] used a 3D virtual world based on Open Wonderland to support a workshop activity based on agile software development processes. Based on the SimSE game developed at University of California at Irvine, [Wang and Zhu 2009] developed the educational game in SL. It provides the students the simulated experience as software engineers, especially the communication and collaboration with other team members in a project.

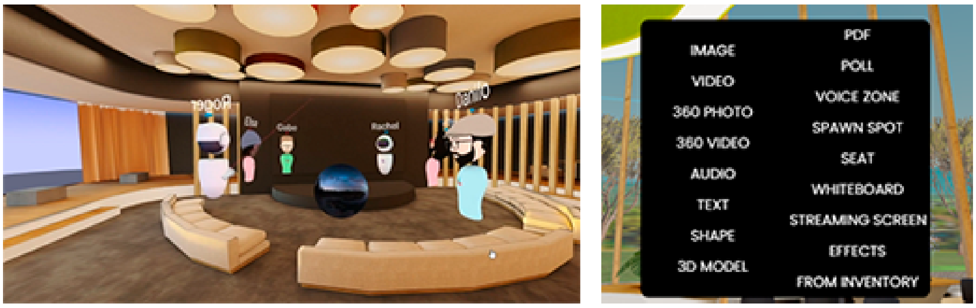
With technological advances, browser-based platforms have been adopted to provide social and educational experiences in three-dimensional environments. Two tools most used in the educational context Mozilla Hubs[2] and FRAME. In terms of perfor-

[1]https://framevr.io/
[2]https://hubs.mozilla.com/

mance and usability, Mozila Hubs has advantages and disadvantages, being extremely easy for the user to access and interact with the environment, since it is based on the web, but being significantly heavier than FRAME and spending more resources. While Mozilla does not specify minimum requirements, it does mention that several of its limitations, such as capacity, stem from the fact that it has to support the latest VR headsets [Eriksson 2021]. In this way, FRAME was chosen for its advantages and an overview of the tool is presented in the following.

2.1. FRAME

FRAME is a web tool that allows to create a space in which students can meet and interact with each other through an immersive environment. Figure 1(a) shows the avatars of users present in the same virtual space. To support communication, the tool provides text chat, device screen and webcam sharing, as well as voice communication. In addition, FRAME has a set of features that allow to customize the virtual environment in a way that meets educational purposes. Figure 1(b) presents the available features, such as inserting 2D images and videos, as well as in 360º; audio; 3D models; PDF files; whiteboard; among others.



(a) FRAME environment (b) FRAME features

Figure 1. FRAME overview. Source: framevr.io

FRAME's editing tools are intuitive. However, the insertion of 3D objects within the environment can become a usability problem, as the insertion is done through the interface itself, in which the user moves the mouse to modify the size, translation and rotation of the object [Lee and Hwang 2022]. For example, to move an object, the user needs to drag it with the mouse to the desired location. Most 3D editing tools solve this problem by allowing the user to modify the object by entering numerical data. Thus, it allows to leave the object as expected effectively and quickly. Another limitation of FRAME regards access restrictions. Its free support allows to create up to 3 virtual environments per account and 15 users per environment. However, there are paid plans to extend the limits of users and environments if needed.

One of the advantages of FRAME is that it is a web platform, that is, it runs via browser and is therefore cross-platform [Lee and Hwang 2022]. Therefore, it works on desktops, smartphones, tablets and VR headsets, as long as they have compatible browsers. However, the ways of interacting with the virtual environment are adapted according to the device used. For example, through the desktop it is possible to increase the speed of the avatar by combining the shift key with the direction key, however through the smartphone this is not possible. Standard functionality includes camera, screen sharing, slideshow and spatial sound. In addition, it has a very refined editing tool, with a high level of customization and the ability to move numerical data to configure the desired environment.

3. SEE Virtual Classroom Overview

The virtual classroom prototype was conceived through the design and development phases. In the design phase, a set of features was defined and a development platform chosen. The prototype was developed by the students during the course on special topics in SE. The course was divided into three parts: the first corresponds to classes on subjects related to AVR environments and serious games, the second part is about the development of the prototype itself and, finally, presentation and delivery of the developed environment. The design and development details, as well as the prototype features are next described.

3.1. Prototype Design and Development

The design of the virtual classroom prototype was carried out by the team of experts and they adopted Immersive Software Engineering Education (iSEE) framework [Fernandes and Werner 2021] to support the planning of the virtual environment.

The framework is composed of guidelines grouped in two dimensions: objective and subjective affordances. The iSEE framework guidelines support the definition of requirements that the virtual environment must have, in order to meet the educational purposes in SE, under the restrictions of immersive technologies. The detailed description of the iSEE framework can be found in [Fernandes and Werner 2021]. The framework is the result of an ongoing doctoral research carried out by the iL specialist and one of the purposes of adopting the framework is to help in its construction. Therefore, in an online session with the team, iSEE framework was presented by its author and soon after, the planning of the virtual environment for teaching SE began, which is the main object of study of this paper. During the definition of requirements, opportunities for improvement in the framework guidelines were identified, such as reformulation of some terms, addition of some guidelines, among others. As a result of the defined requirements, the FRAME tool was chosen for the development of the environment.

During the course, each student was guided by an expert in order to help building the environment prototype with items that support the teaching of a certain subject. In the months of September to October 2021, the students carried out the development of the prototype in an iterative and incremental way, that is, at each weekly sprint they presented what had been done, what had been the challenges and solutions adopted and what would be the future steps.

As mentioned before, the main objective of the virtual environment is to support the teaching of topics in SEE. Therefore, the environment was divided into thematic zones, which address the topics of analysis and modeling of software requirements; AVR and game concepts and their application in teaching SE. AVR theme was chosen to facilitate the user's familiarization with virtual environments and their potential in education, as well as in other areas. Additionally, research and projects developed by the Virtual Reality Laboratory (Lab3D)[3] are also exposed in the environment.

[3]https://lab3d.coppe.ufrj.br/

3.2. Prototype Zones

As shown in Figure 2(a), when users enter the room via URL, they will find the entrance hall and a part of the zones with the instructional content. The user, through his/her avatar, will be able to explore the environment and go to the areas that contain the instructional content. Figure 2(b) shows the AVR zone, in which it presents some of the technology history through the evolution timeline and slides, also it shows some examples of AVR devices and some related videos and allows accessing a sub-environment that presents some application examples in several areas.

(a) Entrance Hall **(b) AVR Zone**

Figure 2. Entrance hall and AVR Zone. Source: authors

Zones 2 and 3 correspond, respectively, to teaching software requirements and requirements modeling. As can be seen in Figure 3, Zone 2 on the left contains resources such as video and slides that support the user in obtaining information on the subject. In addition, the zone contains an exercise to facilitate requirements elicitation practice.

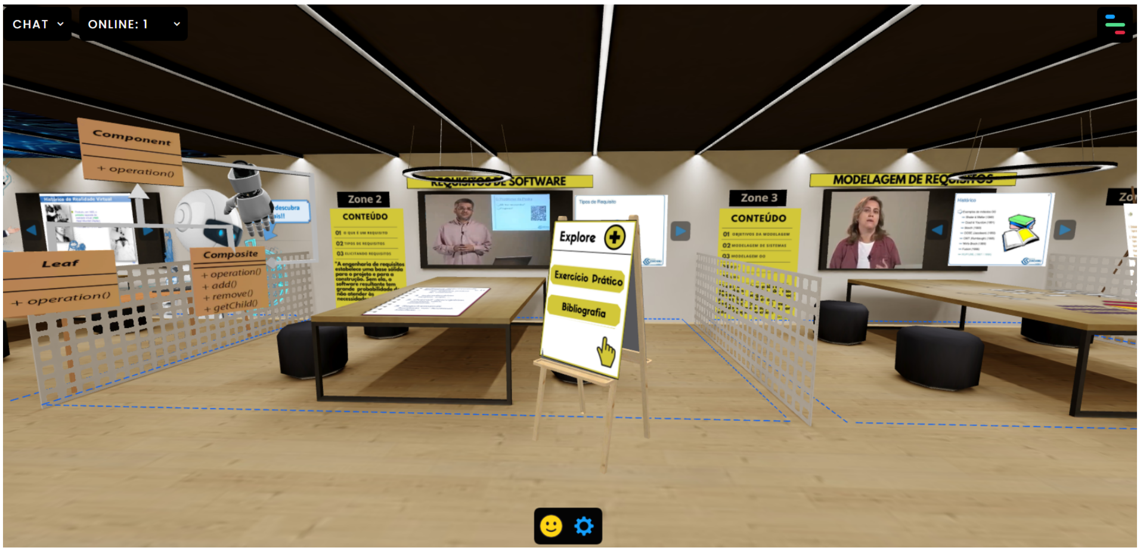


Figure 3. Software requirements zone on the left and requirements modeling zone on the right. Source: authors

According to technical literature, one of the problems in SEE is the demotivation of students due to the large volume of theoretical content, as well as the difficulty in applying the learned techniques in practice [LaValle 2016]. In particular, requirements elicitation is an activity that aims to identify what functionality the software will have in order to meet the needs of stakeholders, as well as computational constraints. In general, the practice of this activity requires the application of interview techniques between the specialist and stakeholders. However, in the educational field, learning is limited to memorizing the techniques, applying them among students or, rarely, bringing an industry professional to the classroom [LaValle 2016].

With the virtual environment it was possible to simulate the interview activity in order to support the requirements elicitation practice. The environment simulates an office and has several avatars distributed, in addition to instructions on how to perform the exercise. The student's objective is to explore this environment and interview the avatars in order to create a requirements document for the development of an application that compares prices of products between supermarkets. In this way, the user needs to walk across the office, meet the avatars, click on the video to the side and hear what each one has to say. Figure 4(a) shows an example of an avatar available for interview. However, not all avatars are available. If an avatar is unavailable, the video displays the message that the employee is unavailable for interview, as shown in Figure 4(b). In this way, the student is obliged to "interview" all the avatars that are in the environment.

(a) Available for interview

(b) Unavailable for interview

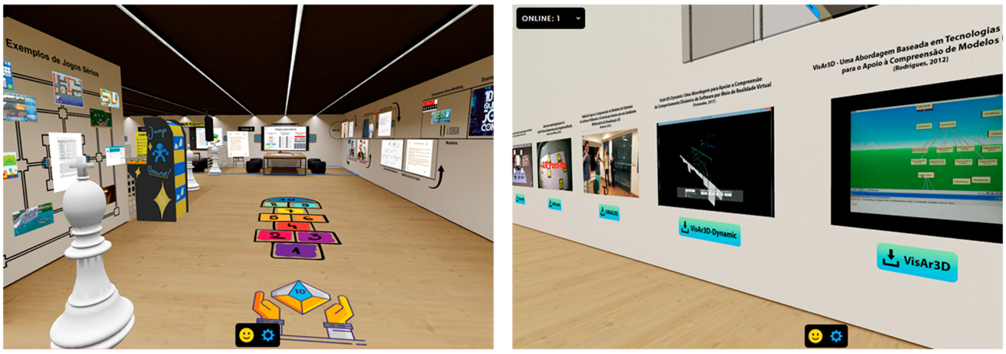
Figure 4. Available and unavailable avatar for interview. Source: authors

Regarding requirements modeling, as can be see in Figure 3, Zone 3 on the right, makes the content available in video and slide format. In addition, it also provides a link to the OO Game VR prototype [Fernandes and Werner 2019], which supports the teaching of object-oriented concepts through an immersive virtual environment.

Zone 4 presents some serious game concepts and some works that involve gamification in SE teaching. Figure 5(a) shows the elements that make up the subject of games in the virtual environment. In addition to the above zones having a set of elements to support the teaching of a certain subject, the environment has Zones 5 and 6 so that users can share the screen of their devices or webcam, as well as communicate among them through the whiteboard. Finally, areas to disseminate research and projects carried out by Lab3D also make up the environment. According to Figure 5(b), the demo video of each survey, as well as the link to the corresponding paper or thesis, are displayed outside the areas that address AVR, SE and serious game issues.

4. Evaluation Design

The initial evaluation is organized in three stages: familiarization with the virtual environment; carrying out tasks and evaluating the usability. The first step involves allowing the



(a) Serious Game Zone **(b) Research Zone**

Figure 5. Serious game and Research developed by Lab3D. Source: authors

specialist to freely explore the environment for up to 30 minutes. After the exploration, the participant must perform some tasks (see Table 1), which were planned collaboratively by the environment designers. In addition, for each task performed, the participant must indicate the degree of difficulty using a 5-point Likert scale, as well as the justification for the score.

Finally, the specialist evaluates the virtual classroom prototype through an usability questionnaire. In order to prepare this questionnaire, firstly, a review of the questionnaires consolidated in the literature that meet the objective of this initial evaluation was carried out. We analyzed the Schwind *et al.*'s study that compared 15 questionnaires to assess virtual environments [Schwind *et al.* 2019], besides [Kim *et al.* 2020] and [Rebelo *et al.* 2012] that reviewed the literature in search of research related to User eXperience (UX) in VR systems. The System Usability Scale (SUS) [Brooke 1996], IPQ [Schubert *et al.* 2001], PQ [Witmer and Singer 1998] and Motion Sickness Assessment Questionnaire (MSAQ) [Gianaros *et al.* 2001] questionnaires were selected for analysis because they comply with the purpose of the assessment.

Posteriorly, through analysis and discussion in an online session by the team, it was decided to use 13 of the 32 Presence Questionnaire (PQ) [Witmer and Singer 1998] questions and the 7-point Likert scale for each question. Only a few questions were used because they are aligned with the objective of the evaluation, which is to obtain evidence about the interaction with the environment instead of evaluating how much the user feels present or how much he/she learned about the subjects. Furthermore, we did not use SUS, as we believe that its questions are too general for our initial assessment, and for this reason we used the PQ questions because they provide a greater level of detail when investigating the study objective. Table 2 shows the selected questions.

In addition to the usability questions, 6 open questions were also designed to obtain participant's feedback regarding the evaluation in general and the importance of virtual environments in education. Table 3 presents these questions.

5. Results and Discussions

In this initial evaluation, we emphasize that the only specialist who participated in the evaluation did not work in the development and was completely unaware of the environment developed. The specialist has a master's degree in computing; is familiar with

Id	Tasks
T1	Zone 2 presents some resources to support the teaching of software requirements gathering stage. In particular, a new virtual environment was developed to simulate the interview with users. Your task is to access this environment.
T2	Zone 3 presents some resources to support teaching requirements modeling. Your task is to find out what these features are.
T3	Zone 1 displays motivation, curiosities, history, devices and application areas of Virtual and Augmented Reality. Your task is to visualize this information by clicking on links and accessing another virtual environment with more information available.
T4	Lab3D area presents the scientific production of Lab3D in relation to Virtual and Augmented Reality. Your task is to access the videos and associated documents.
T5	Zone 4 presents theoretical concepts about serious game development. Your task is to access the videos and associated documents.
T6	Zone 4 presents introductory concepts about game modifiers (mods). Your task is to read the documents demonstrated in the environment.
T7	In Zone 4 some games that were created to assist in the teaching of Software Engineering are presented. Your task is to identify each of the games demonstrated.
T8	Zone 5 was created so that users can share the webcam as well as the computer screen. Your task is to test these functions.
T9	In order to facilitate communication between users, zone 6 has a function that simulates a whiteboard. Your task is to record something on the board.
T10	Augmented Reality was used in a museum to provide a virtual tour and show the elements of our planet Earth's geodiversity. Your task is to access the link to the demonstration video of this virtual tour through an object in the external area of the virtual environment.
T11	The development of this environment is an initiative between two UFRJ laboratories. Your task is to locate one or more objects that show what these laboratories are.
T12	Your task is to explore the environment and locate one or more whiteboards beyond zone 6.

Table 1. Environment Tasks. Source: authors

devices such as computers and mobile devices, including immersive devices and experience with AVR; but rarely has contact with games. The evaluation was carried out in two rounds due to technical problems with the participant's equipment, as described in the following.

5.1. Round 1

Before the beginning of the evaluation session, profile and device describing questionnaires were sent by e-mail in order to obtain demographic data, as well as device and network information, which would be used by the specialist. In December 2021, the evaluation started through Google Meet. However, due to technical problems with the specialist's device, it was not possible to complete the first step, which was to freely explore the virtual environment. In this way, the researcher informed that the session should be ended and that on another date the specialist should access it from another device. In addition, the specialist promised not to access the environment until the next assessment session.

In the session, the researcher informed the specialist about the purpose of the prototype, the URL to access it, as well as the maximum time to explore the environment. The entire session was recorded with the specialist's permission. During the exploration of the environment, the participant used an iMac with a 3.06 GHz Intel Core 2 Duo processor,

Id	Questions
Q1	How responsive was the environment to actions that you initiated (or performed)?
Q2	How natural did your interactions with the environment seem?
Q3	How natural was the mechanism which controlled movement through the environment?
Q4	How much did your experiences in the virtual environment seem consistent with your real world experiences?
Q5	Were you able to anticipate what would happen next in response to the actions that you performed?
Q6	How compelling was your sense of moving around inside the virtual environment?
Q7	How closely were you able to examine objects?
Q8	How well could you examine 3D objects?
Q9	How much delay did you experience between your actions and expected outcomes?
Q10	How quickly did you adjust to the virtual environment experience?
Q11	How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?
Q12	How much did the visual display quality (e.g. color and size of the 3D objects) interfere or distract you from performing assigned tasks or required activities?
Q13	How much did the control devices interfere with the performance of assigned tasks or with other activities?

Table 2. Usability questions. Source: adapted from [Witmer and Singer 1998]

Questions
Was the time of 30 minutes to explore the virtual environment enough?
Are the usability questionnaire questions understandable?
In your opinion, how can 3D virtual environments support education?
In your opinion, what are the advantages of 3D virtual environments?
In your opinion, what are the disadvantages of 3D virtual environments?
What do you have to say about the assessment session?

Table 3. Feedback questions. Source: authors

4 GB RAM and an NVIDIA GeForce 9400 256 MB video card. The internet connection was through wifi with a speed of 78 Mpbs of download and 94 Mpbs of upload. The browser used was Google Chrome version 96.0.4664.55.

When accessing the environment, the items that compose them took a long time to load. For 5 minutes, approximately, after loading the items, the specialist interacted with the environment only with the mouse and began to experience some difficulties in locomotion and interaction in the environment. Thus, she sought some support from the tool to help with the difficulty faced. After 13 minutes of session, she was unable to move the avatar and the interaction was still by mouse.

During the entire session, the virtual classroom presented a delay in loading the items, which caused discomfort for the specialist. After the exploration time had passed, the researcher informed the specialist to close the browser and open the environment again in order to continue the evaluation. However, the environment continued to present problems of slowness.

5.2. Round 2

The evaluation of the environment with the same specialist was carried out in January 2022. Considering the challenges encountered in the previous session, Zoom was used as an alternative. As the Google Meet environment and virtual room are accessed via browser, this decision was made not to overload the environment and compromise the experiment again. In this session the specialist used another device. In this session the specialist used the following configuration: desktop with Intel Core i7-7700 CPU @ 3.60 GHz, 16 GB RAM and Windows 10 Pro; wired internet connection with 92.8 mbps download and 90.4 mbps upload; Google Chrome browser version 96.0.4664.110.

During the exploration stage, the environment did not present problems of slow loading of items as occurred in round 1. In addition, the specialist was able to interact with the keyboard and, consequently, the environment was explored in its entirety. In FRAME, the camera movement that simulates the avatar's head is performed through the interaction with the mouse and the movement, that is, the "walking' action of the avatar, is through the A,S,D and W keys or directional arrow keys on the keyboard. After exploring the environment, the specialist performed the tasks successfully. The participant judged that 34% of the tasks were easy to perform (T1, T7, T8, T10), 8% of the tasks were neutral (T4) and 58% very easy (T2, T3, T5, T6, T9, T11, T12).

Finally, the usability questionnaire was completed by the specialist. In general, the environment was well evaluated. Most usability questions got positive scores. However, Q9 and Q10 were evaluated as critical aspects that must be improved in the prototype. These critical aspects are related to the problems faced during first evaluation session. Analyzing the situation in detail, the equipment used interfered with the execution performance of the environment and, in turn, provided a bad interaction experience, presenting delay in the response time of the interaction with the virtual classroom prototype.

Regarding the evaluation feedback applied after the usability questionnaire, the specialist agrees that the time for exploration was sufficient. Regarding the understanding of usability issues, the participant states that "*depending on the degree of knowledge of the English language and even the concepts and definitions of technical terms, this may result in difficulties for users to answer the usability questionnaire* ". When asked how virtual environments can support education, the specialist stated: "*I believe it is a new way of not only disseminating content, but also for people to interact with each other and with the content*". About virtual environments, the specialist stated that the advantages are "*being able to explore interactive content such as multimedia, videos, audios, webcam, in addition to simulating real-world scenarios and environments*" and the disadvantage "*at the moment, the need to have an infrastructure (machine, internet) that supports the execution of the technology and perhaps the lack of knowledge of how it works by a group of people*".

Finally, the specialist indicated some points in the questionnaires that should be improved, such as reformulating some questions to improve understanding and avoid ambiguities, insert a visual element so that the user can follow the progress of filling in the answers and inform the total number of questions that must be answered.

5.3. Threats to Validity

We consider as one of the threats to validity of the study, the fact that the evaluation session was interrupted due to technical problems. Although the specialist made a commitment not to access other environments of the FRAME tool, there is no guarantee that the specialist did not obtain biases that could influence the second evaluation session. Furthermore, despite being common in the literature not to apply questionnaires in their entirety, we also consider that our usability questionnaire can be a threat to validity by using some PQ questions. Regarding the number of evaluators, more usability experts could have participated in the evaluation. However, the results of this evaluation are relevant, as they will support the improvement of the environment, as well as the execution of future evaluations.

6. Conclusions

This work presented the development of a virtual environment prototype to support the teaching of Software Engineering through the FRAME tool. In order to verify the usability of the SEE Virtual Classroom, an initial evaluation was conducted with a systems usability specialist. Through a questionnaire adapted from [Witmer and Singer 1998], the specialist reported that the performance of the environment needs improvement, that is, the environment items take time to be loaded. However, this behavior was only presented in the first evaluation session because of the use of an inferior equipment than in the second session. In addition, the participant indicated improvements in the evaluation design. From the point of view of the ease of use of FRAME to create environments, students reported in the weekly sprints of the discipline that the challenges encountered were related to the learning curve of the tool and that the support of FRAME and the guidance of experts helped in solving the problems.

As future works, the evaluation design will be modified according to the critical aspects pointed out in this study and another evaluation with 3 to 5 XR specialists [Nielsen 1992] with a focus on UX and another evaluation with students to measuring the improvement of learning certain Software Engineering topics through the SEE Virtual Classroom will be carried out.

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