Virtual Reality Applications in Software Engineering Education: A Systematic Review

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Abstract

Requirement Engineering (RE) is a Software Engineering (SE) process of defining, documenting, and maintaining the requirements from a problem. It is one of the most complex processes of SE because it addresses the relation between customer and developer. RE learning may be abstract and complex for most students because many of them cannot visualize the subject directly applied. Through the advancement of technology, Virtual Reality (VR) hardware is becoming increasingly more accessible, and it is not rare to use it in education. Little research and systematic studies explain the integration between SE and VR, and even less between RE and VR. Hence, this systematic review proposes to select and present studies that relate the use of VR applications to teach SE and RE concepts. We selected nine studies to include in this review. Despite the lack of articles addressing the topic, the results from this study showed that the use of VR technologies for learning SE is still very seminal. The projects based essentially on visualization. There are lack of tasks to build modeling artifacts, and also interaction with stakeholders and other software engineers. Learning tasks and the monitoring of students’ progress by teachers also need to be considered.

Keywords: Educational software; Requirements engineering; Software engineering; Virtual reality;

1 Introduction

Using Virtual Reality (VR) in education can be considered a natural evolution in using technology to support learning (Pantelidis, 2010). VR allows novel forms and methods of visualization and interaction, providing the student with more proximity and depth in the observation and examination of objects and processes. Students feel motivated and challenged to walk and interact in a 3D environment, and even more with the possibility of changing that environment (Pantelidis, 2010). Because of these qualities, the idea of combining VR with Software Engineering (SE) to make abstract subjects tangible arises. In the past, one disadvantage of VR was related to the cost. This problem has already been overcome because, with the latest generation of smartphones and a foldable cardboard display, users can reach these immersive environments (Tori and Hounsell, 2018). However, according to Hillmann (2019), the quality of VR hardware and software is not yet good enough for a mass market.

Requirements elicitation and specification are the first phase of software development. Problems at this
stage account for over 50% of software errors (Ávila and Spinola, 2007). Therefore, the quality in elicitation and specification of requirements is critical to the success of a software project. For this reason, there is a need to prepare students for Software Engineering courses, offering them the opportunity to experience this process during their training. Universities may not be creating enough skills for future engineers to perform this task (Thiry et al., 2010). It is still necessary for the academic environment to develop maturity and practices with real projects for students to develop the skills to conduct Requirement Engineering (RE) (Romero et al., 2008). However, this task depends on external factors, in which real or fictitious customers are available to assist students.

In this article, we carry out a systematic review of the existing VR applications to SE education and highlight the immersive aspect of VR to answer seven research questions aiming to identify the features and resources developed in these studies. Although our initial focus was on studies in RE, we have expanded the study to find features from other applications related to SE that can contribute to the teaching of RE. Our goal is to contribute to the existing body of knowledge on the application of VR for educational purposes in RE. We did not find reviews involving the use of VR in the SE context. Many reviews that we found claimed to have used VR, but in reality, they used just 3D environments (such as a 3D rendered on a computer or smartphone screen). It was very difficult to base and answer the proposed questions because we found few studies that include both VR and SE education concepts. We can consider this paper a pioneer in addressing the theme.

2 Background and related work

Following the definition from Biocca and Levy (1995), VR results from the sum of hardware and software seeking to give users the immersive feeling that they are in another reality. Wang et al. (2018) define VR as the visualization technique referred to a pure virtual presence. They also split VR into five categories: Desktop–Based VR, Immersive VR, 3D Game based VR, BIM–Enabled VR, and Augmented Reality. The present paper focuses on reviewing the use of immersive VR, which is the category of visualization that requires special hardware, such as head–mounted displays (HMDs) and Projection–based displays (PBDs) (Feng et al., 2018). HMDs comprise goggles attached to a helmet that displays images for each eye and PBDs are related to creating immersive rooms by displaying images in one or more walls (Lanzagorto et al., 2000).

To give the user high immersion, a newer generation of HMDs is being used (Radianti et al., 2020). In the past, the use of HMDs was expensive and uncomfortable (Kerawalla et al., 2006). Users can overcome the problems that have arisen with price when they have access to new generations of smartphones, allowing a greater possibility of accessing VR environments (Tori and Hounsell, 2018). One of the key problems arising from the physical problems is cybersickness, which can mainly affect people who are not used to VR games (Jensen and Konradsen, 2018).

It is common to have studies applying VR in education (Abdullah et al., 2019, Gutiérrez-Braojos et al., 2019, Vretos et al., 2019). Usually, its conclusions claim the results are positive, somehow fostering and increasing student’s productivity. The literature review presented by Radianti et al. (2020) searched how VR applications are applying for high educational purposes. To do that, the authors analyzed and categorized 38 papers into eight questions. We used many definitions and categorizations defined by this review to base our questions, such as immersive VR designs and validations designs. That review concludes that the variety of papers using VR shows that there is a high expectation in the content, but the maturity of the studies still can be questionable because few of them showed how their experiments can be implemented in the teaching curriculum.

Software are computer programs and associated documentation, which can be developed for a particular customer, or for the general market (Sommerville, 2015). SE is the engineering discipline responsible for software production, from initial conception to operation and maintenance. SE is fundamental to society because it affects almost every aspect of our lives, changing the way we, as humanity, deal with commerce, culture, and our everyday activities (Pressman, 2010).

Sommerville (2015) defines requirements as descriptions of the services that a system should provide and the constraints in its operation. RE can be considered the process of finding out, analyzing, documenting, and checking these services and constraints. That means RE is the first step in software development. It handles the communication between customers and the development team. It might seem like a simple process, but usually, customers and users are not familiar with SE processes, which may cause problems of scope, understanding, and volatility (Pressman, 2010). Fig. 1 describes how the RE process works. Sommerville (2015) separated RE into three key activities: requirements elicitation, specification, and validation. In requirements elicitation, the engineer must discover the requirements by interacting with the stakeholder. In requirements specification, the engineer must convert the collected requirements into a standard form, such as a requirements specification document. In requirements validation, the engineer must check if the requirements define the system that the user asked for.

Designing an approach to convey RE concepts, which must encompass practical experience, is considered a hard task for technology courses (Portugal et al., 2016). Sikkel and Daneva (2011) presented some problems for those who are not teachers, such as the difficulty in validating the requirements in a practical way. The study also claims that in university, students are used to a perfect, self-contained problem description. There are studies describing the integration of students with industry, but usually students and instructors assume different roles to enact the practical experience (Portugal et al., 2016).

Santos et al. (2013) presented a review where they merged evidence regarding the use of the RE process for VR systems and the VR contributions to the RE process. The results claimed few researches were describing the
use of RE for VR, or VR to support the RE process. The review identified the use of many SE models and adapted them to the RE process for VR systems.

3 Methodology

Systematic Literature Review (RLS) is defined by Kitchenham (2004) as “[...] identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest.” We conducted the overall review process of this research in four main stages as illustrated in Fig. 2. Therefore, the following sections will report the complete process.

3.1 Conception Stage

The first step to conduct the SLR was the conception stage, by defining the scope, protocol, and research questions. The protocol development is a vital part of any SRL because it allows other researchers to recreate the same review and “reduce the possibility of researcher bias” (Kitchenham, 2004). Being aware of this study, which is to review the use of VR in the educational application of SE and RE, we defined the research questions as described in Table 1.

We will better explain the questions and describe how each found paper answers the questions, in the result section.

To find the relevant studies, we defined the search string (search stage shown in Fig. 2) following the question structure (population, intervention, outcomes, and experimental designs) proposed by Kitchenham (2004). We illustrate the keywords used on the string in Fig. 3. We performed the investigation manually using research databases strengthened for its high range and quality of publications Table 2).

| # | Research Question (RQ)                                                                 |
|---|---------------------------------------------------------------------------------------|
| RQ1| What subjects of SE or RE were simulated in VR environments?                          |
| RQ2| What were the VR features in SE or RE teaching environments?                           |
| RQ3| How were the students’ interactions performed?                                         |
| RQ4| What and how were the developer–customer-user interactions?                           |
| RQ5| Which Unified Model Language (UML) diagrams were adopted and how they were used and designed by students in VR systems? |
| RQ6| Which were the target hardware of the studies?                                         |
| RQ7| How were the virtual teaching environments in SE or RE evaluated?                     |

| Acronym | Name                                      |
|---------|-------------------------------------------|
| ACM     | Library Association for Computing Machinery |
| IEEEXPLORER | IEEE Xplore digital library             |
| ResearchGate | ResearchGate                             |
| Scielo  | Scientific Electronic Library Online      |
| ScienceDirect | ScienceDirect                           |
| Scopus  | Scopus                                    |

The search string returned a different quantity of studies on each site. Then, we defined inclusion and exclusion criteria (Table 3) to filter the primary studies selected, aiming to choose those that were part of this study’s goal.

| Type          | Criteria                                                                 |
|---------------|--------------------------------------------------------------------------|
| Inclusion     | Environments for teaching or simulating SE and RE in VR                  |
| Exclusion     | SE processes for VR development Studies in the field of medicine and robotics Virtual environments unrelated to SE context |

After defined the inclusion and exclusion criteria, as well as the search terms, we carried out the systematic review following the previously planned steps.
Figure 2: Systematic Literature Review process. Adapted from Kitchenham (2004)

Figure 3: Search string defined for the scope of this work

3.2 Search Stage

This stage of the research process aimed to build a list of articles that will be the object of study in the next stage. Fig. 4 shows the overall view and the number of resulting studies in each phase of the research process, and the same total number of studies are separated by knowledge bases in Table 4.

First, the search string (Fig. 3) was applied on each research base listed in Table 2, returned the total amount of related works as a preliminary result (First Phase: 3104 studies - Table 4). Then, we read each paper title and excluded the ones that do not explicitly address the subject, according to the inclusion and exclusion criteria (Table 3), resulted in 49 studies in the second phase. Thereafter, we read the Abstract, Introduction, and Conclusion sections, resulted in the removal of eighteen papers. We removed the replicated papers (Third Phase: 23 studies). Finally, we read each selected paper in its totality to identify a misunderstanding regarding the concept of VR environments. Some papers described VR environments without the use of dedicated hardware, i.e. the user just had to be inserted into a 3D environment through the computer screen, instead of defined VR by Biocca and Levy (1995) as the sum of hardware and software. Thus, we selected only the studies that explicitly used a VR head-mounted display, resulting in a list of eight studies in the fourth phase.

As an additional step, we looked for papers referenced by the eight selected studies, considering the inclusion and exclusion criteria, to avoid that some relevant papers were not included because they are outside the research bases. In this step, we added one new study resulting in the total of nine studies on VR learning environments applied in software and requirements engineering (fifth phase).

Table 4: Number of studies by research database

| Source         | Number of studies |
|----------------|-------------------|
| ACM            | 1097              |
| IEEEXPLORE     | 182               |
| Researchgate   | 100               |
| Scielo         | 1                 |
| Science direct | 1281              |
| Scopus         | 443               |
| **Total**      | **3104**          |

Each phase was performed by one author and repeated by two other researchers to ensure consistency in the outcomes. If some work was not included or excluded, all the researchers discussed it until they reached a consensus.

3.3 Evaluation Stage

Once we finished the search stage, we collected and tabulated the relevant information of each nine studies found, to answer each of the research questions listed in Table 1. It will organize the details about the results for each paper in the next section, composing the Last Stage of this RSL (shown in Fig. 2). Table 5 lists the nine studies.
and Vincur et al. are also applications focused present environments of programming course, with virtual reality are quite recent, as shown in Fig. The area of software engineering is subdivided into

The selected studies were from 2015 to 2019. This emphasizes the idea that studies in the SE area that work with virtual reality are quite recent, as shown in Fig. 5.

4 Results

The selected studies were from 2015 to 2019. This emphasizes the idea that studies in the SE area that work with virtual reality are quite recent, as shown in Fig. 5.

4.1 RQ1: What subjects of SE or RE were simulated in VR environments?

The area of software engineering is subdivided into several others, and some of the selected papers were related to other SE content requirements engineering. Fittkau et al. (2017), Merino et al. (2017), Oberhauser and Lecon (2017), Tanielu et al. (2019) and Vincure et al. (2017) present environments of programming course, and are related to the software visualization, in which the user is a floating spectator who can observe the classes and packages of her/his system in a more playful environment, using the abstraction of cities and buildings to understand the connections of an application. Fittkau et al. (2017), Merino et al. (2017), Oberhauser and Lecon (2017) and Vincure et al. (2017) are also applications focused on software architecture. Elliott et al. (2015) present a VR programming system, in which the student has real-time feedback on what is programmed, being able to instantiate trees, birds, and leaves that appear in a virtual world. Akbulut et al. (2018) show an application that aims to teach software concepts controlled by a main user (possibly a teacher) to other users with a VR display. The students cannot interact with the software. Ochoa and Babbit (2019) and Zhao et al. (2019) deal with requirements engineering. In the application presented in Ochoa and Babbit (2019), the user connects floating UML diagram elements, which are usually performed in two-dimensional environments. Zhao et al. (2019) aims to train people in the stages of the manufactured production process, using the analysis of functional requirements for the creation of a product requested by a customer. According to the subject covered by each paper, we define three categories: Programming, Requirement, and Software Architecture, which are shown in Table 6. Programming refers to any VR application related to code and to construct algorithms. Requirement is referred to as any VR application related to RE. Software architecture is related to any VR application related to structural decisions and management.

4.2 RQ2: What were the VR features in the SE or RE teaching environments?

With this question, we want to identify how VR resources are used in teaching software or requirements engineering.
The features are described and listed in Table 7. By collecting these features, we will analyze and see some similarities in them, such as the absence to contemplate the entire process of creating and maintaining a software, but focusing on smaller, specific parts of the complete process. It also shows that interactivity with the user is a key principle in VR. In the next question, according to the interaction with the system, we will separate each VR application into one or more categories.

None of the studies described the definition of an instructional unit, nor evaluations or monitoring of students’ progress.

4.3 RQ3: How were the students’ interactions performed?

The review of Radianti et al. (2020) conceptualized fourteen categories of educational design elements: realistic surroundings, passive observation, moving around, basic interaction with objects, assembling objects, interaction with other users, role management, screen sharing, user-generated content, instructions, immediate feedback, knowledge test, virtual rewards, and making meaningful choices. To answer our question, we retrieved the attributes of each application in research question 1 and classified them in at least the category quoted before, as shown in Table 8.

We have not found papers that match the other eight categories. It is also worth saying that some papers can fit into over one category. We could identify that the moving around and the user-generated content category are the most popular categories of user-application interaction.

Most applications do not have a direct and deeper interaction, containing decisions and choices that could help the learning process. In addition, only one study (Zhao et al., 2019) tried to simulate the requirements process, but it is not specific to the software requirements process.

4.4 RQ4: What and how are the developer-client-user interactions?

Software development involves interaction between users and developers. Through this question, we would like to identify how applications have solved this communication...
Despite not approaching the subject directly, Zhao et al. (2019) is the only one that represents the interactions by dealing directly with requirements. We could identify the

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**Table 7: VR features applied in SE or RE teaching environments.**

| Study             | Features                                                                                                                                                                                                 |
|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Akbulut et al. (2018) | The teacher sets up the experiments by defining the size of array and the algorithm: selection sort, bubble sort, insertions sort, or merge sort. Each student, equipped with an iOS smartphone, plays the role of an array element to be organized. The rearrangement of the array is captured when students change their position. |
| Elliott et al. (2015) | Riftsketch allows the user to code in JavaScript and see real-time scene updates, such as the creation of animals and plants. Immersion allows the user to review code inside the VR environment by representing methods as code fragments in squared blocks. Both applications use an HMD, Oculus Rift development kit 2, and a Leap Motion Controller for gesture recognition. |
| Fittkau et al. (2017) | The system allows users to view the system architecture (class, packages, and their connections) by moving, rotating, and zooming in on the virtual scope. Students visualize the architecture as UML diagrams. It used colored boxes to identify classes or packages. There are four types of visualization. |
| Merino et al. (2017) | CityVR is an application which uses VR to visualize object-oriented programming concepts using an analogy of buildings, such as Fittkau et al. (2017), Ochoa and Babbit (2019), and Zhao et al. (2019). The system represents each class as a building in the city and the districts as software packages and allows the user to inspect the source code of the class, pointing the controller at it, and pressing a button to select it. |
| Oberhauser and Lecon (2017) | The system allows the user to control altitude (up, down) using one HTC touchpad; control directions (left, right, forward, backward) using another HTC touchpad; select an object and change its color; visualize his Java application in the city metaphor, where the higher the building, the bigger it is within its package. The system shows a laser pointer for selection when the controller enters the view field and has a virtual keyboard that supports text input for searching, filtering, and tagging. When a controller is near to and pointing at the oracle (virtual tablet), the system changes the virtual controller mesh to a finger for intuitive interaction. |
| Vincur et al. (2017) | VRCity is an application which uses VR to visualize object-oriented programming concepts using an analogy of buildings. The system represents classes as buildings and methods as floors. It allows the user (1) to scale the buildings (zoom in and zoom out); (2) to browse source code directly in a virtual reality environment; (3) to change the color scheme to filter between static aspects (metrics and coupling), dynamic aspects (trace visualization using disharmony maps), evolution (contribution of authors and the change of static aspects in a specified period); (4) to select objects that could be grabbed or triggered. To grab an object, they simply push grip buttons, which is like the motion required to grab a real-world object. To trigger an action attached to an object, a user must push the trigger button. Scrolling is provided by the trackpad button. To scroll up or down, a user just simply swipes his finger across the track pad area on the HTC Vive controller. |
| Ochoa and Babbit (2019) | The system allows the user of the HTC Vive Controller to: draw lines between models, move models, filter the element; spawn UML elements in hand, in other words, students could create software analysis models which are typically created (as use case models) and manipulate their elements. The system presents the elements in a digital menu with all available models and their elements. The requirements found throughout the text are at the user level. |
| Tanielu et al. (2019) | OopVR is an application which uses VR to visualize object-oriented programming concepts using an analogy of buildings. The system allows the user to: visualize classes as a blueprint of a house, view instances of a class in the form of houses, visualize a method in the form of rooms inside the house; view variables and their values in the form of boxes inside the room; visualize the entry point of a method as the shape of a bedroom door; visualize method arguments placed on windowsills outside a room; visualize the accessibility of the fields in the center of the house; visualize the allocation in memory like the land of a house; visualize the address in memory in the form of a house mailbox; visualize the encapsulations by solidifying the walls of the house. |
| Zhao et al. (2019) | The paper describes an application where the student can see the visualization of the functional requirements of a customer’s request, and the parts that the user can select for the construction of the selected object; interaction with objects; construction of objects; the user to teleport between seven stations related to the object’s assembly process. To display that, the student uses HTC Vive, wireless controllers, and base stations for motion tracking. |
Table 8: Studies per interaction categories.

| Category               | Description                                                                 | Related Studies                                                                 |
|------------------------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Moving around          | Students can explore the virtual environment, whether by teleporting or flying. | Elliott et al. (2015) Merino et al. (2017) Oberhauser and Lecon (2017) Tanielu et al. (2019) Vincur et al. (2017) |
| User-generated content | Students can create new content, such as 3D models, and upload that new content to the virtual environment. This design element also applies when user-generated content can be shared with other users so that they can use it in their virtual environment. This design element does not apply when students can only access virtual objects that were created by developers and provided by a library in the virtual environment. | Elliott et al. (2015) Merino et al. (2017) Oberhauser and Lecon (2017) Tanielu et al. (2019) Vincur et al. (2017) |
| Assembling             | Students can select virtual objects and place them together, including creating new objects by assembling multiple individual objects. | Elliott et al. (2015) Ochoa and Babbit (2019) Zhao et al. (2019) |
| Basic interaction with objects | Students can select virtual objects and interact with them in different ways. This includes retrieving information about an object in written or spoken form, picking and rotating, zooming in on objects to see more details, and changing an object's color or shape. | Fittkau et al. (2017) Merino et al. (2017) Vincur et al. (2017) |
| Instructions           | Students have access to a tutorial or to instructions on how to use the VR application and how to perform the learning tasks. The instructions can be given by text, audio, or a virtual agent. This design element does not apply when students have to discover how to use the virtual environment or how to perform learning tasks on their own. | Zhao et al. (2019) |
| Passive observation    | Students can look around the virtual environment. This design also applies to applications where users can travel predefined paths and look around while doing so. However, they are not able to move around the environment through them, nor are they able to interact with virtual objects or interact with other users. | Akbulut et al. (2018) |

first station as a customer demanding requirement. We could identify the developer as the student producing the manufactured product. There were no interactions with virtual users.

4.5 RQ5: Which Unified Model Language (UML) diagrams were adopted and how they were used and designed by students in VR systems?

With this question, we wanted to identify which and how UML diagrams and models are manipulated in systems with VR.

Only two studies used UML elements and diagrams. By analyzing the attributes in question 2, we could identify that the Tanielu et al. (2019) VR application is a playful version of a class diagram. It allows the user to visualize classes, instances of methods, variables, the entry point of a method, parameters of a method, accessibility of fields, the instance in memory, and its address. Ochoa and Babbit (2019) presented an interactive software that comprises the connection of floating instances to each other, containing diagrams of use case, state, and data flow.

Ochoa and Babbit (2019) and Tanielu et al. (2019) gave us different perspectives on how to display UML diagrams to the student. Ochoa and Babbit (2019) allowed the user to connect UML diagrams interacting with it inside the HMDs, with an approach aiming at a requirement engineering educational tool. On the other hand, Tanielu et al. (2019) exploited VR playfully, but did not allow much interactivity with objects, keeping the application as a fly-through.

4.6 RQ6: Which were the target hardware of the studies?

To understand what each application could offer to the student, it is important to understand what each hardware can offer to the developers. In order to answer this research question, Table 9 shows which HMDs are being used in the selected educational projects.

It is worth mentioning that we contacted by email the authors from Tanielu et al. (2019) and Vincur et al. (2017) studies to clear doubts regarding the hardware used.
was applied to all students in both groups, and when
To identify the effectiveness of VR environments for
applications using a small sample. This makes it difficult
observe that all the selected studies evaluated their
application to support teaching a subject. But we could
research on user feelings before and after using a VR
evaluate their applications. Most studies base their
results. following the definitions of Radianti
selected articles, with Positive (P), Negative (N) or Not
evaluated and what their results are. Of the nine selected
articles, only seven describe some type of evaluation.

The application of Akbulut et al. (2018) was used by
a group of 18 students during 2 hours of practical class
per week, while another group of the same size and class
schedule was not exposed to the VR class. At the end of
the teaching period, a questionnaire with 10 questions
was applied to all students in both groups, and when
comparing the results, it was noticeable that there was
a higher learning gain in the group that had used the
technology.

Two students used the application of Oberhauser and
Lecon (2017), who had to analyze in VR and non–VR a
project and its classes, dependencies, sizes and answer
a questionnaire about the system usability in a learning
context. It was concluded that there was no significant
difference between analysis times.

The application of Tanielu et al. (2019), on the
other hand, was evaluated by measuring the degree of
confidence of students through questionnaires before and
after the use of virtual reality. The study was applied to 17
students in the computer science course and the results
were positive.

In Zhao et al. (2019), twelve engineering students took
part in the evaluation. First, they answered a survey with
conceptual, analytical, and cognitive questions. Then they
tested the game in virtual reality. The same survey was
inside the game to verify learning. The paper unpublished
the results.

| Utilized hardware | Studies |
|-------------------|---------|
| Google Cardboard  | Akbulut et al. (2018) |
|                   | Tanielu et al. (2019) |
| HTC Vive          | Merino et al. (2017)  |
|                   | Oberhauser and Lecon (2017) |
|                   | Ochoa and Babbit (2019) |
|                   | Vincur et al. (2017)  |
|                   | Zhao et al. (2019)    |
| Oculus Rift       | Elliott et al. (2015) |
|                   | Fittkau et al. (2017) |

4.7 RQ7: How were the virtual teaching environments in SE or RE evaluated?

To identify the effectiveness of VR environments for
education, it is important to understand how they were
evaluated and what their results are. Of the nine selected
articles, only seven describe some type of evaluation.

The application of Akbulut et al. (2018) was used by
a group of 18 students during 2 hours of practical class
per week, while another group of the same size and class
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the results.

Table 9 shows the validation strategies used by the
selected articles, with Positive (P), Negative (N) or Not
Informed (NI) results. following the definitions of Radianti et al. (2020).

Despite the lack of evaluation of some articles, we
can identify that all articles take an empirical approach
to evaluate their applications. Most studies base their
research on user feelings before and after using a VR
application to support teaching a subject. But we could
observe that all the selected studies evaluated their
applications using a small sample. This makes it difficult
to confirm the validity of the experiment.

| Utilized hardware | Studies |
|-------------------|---------|
| Google Cardboard  | Akbulut et al. (2018) |
|                   | Tanielu et al. (2019) |
| HTC Vive          | Merino et al. (2017)  |
|                   | Oberhauser and Lecon (2017) |
|                   | Ochoa and Babbit (2019) |
|                   | Vincur et al. (2017)  |
|                   | Zhao et al. (2019)    |
| Oculus Rift       | Elliott et al. (2015) |
|                   | Fittkau et al. (2017) |

4.7 RQ7: How were the virtual teaching environments in SE or RE evaluated?

5 Discussions and conclusions

The aim of this paper was to review the literature to
develop applications with Virtual Reality in Software
and Requirements Engineering education. Virtual
reality technology can assist in the development of
applications that require user immersion to make learning
more effective. One task of a software engineer is
to communicate constantly with the stakeholders and
teammates. So, one skill that could be improved in
the students, with the immersion characteristics of VR,
is this communication with these partners. From this
conversation, several software models (use cases, classes,
etc.) emerged and are improved. These were the features
we sought in this systematic review of how they would
have been developed. The review conducted of only
nine papers found using explicitly VR HMD in software
engineering education.

We found it three subjects using simple interactions or
immersive visualizations: Programming, Requirement,
and Software Architecture. By checking the other project
categories of Radianti et al. (2020), we can note the
absence of replication of real worlds and the interaction
with other users. We found only one paper (Ochoa
and Babbit, 2019) that students can create use cases
and data flow diagrams. Although Zhao et al. (2019)
is not specific to Software Engineering, we selected it
because it simulates a very simple software development
process, starting with user requirement. Still using the
Classification of Radianti et al. (2020), we noted a lack
of resources from the learning environment, such as
immediate feedback, knowledge testing, virtual reward,
the possibility for the teacher to assign and evaluate
learning tasks and view student progress.

Almost all papers used expensive technologies as HTC
Vive and Oculus Rift. If we want to spread the application
or that it is replicable by other researchers, it is more
interesting to look for cheaper technologies. Even allowing
students to use the learning environments from their
homes, or anywhere they went from the educational
institution, an alternative is to use mobile devices like
Google Cardboard or Apple Glasses.

Finally, many authors consider VR as a valid tool
for teaching practically. However, for methodological
approaches, we did not find statistical evidence. This happened because the researched works are pilot studies with a small sample and in a specific context. As noted by Radianti et al. (2020), this may raise doubts about the real effectiveness of validations.

Although virtual reality is being widely used in the teaching of medicine and other engineering courses, remarkably, how this technology still lacks maturity in the teaching of software engineering. Reaffirming what was mentioned earlier by Thiry et al. (2010), universities are not properly preparing students for software requirements tasks. We believe that simulating real environments with virtual reality can offer the chance for these students to learn as if they were already in their professional lives.

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