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IMMERSIVE TECHNOLOGIES APPLIED TO COMPUTER PROGRAMMING TEACHING: A SYSTEMATIC REVIEW

Tecnologias imersivas aplicadas ao ensino de programação de computadores: uma revisão sistemática

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ABSTRACT

One of the first challenges for the students that begin to study the computing field is to learn how to program a computer. Nowadays, digital immersive environments are being used in Education with positive results. This paper presents a systematic literature review about the usage of immersive environments (VR or AR) in the teaching and learning of logic and/or computer programming. This paper presents the bases of scientific papers used to search the literature, the results and an analysis of the papers found.
Keywords: Immersive Technologies; Computer Programming Teaching; Computer Program Learning

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TECNOLOGIAS IMERSIVAS APLICADAS AO ENSINO DE PROGRAMAÇÃO DE COMPUTADORES: UMA REVISÃO SISTEMÁTICA

Immersive technologies applied to computer programming teaching: a systematic review

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RESUMO

Um dos primeiros desafios para os alunos que começam a estudar a área de computação é aprender a programar um computador. Atualmente, os ambientes digitais imersivos estão sendo utilizados na Educação com resultados positivos. Este artigo apresenta uma revisão sistemática da literatura sobre o uso de ambientes imersivos (RV ou RA) no ensino e aprendizagem de lógica e / ou programação de computadores. Este artigo apresenta as bases de artigos científicos utilizados para a busca na literatura, os resultados e uma análise dos artigos encontrados.
Palavras-chave: Tecnologias Imersivas; Ensino de Programação de Computadores; Aprendizagem de programas de computador.

INTRODUCTION

For every teacher, the act of teaching is a constant challenge. It is common teachers to face with subjects that demands creativity to be clearly explained for the students, in a way that allows the students to complete understand it. In this context, more precisely related to the teaching of technological skills, one of the initial concepts in the Information Technology (IT) field is the programming logic. This subject, together with the learning of programming languages, allows the student to begin having autonomy in this vast knowledge field. By using programming logic and, consequently, programming languages, the student comes to understand how computer programs are created and how to create their own. One may say that to learn programming logic, by algorithm creation and the learning of a programming language, is a fundamental and very important step to any student, which desire to enter the IT field. In addition, some countries have the concerning to develop these skills in students starting from the early school years, as their educational managers understand that this action will generate positive impacts in future, both economically and in the ability of their citizens do adapt to possible changes that may occur (da Silva, 2015).

There are many challenges in teaching and learning computer programming. In a paper that presents and categorize these difficulties, some of these challenges are divided in five categories (Du Boulay's, 1986 as cited in Kinnunen, 2009):

1 - Problem of Orientation: indicates this challenge as the problem of the student to understand how important is to learn computer programming and which are the types of problems that may be solved using this skill.

2 - Notional Machine: indicates this as the challenge of understanding the relation of the hardware and the conceptual machine that a computer represents. It is indicated, for example, that some students may have the wrong understanding about how a variable is stored in memory and that this fact can make it difficult to understand the subject as a whole.

3 - Notation of Formal Languages: indicates that this challenge is related with the understanding the syntax and semantics related to programming languages. It is indicated that it is the most common issue and the one that the students ask for help the most (Garner, Haden, & Robins, 2005 as cited in Kinnunen, 2009). In other paper, it is indicated that following issues about basic syntax, doubts about data flow are also the causes of the asking for help from the students (Robins, Haden & Garner, 2006 as cited in Kinnunen, 2009).

4 - Acquiring Structures: another challenge cited by (Kinnunen, 2009) is the one about the acquisition of structures by the student, being structure, in this context, the abstract solutions for standard problems. Some of these structures are: recursion, vectors, repeat loops, constructors, heritage, polymorphism, advanced data structures, pointers, algorithms, references, libraries, methods, operators overload and dynamic memory allocation.

5 - Pragmatics of Programming: this aspect includes developing, testing and debugging programs. Other studies indicate that some students have difficult to understand what have to be solved by a program, i.e., what a program is supposed to do; and how to build programs, i.e., sometimes they understand what the program should do, but they can't think of it in form of an algorithm (Garner, Haden, & Robins, 2005 as cited in Kinnunen, 2009).

The paper of Kinnunen (2009) presents that there are several challenges to teach students how to program a computer. In this way, new manners of teaching have to be used, trying to eliminate or, at least, to decrease the challenges described about this subject.

Immersive Technologies

Nowadays, immersive technologies are being used in several fields of the human knowledge. These technologies gives to the user the sensation of immersion and presence and, for that, virtual artifacts are used. Among immersive technologies, the most used are Virtual Reality and Augmented Reality.

The Virtual Reality (VR) may be summed up, as defined by Jerald (2015), as a total digital environment, totally generated by computer, which has a level of interactivity as if it were real. The goal of this kind of

environment is to remove the perception of the real world from the user, making him/her to feel only the created world, the virtual world.

The Augmented Reality (AR) approach mixes the real world with digital artifacts. May be summed up as an environment in which the user, feeling himself/herself in the real world, interacts with virtual digital elements in a real physical space, in such way that this virtual elements may be seem as something that is real (Tori & Hounsell, 2018).

Both VR and AR are, nowadays, applied to different contexts and knowledge fields. The use of these technologies has stood out in the fields of Medicine, Architecture, Arts, Education, Entertainment, in scientific applications, to assist in the visualization and information control, and others. In all of them, these technologies have allowed results in situations in which were impossible to simulate before (Tori & Hounsell, 2018).

In Education, VR and AR provide immersion and presence to students, increasing their motivation and engagement. In some papers, like (Šašinka et al, 2019), among others, it is presented interesting results about the usage of these kind of technology in the educational context. This type of technology, if applied in educational context of fields like Chemistry, Geography, History and others, allow direct benefits to the students. For example, to watch interactive 3D animations that represent chemistry reactions, to visit virtually specific geographic places or to participate of relevant historical moments, are some of the benefits provided by this technology.

The purpose of this paper is to present a systematic review of the literature about immersive environments being used to teach logic and computer programming. Papers repositories were searched about this subject. The used methodology is described in the next section and the research questions to be answered in this paper are: "how immersive technologies are impacting the teaching and learning of computer programming?" and "what are the benefits and challenges of the use of immersive technologies in this subject?".

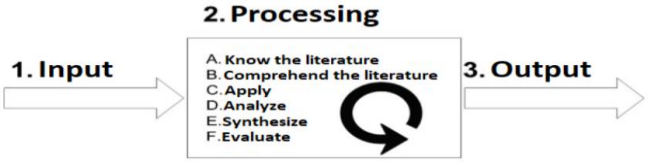
The next sections of this paper are organized in the following order: in Section 2 is presented the methodology used to the systematic review and the paper repositories that were searched and the results. In Section 3 the results of the search and a discussion about them are presented, also how they contribute for the teaching and learning of logic and computer programming using immersive environments. And, finally, in Section 4, the conclusions and final considerations about the subject are presented.

1 METHODOLOGY

The Systematic Review of the Literature (SRL) is a methodology widely used in the Health field, because it ensures that researchers do a wide search in literature to know what has already been researched about some subject and their results. This avoids the waste of resources and time with questions already addressed, allowing the advance in other studies from the state of the art. In this paper, the SRL was used to present a wide panorama about the use of VR and AR in the teaching and learning of computer programming. The chosen methodology is appropriate to the proposed objective, as it involves an extensive and rigorous search of papers in relevant paper repositories (Tranfield, Denyer & Smart, 2003). Furthermore, it is not subject to the researcher bias, as it has a rigorous and explicit investigation process to answer a well-formulated research question (Ferenhof & Fernandes, 2016; González & Toledo, 2012).

Levy & Ellis (2006) claim that a systematic review of literature is proper to demonstrate if a proposal of a research advances to something new and contributes to build knowledge. They propose three steps to a proper SRL, as presented in Figure 1. The Input (Step 1) is the phase in which it is selected the types of documents and platforms that will be researched and establishes a search protocol for a SRL; in Step 2 – Processing, it is the moment in which all the processing is performed, and; Step 3 – Output, it is the consolidation and presentation of insights and conclusions.

Figure 1. 3 steps for a literature systematic review



Source: Levy & Ellis (2006)

The Step 1, in this work, consisted in establish the research question, the general and specific objectives, as described in the following sequence and presented in Figure 2:

Research Questions (RQ): RQ1 - How immersive technologies are impacting the teaching and learning of computer programming? RQ2 - What are the benefits and challenges of using immersive technology in this subject?

General Objective: to understand the general panorama of the use of VR and AR in the programming teaching.

Specifics Objectives (SO): SO1 - To present a panorama of the use of VR and AR in computer programming teaching and learning (methodologies, results and presented conclusions); SO2 - To raise the benefits and challenges of the usage of immersive technologies in this field; SO3 - To identify what are the subjects in the teaching and learning computer programming field in which VR and AR are the most used.

After these considerations, three bases were selected: the platform Web of Science, the digital library of Institute of Electrical and Electronic Engineers (IEEE), IEEExplore, and the digital repository of Association for Computing Machinery (ACM), ACM Digital Library.

The Web of Science was selected for its notorious world reputation (Conforto, Amaral & Silva, 2011), and, it has in its archives more than 21.000 high quality academic periodicals with peer reviewing published all over the world, more than 205.000 conference proceedings; and more than 104.000 selected books (Web Of Science Group, 2019)[1].

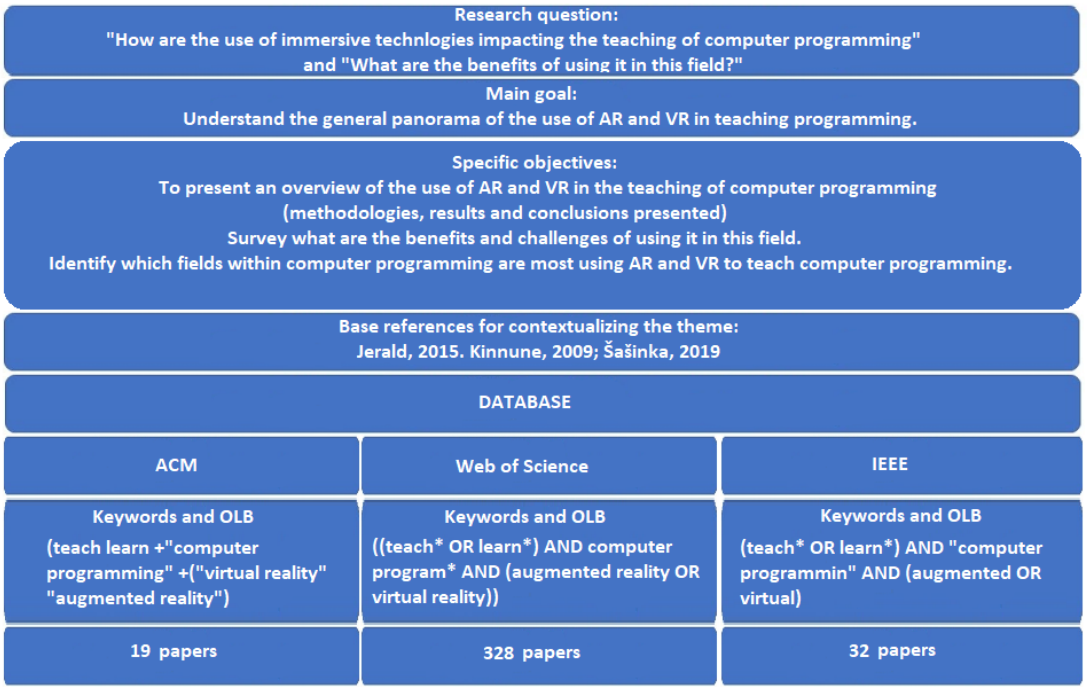
The IEEE is a world-known association dedicated to the advance of innovation and technology and it is the larger technical society of professionals of the world (IEEE, 2019)[2]. For that reason, IEEE's digital library, IEEExplore, was also chosen.

The motivation to choose ACM Digital Library repository was the same, as ACM's purpose is to gather educators, researchers and professionals of computing to inspire the dialog, share resources and discuss the challenges of the area, building the larger society of computing in the world (ACM, 2019)[3].

After the decision about the research question, objectives and repositories, the keywords and Boolean Logical Operators (BLO) were defined based on the subject. The search for the right keywords is a great challenge in SRL and, because of that, the authors opted by using some base papers and two research constructs: computer programming teaching and learning and VR and AR, as depicted in Figure 2, to find the better words and their synonyms and terms. As each base has its own characteristics in its search engine, it was necessary to run tests to know what are the more appropriated set of keywords and BLOs. After the searches, that were done between 13th and 23rd of September of 2019, the total of 379 papers were selected from the chosen repositories. The queries used are presented in Figure 2.

[1] https://clarivate.com/webofsciencegroup/solutions/webofscience-platform
[2] http://www.wwwieee.org
[3] dl.acm.org

Figure 2. Base structure of the research



Source: Elaborated by the authors

The Step 2 started with a brief reading of the titles of the papers. But, in the case of Web of Science, it was noticed that the search brought more papers from fields very different from Education, programming, computing, VR and AR. Because of this fact, it was necessary to exclude papers of those fields and also papers that were not scientific papers peer reviewed. After the application of these criteria, 68 papers from the Web of Science were selected to the reading of title and abstract, resulting 119 papers in this stage from all repositories.

After that, all titles and abstracts of all 119 selected papers were read, and the following criteria were defined to exclude some of them: i) papers that do not present studies of VR and/or AR being applied to teaching or learning of computer programming; ii) papers in languages other than English or Portuguese; iii) documents that were not peer reviewed. After this stage, 18 papers were selected for a full reading and analysis. In Table 1 is presented the results of this selection, for all stages, for all repositories.

Table 1: Final selection of resulting papers from researched bases.

Repository	Papers from used keywords and BLO	Papers after exclusion of other themes and document types	Papers for analysis after reading the titles and abstracts
ACM Digital Library	19	19	04
IEEE XPlore	32	32	11
Web of Science	328	68	03
Total	379	119	18

Source: Elaborated by the authors

Still in Step 2, the papers were submitted to the content analysis technique. According to Vergara (2005), the content analysis aims to understand what is being said about some subject. A central element for content analysis is the construction of analysis categories. In this sense, the initial categories, according to Vergara (2005), are redefined in the analysis process until a final set is obtained. In this paper, three categories were defined:

1 - Applicability to the problem of teaching and learning of computer programming: the papers were analyzed in relation to their contribution into the subject. Five subcategories were defined, the same found in (Kinnunen, 2009) and presented in Section 1 of this paper.

2 - Methodology: the papers were analyzed in relation to their methodology. Four subcategories were defined: i) case study; ii) research/action; iii) experiment; iv) others;

3 - Results: the papers were analyzed in relation to their results, being considered as i) conclusive; ii) a paper that presents the benefits of applying VR or AR in the teaching and learning of computer programming; iii) a paper that presents the challenges of this subject.

All analysis categories, their subcategories and their purposes are presented in Table 2.

Table 2. Categories of analysis, their subcategories and purpose

Category	Subcategories	Purpose of the paper
1- Applicability to the subject of teaching and learning computer programming	i) Problem of Orientation ii) Notional Machine iii) Notation of Formal Languages iv) Acquiring Structures v) Pragmatics of Programming * All this subcategories are based on (Kinnunen, 2009)	To understand what kind of challenge is being solved with the use of VR and AR in teaching and learning computer programming; the importance of learning computer programming; the challenge of understanding the relationship between the computer (hardware) and the conceptual machine by the student; the learning of the syntax and semantics related to computer programming languages; the abstraction of solutions of standard problems; the difficult to understand what a program should solve; others.
2- Methodology	i) case study ii) research/action iii) experiment iv) others	To define the methodology used and the size of the sample.
3- Results	i) conclusives or not ii) benefits iii) challenges	To identify if the results are conclusive or not. If benefits and challenges were addressed and what they are.

Source: Elaborated by the authors

Finally, the information triangulation process was carried out, analyzing convergent and divergent points of the papers. They were also counted by categories and subcategories, authors, year, publishing type (journal or conference proceedings) and knowledge field. According to the objectives of the papers, they can be classified into more than one category.

2 RESULTS

In this section the results (Step 3) related to the search and reading of selected papers are presented, considering the categories and subcategories presented in Table 2.

2.1 Applicability to the problem of teaching and learning computer programming

In Table 3 it is presented the relation between the papers and their subcategories in Category 1, as described in Section 2. For each subcategory, the following were considered: i) Papers that address the importance of computer programming were considered in the subcategory “Problem of Orientation”; ii) Papers that describe systems that present, even superficially, how is the abstract machine a computer represents, were considered in subcategory “Notional machine”; iii) Papers that present approaches in which the student must code, even code snippets, using some programming language, and not only manipulating virtual artifacts, were considered in the subcategory “Notation of formal languages”; iv) Papers that describe systems that present, even if conceptually, structures of programming, whether structures of decision, repetition or even data structures, were considered in the subcategory “Acquiring structures”; v) Papers that present activities that students must chain or order instructions to obtain a certain result, were considered in subcategory “Pragmatics of programming”.

As presented in Table 3, only 4 of the papers were considered entirely within the scope of this paper. An important characteristic to be mentioned here is that it was common to find papers that present computer games (both 2D and 3D) to assist in teaching and learning computer programming. These papers, although interesting, were excluded from the analysis presented here, as immersive technologies were not used by their authors. This is perhaps the biggest reason why, in the end, few papers were selected as suitable for the scope of this paper. It is possible, therefore, to increase the number of papers selected in a future research by relaxing the criteria not consider only immersive technologies.

Table 3. Subcategories of Category 1 found in the read papers.

Cat. 1 - Subcategories (Kinnunen, 2009)	Analyzed papers
a) Problem of Orientation	(Chandramouli, Zahraee & Winer, 2014)
b) Notional Machine	(Singh, 2017)
c) Notation of Formal Languages	(Lückemeyer, 2015), (Chandramouli, Zahraee & Winer, 2014)
d) Acquiring Structures	(Singh, 2017), (Masso & Grace, 2011), (Lückemeyer, 2015), (Chandramouli, Zahraee & Winer, 2014)
e) Pragmatics of Programming	(Singh, 2017), (Lückemeyer, 2015)

Source: Elaborated by the authors

2.1.1 Description of the papers considered within the scope of the research

In (Singh, 2017) it is described the use of a VR environment for teaching computer programming. Within the environment the user can visualize variables, which are represented by virtual cubes, and the assignment of values to it, as virtual spheres, on top variables, with the value on its surface (subcategory “Notional machine”). As the user progresses, other structures of programming languages are presented, such as repetition loops (subcategory “Acquiring structures” and “Pragmatics of programming”). The paper does not present tests or data about the success or failure of the project from the user perspective.

In (Masso, Grace, 2011) it is presented a game that uses AR to teach the fundamentals of computer programming. Using a digital board, users play virtual cards to solve challenges programming concepts (subcategory "Acquiring structures"). The game was tested by volunteers, that reported to be interested and suggested some improvements.

In (Lückemeyer, 2015) it is presented a VR environment solution shared among students to learn computer programming. The author mentions that the idea originated from the need to engage students and avoid dropout. A 3D environment was created in which students can interact with each other and, using virtual panels, write codes and solve programming exercises (subcategories "Notation of formal languages", "Acquiring structures" and "Pragmatics of programming"). Although it is reported in the paper that any immersion equipment was not used, due to its high cost, the system is fully compatible with these devices. There were no tests or results presented in the article.

The research by Chandramouli, Zahraee & Winer (2014) sought to solve the lack of motivation to learn computer programming. To this purpose, they built a VR framework with interactive and fun instructions. According to the authors, students have difficult to learn the subject and do not feel motivated to face this challenge, since they do not understand the importance of this knowledge for their professional life (the “Problem of Orientation”). However, despite the VR environment helped to explain variables and data types, present actual code (“Structures acquisition” and “Notation of formal languages”) and develop critical thinking and problem solving skills, the paper didn’t evaluated the effectiveness.

2.2 Methodology used by the selected papers

The papers were considered: i) case study, ii) research/action, iii) experiment or iv) others. A problem in several papers read was the lack of methodology. Most papers, including those outside the scope of this research, only present the application developed. Some do not have any methodology and/or testing, such as (Singh, 2017), (Chandramouli, Zahraee & Winer, 2014) and (Lückemeyer, 2015). Only Masso & Grace (2011), of the 4 selected, presented test results from interviews with users, without analysis of the answers. In this regard, the papers that were analyzed are more similar to project reports, due the lack of literature review, analysis of data and results. This facts occurred, even though the selected papers were obtained in repositories recognized by the scientific academy. It is believed that these facts are due to lack of research within the scope chosen for this systematic review.

2.3 Results

The papers may be analyzed from 3 perspectives: if the paper is conclusive, presents benefits of the usage of VR or AR in the teaching and learning of computer programming or presents the challenges of this approach. None of the 4 papers are conclusive, since their methodologies were not sufficient to support final considerations (Singh, 2017; Chandramouli, Zahraee & Winer, 2014; Lückemeyer, 2015). Masso & Grace (2011) conducted interviews, but they did not have much rigor for their conclusions. On the challenges, Chandramouli, Zahraee & Winer (2014) generally point out the issue of creating something new, different from the usual, as the 3D scenarios for this purpose. Regarding the benefits, the authors state that the technique allows students to overcome the inhibitions they may have due to complexity involved in learning computer programming, as they are encouraged to explore the subject using practical examples.

2.4 Quantitative Results

As the number of papers selected is low, the quantitative analysis is not broad. Regarding the authors of the 4 selected papers, none has participated in more than one paper. Regarding the publication, all were published in congress proceedings, none in journal. Table 4 presents information about the 4 papers.

Table 4. Overview of the papers analyzed within the objective of this study

Authors	Title	Congress/Event/Journal	Field
Masso & Grace, 2011	Shapemaker: A game-based introduction to programming	16th International Conf. on Computer Games (CGAMES)	Games
Lückemeyer, 2015	Virtual blended learning enriched by gamification and social aspects in programming education.	10th International Conference on Computer Science & Education (ICCSE)	Computing and Education
Chandramouli, Zahraee & Winer, 2014	A fun-learning approach to programming: An adaptive VR platform to teach programming to engineering students	IEEE International Conference on Electro/Information Technology	Electronic and IT
Singh, 2017	Using Virtual Reality for Scaffolding Computer Programming Learning computer programming, interactive learning environments, technology-enhanced learning, virtual reality in education	VRST 17 - Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology	Virtual Reality

Source: Elaborated by the authors

As seen, all events are related to technology and only one has the Education field explicitly in its scope. The years of publication of the 4 papers range from 2011 to 2017, which shows that there is been interest in this matter. Considering all the papers selected, the years vary from 2005 to 2018, which corroborates this deduction. The knowledge fields involved are Engineering and Informatics in Education, which was expected.

CONCLUSION

In this paper, a systematically review of the literature about "use of immersive technologies in the teaching and learning of logic and computer programming" was presented. After the initial search, some papers were selected according to their relevance to the subject. Due to the criteria defined, only 4 papers met the requirements. They were classified within the categories and subcategories and analyzed in relation to their contribution to the subject. It is possible to conclude that, due to the specificity of the subject, it is something scarce in the literature, thus opening research opportunities for the future.

As a future work, a new analysis of papers about the use of immersive environments in all Education field, in order to consider a greater number of articles for analysis is suggested.

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