Use of Virtual Reality and Augmented Reality in Learning Objects: a case study for technical drawing teaching

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Abstract
Educational resources are being used by teachers to facilitate the way students learn content. Information and Communication Technologies provide greater opportunities for making learning more effective, given that visualization and interaction assist students in effectively mastering materials. However, technologies such as Virtual Reality (VR) and Augmented Reality (AR) are difficult to be implemented by teachers with minor computer experience. Thus, this paper presents a method for the generation of Learning Objects (LO) with the use of VR, AR and open source software for Internet applications. A case study was carried out with an application development for discipline of Technical Drawing. As a result, in addition to a LO, a flowchart for the implementation of VR and AR projects was developed. The feasibility of execution highlights the possibility of extending the proposed LO and the flowchart to other topics of Technical Drawing as well as to other disciplines.
Keywords: learning objects; higher education; virtual reality; augmented reality; technical drawing.

1 Introduction

Mediated by multiple and sophisticated technologies, new ways of thinking, acting and communicating are becoming everyday habits (Porto, 2006). That statement which is focused on the constant changes in daily life can also be applied to the classroom environment.

There is a growing interest among young people for computers, games and the internet. In contrast, there is a discouragement by the traditional teaching methods. The textbook and the classroom board are still widely employed in the classrooms. However, these materials do not attract the attention of students anymore. They are considered tedious and boring and do not provide an adequate interaction (Silva, 2012).

A new communication scenario has been defined by the use of information technology in education. This tool enriches the curricular activities and strengthens effective participation of students, based on operational and/or cognitive interactivity (Silva, 2001; Souza Filho, 2010). Consequently, the acquisition of knowledge becomes more efficient and enjoyable. According to Cavalcante, Bonizzia & Gomes (2009), teaching specific contents, which results were obtained only in paper, may, by computer assisted instruction, be visualized through movements, sensations and images. Among the technologies that have been used as support tools for education, Virtual Reality (VR) and Augmented Reality (AR) can be highlighted.

Able to support the process of knowledge transmission, VR and AR can simulate real situations, or not, in controlled environments, without the need for users to be physically in the place where they are interacting (Azuma et al., 2001; Tori, Kirner & Siscoutto, 2006). However, despite being mature in the scientific area, such technologies are not present, effectively, in the educational area. In the survey carried out by Guimarães & Martins (2013), the authors verified that, due to the complexity involved, these applications are developed by computer specialists. Content creation to the common user is a challenge if technology is not applied in everyday life (Van Krevelen & Poelman, 2010). Therefore, it is still difficult to verify the widespread adoption of these technologies by teachers (Martins & Guimarães, 2012).

In this context, this article aims to present a method for the generation of Learning Objects (LO) with the use of VR and AR. With this, it is intended to aid teachers, especially those with minor experience in computing, in the use of internet technologies based on open source software.

To demonstrate the feasibility of the method, a case study was carried out, with the application of Virtual Reality and Augmented Reality in an LO for the discipline of technical drawing. In addition to being the basis for so many undergraduate courses, the technical drawing extends beyond the frontier of the classroom and permeates the entire education of engineers, architects and product designers.

2 Teaching and motivation

The teaching process is characterized by activities that involve teachers and students. Under the teacher’s instructions, the students will progressively reach the development of their cognitive skills. Effective teaching practice depends on the systematic work of the teacher who should combine objectives, contents, and teaching methods for both planning and development in the classroom (Libâneo, 1994).

In higher education, most students are adults. Unlike children and adolescents, these individuals have acquired information and experience through their life trajectory. To keep adults motivated, the teacher should not focus on learning itself, but should share it and build it along with the student. Otherwise, recurrent reports of teachers reveal that undergraduate students demonstrate little interest, act passively and present low academic results (Oliveira, 2017).

Motivation is an important factor for students to learn certain content. When motivated, the students’ mental states, including attention and perception, are activated and can contribute to the learning process (Silva, 2012).

Neves & Boruchovitch (2004) claimed that the quality of education has been widely discussed by psychologists, teachers, educational psychologists, sociologists and education related agencies. These professional seek to ascertain the factors that interfere with school success. In addition, the authors pointed out that there is a serious concern with the high levels of violence, lack of interest and fail. Cunha, Tunes, Silva (2001); Gilioli (2016) referred to the latter as one of the main factors for students to abandon the public higher education courses, especially when fail occurs during the first four semesters. In order to reduce the dropout, it is the responsibility of the teacher to help students by integrating learning strategies into instruction and creating educational resources to improve motivation.

Among the learning strategies, Amaral (2007) described five types that help enhance knowledge acquisition in adults: (1) rehearsal strategy (repeat what the individual wants to learn); (2) development strategy (establish relationships between what is already known about the subject and what the individual wants to learn); (3) organizational strategies (list, classify and organize the material to be studied); (4) comprehension monitoring strategies (be aware of what has been understood and what has not); and (5) affective strategies (control emotional factors to maintain attention, performance and motivation). The students should also be able to define the best strategy to be used in the learning process. In addition, the teacher can also use them in the classroom in order to contribute to their learning process (Oliveira, 2017).

In turn, teaching resources are used by teachers to facilitate the understanding of what is being proposed to the student and convert data into meaningful information (Gil, Garcia, Lino & Gil, 2012). Some classroom resources include lectures, practical classes, group discussions, conceptual maps, seminars and the use of Information and Communication Technologies (ICTs).

For Silva (2012); Oliveira (2017), the use of ICTs is more beneficial to the student learning process, given that visualization and interaction assist students in effectively mastering materials. ICTs may include software, electronic games, blogs, audio visual resources, among others. Teachers are turning to innovative methodologies to make classroom activities more practical and exciting and thus contribute to the construction of knowledge.

Among the technological tools used in education, the internet has caused a great impact on the teaching-learning process. The use of internet has (re)signified the educational process, taking into account the increasing amounts of data that are transmitted to students at higher speed (Braga, 2014). Although it is regarded as an advantage, this availability can become a barrier since it is difficult to select what can be useful. Also, a great amount of materials were developed in large blocks (such as complete courses, software and videos) and were considered limiting factors for its use (Miranda, 2004).

Therefore, the concept of Learning Objects (LO) was created to overcome these barriers. Based on Object-Oriented Programming of Computer Science, the teaching modular elements of ICT-based education can still be considered a recent technology. However, there is still no consensus with regards to its definition. Wiley (2000), one of the pioneer researchers in this area, defined LOs as any digital entity which can be used, re-used or referenced during technology supported learning.

In this context, VR and AR are tools that may be applied to the improvement and/or development of LOs to facilitate learning in a classroom setting as well as in Distance Education.

3 Virtual reality and augmented reality in education

VR consists of an advanced interface for computational applications with which the user can move and interact in real time in a 3D environment (Pimentel & Teixeira, 1995; Bryson, 1996; Romão & Gonçalves, 2013; Tonin & Gonçalves, 2013). VR can be classified as immersive or non-immersive due the sense of presence that it provides. In immersive VR, the user is transported to the virtual world through the interaction related to the computer's ability to detect the user movements (captured by multisensory devices, such as head-mounted display and electronic gloves). In nonimmersive VR, there is a predominance of the virtual, but the user interact with the application through a monitor or a projector and the input devices are, for example, keyboard and mouse (Tori, Kirner & Siscoutto, 2006; Tonin & Gonçalves, 2013).

Augmented reality is a subcategory of Mixed Reality which can be defined as the merging of virtual 3D objects (Virtual Environment) into the Real Environment in which is shown to the user by means of technological devices in real time (Azuma et al., 2001; Huff, Nedel, Oliveira & Freitas, 2004; Tori, Kirner & Siscoutto, 2006). The transition between the Virtual Environment and the Real Environment divides Mixed Reality into two categories: Augmented Reality, which is closer to the real world; and Augmented Virtuality, which is closer to the virtual world (Milgram, 1994; Siscoutto & Tori, 2004; Providelo et al., 2004). As AR integrates the scope of this work, a major focus will be given to this technology. According to Azuma (1997), Tori, Kirner & Siscoutto (2006), Tonin & Gonçalves (2013), AR can be classified according to four visualization displays:

- *Monitor-based image*: images of real objects are captured by a video camera, merged to images of the virtual environment and shown to the user through a monitor;
- *Direct optical vision system*: allows the users to see the real environment. Users can see virtual images generated by computer using a head-worn system;
- *Vision system based on video camera*: the real environment is captured by a video camera. This image is merged to the virtual computer images projected along the viewer's line of sight through small displays attached to a head worn projector;
- *Optical vision system based on projection*: images containing information about a particular real object are projected directly on its surface.

Due to numerous possibilities provided by VR and AR, these technologies are being applied as tools to support different education levels. Yilmaz (2016) describes educational toys developed with AR for early childhood education. The results of the study showed that the use of educational toys (which included puzzles and learning cards of animals, fruits, vegetables, vehicles, objects, professions, colors, numbers and shapes) could be effectively used in early childhood education. The didactic model developed by Huang, Chen & Chou (2016) investigated how AR was used in environmental education of middle school students. Compared to traditional didactic field trips, the interactive interface of the AR system motivated students to learn to a greater degree. In higher education, VR had been applied in Medical School by Lam, Sundaraj & Sulaiman (2013). Meanwhile AR had been used in Mechanical Engineering by Okimoto, Okimoto & Goldbach (2015). Although these virtual technologies and areas of knowledge are distinct, both studies have showed that the use of these tools helped teachers to strengthen certain topics before engaging students in practice activities.

Given this scenario, tools such as Virtual Reality and Augmented Reality have been used in several areas of knowledge and, therefore, can be considered viable alternatives to be implemented in the discipline of Technical Drawing.

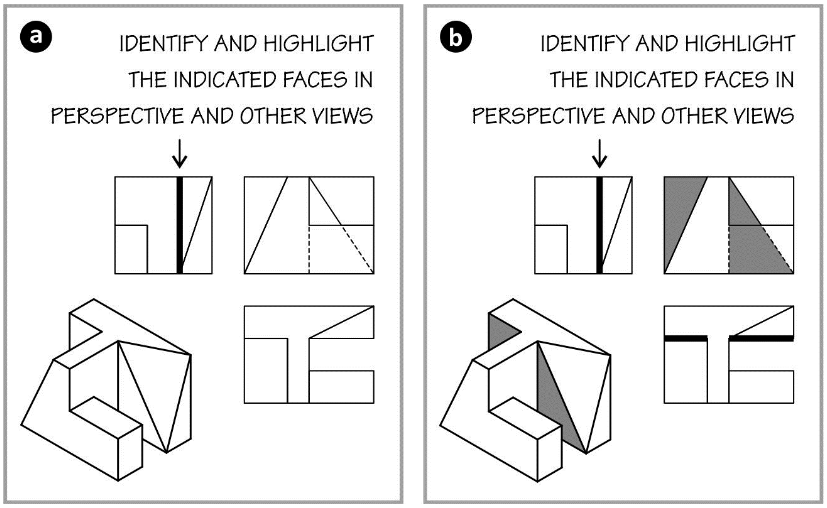
4 Case study: Development of a Learning Object for Technical Drawing

In the disciplines of Technical Drawing at the Federal University of Rio Grande do Sul (UFRGS), two representation systems were applied: orthographic views and perspectives. The research developed by Peixoto (2004) revealed the difficulty of engineering students in interpreting and transforming the objects from one system into another.

This finding corroborates a survey conducted during four consecutive semesters in the disciplines of Technical Drawing. It was observed an average of 48% errors in the assignments involving both the drawing of the orthographic views of an object in perspective. Remedial instructions were applied to approximately 25% of the students and the error rate was 58%.

To demonstrate the method to develop a Learning Object with VR and AR, an exercise from the textbook used in the classroom was selected. For the assignment (Figure 1), an object in perspective and the three orthographic views that represent it were displayed. The student was instructed to identify the element in question (face or edge) and then highlight it in other object projections.

Figure 1: Question (a) and answer (b) of the exercise.



Adapted from Bornancini, Petzold & Orlandi Junior (1987).

Considering that this was the first contact the students had with the two representation systems, it was considered appropriate that the LO was developed to support this learning activity.

4.1 Development of a Learning Object using VR

The development of a LO using VR was based on open source software for Internet applications, with WebGL (Web Graphics Library). WebGL is an application programming interface (API), i.e. a library, a set of subroutines and patterns used for the application development. Specifically, the WebGL is an API intended to generate low-level 3D graphics with ECMAScript, which is a script-based programming language. JavaScript is the main implementation of ECMAScript and it was used in this work. JavaScript is most commonly used as a client side scripting. It enables interaction with the user without having to wait for the server to react. Thus, the browser can be controlled and the displayed content can be changed in real time.

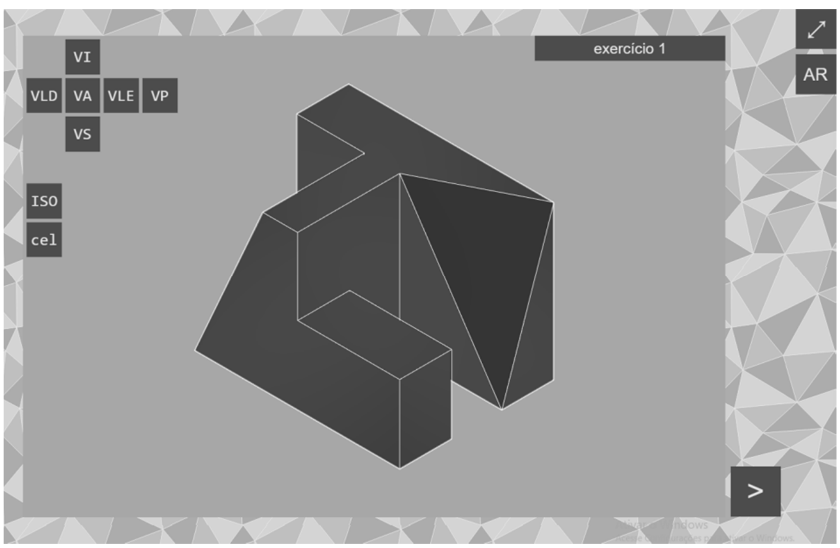
The application was designed to display a 3D model on a web page, using HTML5 (Hypertext Markup Language, version 5) which is a language for structuring and presenting content on the Internet. This is done using Canvas element, which is a container to dynamic rendering of graphics, 2D shapes and bitmap images via scripting (usually JavaScript). Dynamic graphics manipulation is what allows the generation of animations, games and interactive 3D content. With this, interactive 3D content can be displayed directly in the web browser, without the need to install extensions or plug-ins.

With the purpose of achieving independence of specific browsers or operating systems, all codes were developed using the World Wide Web Consortium (W3C) specifications. W3C is an international community community that develops open standards to the Web. WebGL is designed and maintained by the non-profit Khronos Group. Major browser vendors Apple (Safari), Google (Chrome), Microsoft (Edge), and Mozilla (Firefox) are members of the WebGL Working Group.

The present study has also used the Three.js framework. It is a high-level library that uses WebGL to create and display animated 3D computer graphics in a web browser. This open source JavaScript library is hosted on GitHub repository (https://github.com/mrdoob/three.js). Thus, the codes have been downloaded and embedded in the web page.

The developed web page aims to assist the solution of the proposed exercise (Figure 1). It consists in the presentation of the described object in a scene using VR (Figure 2). The scene is composed of one ambient light and four directional lights (*AmbientLight* and *DirectionalLight*) that cast onto the 3D model. The 3D model consists of a group of geometries (*Group* entity) that represent the edges and the surfaces of the object. For the edges (*Line* entity), vertices (*Vector3* entity) were used to form triangular faces (*Face3* entity) that generated the meshes (*Mesh* entity) to represent the surfaces. Two types of materials (*LineBasicMaterial* and *MeshPhongMaterial*) were applied to each geometry. Each material has specific properties for the entities to be rendered. In particular, the mesh material can simulate shiny surfaces with specular highlights. The selected colors were blue for the surfaces and white for the edges. In order to obtain contrast of the element to be highlighted in the exercise, the red color was used. An important issue for technical drawing is the type of camera that points to the scene. In this case, the camera must provide an orthographic projection (*OrthographicCamera*), instead of a perspective projection (*PerspectiveCamera*) which is commonly used for 3D rendering.

Figure 2: Object represented in a scene using VR.



For the student interaction with the object, the camera can be controlled by means of an orbital control (*OrbitControls*). This control allows the camera to orbit around the object and to be manipulated with mouse or touchscreen device. Another way to control the camera is using the device orientation (*DeviceOrientationControls*). In this case, for example, when the smartphone is rotated, the camera also rotates based on embedded sensors, such as accelerometers. Thus, the system is also compatible with the use of a virtual reality headset, such as Google Cardboard. To do so, it is necessary to add a stereo effect (*StereoEffect*) to the renderer. This option not only increases interaction, but can also add immersion effects to the Learning Object. Finally, another interesting means of interaction for teaching technical drawing is the use of animation (*Tween*) to the represent orthographic views: right side view (RSV), front view (FV), left side view (LSV), back view (BV), upper view (UV) and lower view (LV), respectively, in addition to the isometric view (IV), as shown in Figure 2.

4.2 Development of a Learning Object using AR

Following the same procedures for the development of the LO using VR, the library AR.js was used for the Augmented Reality implementation. This open source library is also hosted on GitHub (https://github.com/jeromeetienne/ar.js). It is based on WebGL and WebRTC (Web Real-Time Communication), which is an API that allows audio and video communication to work inside web pages. In AR applications, WebRTC gives website access to the device's camera. The AR.js library uses Three.js and ARToolKit v5 frameworks. The latter is a robust open source JavaScript library for creation of AR applications. In this context, the AR.js is a simplified library for Web applications. In the present study, AR.js was added to Three.js, which was already embedded in the web page.

The web page developed for the presentation of an object using AR (Figure 3) is based on the previous VR scene. The same VR elements remains, except the camera controls, the animation of the orthographic views and the interactions with VR headset. The interaction occurs with the visualization of the exercise on a printed handout by the camera of a mobile device or a computer (webcam). It was also possible to visualize the exercise on a computer screen while pointing a smartphone camera at it.

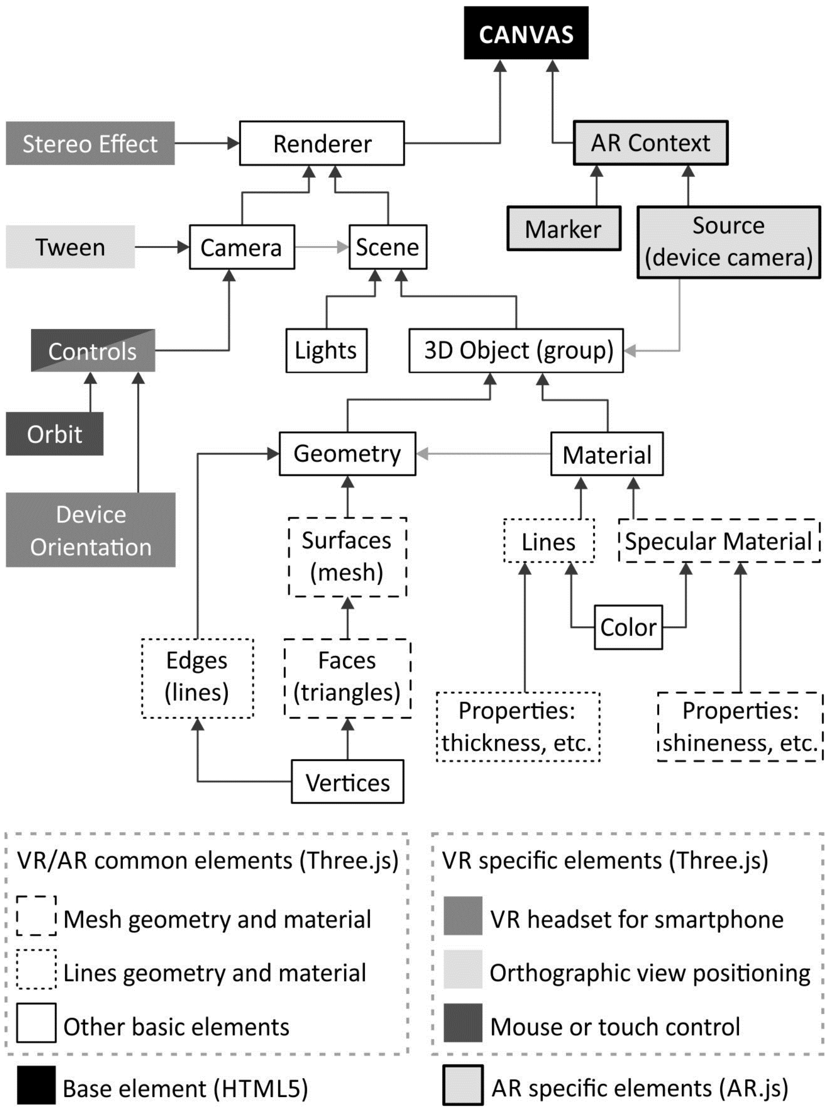
Figure 3: Object represented in a scene for use with AR.

In technical terms, the implementation of the script in AR requires a task context (*ArToolkitContext*), an image source (*ArToolkitSource*), such as the phone camera, and the marker (*ArMarkerControls*) to be detected. As marker, it is possible to use a pattern or a QR code. In the AR.js repository, there is a marker-generator that allows you to customize the marker to be used. It is worth mentioning that the marker detection performance depends on the resolution of the image and the camera. Moreover, in case of high resolutions, the frame rate can be reduced and this is an issue to be adjusted for a better user experience.

4.3 Flowchart of implementation proposal on VR and AR

The flowchart obtained as result after the implementation of VR and AR technologies is shown in Figure 4. All the steps of development and the hierarchal organization of the elements used in the programming are displayed in it. This flowchart can be used to assist other similar projects involving both VR and AR, in particular with the purpose of developing LOs.

Figure 4: Flowchart for project implementation using VR and AR.



5 Conclusion

Tools such as Virtual Reality and Augmented Reality have been used in Learning Objects of several areas of knowledge. However, content development is still a challenge for many teachers. The flowchart elaborated in this work can aid teachers, with minor experience in computing, in the implementation of internet applications. The proposed method can be replicated and adapted to new Learning Objects, as well as to other similar projects involving Virtual Reality and Augmented Reality.

The Learning Object proposed as case study can be applied in different courses that include technical drawing in higher education curriculum, such as Architecture, Design and Engineering. With the verification of feasibility of execution of this Learning Object, it is highlighted the possibility of extending this resource to other topics in the discipline of Technical Drawing, as well as to other disciplines. In addition, in view of its nature, the Learning Object can still be made available to other education institutions in different locations.

References

Amaral, V. L. (2007). Estratégias e estilos de aprendizagem: a aprendizagem no adulto. Psicologia da educação. Natal: EDUFRN, (Chapter 9).

Azuma, R. (1997). A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments, 6, 355-385.

Azuma, R., Billot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent Advances in Augmented Reality. IEEE Computer Graphics and Applications, 21 (6), 34-47

Bornancini, J. C. M., Petzold, N. I., & Orlandi Junior, H. (1987). Desenho técnico básico: fundamentos teóricos e exercícios a mão livre. Porto Alegre: Sulina.

Braga, J. C. (2014). Objetos de aprendizagem: introdução e fundamentos, Santo André: Editora da UFABC.

Bryson, S. (1996). Virtual reality in scientific visualization. Communications of the ACM, 39 (5), 62-71.

Cavalcante, M. A., Bonizzia, A., & Gomes, L. P. C. (2009). O ensino e aprendizagem de física no século XXI: sistemas de aquisição de dados nas escolas brasileiras, uma possibilidade real. Revista Brasileira de Ensino de Física, 31 (4), 4501-4506.

Cunha, A. M., Tunes, E., & Silva, R. R. (2001). Evasão do curso de química da Universidade de Brasília: a interpretação do aluno evadido. Química Nova, 24 (1), 262-280.

Gil, E. S., Garcia, E. Y. A., Lino, F. M. A., & Gil, J. L. V. (2012). Estratégias de ensino e motivação de estudantes no ensino superior. Vita et Sanitas, 06, 57-81.

Gilioli, R. S. P. (2016). Evasão em instituições federais de ensino superior no Brasil: expansão da rede, Sisu e desafios. Brasília: Câmara dos Deputados.

Guimarães, M. P., & Martins, V. F. (2013). Desafios a serem superados para o uso de Realidade Virtual e Aumentada no cotidiano do ensino. Revista de Informática Aplicada, 9 (1), 14-23.

Huang, T. C., Chen, C. C., & Chou, Y. W. (2016). Animating eco-education: to see, feel, and discover in an augmented reality-based experiential learning environment. Computers & Education, 96, 72-82.

Huff, R., Nedel, L. P., Oliveira, M. M., & Freitas, C. M. D. S. (2004). Usando Iluminação Baseada em Imagens na Geração de Ambientes de Realidade Mista. In Proceedings of VII Symposium on Virtual Reality.

Lam, C. K., Sundaraj, K., & Sulaiman, M. N. (2013). Virtual reality simulator for phacoemulsification cataract surgery education and training. Procedia Computer Science, 18, 742-748.

Libâneo, J. C. (1994). Didática. São Paulo: Cortez.

Martins, V. F., & Guimarães, M. P. (2012). Desafios para o uso de Realidade Virtual e Aumentada de maneira efetiva no ensino. In Workshop de Desafios da Computação Aplicada à Educação (pp. 100-109).

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1994). Augmented Reality: A Class of Displays on the Reality-Virtuality Continuum. Telemanipulator and Telepresence Technologies, 2351, 282-292.

Miranda, R. M. (2004). GROA: um gerenciador de repositórios de objetos de aprendizagem (Master's thesis). Programa de Pós-Graduação em Computação, UFRGS.

Neves, E. R. C., & Boruchovitch, E. A. (2004). Motivação de Alunos no Contexto da Progressão Continuada. Psicologia: Teoria e Pesquisa, 20 (1), 77-85.

Okimoto, M. L. L. R., Okimoto, P. C., & Goldbach, C. E. (2015). User Experience in Augmented Reality applied to the Welding Education. Procedia Manufacturing, 03, 6223-6227.

Oliveira, E. S. (2017). Motivação no Ensino Superior: Estratégias e Desafios. Contexto & Educação, 101, 212-32.

Peixoto, V. V. (2004). Estimulando a visão espacial em desenho técnico (Master's thesis). Programa de Pós-graduação em Engenharia de Produção, UFSC.

Pimentel, K., & Teixeira, K. (1995). Virtual reality - through the new looking glass. New York: McGraw-Hill.

Porto, T. M. E. (2006). As tecnologias de comunicação e informação na escola; relações possíveis... relações construídas. Revista Brasileira de Educação, 11 (31), 43-57.

Providelo, C., Debonzi, D. H., Gazziro, M. A., Queiroz, I. C. A. S., Kirner, C., & Saito, J. H. (2004). Ambiente Dedicado para Aplicações Educacionais Interativas com Realidade Misturada. In Proceedings of VII Symposium on Virtual Reality.

Romão, V. P. A., & Gonçalves, M. M. (2013). Realidade Aumentada: conceitos e aplicações no design. Unoesc & Ciência - ACET, 4 (1), 23-34.

Silva, A. (2012). Realidade Aumentada: Recurso Multimidiático e sua Contribuição no Processo de Ensino e Aprendizado (Graduation monograph). Curso de Licenciatura em Computação, UEPB.

Silva, M. (2001). Sala de Aula Interativa. Rio de Janeiro: Quartet.

Siscoutto, R. A., & Tori, R. (2004). AVTC-Augmented virtuality tele-conferencing. In Proceedings of VII Symposium on Virtual Reality (pp. 124-136).

Souza Filho, G. F. (2010). Simulações computacionais para o ensino de Física: uma discussão sobre produção e uso (Master's thesis). Mestrado Profissional em Ensino de Física, UFRJ.

Tonin, L., & Gonçalves, K. V. (2013). Desenvolvimento de aplicações utilizando realidade aumentada. Revista das Faculdades Integradas Claretianas, 06, 93-106.

Tori, R., Kirner, C., & Siscoutto, R. (2006). Fundamentos e Tecnologia de Realidade Virtual e Aumentada. Porto Alegre: Editora SBC.

Van Krevelen, D. W. F., & Poelman, R. A. (2010). Survey of Augmented Reality Technologies, Applications and Limitations. The International Journal of Virtual Reality, 9(2), 1-20.

Wiley, D. (2002). Learning objects need instructional design theory. In A. Rosset (Ed.), The ASTD E-Learning Handbook: Best Practices, Strategies and Case Studies for an Emerging Field (pp. 115-126). New York: McGraw Hill.

Yilmaz, R. M. (2016). Educational magic toys developed with augmented reality technology for early childhood education. Computers in Human Behavior, 54, 240-248.