Systematic Mapping on the Creation of Learning Activities Using Virtual Reality

Juan Pablo Valencia-Rosada [a], Santiago Andrés Aragón-Guzmán [a], Sandra Milena Roa-Martínez [a,*], Hendrys Tobar-Muñoz [a]

[a] *Computational Intelligence Research Group (GICO), System´s Department, Universidad del Cauca, Popayán, 190001, Colombia*

Corresponding author: [*]smroa@unicauca.edu.co

***Abstract*— Virtual Reality (VR) is a technology well equipped to enhance learning processes. The development of Learning Activities with Virtual Reality (LAVR), however, remains a complex process. This makes it a somewhat costly process, the full cost of which can be reduced by using a set of tools (framework) for implementing LAVR, involving an educational model with which to guide the developer. In this paper, we review scientific articles that focus on learning processes that use immersive technologies, seeking to identify frameworks and guidelines for the creation of LAVR. To do this, a systematic mapping of the scientific production in ScienceDirect was carried out, observing those studies from 2015 onward that involved topics including virtual reality, learning activities, Bloom taxonomy, and the state of the practice in which they are found. The results show that no studies are to be found in the literature on frameworks, guidelines, or recommendations either for the creation of LAVR or for the production of frameworks that facilitate this process using the Bloom taxonomy. However, studies can be found that guide the creation of LAVR, and these could be used as the basis for creating a framework. Based on the review, it could be concluded that VR favors learning processes at the various levels of education in a range of areas but that there is a paucity of directives able to facilitate the creation, adaptation, and incorporation of LAVR. This, therefore, constitutes a field of interest that merits further research.**

***Keywords*— Virtual reality; learning activity; working framework; Bloom taxonomy; systematic mapping.**

Manuscript received 26 Aug. 2021; revised 14 Oct. 2021; accepted 9 Dec. 2021. Date of publication 30 Apr. 2022.

I. INTRODUCTION

With the passage of time, technology has proven to facilitate the learning process at different levels of education [1]. A recent type of educational technology that is effective, according to the 2020 Horizon report [2], is immersive technologies, which generate immersive realities that can be understood as those real or simulated environments in which a perceiver (who perceives the interaction) experiences telepresence (*"defined as a psychological state of feeling present in a mediated environment"* [3], or where he experiences a virtual simulated world that surrounds him. According to de Freitas and Neumann [4]: "*The main advantages with more immersive media-rich learning experiences for the learner include the potential to provide better simulations of real-life contexts for training or to enhance deeper conceptual thinking for learning* ".

To use immersive technologies in learning, Virtual Reality (VR) devices are employed. These software and hardware make it possible to generate the illusion for the user of being present in another environment. The literature reveals VR learning experiences to have been used as a strategy for improving pedagogy during the teaching process, thus highlighting optimal results [1], [5], [6]. This is because students show greater interest in the learning process using VR [7]. Therefore, it is pertinent to carry out research and make the most of the advantages concomitant with VR to best support educational processes.

Although numerous educational applications implemented with VR are found in the literature, developing this type of software requires more time and specific knowledge, making its development costs. Because the development of these types of experience requires expertise in education and development, developing Learning Activities in Virtual Reality (LAVR) presents particular difficulties related to general application frameworks, which are more difficult to develop in terms of costs and developer effort. Therefore, a way needs to be found to make this development less costly concerning time, effort, and knowledge for programmers and thus more affordable for users. Development Frameworks are used to develop VR applications, which is to reduce the

knowledge necessary to implement a solution by making use of configurable parameters that reduce the time required to finalize the expected product [8]. These Frameworks thus allow the development of applications that are compatible with commonly used VR devices without requiring advanced knowledge in technology.

From an educational viewpoint, it is convenient to use learning models that guide the design of educational experiences such as LAVR. Among these is Bloom's taxonomy, a cognitive model [9] widely used by educators because it allows, through learning objectives divided into levels, structuring the teaching processes and planning of instructional activities that ensure the acquisition of student knowledge within different environments. That said, it is convenient to have tools (such as a framework) that facilitate the creation of LAVR following educational guidelines such as the Bloom taxonomy.

Since the interest in developing LAVR is relatively recent, it is well worth discovering what guidelines already exist for creating LAVR and if there are frameworks for the creation of LAVR following Bloom's taxonomy. This article shows the results of a systematic mapping whose objective was to review articles from the literature in which the main focus was on learning processes using immersive technologies [10]. In the course of the review, a set of VR education processes were inspected, specifying whether or not these included taxonomies or methodologies. It allows the acquisition of knowledge to be positively developed, thereby significantly impacting the learning process.

The methodological aspects are presented below. Subsequently, the results section describes the data found, together with the classification of the articles and the answer to the research questions posed following the methodological approach. Then, in the discussion, the interpretation and explanation are given to the data and previously presented related results. Finally, the conclusions and possible future work derived from the work carried out are presented.

II. Materials and Methods

In the review of work carried out on the use of Virtual Reality for the learning process, the following three (3) research questions were raised:

- Is there a framework that allows the creation of learning activities in VR using Bloom's taxonomy?
- What guidelines and recommendations exist for creating learning activities using VR?
- What guidelines and recommendations exist for creating a framework for the creation of learning activities using VR?

Once the research questions and the scope of the review had been defined, the search strings were constructed (see Table 1). It is worth noting that it was necessary to use the term "Immersive Technologies" to recover "Virtual Reality" resources because many authors do not specify the technology but refer to its broader category. Table 1 presents the questions with their respective motivation, the search string to be used, and the results initially obtained.

TABLE I
PROPOSED SEARCH STRINGS AND RESULTS OBTAINED BY STAGE

Question	Search string	Motivation	Number of initial articles
RQ1: Is there a framework that allows the creation of learning activities in VR using Bloom's taxonomy?	("Framework" OR "Frameworks") AND ("Virtual Reality" OR "VR" OR "Immersive Technology" OR "Immersive Technologies") AND ("Bloom's Taxonomy" OR "bloom taxonomy" OR "Taxonomy of Bloom") AND ("Learn Activity" OR "Learn Activities" OR (learn AND activity))	Determine studies carried out and their characteristics, if any, analyze possible improvements to the solution	48
RQ2: What guidelines and recommendations exist for creating learning activities using VR?	("guideline" OR" Guidelines") AND ("Virtual Reality" OR "VR" OR "Immersive Technology" OR "Immersive Technologies") AND("learning activities" OR "learning activity" OR (learning AND activities))	Establish the guidelines that allow the creation of learning activities using VR	4413
RQ3: What guidelines and recommendations exist for creating a framework for the creation of learning activities using VR?	("guideline" OR" Guidelines") AND ("Virtual Reality" OR "VR" OR "Immersive Technology" OR "Immersive Technologies") AND("Framework" OR "Frameworks")	Identify the guidelines to follow during the creation of frameworks using VR	3948

After having formulated them, the search strings were consulted in ScienceDirect. The articles were obtained during March 2020, resulting in a quantity of 48 articles for question one. 4413 articles were found for the second question, and for the third question, 3948 were found. Due to the number of resulting articles, it was necessary to filter them to continue with the research process.

In order to narrow the search, some inclusion and exclusion criteria, as well as criteria of quality assessment, data extraction, and classification were defined, in order to determine whether or not there were previous studies concerning the creation of learning activities using Bloom's taxonomy with immersive technologies such as Virtual Reality, to characterize them and establish guidelines that allow the future creation of these activities. Additionally, it was sought to identify guidelines that facilitate the creation of a framework for the implementation of learning activities using Virtual Reality.

A. Inclusion

- Review articles
- Research articles
- Articles that include learning models in their summary
- Titles, abstract and keywords where included (VR or "Virtual Reality")

B. Exclusion

- Articles prior to 2015
- Articles written in a language other than Spanish or English
- Articles found only in the form of slides or grey literature

Having applied these criteria to the searches, 20 articles were obtained for the first research question, 302 for the second question, and 195 articles for the third. Since the number of articles was still considerable, filtering of the articles was continued by reviewing the abstract and conclusions. Once the reading was done, a total of 46 articles were obtained, for which each was fully read to have a clear idea of the content of each reading. Subsequently, the "Evaluation criteria" were proposed, by means of which those articles that did not suggest a contribution regarding the objective of this systematic mapping could then be discarded.

C. *Evaluation criteria*

- The study describes in detail a learning approach.
- Document of a proposal that has built the solution using VR.
- The study presents a case study where the results obtained after carrying out the learning activities are evidenced in detail.
- The study prioritizes the use of immersive technologies (Virtual Reality, Augmented Reality, Gesture Detection technologies).
- Studies that do not report a design experiment.

After applying the aforementioned evaluation criteria, several articles failed to meet the criteria and thus did not significantly contribute to the questions posed. These were discarded, leaving a total of 33 articles - 3 for Question One, 24 for Question Two, and 6 for Question Three.

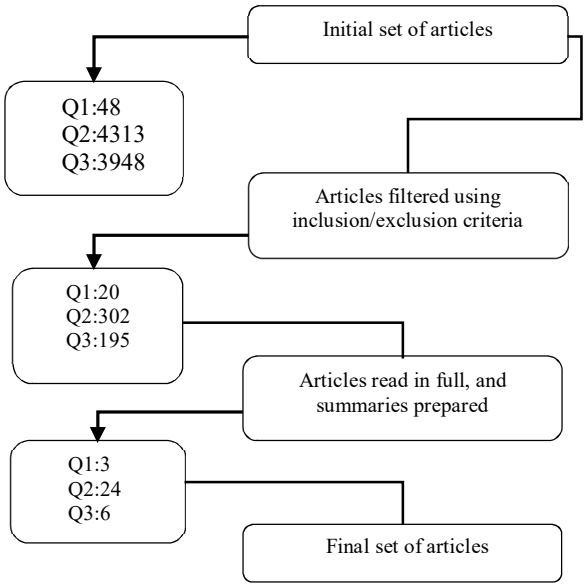

Fig. 1 Proposed search strings and results obtained by stage

A review of each article was then written that could answer Questions 1 and 3. The articles that answered Question 2 were grouped by subject and purpose in order to write a review for each of the groups, to be able later to conduct a discussion on it. In Figure 1, the methodological procedure applied is briefly presented, including the number of articles found for each of the questions posed, which, with the respective reviews prepared, will provide answers to the research questions.

III. Results and Discussion

This section presents the results obtained on carrying out the aforementioned methodological procedures. Initially, the answer to each of the research questions that guided this systematic mapping - and that were previously cited - will be described. It is worth noting that a constant trend is observed in the studies found. These include Virtual Reality for the creation of applications using learning activities/tasks.

A. *Question Q1: Is there a framework that allows the creation of learning activities in VR using Bloom's taxonomy?*

According to the analysis of the articles made in the present systematic mapping, a framework was not found that specified Bloom's taxonomy for the creation of learning activities. On the other hand, there are ontologies based on Bloom's taxonomy for the creation of these activities [11]–[14]. These ontologies (Conali, ON-SMMILE, Anderson's Taxonomy, Experimental learning models - Inventory of learning styles) optimize the development of the projects proposed by the authors and optimize the creation of learning activities with Virtual Reality.

B. *Question P2: What guidelines and recommendations exist for creating learning activities using VR?*

It was found that roughly 45% of the articles provide a guide that establishes guidelines and recommendations about carrying out learning activities using Virtual Reality. Below is a list of phases that serve as a tool to discover the frequency of use of a learning activity in each of the articles. Based on this, the most commonly used phases are listed below, and Table 2 indicates the use of each phase in each of the articles reviewed.

- Pre-evaluation: knowing the strengths and weaknesses of the students and the skills and knowledge they possess before receiving the instruction.
- Post-evaluation: verification of the degree of achievement of objectives and goals formulated in the program or project.
- Requirement's analysis: requirements capture and analysis stage.
- Learning activity: each of the learning activities used to learn a specific objective.
- Planning phase: represents graphically or virtually how the software performs.
- Design phase: the action is structured and formalized, and the definitive features of the project are established.
- Implementation phase: the stage of the planning process carried out once the design is validated.
- Specific framework construction guide: guide provided to teach the step-by-step development of the framework.
- Case study/evaluation: assessment of knowledge, attitude, and performance of a person.
- Systematic review: a review of quantitative and qualitative aspects of primary studies to summarize existing information regarding a particular topic.
- Literature review: analyzes and discusses articles and reports, general scientific and academic.
- Specific approach: refers to specific approaches used by the authors, including Ace Star, Modular Approach,

Hybrid Model, ARCS, Anderson Taxonomy, PEAR, Review Model Based on Competency Analysis, IA Model, Conali Ontology, and Blended Learning Model.

- Framework: a standardized set of concepts to approach a problem that serves as a reference, facilitating the resolution of problems of a similar nature.
- Detail of use: detail of use and development of the project.
- Feedback: system/process that regulates itself; an action by which each result of the process affects the whole process, integrating and modifying it.

TABLE II
USE OF PHASES BY ARTICLE

Year	Reference	Phases														
		Pre-evaluation	Learning activity	Post-evaluation	Analysis of requirements	Design	Planning	Implementation	Case study/evaluation	Specific approach	Framework guide	Systematic review	Literature review	Framework	Detail of use	Feedback
2015	[15]	x	x	x						x						x
	[16]			x					x	x	x			x		
	[17]		x	x		x		x	x				x			
	[18]	x	x	x						x			x		x	x
2016	[1]			x						x					x	
	[12]		x	x				x		x						
	[10]	x	x	x												x
	[19]		x	x											x	x
	[20]		x			x		x						x	x	
2017	[21]	x	x	x		x									x	
	[22]		x												x	x
	[23]		x					x	x	x	x		x	x		
	[24]	x	x	x		x		x	x							x
	[25]		x													x
2018	[5]											x				x
	[26]	x	x	x												
	[27]		x							x		x	x			
	[28]	x	x	x		x	x								x	x
	[29]					x	x	x	x						x	
	[11]								x	x	x					
	[30]											x				
	[31]		x	x											x	
	[32]			x		x	x		x		x			x		x
2019	[26]		x	x	x			x			x		x	x		x
	[33]		x							x			x		x	
	[34]		x	x		x		x	x	x	x	x		x	x	x
	[35]	x	x	x		x			x						x	x
	[36]			x											x	x
2020	[13]								x	x	x			x		
	[37]		x	x												x
	[38]	x	x	x				x		x	x			x	x	x
	[39]		x								x	x	x	x	x	
	[14]		x					x	x							

Table 2 shows the phases such as requirements analysis, planning, design, implementation, and case study of the software development life cycle are key in the software development process.

C. *Question Q3: What guidelines and recommendations exist for creating a framework for creating learning activities using VR?*

From reading each of the articles, it is important to highlight that no articles were found that specify developing a framework for creating learning activities with VR. However, some 27% of the articles detail the process used to create a framework in general, among which are mentioned (classification, design, data collection, data analysis, and theory of learning [39].

Additionally, after answering the questions posed in Figure 2, the number of articles that use VR and focus on education using learning activities is shown from the beginning of 2015 to the first quarter of 2020.

Figure 2 shows an increasing trend in the inclusion of Virtual Reality in education, which continues to be interesting research subject due to each of the advantages that its use entails. In addition, Figure 3 shows the percentage of articles related to the previously tabulated phases, including Pre-evaluation, Feedback, Framework Guide, and Systematic Review.

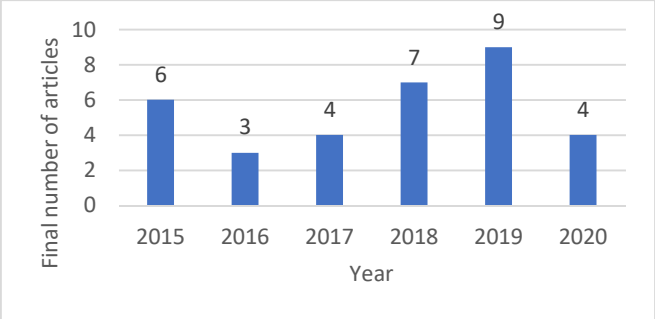

Fig. 2 Number of articles published per year

From the frequency of use of the activities presented in Figure 3, it was identified that the authors made more use of the activities previously mentioned in answer to question two (Pre-evaluation, Feedback, Post-evaluation, Framework guide). These activities are important for optimal performance during the development of their respective projects and the fulfillment of each of their objectives.

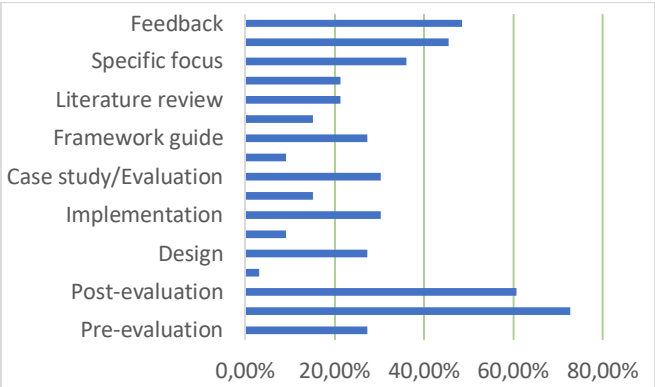

Fig. 3 Frequency of phases on reviewed articles

In addition, it is observed that more than a quarter (27%) of the respective authors were interested enough to include a pre-evaluation stage to mostly identify the current knowledge of the test subjects on the topic addressed. Thus, this study contrasted with a post-evaluation, which is used by 60% of the authors to validate the results of their projects (framework, application, systematic review, among others) and seeks to determine the effectiveness of their research work.

Figure 4 uses the UNESCO International Standard Classification of Education as a reference in order to determine the academic areas in which VR has been applied, observing that those areas in which learning activities have been used the most for the instruction of their learners are Computer Science (which includes the area of engineering), Construction and Medicine.

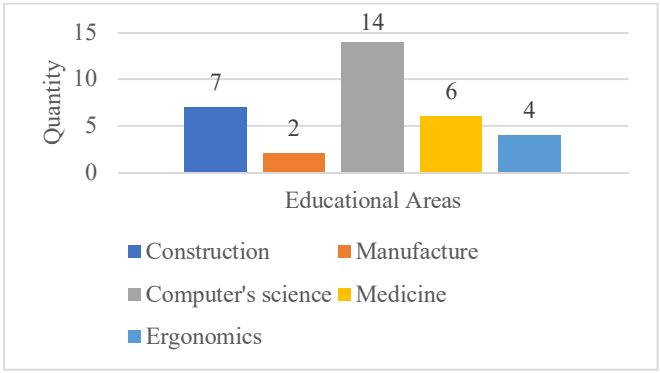

Fig. 4 Number of articles by educational areas

In addition, an emphasis was found on the use of simulators for the acquisition of knowledge in a practical way in the virtual environment [8], [9], [17], [22]. The field of Medicine meanwhile focuses on the learning of laparoscopic skills with simulators and cognitive approaches. When the required process is learning, it focuses on spatial knowledge [33], [35], [36]. It was also observed that the construction field is the next most frequent and main articles are found that optimize learning environments so that they are as real as possible, and one of their main objectives is the safety of apprentices in construction [25], [27], [30].

Although no frameworks were found to create learning activities with Virtual Reality (VR) using Bloom's taxonomy, ontologies based on this taxonomy were found, whose objective continues to be the creation of learning activities. These ontologies can be considered since they become useful to orient and guide developing research projects.

The existence of guidelines and recommendations to be considered for creating learning activities using VR is highlighted. In light of this, it could be seen that these activities have been widely considered during the preparation of the projects. We can highlight that those phases most used (Post-evaluation, Pre-evaluation, Activities/Learning tasks, Design phase, Implementation phase, Framework construction guide, Case study/Evaluation, Specific approach, Detail of use, Feedback) can be considered in the development of research projects and are the objective of this systematic mapping.

The establishment and creation of the learning objectives set out in the Bloom taxonomy are an important resource for the theoretical base that supports the creation of the learning activities in Virtual Reality since it contemplates the creation of objectives for the Remember, Understand, Apply , Analyze and Evaluate levels. In addition, it explains the types of

Factual, Conceptual, Procedural, and Metacognitive knowledge. Therefore, it is recommended to take this taxonomy into account.

It should be noted that no articles were found that specify the process of developing a Framework for the creation of learning activities in VR using Bloom's taxonomy. However, around 27% of the articles that detail the process used to create a Framework will be considered since the guidelines and recommendations set out there allow establishing those bases needed for the development of research projects that include Frameworks.

It is also important to mention that a high 73% of the articles include learning activities (these are the actions that the learner follows as part of the instructional process), while only just over 45% describe the process of how to develop them. Therefore, the step-by-step must be considered for creating each of the learning activities to facilitate the fulfillment of the learning objectives that the learners must achieve. The most commonly used phases during the project development process are implementation (30%) and design (27%). The inclusion of these phases should therefore be considered for the development of research projects.

In 21% of the articles, the creation of Frameworks for learning is proposed. Most of the authors implement it, but only in 27% of the articles is a guide specified on how to elaborate Frameworks. Therefore, it is recommended to make a guide for creating a Framework, as it provides the necessary material that can be used in future research projects that consist of the creation of a Framework for learning.

In addition, 36% of the articles (12 articles) propose unique approaches and models that are applied throughout the process to create their projects. These articles include techniques, tools, and educational innovations for the specific learning of the corresponding topics within which comprise Review model based on content analysis [27], Modular approach [16], CAD model [33], Model hybrid [18], AI-based model [34], blended learning model [38], Motivational categories of attention, relevance, trust and satisfaction [1], Conali ontology, education based on social networks, Constructive alignment (CA) [13], ON-SMMILE ontology [11], and Anderson's taxonomy [12].

As regards Computer Science, the assignment of tasks within a virtual learning environment is frequently used so that the user can perform them using the HMD and HMD devices with special control. During the interaction, it was observed that the authors use different forms (scoring systems, intelligent tutor) to give feedback that determines how the learner performs. For the field of Medicine, to a greater extent a theoretical approach is used at the beginning before experimental learning. The critical activities require a higher degree of precision, which is why HMD and haptic devices are used.

In the Construction field, the safety of the apprentice is very important. Therefore, Virtual Reality projects aim at optimizing very realistic learning environments for the training of apprentices in construction. In addition, they prioritize the use of machinery and adaptation of work environments through simulators for handling these pieces of equipment and construction of structures.

IV. Conclusion

For the implementation of Virtual Reality in the educational area, it is necessary to create learning activities that will allow the learner to build knowledge to meet the learning objectives set by the teacher. Additionally, these learning activities must be adapted and later included in the virtual environment, not a simple process because they imply development knowledge. For this reason, it is likely that the advantages of VR are not being used in learning processes.

As things stand, VR is an interesting tool that can be used in education to increase student motivation and learning. For this reason, it has become a trend that has allowed the development of multiple projects in different subject areas, mainly in construction, Medicine, Engineering, and Emergencies. During the present systematic mapping, no tools were found that specify a guide or emphasize facilitating the creation, adaptation, and inclusion of Learning Activities in Virtual Reality (LAVR), which constitutes an area of interest for future research. Therefore, developing a Framework that provides guidance and support for the creation of LAVR is considered future work.

Acknowledgment

The authors acknowledge the Computational Intelligence Research Group (GICO) of the System´s Department at the Universidad del Cauca for their support in developing this work (https://www.unicauca.edu.co/gico).

References

[1] X. Wei, D. Weng, Y. Liu, and Y. Wang, "Teaching based on augmented reality for a technical creative design course," *Comput. Educ.*, vol. 81, pp. 221–234, Feb. 2015, DOI: 10.1016/j.compedu.2014.10.017.

[2] M. Brown *et al.*, *2020 EDUCAUSE Horizon Report. Teaching and Learning Edition*. 2020.

[3] A. Martín-Barrio, J. J. Roldán, S. Terrile, J. del Cerro, and A. Barrientos, "Application of immersive technologies and natural language to hyper-redundant robot teleoperation," *Virtual Real.*, vol. 24, no. 3, 2019, DOI: 10.1007/s10055-019-00414-9.

[4] S. de Freitas and T. Neumann, "The use of 'exploratory learning' for supporting immersive learning in virtual environments," *Comput. Educ.*, vol. 52, no. 2, pp. 343–352, 2009, DOI: 10.1016/j.compedu.2008.09.010.

[5] Z. Feng, V. A. González, R. Amor, R. Lovreglio, and G. Cabrera-Guerrero, "Immersive virtual reality serious games for evacuation training and research: A systematic literature review," *Comput. Educ.*, vol. 127, pp. 252–266, Dec. 2018, DOI: 10.1016/j.compedu.2018.09.002.

[6] M. Seifan, N. Robertson, and A. Berenjian, "Use of virtual learning to increase key laboratory skills and essential non-cognitive characteristics," Educ. Chem. Eng., vol. 33, pp. 66–75, 2020, DOI: 10.1016/j.ece.2020.07.006.

[7] J. Martín-Gutiérrez, C. E. Mora, B. Añorbe-Díaz, and A. González-Marrero, "Virtual technologies trends in education," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 13, no. 2, pp. 469–486, 2017, DOI: 10.12973/eurasia.2017.00626a.

[8] N. Yadav, D. S. Rajpoot, and S. K. Dhakad, "LARAVEL: A PHP Framework for E-Commerce Website," *Proc. IEEE Int. Conf. Image Inf. Process.*, vol. 2019-November, pp. 503–508, 2019, DOI: 10.1109/ICIIP47207.2019.8985771.

[9] L. O. Wilson, "Anderson and Krathwohl Bloom's Taxonomy Revised Understanding the New Version of Bloom's Taxonomy," *Second Princ.*, pp. 1–8, 2016, [Online]. Available: https://quincycollege.edu/content/uploads/Anderson-and-Krathwohl_Revised-Blooms-Taxonomy.pdf%0Ahttps://thesecondprinciple.com/teaching-essentials/beyond-bloom-cognitive-taxonomy-revised/%0Ahttp://thesecondprinciple.com/teaching-

essentials/beyond-bloom-cog.
[10] H. S. Hsiao and J. C. Chen, "Using a gesture interactive game-based learning approach to improve preschool children's learning performance and motor skills," *Comput. Educ.*, vol. 95, pp. 151–162, Apr. 2016, DOI: 10.1016/j.compedu.2016.01.005.
[11] H. Yago, J. Clemente, D. Rodriguez, and P. Fernandez-de-Cordoba, "ON-SMMILE: Ontology Network-based Student Model for MultIple Learning Environments," *Data Knowl. Eng.*, vol. 115, pp. 48–67, May 2018, DOI: 10.1016/j.datak.2018.02.002.
[12] M. Minović, M. Milovanović, U. Šošević, and M. Á. Conde González, "Visualisation of student learning model in serious games," *Comput. Human Behav.*, vol. 47, pp. 98–107, 2015, DOI: 10.1016/j.chb.2014.09.005.
[13] D. Antonelli *et al.*, "Tiphys: An Open Networked Platform for Higher Education on Industry 4.0," in *Procedia CIRP*, 2019, vol. 79, pp. 706–711, DOI: 10.1016/j.procir.2019.02.128.
[14] R. Wang, R. Lowe, S. Newton, and T. Kocaturk, "Task complexity and learning styles in situated virtual learning environments for construction higher education," *Autom. Constr.*, vol. 113, p. 103148, May 2020, DOI: 10.1016/j.autcon.2020.103148.
[15] S. L. Farra, E. T. Miller, and E. Hodgson, "Virtual reality disaster training: Translation to practice," *Nurse Educ. Pract.*, vol. 15, no. 1, pp. 53–57, Jan. 2015, DOI: 10.1016/j.nepr.2013.08.017.
[16] J. Pan, X. Su, and Z. Zhou, "An Alternate Reality Game for Facility Resilience (ARGFR)," in *Procedia Engineering*, Jan. 2015, vol. 118, pp. 296–303, DOI: 10.1016/j.proeng.2015.08.430.
[17] D. Grajewski, F. Górski, A. Hamrol, and P. Zawadzki, "Immersive and Haptic Educational Simulations of Assembly Workplace Conditions," in *Procedia Computer Science*, Jan. 2015, vol. 75, pp. 359–368, DOI: 10.1016/j.procs.2015.12.258.
[18] J. Wang and R. Lindeman, "Coordinated hybrid virtual environments: Seamless interaction contexts for effective virtual reality," *Comput. Graph.*, vol. 48, pp. 71–83, May 2015, DOI: 10.1016/j.cag.2015.02.007.
[19] S. Farra *et al.*, "Storyboard Development for Virtual Reality Simulation," *Clin. Simul. Nurs.*, vol. 12, no. 9, pp. 392–399, Sep. 2016, DOI: 10.1016/j.ecns.2016.04.002.
[20] C. M. Nakano *et al.*, "IBET: Immersive visualization of biological electron-transfer dynamics," *J. Mol. Graph. Model.*, vol. 65, pp. 94–99, Apr. 2016, DOI: 10.1016/j.jmgm.2016.02.009.
[21] J. A. Frank and V. Kapila, "Mixed-reality learning environments: Integrating mobile interfaces with laboratory test-beds," *Comput. Educ.*, vol. 110, pp. 88–104, Jul. 2017, DOI: 10.1016/j.compedu.2017.02.009.
[22] S. Tretsiakova-McNally, E. Maranne, F. Verbecke, and V. Molkov, "Mixed e-learning and virtual reality pedagogical approach for innovative hydrogen safety training of first responders," *Int. J. Hydrogen Energy*, vol. 42, no. 11, pp. 7504–7512, Mar. 2017, DOI: 10.1016/j.ijhydene.2016.03.175.
[23] L. Hou, H. L. Chi, W. Tarng, J. Chai, K. Panuwatwanich, and X. Wang, "A framework of innovative learning for skill development in complex operational tasks," *Autom. Constr.*, vol. 83, pp. 29–40, Nov. 2017, DOI: 10.1016/j.autcon.2017.07.001.
[24] M. Galaup, N. Muller, C. Pons Lelardeux, D. Panzoli, J. P. Jessel, and P. Lagarrigue, "Design of learning environments for Mechanical Engineering," *Procedia Manuf.*, vol. 13, pp. 1440–1446, Jan. 2017, DOI: 10.1016/j.promfg.2017.09.126.
[25] A. W. de Vries, G. Faber, I. Jonkers, J. H. Van Dieen, and S. M. P. Verschueren, "Virtual reality balance training for elderly: Similar skiing games elicit different challenges in balance training," *Gait Posture*, vol. 59, pp. 111–116, Jan. 2018, DOI: 10.1016/j.gaitpost.2017.10.006.
[26] F. Vahdatikhaki, K. El Ammari, A. K. Langroodi, S. Miller, A. Hammad, and A. Doree, "Beyond data visualization: A context-realistic construction equipment training simulators," *Autom. Constr.*, vol. 106, p. 102853, Oct. 2019, DOI: 10.1016/j.autcon.2019.102853.
[27] X. Li, W. Yi, H. L. Chi, X. Wang, and A. P. C. Chan, "A critical review of virtual and augmented reality (VR/AR) applications in construction safety," *Autom. Constr.*, vol. 86, pp. 150–162, Feb. 2018, DOI: 10.1016/j.autcon.2017.11.003.
[28] H. Boessenkool, J. G. W. Wildenbeest, C. J. M. Heemskerk, M. R. de Baar, M. Steinbuch, and D. A. Abbink, "A task analysis approach to quantify bottlenecks in task completion time of telemanipulated maintenance," *Fusion Eng. Des.*, vol. 129, pp. 300–308, Apr. 2018, DOI: 10.1016/j.fusengdes.2017.10.002.
[29] C. Boton, "Supporting constructability analysis meetings with Immersive Virtual Reality-based collaborative BIM 4D simulation," *Autom. Constr.*, vol. 96, pp. 1–15, Dec. 2018, DOI: 10.1016/j.autcon.2018.08.020.
[30] M. Almestehi, W. Alomaim, L. Rainford, D. Stokes, M. Stanton, and M. Moran, "Role of the virtual reality simulator (ScanTrainer) as a multidisciplinary training tool in transvaginal ultrasound: A systematic review and narrative synthesis," *Radiography*, vol. 25, no. 3. W.B. Saunders Ltd, pp. 260–268, Aug. 01, 2019, DOI: 10.1016/j.radi.2018.12.009.
[31] C. R. Bruns and B. C. Chamberlain, "The influence of landmarks and urban form on cognitive maps using virtual reality," *Landsc. Urban Plan.*, vol. 189, pp. 296–306, Sep. 2019, DOI: 10.1016/j.landurbplan.2019.05.006.
[32] Z. Ding, S. Liu, L. Liao, and L. Zhang, "A digital construction framework integrating building information modeling and reverse engineering technologies for renovation projects," *Autom. Constr.*, vol. 102, pp. 45–58, Jun. 2019, DOI: 10.1016/j.autcon.2019.02.012.
[33] D. Stadnicka, P. Litwin, and D. Antonelli, "Human factor in intelligent manufacturing systems - Knowledge acquisition and motivation," in *Procedia CIRP*, Jan. 2019, vol. 79, pp. 718–723, DOI: 10.1016/j.procir.2019.02.023.
[34] A. Winkler-Schwartz *et al.*, "Artificial Intelligence in Medical Education: Best Practices Using Machine Learning to Assess Surgical Expertise in Virtual Reality Simulation," *J. Surg. Educ.*, vol. 76, no. 6, pp. 1681–1690, Nov. 2019, DOI: 10.1016/j.jsurg.2019.05.015.
[35] J. M. Goderstad, L. Sandvik, E. Fosse, and M. Lieng, "Development and validation of a general and easy assessable scoring system for laparoscopic skills using a virtual reality simulator," *Eur. J. Obstet. Gynecol. Reprod. Biol. X*, vol. 4, p. 100092, Oct. 2019, DOI: 10.1016/j.eurox.2019.100092.
[36] C. F. Cano and A. Roudaut, "MorphBenches: Using mixed reality experimentation platforms to study dynamic affordances in shape-changing devices," *Int. J. Hum. Comput. Stud.*, vol. 132, pp. 1–11, Dec. 2019, DOI: 10.1016/j.ijhcs.2019.07.006.
[37] N. Mirchi, V. Bissonnette, R. Yilmaz, N. Ledwos, A. Winkler-Schwartz, and R. F. Del Maestro, "The virtual operative assistant: An explainable artificial intelligence tool for simulation-based training in surgery and medicine," *PLoS One*, vol. 15, no. 2, 2020, DOI: 10.1371/journal.pone.0229596.
[38] I. Czaplinski and A. L. Fielding, "Developing a contextualised blended learning framework to enhance medical physics student learning and engagement," *Phys. Medica*, vol. 72, pp. 22–29, Apr. 2020, DOI: 10.1016/j.ejmp.2020.03.010.
[39] J. Radianti, T. A. Majchrzak, J. Fromm, and I. Wohlgenannt, "A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda," *Comput. Educ.*, vol. 147, Apr. 2020, DOI: 10.1016/j.compedu.2019.103778.
[40] S. Skard, E. S. Knudsen, H. Sjåstad, and H. Thorbjørnsen, "How virtual reality influences travel intentions: The role of mental imagery and happiness forecasting," Tour. Manag., vol. 87, no. February, 2021, DOI: 10.1016/j.tourman.2021.104360