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Digital competency, tpack and technological ethics:
challenges for the information and knowledge society (IKS)

Isabel María Gómez-Trigueros y Carolina Bustamante
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AN ANALYSIS OF VIRTUAL SIMULATIONS FROM THE TPACK PERSPECTIVE

Un análisis de las simulaciones virtuales desde la óptica del modelo TPACK

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INTRODUCTION. Virtual simulations (VS) have increased their presence in the higher education training actions during the last years and have been consolidated as a result of the COVID-19 pandemic as a powerful tool that allows us to overcome many of the limitations of the face to face simulation rooms, related to costs and replicability. However, there is a lack of studies about the use of theoretical models, such as the TPACK, for the analysis of VS. **METHOD**. In this article a systematic review of the literature is conducted with the main aim of analysing the characteristics of the VS used in higher education during the last decade (2012-2022) from the optic of the TPACK model. **RESULTS**. The main findings are the big use of VS in Health-related areas and especially in the American continent (Unite States and Canada); the screen-based and computer-based simulation played online as the most common technological features; and the Experiential learning, the Situated learning and the Problem-based learning as the most common theories for the pedagogical justification of VS in higher education. **DISCUSSION**. A series of relationships has been spotted among the technological, pedagogical and content features of the VS that help us to better understand this tool that has a growing use, especially in the health field. Conclusions show, on the one hand, the lack of articles that properly describe the use of VS according to the TPACK requirements and, on the other hand, the adequacy and viability of this model for the analysis and development of VS.

Keywords: *Simulation, Virtuality, Higher education, Training, Systematic review.*

Introduction

Simulation is defined by the *Health care simulation* dictionary as a situation or environment that allows the experimentation of real events' representations with the purpose of practising, learning, understanding or evaluating some skills or knowledge (Lioce, 2020). A Virtual Simulation (VS) is a simulation of a real-life situation, that takes place in a virtual environment that is accessible to the user through technological devices (Gordon & McGonigle, 2018). Although there is great variability among VS in higher education depending on their technological features, some shared characteristics are immersion, interactivity, illusion and perceptual aspects (Li *et al.*, 2021). Apart from these core characteristics, VS are also defined by the way in which they are implemented, with a 3-step application protocol (prebriefing, enactment or playing, and debriefing) that is completely essential for this technological tool to become a didactic tool with a big impact in the learning process of students (INACSL Standards Committee *et al.*, 2021). These phases are designed to make the VS efficient in terms of learning. In particular, some authors state that the biggest educational potential of VS resides in the debriefing phase, that is the final stage of the simulation process, aimed to reflect and extract conclusions of the playing experience, and especially to support the transfer of knowledge and skills from the simulated experience to real life (Bradley *et al.*, 2020; Zigmont *et al.*, 2011).

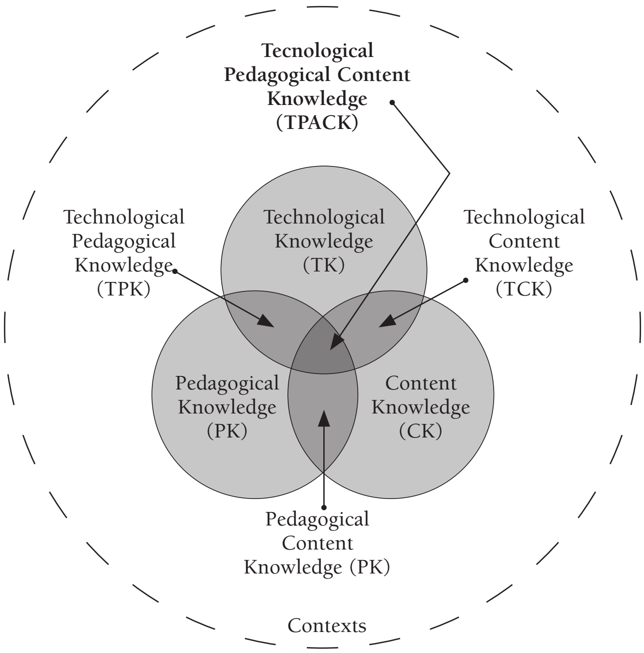
Different studies justify the use of VS as tools for training in higher education, arguing that they enhance learners' motivation, provide a better contextualization of the learning material and help students to develop higher technical abilities (McGrath *et al.*, 2018). VS also increase the completion rates and reduce the time needed for learning the materials (Zhang, 2021); provide a safe environment to train different skills without risk of hurting other people or damaging equipment (Koivisto *et al.*, 2017); allow the reduction of huge costs (buying equipment and organizing rooms or laboratories for the training of students) (Verkuyl *et al.*, 2017); allow the reproduction of processes and phenomena that cannot be observed in such detail, or that are difficult to experience based on their exceptionality or rarity (Šidjanin *et al.*, 2020); and have unlimited access and repeatability (MacKenna *et al.*, 2021).

In addition to these VS characteristics, a decisive event has contributed to spreading VS during the last years: The COVID-19 pandemic. This unexpected situation has forced higher education to change the traditional onsite simulation facilities to online learning contexts. In this situation, VS appear as an alternative to onsite training simulations (Liu, 2021).

Nonetheless, the spread use of VS in higher education claims for standardization regarding both the use and the research on the technological and pedagogical aspects of these tools (Verkuyl & Mastrilli, 2017), in order to make them a valid and reliable alternative to onsite simulations (Jiang-Bo & Jin, 2021). Up to authors' knowledge, there is an absence of literature reviews and meta-analysis focused on the study of VS from a tecno-pedagogical standpoint; Ledger *et al.* (2022) claim that more research about the pedagogical role of technology is needed to fully take profit from the new developments of the educational technology in the future, as well as from the statements of others authors such us Jiang-Bo and Jin (2021) who state that teachers are still confused about how to effectively apply VS.

Therefore, this study proposes a systematic literature review with the goal of taking a closer look to the application of VS in higher education under the framework of the TPACK model, which will allow us to see the big picture in the implementation of VS in higher education. The TPACK model was proposed by Koehler and Mishra (2009) and allows the analysis of the technological characteristics of VS (Technology), the pedagogical theories used to justify the application of these tools (Pedagogy), the field of knowledge and their learning objectives (Content), as well as their relationships.

FIGURE 1. TPACK model



Note: Koehler & Mishra, 2009.

Method

This literature review has been conducted following a three-phase process: Planning, conducting and reporting (Kitchenham, 2004). In the planning phase, a quick exploration of the literature, especially, of other systematic literature reviews or meta-analysis in the topic of VS in higher education helped us to set the goals:

- General objective: Describe the use of VS in higher education according to their technological, pedagogical and content features.
- Specific objectives:
  - O1. Define the technological features of VS used in higher education (TK).
  - O2. Identify the pedagogical theories that justify the use of VS in higher education (PK).
  - O3. Identify the field of knowledge in which VS are used in higher education (CK).
  - O4. Analyse the relationships between the technological features of VS and its content (TCK).

- O5. Analyse the relationship between the pedagogical justification of VS and its content (PCK).
- O6. Analyse the relationship between the pedagogical justification of VS and its technological features (TPK).

The research strategy started with the following search string: ("virtual simulation" OR "virtual reality simulation" OR "simulation game" OR "virtual gaming simulation" OR "online virtual simulation") AND ("university" OR "higher education"). This was applied in different platforms such as Scopus, Web of science and Eric, all of them containing high quality journal articles, conference papers, books, etc. in educational technology. The search was restricted to study title, abstract and keywords. The selection and exclusion criteria for the articles included in the systematic literature review is shown in table 1. Criteria 9 to 12 are focused on the TPACK model. When a study met at least one exclusion criteria, it was removed from the review. The selection process is presented in detail.

Table 1. Exclusion and selection criteria

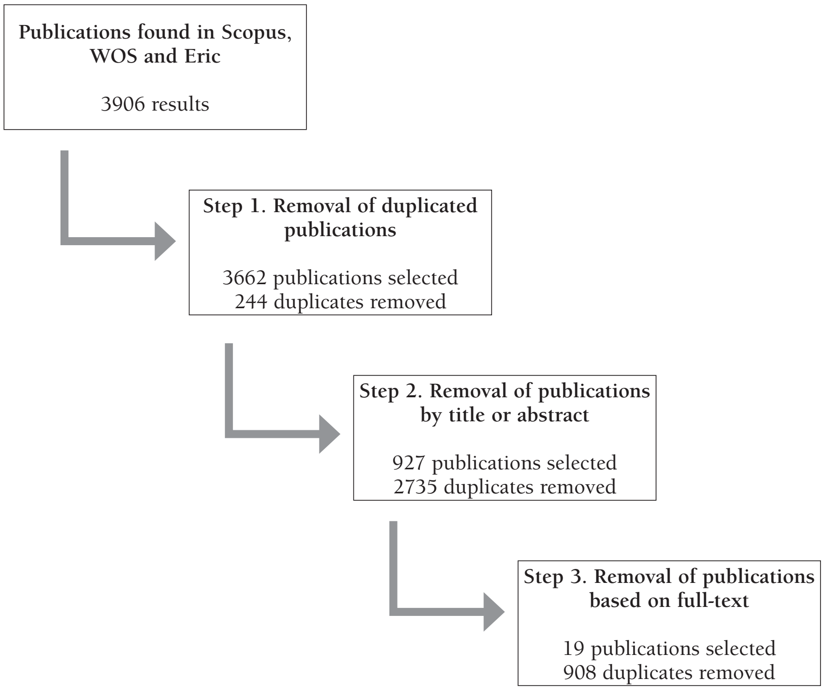
Exclusion criteria		Selection criteria	
EC 1	The publication is not in English or Spanish	SC 1	The publication is in English or Spanish
EC 2	The date of the publication is not between 2012 and 2022	SC 2	The date of the publication is between 2012 and 2022
EC 3	The type of document is not a journal article or conference paper	SC 3	The type of document is a journal article or conference paper
EC 4	The type of study is not empirical	SC 4	The study is empirical
EC 5	Text is not fully available	SC 5	Text is fully available
EC 6	The training level is not higher education	SC 6	The training level is higher education
EC 7	The simulation used is not virtual	SC 7	A VS is used /studied
EC 8	The VS is not used with educational or training purposes	SC 8	The VS is used with educational or training purposes
EC 9	The field of knowledge of the VS and the specific skills that it aims to develop are not described.	SC 9	The field of knowledge of the VS and the specific skills that it aims to develop are described.
EC 10	The technological features of the VS are not clearly explained	SC 10	The technological features of the virtual simulation are clearly explained
EC 11	The pedagogical justification for the application of the VS is not explained	SC 11	The pedagogical justification for the application of the VS is explained
EC 12	The application process of the VS is not detailed.	SC 12	The application process of the VS is detailed.

During the Conducting phase, the literature review is carried out. The analysis of the references was conducted between December 2021 and September 2022. A total of 3906 articles emerged from the searches. A 90% of them came from the SCOPUS repository, an 8% from Web of science, and a 2% from the ERIC database. All of them published in these data bases from 2012 and 2022.

Publication selection process: The refinement of the articles in order to obtain the 19 articles from the 3906 found publications was divided into three steps (see figure 2):

1. Duplicated articles were deleted from the database (244).
2. Remaining articles were analysed taking into consideration their title and abstract in order to consider their adequacy to the inclusion criteria (2735).
3. 927 remaining publications were fully examined and applied all the inclusion and exclusion criteria, obtaining a final amount of 19 publications that met all the requirements.

Figure 2. Summary of the publication selection process

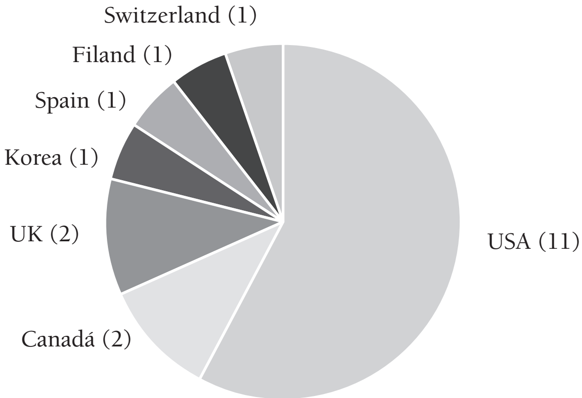


A total of 19 publications were selected for this literature review (0,5% of the initial publications). Several publications were removed in the steps 1, 2 and 3 following the exclusion criteria outlined in table 1. The most common exclusion criteria were those related to TPACK (EC 9-EC12). These criteria excluded a 40% of the remaining articles in step 3. Other relevant exclusion criteria were EC 4 ("The type of study is not empiric") and EC5 ("The text is not fully available"), which excluded respectively 15% and 10% of the step 3 publications. In the next section the results of this review are presented in accordance with the objectives.

Results and discussion

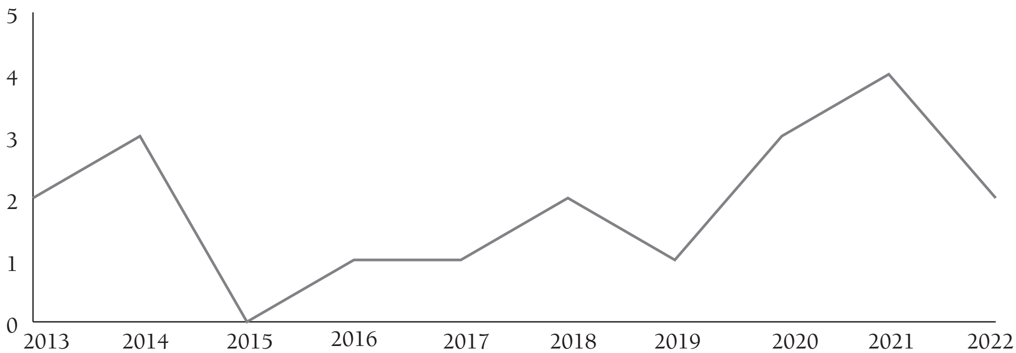
Descriptive analysis of the selected articles shows that VS in higher education are mostly conducted in the American continent, and specifically in USA and Canada (see Fig. 3). Nonetheless, the use of VS is spreading in the last years in Europe and also Asiatic countries like Korea.

Figure 3. Countries where VS are applied



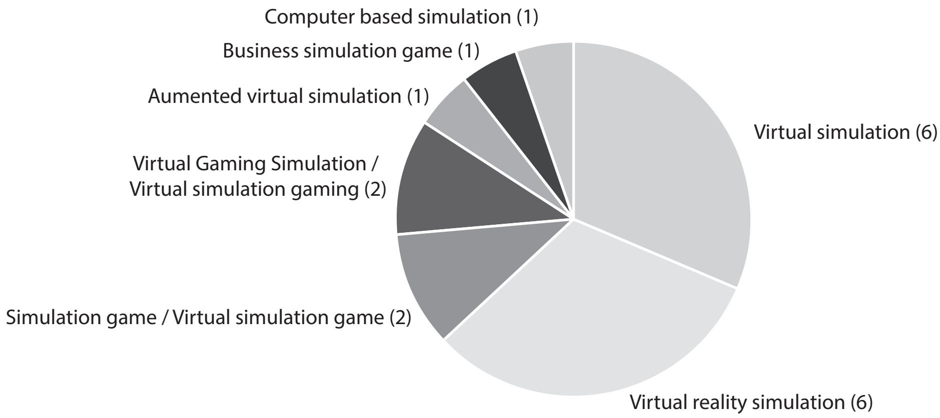
The number of publications is increasing, mostly during the pandemic. This was expected, based on the validity of this training tool for online learning modalities of education. This trend is highly likely to continue because even in last months of 2021, when the collection of articles was conducted, there were already some publications for 2022 gathering the TPACK requirements of this review (see Fig. 4).

Figure 4. Years of publication



There is a huge variability and inconsistency of terms regarding the terminology about virtual simulated environments. Researchers commonly do not provide with definitions for the terms they use (Cant *et al.*, 2019; Verkuyl & Mastrilli, 2017). Virtual Simulation (VS) is the most common term among the selected articles (see figure 5), followed by Virtual Reallity Simulation (VRS), which already implies some features of the simulation as it is the used of virtual reality features within the simulation, or simulation game, which also includes the presence of gaming elements into de conceptualization of the VS.

Figure 5. Terminology used to name the VS



According to the **first specific objective**, the technological feature (TK) that outstands in the analized articles is that most of the VS are screen-based, what means that a computer or a smartphone's screen is used as the support for the VS environment. Furthermore, most of VS are computer-based, meaning that the user can experience the situation through the common components of a computer such as screen, mouse, keyboard and speakers (Lioce, 2020).

However, other technological features such as virtual reality glasses and haptic devices are also present in the literature review, which significantly contribute to the feeling of immersion during the simulation play (Dunleavy *et al.*, 2009), but these are less common in the literature review (Hannans *et al.*, 2021; Lanzieri *et al.*, 2020; Smith *et al.*, 2016). Nonetheless, screen-based simulations also have some technological resources to immerse users into the experience, such as the creation of avatars that can be freely moved in a 3D environment, the presence of other users in the VS and the communication among them, or the first person view perspective, features also found in the analysed articles.

Another important technical aspect is that the vast majority of VS do not need downloading any specific software to play, but they are accessible online.

Table 2 describes the main technological features of each simulation.

Table 2. Main technological, pedagogical and content features of the VS

Publication	Technological features	Pedagogical theories	Content field
Aebersold *et al.* (2018)	2D, first person view (FPV), Screen based, Single player	Situated learning	Medical sciences
Buil *et al.* (2018)	2D, Computer based, Screen based, Single played (per groups), Online	Theory of flow	Economic sciences
Espitia *et al.* (2021)	3D, Avatar, Multiuser, Communication, Computer based, Free movement, Screen based, Online	Problem Based Learning (PBL)	Agricultural sciences

TABLE 2. Main technological, pedagogical and content features of the VS (cont.)

Publication	Technological features	Pedagogical theories	Content field
Falconer (2013)	3D, Avatar, Communication, Computer based, Free movement, Multiuser Screen based, Synchronous, Online	Situated learning	Earth and space sciences
Hannans *et al.* (2021)	3D, Communication, FPV, Single played, VR headset	Experiential learning	Medical sciences
Holthaus and Longhi (2022)	2D, Filmed, Screen based, Single played (per groups)	Concept based learning	Medical sciences
Keys *et al.* (2021)	Screen based, Single player, 2D, Filmed, Asynchronous, FPV, Computer based	Theory of deliberate practice	Medical sciences
Lanzieri (2020)	3D, 360º video, FPV, Single player, Online, VR headset	Situated learning	Sociology
Legner *et al.* (2013)	2D, Computer based, Multiuser, Single played (per groups), Screen based, Synchronous	PBL	Economic sciences
Menzel *et al.* (2014)	3D, Avatar, Communication, Computer based, Free of movement, Multiuser, Screen based, Online	Collaborative learning	Medical sciences
Ranchhod *et al.* (2014)	3D, Avatar, Communication, Computer based, Free of movement, Multiuser, Screen based, Online	Experiential learning	Economic sciences
Riivari *et al.* (2021)	3D, Avatar, Computer based, Free of movement, Multiuser, Screen based, Online	Active cooperative learning	Economic sciences
Rim and Shin (2022)	Simulation 1: 3D, Computer based, Screen based, Single played, Online. Simulation 2: 3D, Avatar, Free of movement, Communication, Computer based, Multiuser, Screen based, Online	Experiential learning	Medical sciences
Rose *et al.* (2020)	3D, Avatar, Communication Free movement, Multiuser, Screen based, Synchronous	Observational learning	Medical sciences
Sanborn *et al.* (2019)	3D, Avatar, Computer based, Free of movement, Multiuser, Screen based, Online	Situated learning	Medical sciences
Savadatti and Johnsen (2017)	3D, Computer based FPV, Screen based, Single played	Inductive learning	Physics
Smith *et al.* (2016)	3D, FPV, Free of movement, Hand controllers, Single played	Situated learning	Medical sciences
Tiffany and Hoglund (2014)	3D, Avatar, Communication, Computer based, Free movement, Multiuser, Screen based, Online	Constructivism	Medical sciences
Verkuyl *et al.* (2020)	2D, Computer based, FPV, Screen based, Single player, Online	Experiential learning	Medical sciences

Note: Rim and Shin (2022) used two kinds of VS.

Based on the aforementioned technological features, VS can be grouped in the following way:

- 3D multiplayer environments. In these VS a higher degree of immersion is achieved through avatars that can handle conversations and have movement freedom in the

environment. These VS incorporate at a times virtual reality glasses to make the experience even more immersive.
- 2D single player environments. In these VS a higher degree of immersion is achieved in some cases by including a first view perspective and real actors playing different roles involved in the simulation, while others simply try to recreate a system with different parameters that the users can manipulate.

The **second specific objective** is related to pedagogical knowledge (PK). Every technological tool that is incorporated into an educational training program should be designed and / or implemented with pedagogical principles that support its use and set the educational goals. In table 2 the learning theories used to justify the VS analysed are shown. Authors use different theories to support the implementation of VS in higher education, but the more recurrent theories are Situated learning, with 5 authors (Aebersold, 2018; Falconer, 2013; Lanzieri *et al.*, 2020; Sanborn *et al.*, 2019; Smith *et al.*, 2016), Experiencial learning with 4 authors (Hannans *et al.*, 2021; Ranchhod *et al.*, 2014; Rim & Shin, 2022; Verkuyl *et al.*, 2020), and Problem-based learning with 2 authors (Espitia *et al.*, 2021; Legner *et al.*, 2013). The rest of them are mentioned by just one author.

In table 3, and brief explanation of the most used theories is provided.

Table 3. Most frequent learning theories used in VS

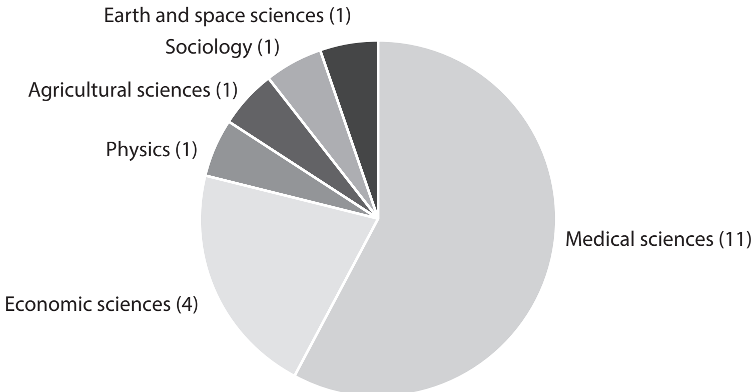
Theory	Authors	Explanation
Situated learning	Lave and Wenger (1991)	This theory highlights the importance of the situation (Context, tools, culture, people, etc) in which the learning occurs. It sees learning as a process of social and personal transformation that takes place in specific communities of practice
Experiential learning	Dewey (1938); Kolb (1984)	This theory claims that it is not possible to completely know about something without practicing it, and highlights practise and experience as the most important elements of learning. Learning is seen as a process of constant evolution and refinement in which knowledge is developed through the transformation of the experiences of the learners
Problem based learning	Savery and Duffy (1995)	Problem based learning is "an instructional learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (Savery, 2006). This learning approach tries to re-connect the knowledge acquisition and the knowledge application proccesses by immersing students in a situation in which they have to solve a realistic problem with a real-world significance

In the common ground of these theories there are some shared features. First, students and teacher must change their traditional roles; while students become active, researching and solving problems, teachers become facilitators, guiding students in the process. Second, reflection periods are seen as a key element in order to refine and consolidate knowledge. Third, the engagement with the learning activity is achieved by involving students in a realistic and authentic environment in which they have to solve a situation that is meaningful to them. Therefore, all these theories relate to the constructivist paradigm of learning, sharing the central statement that knowledge is actively constructed by the individuals rather than received or conveyed from a mentor.

Finally, it can also be noted that Situated learning and Problem-based learning pay a closer attention to the social character of the learning process, considering the exchange and discussion among pairs as key elements of a complete learning experience.

The **third specific objective** is focused on content knowledge (CK). Based on GTIWEB's (2021) classification, the field of knowledge in which VS has major use is Medical sciences (including nursing, medicine, pharmacy and other related degrees). Twelve out of the nineteen articles come from this health-realted sector of science which clearly dominate the production and use of VS nowadays. Nonetheless, the use of VS in higher education is also beginning to spread to others fields of knowledge such as Economic sciences in which 4 articles has been identified (see table 3). Other fields such as Physics, Agricultural sciences, Sociology or Earth and space sciences are also found.

Figure 6. Fields of knowledge in which VS are applied



Related to content knowledge, it is also relevant to take into consideration the VS learning objectives. Table 4 outlines these pedagogical objectives grouped by the field of knowledge in which simulations are used, where three different cathegories of goals emerge:

1. Technical learning goals: specific objectives for the field of knowledge and speciality of the subject that the VS is inserted in.
2. Transversal learning goals: more general objectives aimed at trainning transversal soft skills that are also highly important for their professional practice.
3. A mixture between the technical and transversal side of the objectives.

Table 4. Field of knowledge and learning objectives in VS

Article	Content			
	Field of knowledge	Learning objectives		
		Technical	Technical and transversal	Transversal
Rim and Shin (2022)	Medical sciences	• To improve learners' knowledge, self-confidence, and learning motivation through home visits in the community and providing health assessment	• To improve clinical judgment, communication, and knowledge in the context of nursing child diagnosed with type 1 diabetes • To facilitate critical thinking, clinical judgment, and communication with nursing activities for symptom management infant with fever	• Enhancing decision-making
Menzel (2014)	Medical sciences		• Develop social justice attitudes towards poor people	
Verkuyl (2020)	Medical sciences	• Prenatal health assessment • Apply knowledge of physical and psychosocial prenatal nursing assessment • Identify normal findings, abnormal variations and potential complications during a prenatal visit • Demonstrate therapeutic interventions when caring for a pregnant woman		• Training decision making
Tiffany and Hoglund (2014)	Medical sciences	• Integrate an understanding of population-focused principles, family theory, disaster planning/emergency preparedness, and the Christian worldview in the care of clients in the community • Critically analyse health disparities, barriers to adequate healthcare, and community assets/resources for improving health quality from an ethical perspective • Identify the incidence and/or prevalence, distribution, and control of disease in a population as well as the protective factors, risk factors and environmental factors related to communities	• Evaluate evidence-based public health nursing interventions to address health disparities in a given population, emphasizing the roles of advocate and collaborator	• Demonstrate effective verbal, electronic, and written communication skills

Table 4. Field of knowledge and learning objectives in VS (cont.)

Article	Content			
	Field of knowledge	Learning objectives		
		Technical	Technical and transversal	Transversal
Aebersold *et al.* (2018)	Medical sciences	• Train clinical psychomotor skills to place a nasogastric tube		
Smith *et al.* (2018)	Medical sciences	• Prepare to respond and safely perform when a disaster occurs • Train the skill of decontamination		
Sanborn *et al.* (2019)	Medical sciences		• Share a list of the patient/family goals for end-of-life care that were identified during the care conference • Propose at least three different strategies that could be used in their future practice to facilitate effective interprofessional care delivery	• Practising interprofessional communication • Critique their individual team communication performance using selected sections of the Interprofessional Collaborator Assessment Rubric (ICAR) • Demonstrate at least two specific interprofessional communication skills while participating in the activity
Hannans *et al.* (2021)	Medical sciences	• Understand how hearing and vision loss can mimic cognitive impairment • Describe what happens inside the eyeball as macular degeneration progresses	• Identify effective modes of communication between the patient, family, health-care personnel and systems that contribute to patient quality of life • Pinpoint ways people with macular degeneration can use technology and assistive devices to improve quality of life	
Rose *et al.* (2020)	Medical sciences			• Enhance nursing students' awareness of civility and incivility • Recognize civility and incivility in themselves and others
Keys *et al.* (2021)	Medical sciences	• Receive education on cardiac resuscitation so that when they enter independent practice they can safely and effectively respond to patients in cardiac arrest • Reinforce key aspects of the Heart and Stroke Foundation's (2015) BLS and ACLS algorithms		

Table 4. Field of knowledge and learning objectives in VS (cont.)

Article	Content			
	Field of knowledge	Learning objectives		
		Technical	Technical and transversal	Transversal
Holthaus and Longhi (2021)	Medical sciences	• Develop chronic care knowledge		
Legner *et al.* (2013)	Economical sciences	• Define a company strategy • Operationalize the strategy	• Defend the company strategy in a dynamic market, in competition with other teams	• Set goals and analyse performance
Ranchhod *et al.* (2014)	Economical sciences	• Teaching marketing management • Improving students' understanding of strategic marketing concepts and procedures • Develop marketing management skills		• Maximising their motivation and satisfaction
Buil *et al.* (2018)	Economical sciences		• Practise decision making running a company	
Riivari *et al.* (2021)	Economical sciences			• Reflect on team roles and leadership • Decision making • Evaluate team effectiveness
Espitia (2021)	Agricultural sciences	• Development of core competencies • Understand the emergency response system		• Develop problem solving skills • Train of leadership and teamwork *
Savadatti and Johnsen (2017)	Physics	• Learn fluid mechanic concepts		
Falconer (2013)	Earth and space sciences	• Understand risk management and accident causation	• Investigation and assessment of accidents Interviewing witnesses	
Lanzieri (2020)	Sociology		• Feel a deep presence physically and socially with the surroundings / in the community. • Immerse students in a typical NYC neighbourhood.	

*Note: * goals not mentioned in the article.*

Some of the VS cover a lot of learning objectives, from transversal skills to hard skills such as Tiffany and Hoglund (2014) or Legner *et al.* (2013). These simulations include technical learning objectives such as Integrating an understanding of population-focused principles, family theory, disaster planning/emergency preparedness, or defining a company business strategy, which are mixed with other more transversal learning goals such as demonstrating effective verbal, electronic, and written communication skills, or developing goal setting skills.

On the other hand, other simulations just focus on specific and technical skills related with the problem to be solved in the simulation such as Aebersold *et al.* (2018), Smith *et al.* (2016), Holthaus and Longhi (2022) or Savadatti and Johnsen (2017). These simulations include objectives like training clinical psychomotor skills to place a nasogastric tube, preparing to respond and safely perform when a disaster occurs, developing chronic care knowledge, and learning fluid mechanic concepts, goals that are much more technical.

Also, it has been highlighted that the VS found usually recreate situations that although are important for the student to understand and know how to proceed, it is difficult or even dangerous to have access to them for several reasons such as the complexity or impossibility of that situation to happen in real life (Falconer, 2013; Hannans *et al.*, 2021; Menzel *et al.*, 2014; Smith *et al.*, 2016), the high risk for the subjects (patients, populations, etc) or even the own students (Aebersold, 2018; Keys *et al.*, 2021; Rim & Shin, 2022), the huge responsibility that will imply for the learners (Buil *et al.*, 2018; Holthaus & Longhi, 2022; Keys *et al.*, 2021; Legner *et al.*, 2013; Riivari *et al.*, 2021; Rim & Shin, 2022; Tiffany & Hoglund, 2014; Verkuyl *et al.*, 2020), or the need of other professionals or patients to be present to work interprofessional skills, leadership, teamwork, etc. (Espitia *et al.*, 2021; Falconer, 2013; Lanzieri *et al.*, 2020; Riivari *et al.*, 2021; Rose *et al.*, 2020; Sanborn *et al.*, 2019).

The fourth specific **objective** analyses the relationships between the technological features of VS and its content (TCK). Cant *et al.* (2019) established that the level of immersion is one of the key features to take into account to properly describe and understand a VS. Immersion is described in the context of virtual environments as a psychological reaction that makes the participants feel enveloped by the virtual space, what will also increase the feeling of presence in the environment (Witmer & Singer, 1998). Therefore, immersive elements are VS features that help users to feel "inside" of the simulated scenario; thus, allow them to have a closer connection with the situation that is going on.

From this review, features that contribute to the immersion of the user in a VS are: VR glasses and Haptic devices, Avatars, Free of movement, Communication and First-person view. The 19 VS are ordered by their level of immersion, which ranges from 0 in case that the simulations do not have any of the previous features, to 5 in case it has them all- This immersion level is related with the kind of learning objectives of the simulations in terms of technical learning goals, transversal learning goals, or both.

Table 5 shows that all the VS with 3 or more immersive elements include transversal skills in their learning objectives, and 8 from the 10 most immersive simulations include a combination of technical and transversal skills, offering a wider training for the user. However, from the 10 VS with 2 or less immersive elements, just 4 include transversal skills into their learning goals, and the remaining 6 just focus on technical skills of the field of knowledge.

As an example one can see how more immersive simulations such as Hannans *et al.* (2021) that tries to completely introduce the learners into a different situation through the use of a headset and glasses so that users can experience the life of a person with hearing and visions impediments; or Tiffany and Hoglund (2014), that recreate a whole 3D virtual world in which users can freely move and interact with their pairs, usually include a wide range of learning objectives that go from more transversal skills to more technical ones. On the other hand, less immersive simulations such as Savadatti and Johnsen (2017), Keys *et al.* (2021), or Holthaus and Longhi (2021), just mention technical learning objectives of their fields such as learning fluid mechanic concepts, receiving education on cardiac resuscitation, or developing chronic care knowledge.

In the **fifth objective**, pedagogical content Knowledge (PCK) aims to explore the relationship between the pedagogical theories used to justify the use of a VS and the content of that simulation. Table 5 highlights the VS based on the pedagogical theory that support them and the kind of learning objectives that they aim to achieve.

Authors who use theories like Experiential learning, Situated learning, Constructivism, or Problem-based learning, tend to include learning objectives that focus on the improvement of transversal and technical skills. This is because those theories pay attention not only to the specific task or problem to be solved, but also to the general situation that englobes the problem. However, more partial theories such as Concept based learning, Theory of deliberate practice or Inductive learning, which pay a closer attention to the task to be done over the situation in which this task need to be done, commonly are used by authors whose VS aim to achieve technical and specific learning objectives of their field of knowledge.

Finally, the **sixth specific objective** of this study aims to explore the relationship between the technological features of VS and the pedagogy that supports them (TPK). In table 5 both categories of the TPACK are related.

Although the relationship is not as clear as the previous ones, the same pattern can be seen. In this case, the more complete pedagogical theories about the learning experience (Experiential learning, Situated learning and Problem-based learning) are also more frequent in more immersive simulations. 10 out of the 13 VS that include two or more immersive elements use these kinds of theories for the justification of the VS.

On the other hand, VS with less immersive features tend to be justified with more partial and specific pedagogical theories such as Inductive learning, Theory of deliberate practice or Concept based learning. Almost half (3 out of 7) of the simulations with one or less immersive elements use these kinds of theories for the justification.

Table 5. Relationship between the immersion level of the VS and their pedagogical theories and their learning objectives

Publication	Immersion level	Pedagogical theory	Learning objectives		
			Technical	Both	Transversal
Rim and Shin (2022) (2º simulation)	4	Experiential learning	• Improve learners' knowledge, self-confidence, and learning motivation through home visits in the community and providing health assessment		• Enhancing decision-making
Espitia (2021)	4	PBL	• Develop core competencies. • Understand the emergency response system		• Develop problem solving skills. • Train of leadership and teamwork
Menzel et al. (2014)	4	Collaborative learning		• Develop social justice attitudes towards poor people	
Ranchhod et al. (2014)	4	Experiential learning	• Teach marketing management. • Improve students' understanding of strategic marketing concepts and procedures. • Develop marketing management skills		• Maximising their motivation and satisfaction
Tiffany and Hoglund (2014)	4	Constructivism	• Integrate an understanding of population-focused principles, family theory, disaster planning /emergency preparedness, and the Christian worldview in the care of clients in the community. • Critically analyse health disparities, barriers to adequate healthcare, and community assets/resources for improving health quality from an ethical perspective. • Identify the incidence and/or prevalence, distribution, and control of disease in a population as well as the protective factors, risk factors and environmental factors related to communities	• Evaluate evidence-based public health nursing interventions to address health disparities in a given population, emphasizing the roles of advocate and collaborator	• Demonstrate effective verbal, electronic, and written communication skills

TABLE 5. Relationship between the immersion level of the VS and their pedagogical theories and their learning objectives (cont.)

Publication	Immersion level	Pedagogical theory	Learning objectives		
			Technical	Both	Transversal
Sanborn *et al.* (2019)	4	Situated learning		• Share a list of the patient/ family goals for end-of-life care that were identified during the care conference • Propose at least three different strategies that could be used in their future practice to facilitate effective interprofessional care delivery	• Practising interprofessional communication. • -Critique their individual team communication performance using selected sections of the Interprofessional Collaborator Assessment Rubric (ICAR). • -Demonstrate at least two specific interprofessional communication skills while participating in the activity
Hannans *et al.* (2021)	4	Experiential learning	• Understand how hearing and vision loss can mimic cognitive impairment • Describe what happens inside the eyeball as macular degeneration progresses	• Identify effective modes of communication between the patient, family, health-care personnel and systems that contribute to patient quality of life • Pinpoint ways people with macular degeneration can use technology and assistive devices to improve quality of life	
Riivari *et al.* (2021)	3	Active cooperative learning			• Reflect on team roles and leadership. • Decision making. • Evaluate team effectiveness
Falconer (2013)	3	Situated learning	• Understand risk management and accident causation	• Investigation and assessment of accidents Interviewing witnesses	

Table 5. Relationship between the immersion level of the VS and their pedagogical theories and their learning objectives (cont.)

Publication	Immersion level	Pedagogical theory	Learning objectives		
			Technical	Both	Transversal
Rose *et al.* (2020)	3	Observational learning			• Enhance nursing students' awareness of civility and incivility. • Recognize civility and incivility in themselves and others
Lanzieri *et al.* (2020)	2	Situated learning		• Feel a deep presence physically and socially with the surroundings / in the community • Immerse students in a typical NYC neighbourhood	
Aebersold *et al.* (2018)	2	Situated learning	• Train clinical psychomotor skills to place a nasogastric tube		
Smith *et al.* (2018)	2	Situated learning	• Prepare to respond and safely perform when a disaster occurs • Train the skill of decontamination		
Legner *et al.* (2013)	1	PBL	• Define a company strategy • Operationalize the strategy	• Defend the company strategy in a dynamic market, in competition with other teams	• Set goals and analyse performance
Verkuyl *et al.* (2020)	1	Experiential learning	• Prenatal health assessment • Apply knowledge of physical and psychosocial prenatal nursing assessment • Identify normal findings, abnormal variations and potential complications during a prenatal visit • Demonstrate therapeutic interventions when caring for a pregnant woman		• Training decision making
Savadatti and Johnsen (2017)	1	Inductive learning	• Learn fluid mechanic concepts		

Table 5. Relationship between the immersion level of the VS and their pedagogical theories and their learning objectives (cont.)

Publication	Immersion level	Pedagogical theory	Learning objectives		
			Technical	Both	Transversal
Keys *et al.* (2021)	1	Theory of deliberate practice	• Receive education on cardiac resuscitation so that when they enter independent practice they can safely and effectively respond to patients in cardiac arrest • Reinforce key aspects of the Heart and Stroke Foundation's (2015) BLS and ACLS algorithms		
Rim and Shin (2022) (1° simulation)	0	Experiential learning		• Improve clinical judgment, communication, and knowledge in the context of nursing child diagnosed with type 1 diabetes • Facilitate critical thinking, clinical judgment, and communication with nursing activities for symptom management infant with fever	
Buil *et al.* (2018)	0	Theory of flow		• Practise decision making running a company	
Holthaus and Longhi (2021)	0	Concept based learning	• Develop chronic care knowledge		

*Note: * goals not mentioned in the article.*

Conclusions

Description provided in this literature review shows that VS are complex tools that present wide variations in terms of their technological features, their learning goals and, therefore, their pedagogical foundations. Results of these systematic literature review, regarding the first specific objective, agree with previous findings with a domain of screen-based simulations, and a classification of VS in two big groups: 3D multiplayer environments and 2D single player environments. These categories correspond respectively with the Virtual worlds and Virtual patients categories used by authors like Chang *et al.* (2016). Nonetheless, although authors tend to describe 2D Virtual patients as non-immersive simulations and 3D Virtual worlds as immersive simulations (Chang *et al.*, 2016; Sim *et al.*, 2022), it is important, in order to efficiently implement VS in practice, to deepen into the elements that make a VS immersive, so that 2D simulations are considered as partially immersive (Foronda *et al.*, 2020) and can relate the level of immersion with their pedagogical and content characteristics.

Attending to the specific objectives three and four, interesting findings have emerged when exploring the relationships between the level of immersion of the VS and its learning objectives. On the one hand, based on the specific objective three, learning objectives rarely gather the whole range of competences that are trained with the VS, paying a lot of attention to the technical content of the simulation, but not to other related skills that are also directly improved with the use of the VS. On the other hand, based on the specific objective four it has been found that the more immersive simulations tend to cover a wider range of competencies. Nonetheless, it is also worth mentioning that learning objectives hardly ever are formulated taking into account taxonomies like the Bloom's one. So, they usually have a poor formulation and tend to put a lot of attention to the technical content of the simulation, but not to other related skills that are also directly improved with the use of the VS.

In terms of the specific objectives two and five, another interesting finding for practitioners has been made. Although Situated and Experiential learning are the most common theories to justify the use VS, the educational theories are mostly related with the kind of VS used: the more immersive elements included in the VS, the more complete the pedagogical theories are, tending to take into consideration not just the specific content to be learnt, but also the whole context or situation in which the use of that content may arise.

Finally, regarding the specific objective six, a slighter relation can be spotted when combining the pedagogical theories of the VS and its learning objectives. Simulations that give importance to the whole situation that involves the problem to be solved tend to use more complete learning theories such as the experiential learning or the situational learning, whose goal is far beyond the learning of technical aspects of their field of knowledge, but also include the development of other soft skills also highly valuable for the correct performance of their professional activity. Meanwhile, other simulations that are more focused on the development and understanding of specific and technical knowledge use learning theories that pay a closer attention to the specific task or problem to be solved regardless of the situation in which it appears, or the people involved in it.

All these findings allow us to consider the TPACK model as a suitable paradigm for the analysis of this new learning tool that is widely spreading in higher education. Nonetheless, in spite of the wide amount of research articles found in the first stage of the literature review related with the implementation of VS in higher education, just a few describe their features according with the TPACK requirements, what implies to consider their technological, pedagogical and content characteristics in the explanation of the tool.

Further research it is needed to achieve a deeper understanding of VS by using the TPACK model, and to extract more conclusive findings as a result of maximizing the number of VS analysed by including other educational levels.

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Resumen

Un análisis de las simulaciones virtuales desde la óptica del modelo TPACK

INTRODUCCIÓN. Las simulaciones virtuales (SV) han aumentado su presencia como herramientas formativas en educación superior en los últimos años, y se han consolidado, a raíz del COVID-19, como una potente herramienta que permite suplir muchas de las limitaciones que se encuentran en las salas de simulación presenciales, como son el elevado coste y la baja replicabilidad. Ahora bien, pocos estudios han abordado el uso de modelos como el TPACK para el análisis de SV. **MÉTODO**. En este artículo se realiza una revisión sistemática de la literatura con el objetivo de analizar las características de las SV implementadas en educación superior durante la década 2012-2022 desde la óptica del modelo TPACK. **RESULTADOS**. Entre los resultados encontrados destacan el gran uso de SV en el área de la salud, y en especial en el continente americano (Estados Unidos y Canadá); los entornos de simulación 2D online con acceso a través del ordenador como las características tecnológicas más comunes de las SV; y la recurrencia a las teorías del Aprendizaje experiencial, Aprendizaje situado y el Aprendizaje basado en problemas como sus principales justificaciones pedagógicas. **DISCUSIÓN**. Se aprecian una serie de relaciones entre las características tecnológicas, pedagógicas y de contenido de las SV que nos ayudan a comprender mejor esta herramienta en creciente uso, en especial en el área de la salud. Además, destaca, por un lado, la escasez de artículos que propiamente describen el uso de SV de acuerdo a los requerimientos del TPACK, y, por otro, la adecuación y viabilidad de dicho modelo tanto para el análisis como el desarrollo de SV.

Palabras clave: *Simulación, Virtualidad, Educación superior, Formación, Revisión sistemática.*

Résumé

Analyse des simulations virtuelles dans l'optique du modèle TPACK

INTRODUCTION. Ces dernières années les simulations virtuelles (SV) ont accru leur présence en tant qu'outils de formation dans l'enseignement supérieur. Celles ont été consolidées à la suite de la COVID-19 comme outils puissants permettant de surmonter un bon nombre de limites rencontrées dans les salles de simulation présentielles, notamment son coût élevé et sa faible reproductibilité. Toutefois, peu d'études ont abordé l'utilisation du modèle TPACK pour l'analyse de la SV. **MÉTHODE**. Dans cet article, une revue systématique de la littérature est réalisée dans le but d'analyser les caractéristiques des SV mises en œuvre dans l'enseignement supérieur dans l'optique du modèle TPACK au cours de la décennie 2012-2022. **RÉSULTATS**. Parmi les résultats constatés, on s'aperçoit de l'utilisation généralisé des SV dans le domaine de la santé, en particulier sur le continent américain (États-Unis et Canada); les environnements de simulation 2D en ligne accessibles par ordinateur comme caractéristique technologique le plu habituelle dans les SV ; ainsi que l'appel aux théories de l'apprentissage expérientiel, de l'apprentissage situé et de l'apprentissage par problèmes comme leur justification pédagogique. **DISCUSSION**. On peut observer une série de relations entre les caractéristiques technologiques, les caractéristiques pédagogiques et celles de contenu des SV qui nous aident à mieux comprendre cet outil de plus en plus utilisé dans le

domaine de la santé. En outre, il met en évidence, d'une part, la rareté des articles décrivant l'utilisation des SV conformément aux exigences du TPACK et, d'une autre part, l'adéquation et la faisabilité de ce modèle tant pour l'analyse que pour le développement des SV.

Mots-clés : *Simulation, Virtualité, Enseignement supérieur, Formation, Revue systématique.*

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