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Collaborative Skills Training Using Digital Tools: A Systematic Literature Review

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ABSTRACT

The development of information and communication technologies has changed our way of working, emphasizing the need for individuals to develop collaborative skills. The aim of the present systematic review was to examine the extent to which these skills can be developed through the use of digital tools. A search of seven electronic databases, following PRISMA guidelines, yielded 18 relevant peer-reviewed articles. Analysis of the literature revealed that digital tools have the potential to enhance collaborative skills. However, the effects vary considerably, depending on which tools, methods, and measures are used. It also revealed that studies were conducted mainly in the social sciences, mostly among students, and half of them focused on short interventions. Another finding was that little is known about the features of the digital tools that actually contribute to these effects. Work on how digital tools contribute to the development of collaborative skills is still in its infancy, and more research based on rigorous methods and measures is needed.

KEYWORDS




Collaborative skills; team training; soft skills; digital tools; technology-based environments

1. Introduction

The work environment has changed considerably over the past few decades, with the development of information and communications technology (ICT). This has led to the transformation of organizations and the democratization of teleworking and hybrid work. Employee work dynamics have changed to accommodate these new practices, and because of the transformation of activities brought about by ICT, students now need specific skills to become part of the *knowledge society* (Anderson, 2008). These include digital literacy, critical thinking, creativity, and collaborative skills, which are variously referred to as *soft skills*, *transferable skills*, *key skills*, *social skills*, *nontechnical skills*, and *twenty-first century skills* (e.g., Cinque, 2016; Flin et al., 2008; Goggin et al., 2019; Touloumakos, 2020). Similarly, various classifications of these skills have been developed in different domains. For example, Binkley et al. (2012) suggested organizing skills according to whether they are related to *ways of thinking* (e.g., creativity, critical thinking, metacognition), *ways of working* (e.g., communication, collaboration), *tools for working* (e.g., information literacy, ICT literacy), or *living in the world* (e.g., citizenship, personal responsibility, and social responsibility). Taken together with other classifications (Ananiadou & Claro, 2009; Flin et al., 2008; Soulé & Warrick, 2015; Sun et al., 2022), they indicate that some skills are regarded as central (i.e., collaboration, communication, ICT literacy), while others are viewed as more peripheral (e.g., creativity, critical thinking), or are completely overlooked, such as planning and conflict resolution (Voogt & Roblin, 2012).

Despite differences between the classifications and terminologies used in the literature, there is a broad consensus on the need to develop these skills in order to facilitate performance and adaptation in the 21st-century work environment. First, these skills are needed to search, assess, select, and communicate relevant information, and to collaborate within teams (Morrison-Smith & Ruiz, 2020). In today's labor market, these skills are viewed as essential for employability and are much sought after by employers (Abelha et al., 2020; Cimatti, 2016; Succi & Canovi, 2020). They therefore need to be developed not just among students, but also among employees in the course of their professional career, from a lifelong learning perspective (for reviews, see Noah & Abdul Aziz, 2020; Widad & Abdellah, 2022). Second, the transformation of the work environment brought about by ICT has created new and specific challenges for employees (Sun et al., 2022). For example, with the development of digital remote working environments and teleworking, teams are more likely to encounter difficulties when it comes to efficiently making decisions, negotiating, or collaborating (e.g., Swaab et al., 2012; Vayre, 2021). Digital technologies are omnipresent in education and the workplace, presenting fresh challenges when it comes to managing information and working with others. Hence the need to examine the literature concerning the training of individuals' *soft skills* using an ICT environment.

To our knowledge, few systematic reviews have been carried out on the development of *soft skills* using digital tools. van Laar et al. (2017)'s systematic review examined the concepts used to describe the skills needed in a digital

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environment based on a classification of 21st-century skills, and identified seven core skills with digital components: technical, information, communication, collaboration, creativity, critical thinking, and problem solving. In a subsequent literature review, the same authors (van Laar et al., 2020) tried to identify the main determinants of these seven skills. Results indicated that the main determinants were limited to personality and psychological factors. Their systematic review also revealed that a specific category of soft skills related to collaboration and communication tended to be neglected by researchers, concluding that “21st-century skills and 21st-century digital skills studies measured the determinants of problem-solving skills relatively frequently, whereas collaboration and communication skills studies were underreported” (van Laar et al., 2020, p. 9). It therefore seems important to investigate how people develop teamwork and collaborative skills using digital tools. Conceptually, the terms *teamwork* and *collaborative (problem-solving) skills* are often used interchangeably, but the former is generally broader than the latter. Teamwork can be defined as the process whereby team members collaborate to achieve task goals (Driskell et al., 2018). In other words, it refers to “the integration of individuals’ efforts toward the accomplishment of a shared goal” (Mathieu et al., 2008, p. 458). At a more general level, teamwork refers to the skills involved in working with others, such as coordination, collaboration, cooperation, communication, leadership, conflict management, problem solving, and decision making.

A number of international reports have underlined the importance of developing both teamwork and collaborative skills. For example, the OECD Program for International Student Assessment (PISA) highlighted a generally low level of proficiency among students in terms of collaborative problem-solving (OECD, 2017a, 2017b). The OECD Teaching and Learning International Survey (TALIS) asking teachers and school leaders about their learning environments reached the same conclusions for education professionals, as the latter were found to have very poor collaborative skills (OECD, 2019). In commenting collaborative problem-solving skills in education, Fiore et al. (2018) noted that students tend to overestimate their collaborative skills, even though training to develop these skills is rarely included in their curricula. Although numerous studies have described ways of assessing students’ ability to solve problems collaboratively (e.g., Care et al., 2016; Hamet Bagnou et al., 2022; Rojas et al., 2021; Sun et al., 2020, 2022), there continues to be a dearth of research on how best to train students to develop teamwork and collaborative skills (Ahonen & Kinnunen, 2015; Love et al., 2023). In recent studies, authors have advocated for educators and researchers to work together to develop evidence-based training of collaborative skills for students (Fiore et al., 2018; Greiff & Borgonovi, 2022). Moreover, research suggests that various digital tools can be used to develop teamwork and collaborative skills (e.g., Cuomo et al., 2022; Li & Liu, 2022; Makri et al., 2021). For example, robots can promote collaborative skills (Toh et al., 2016), and games and simulations can help develop teamwork skills such as decision-making (Akcaoglu &

Koehler, 2014; Tiwari et al., 2014), problem solving (Lancaster, 2014; Liu et al., 2011), and collaborative skills (Qian & Clark, 2016; Yang & Chang, 2013).

Despite a growing interest in technology-based environments for learning 21st-century skills, there remains a need for empirical evidence to assess how digital tools can be used specifically to develop teamwork and collaborative skills. The purpose of the present systematic review was to fill some of these gaps by comprehensively summarizing existing research on the development of collaborative and communication skills with digital tools.

This present review aims to investigate the following research question: How does training involving the use of digital tools promote the development of collaborative skills? More specifically, we seek to answer the following research questions (RQs):

- RQ1.** In which subject areas and disciplines were previous studies conducted?
- RQ2.** What was the population of these studies?
- RQ3.** Which types of interventions were used to develop collaborative skills?
- RQ4.** Which research designs were used?
- RQ5.** Which digital tools were used?
- RQ6.** How were these skills measured and what were the effects of training?

2. Method

This systematic review was performed according to Preferred Reporting of Items for Systematic reviews and Meta-Analyses Statement (PRISMA) guidelines. PRISMA provides a systematic checklist of 27 criteria and a flow diagram allowing for the reproducibility and transparency of the research (Moher et al., 2015; Page et al., 2021).

2.1. Search strategy

We searched seven databases: Web of Science and six databases available through the EBSCO platform: APA PsycInfo, APA PsycArticles, MEDLINE, Psychology and Behavioral Science Collection, Academic Search Premier, and ERIC. These databases were chosen because they cover various disciplinary areas in psychology, learning sciences, and medicine. Our institution’s access to the selected databases allowed us to use the same Boolean function for each one. The three expanders proposed by EBSCO were used to broaden the scope of the search: apply related words (“include synonyms and plurals of the terms”), search within documents (“search for the keywords within the full text of articles, as well as abstract and citation information”), and apply equivalent subjects (“utilize mapped vocabulary terms to add precision to unqualified keyword searches”).

Our search concerned three concepts: teamwork and collaborative skills, digital tools, and educational context. We used several keywords and synonyms for each one, to ensure a broad coverage of studies. We therefore implemented the following Boolean search: (“teamwork skill*” OR “teamwork

competenc* OR "teamwork abilit*" OR "collaborati* skill*" OR "collaborati* competenc*" OR "collaborati* abilit*") AND ("software" OR "online tool*" OR "online environment" OR "digital tool*" OR "digital environment" OR "numerical tool*" OR "electronic tool*" OR "computer-based tool*" OR "interactive environment" OR "computer-assisted" OR "computer-aided" OR "web-based" OR "groupware") AND ("train*" OR "educat*" OR "learn*" OR "instruct*" OR "teach*"). The final search and final data extraction were performed in January 2023.

2.2. Eligibility criteria

We included studies related to (1) teamwork and collaborative skills development, (2) involving the use of an ICT environment or digital tools, and (3) in the context of education and learning. Studies that did not deal with collaborative skills or teamwork or did not use a digital tool in the context of education and learning were excluded. Given our criteria, we focused on collaborative skills as in computer-supported collaborative learning (CSCL), and not on cooperative skills as in computer-supported cooperative work (CSCW). In the literature, a distinction is made between these two concepts, based on the way in which the task is divided (Schürmann et al., 2024). With cooperation, a given task is divided among group members, whereas collaboration refers to "the mutual engagement of participants in a coordinated effort to solve the problem together" (Roschelle & Teasley, 1995, p. 70). Only the latter was considered in the present systematic review.

To be included, articles also had to be written in English and peer reviewed, and their full texts had to be available. We excluded tests, editorials, dissertations, chapters, proceedings, and book reviews. Gray literature was also excluded.

2.3. Study selection

The search yielded a total of 2475 articles. After eliminating 642 duplicates, we were left with 1833 articles. The abstracts of these articles were read, resulting in the exclusion of 1722 articles. The 111 remaining articles were uploaded in full text (three were not available to our institution and the authors did not respond to our requests, so they were excluded from the next step). After reading the full texts, 90 articles were deleted: 25 that did not involve the use of a digital tool designed to develop learners' collaborative skills; and 65 that did not provide any data on the development of learners' collaborative skills. A total of 18 articles therefore met both our inclusion criteria and were selected for analysis. The procedure is shown in the form of a PRISMA flow chart in Figure 1, and the study selection file is available online in our OSF project (<https://osf.io/u2qez/>).

2.4. Screening and selection bias

To avoid selection bias, the selection process was performed by two authors (A.C. and B.H.). The first selection step based on titles and abstracts was performed independently

by the two coders, who each examined all the articles (Cohen's kappa = 0.76; interrater agreement = 97.76%). To be included in the second step, an article had to be selected by at least one of the two coders. For the last step, requiring full-text assessments, all 18 articles were independently coded by the two coders according to the selection criteria (Cohen's kappa = 0.72; interrater agreement = 90.74%). Any disagreements (10 of the 111 full-text articles) were discussed until a consensus was reached.

2.5. Data extraction

We created a data extraction form to explore the selected studies. This form included the following sections: characteristics of studies (authors, date of publication, country), number of participants and design of studies, ICT environment used, metrics, and main findings (see Appendix A).

2.6. Quality appraisal

We used the Mixed Methods Appraisal Tool (MMAT) to assess the quality of the studies (Hong et al., 2018). MMAT is composed of two screening questions and five core quality criteria. There is one core quality criterion for each of the five categories of study design: qualitative, quantitative (descriptive, randomized, and nonrandomized), and mixed. Studies were considered to be of high quality if they met 100% of the criteria, moderate quality if they met 80–99% of the criteria, average quality if they met 60–79% of the criteria, low quality if they met 40–59% of the criteria, and very low quality if they met < 39% of the criteria. The authors performed a quality assessment for the 18 articles after full-text screening, and discussed the results of this assessment. None of the appraised articles were excluded, even when the quality score was low. Research designs of the selected studies were as follows: qualitative ($n=4$), quantitative descriptive ($n=2$), quantitative randomized ($n=4$), and quantitative nonrandomized ($n=8$). Across all designs, five studies scored 100, five scored 80, five scored 60, one scored 20, and two scored 0. Just over half the studies were rated as being of high or moderate quality.

3. Results

The 18 studies analyzed in the present review are listed in Appendix A.

3.1. Subject areas and disciplines

The selected articles were published between 2001 and 2021. The number of articles was constant over 5-year periods until 2016 (two papers between 2001 and 2006, three papers between 2006 and 2011, and between 2011 and 2016), and half were published after 2016.

We used the Scimago Journal & Country Rank database (<https://www.scimagojr.com>) to establish the subject areas and disciplines covered by the journals in which the selected articles were published (Table 1). The most prevalent subject area was social science ($n=12$), followed by medicine

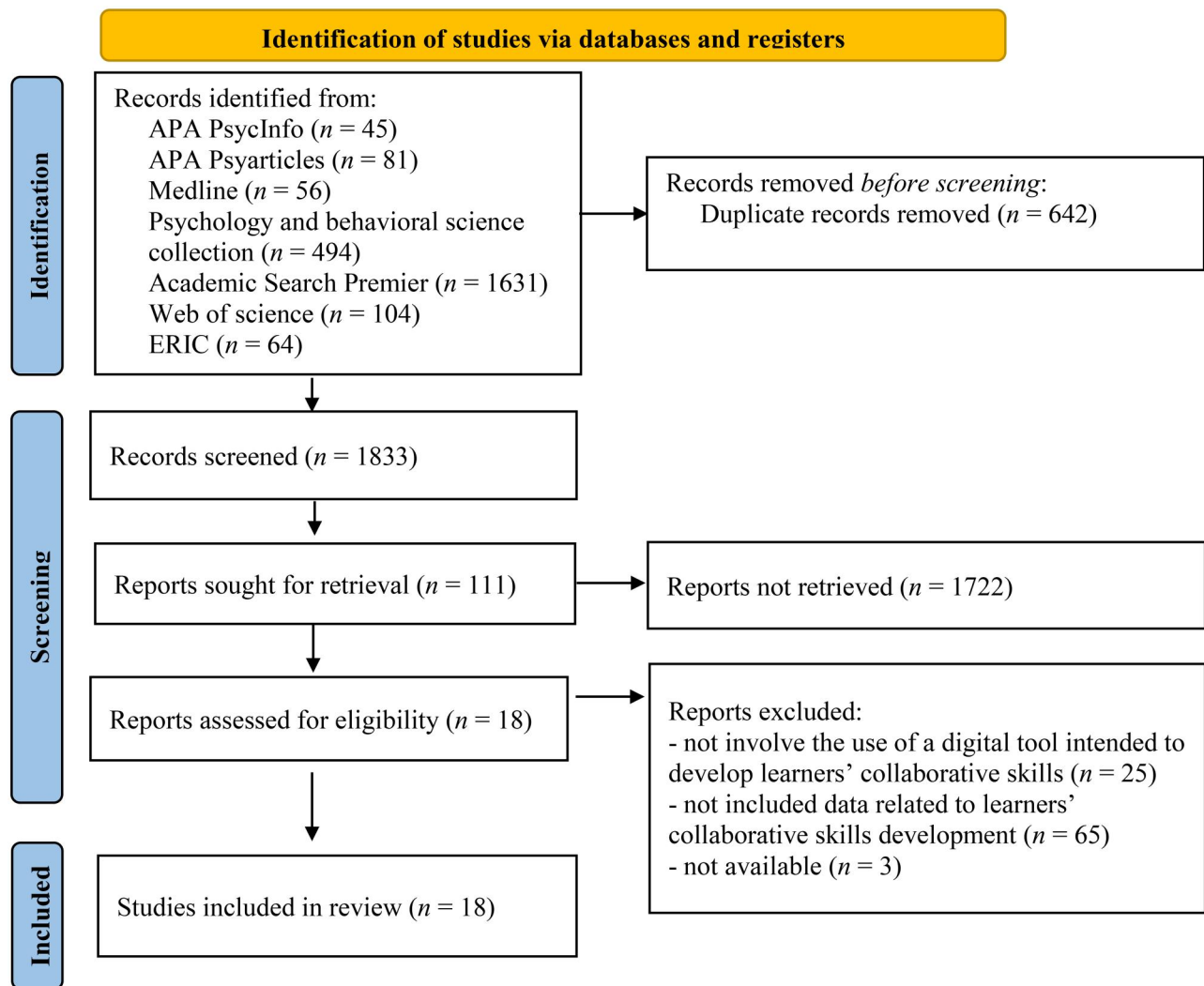


Figure 1. Flow chart of systematic review.

*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *British Medical Journal*, 372(71). doi:10.1136/bmj.n71.

($n = 7$) and computer science ($n = 5$). Education was the most prevalent discipline ($n = 11$), followed by e-learning ($n = 6$) and computer science applications ($n = 5$).

3.2. Population

Studies described in the selected articles were primarily conducted among students ($n = 13$), notably at university ($n = 9$), but also younger ones in middle or high school ($n = 4$), and three of the latter were conducted in Taiwan. Four of the nine studies among university students involved healthcare students, and three engineering students. Five studies focused on employees in aviation ($n = 2$) and healthcare ($n = 3$).

3.3. Intervention programs

All the studies conducted in healthcare were embedded in one of two types of intervention program: either interprofessional education (IPE)¹ (Carbonaro et al., 2008; Djukic et al., 2015; Evans et al., 2016; Lee et al., 2020; Riesen et al., 2012) or

Team Strategy and Tools to Enhance Performance and Patient Safety (TeamSTTEP)² (Burns et al., 2021; Wang et al., 2017). Other intervention programs mentioned in the selected articles pertained to vocational fields such as human resources management programs for business school students (Riivari et al., 2021), crew resources management for employees such as pilots (Brannick et al., 2005), or science technology engineering and mathematics (STEM) for junior high school students (Lin et al., 2018).

3.4. Research design

The selected articles could be divided into case studies ($n = 4$) and (quasi)-experimental studies ($n = 14$). Three distinct designs were used for the latter: between-group ($n = 5$), within-participants ($n = 3$), and mixed ($n = 6$). The activity was mostly performed in groups ($n = 13$), rather than individually ($n = 5$). As shown in Table 2, all four case studies and nine of the 14 experimental designs dealt with a group activity.

Table 1. Categorization of studies according to subject area and discipline.

Categorization	<i>n</i>
Subject Area	
Social Science	12
Medicine	7
Computer Science	5
Psychology	2
Engineering	2
Nursing	2
Multidisciplinary	1
Mathematics	1
Business, Management and Accounting	1
Discipline	
Education	11
E-learning	6
Computer Science Applications	5
Medicine (miscellaneous)	4
Applied Psychology	2
Health Informatics	2
Aerospace Engineering	1
Engineering (miscellaneous)	1
Human Factors and Ergonomics	1
Library and Information Sciences	1
Modeling and Simulation	1
Multidisciplinary	1
Nursing (miscellaneous)	1
Nutrition and Dietetics	1
Organizational Behavior and Human Resource Management	1
Psychology (miscellaneous)	1
Public Health, Environmental and Occupational Health	1
Radiology, Nuclear Medicine and Imaging	1

Note. In the case of multiple subject area and multiple disciplines, the articles were assigned to each one.

Table 2. Numbers of articles referring to Individual or group activities according to study design.

	Longitudinal intervention		One-off intervention		Total
	Individual activity	Group activity	Individual activity	Group activity	
Case study	0	4	0	0	4
Experimental	2	2	3	7	14
Between-groups	0	1	2	2	5
Within-participants	0	1	1	1	3
Mixed design	2	0	0	4	6
Total	2	6	3	7	18

Table 3. Numbers of articles referring to Individual or group activities according to category of digital tool used.

	Individual activity	Group activity	Total
Immersive environments			11
Video games	0	5	5
Simulations with scenarios	3	1	4
PC-based simulators	0	1	1
Augmented reality tools	0	1	1
Non-immersive environments			7
Sharing platforms	0	5	5
Online courses	1	0	1
Collaborative problem-solving tools	1	0	1
Total	5	13	18

Eight of the selected articles described longitudinal interventions where the activity lasted between 6 weeks and 12 months. The 10 remaining articles described a one-off session featuring two activities to develop collaborative skills. Only two of the eight longitudinal studies used repeated training sessions to improve collaborative skills (Jarrett et al., 2016; Riesen et al., 2012).

3.5. Digital tools used

Across the selected articles, a wide variety of digital tools were used, with authors generally using their own tool. These tools could be divided into two categories: immersive environments ($n=10$) and non-immersive environments ($n=7$). In addition, activities using the digital tools were administered either individually or in groups (see Table 3).

3.5.1. Immersive environments

The digital tools classified as immersive environments could be subdivided into four categories: (1) video games (played on a digital device with one or more players through an avatar in a virtual world); (2) simulations with scenarios (programs developed to represent different situations from case studies, using standardized scripts); (3) PC-based simulators (programs developed to use a computer to represent the operation of a machine, system, or phenomenon); and (4) augmented reality tools (integrating 3D virtual elements into a real environment in real time).

The five studies using video games were conducted in an immersive virtual world where players moved using an avatar and played in a team to complete a mission (Chang & Hwang, 2017; Jarrett et al., 2016; Riesen et al., 2012; Riivari et al., 2021; Sancho-Thomas et al., 2009). In Web.Alive, the immersive world is similar to the real world, and participants can interact with other players and access learning content in the form of videos, slide presentations, or other web-based resources (Riesen et al., 2012). NUCLEO plunges players into an immersive world representing an island, where they must form teams to complete several missions assigned to them by an instructor (Sancho-Thomas et al., 2009). Players can interact with their group, the instructor and other players on the island, and through the game they can access Moodle learning management system services, tools and content. In NoviCraft, participants need to complete different tasks as a team in order to escape from an island (Riivari et al., 2021). To be successfully completed, each task requires participants to share information, coordinate their actions, and make collective decisions. Adopting a similar game design, Chang and Hwang (2017) used a video game about biology where teams of players had to perform various tests in order to collect information needed to complete a mission. Finally, Jarrett et al. (2016) used a game in which teams of four played against the computer to destroy enemy tanks. Within each team, participants were split into two pairs, and each pair was assigned a tank, with one member taking on the role of gunner, and the other the role of commander/driver. The four players each had their own computer and communicated with each other using a microphone and headset.

The four studies using simulations with scenarios were conducted among healthcare workers or students in medicine or nursing. Two of the studies involved online simulations using Storyline with standardized scripts (Burns et al., 2021; Wang et al., 2017), and the two others integrated online course modules into the simulation (Djukic et al., 2015; Lee et al., 2020). In Burns et al. (2021), participants performed three simulations of a pediatric patient in septic shock, in

which they had to select optimum medical actions and communication toward other team members from a set of options. After each simulation, participants received automatic feedback through two scores based on their medical and communication selections during the scenario. Wang et al. (2017) used five scenario-based computer simulations featuring videos of a patient with interactive features. In Lee et al. (2020), the e-learning program featured simulations of four case scenarios, coupled with immediate feedback for incorrect answers. In Djukic et al. (2015), participants performed five knowledge-focused modules and two virtual patient modules, in which participants collaborated with a computer agent. The agent's comments and the content were created by the faculty staff.

A single study used a PC-based simulator, resembling line-oriented flight training, to train two-member teams (Brannick et al., 2005). After team-based training provided either by digital tools or by an instructor, participants performed a team-based task designed to assess the development of their collaborative skills using a high-fidelity simulator.

In the only study to use augmented reality tools (Chen et al., 2020), students in groups of three or four used a tablet to access augmented reality material and complete two robot building tasks using interlocking bricks.

3.5.2. Nonimmersive environments

In nonimmersive environments, digital tools can be divided into three categories: sharing platforms (digital tools developed to enable several people to work together on a subject); online courses (digital tools developed to provide online courses); and collaborative problem-solving tools (digital tools developed to solve problems collaboratively).

Five studies involved a sharing platform (Baser et al., 2017; Carbonaro et al., 2008; Carroll et al., 2015; Cortez et al., 2009; Evans et al., 2016). All provided a shared workplace and a synchronous and asynchronous discussion channel. Three used a virtual classroom environment providing a shared workplace such as an interactive whiteboard, instant messaging (Carbonaro et al., 2008), a functionality to participate in team conferences via an asynchronous team discussion board in Blackboard (Evans et al., 2016), or an asynchronous online forum with the possibility of sharing documents in group or class folders (Baser et al., 2017). Basic Resources for Integrated Distributed Group Environments (BRIDGE), another sharing platform, was used during a semester to support collaborative homework activities, providing a space to share information or various documents for planning work, and to interact synchronously and asynchronously with team members (Carroll et al., 2015). Finally, Cortez et al. (2009) used a Pocket PC where participants received two set of elements specific to each group member: one list (riddles) was not interchangeable with other members, but the other one (solutions) was interchangeable. The objective was to associate each riddle with a solution on the Pocket PC. To perform the task, group members had to collaborate, by exchanging their solutions.

An online course was only used in one study (Kraus & Gramopadhye, 2001), where aircraft maintenance technicians

individually received team-based training through Aircraft Maintenance Team Training (AMTT), a computer-based multimedia training tool. This tool provided material in a variety of formats (videos, photos, animations), together with different submodules to develop specific team skills such as communication, leadership, and decision making (Kraus & Gramopadhye, 1999). Finally, a collaborative problem-solving tool was also used in a single study (Lin et al., 2018), where eight collaborative problem-solving tasks were implemented using a digital tool. Four tasks were used for training, and four for the assessment of collaborative skills. A computer-simulated participant served as a teammate during the problem-solving tasks. Participants communicated with the computer agent on the screen, and the computer agent answered by searching for the solution in a database.

3.6. Collaborative skills measured and effects of training

Analysis of the included articles showed that collaborative skills were measured using questionnaires, observations, interviews, written reports, or task performances. Concerning questionnaires, results revealed a considerable variety of assessment tools. We counted 11 different literature-based questionnaires, and only one of these, the University of West England Interprofessional Questionnaire,³ was used in two different articles (Carbonaro et al., 2008; Evans et al., 2016). Concerning observations, several different methods were used, including the subjective rating of behaviors on a Likert scale (Brannick et al., 2005; Carroll et al., 2015; Wang et al., 2017), and the counting of specific behaviors observed during an activity (Chang & Hwang, 2017). Some authors relied on task performances, such as the mean numbers of riddles solved or not solved (Cortez et al., 2009), the number of enemy tanks destroyed (Jarrett et al., 2016) or the number of bottles knocked over by a robot car (Chen et al., 2020). One study used 1-page written reports, where team participants assessed team roles, and analyzed their team's effectiveness and decision making.

Most of the included articles used a combination of tools to assess collaborative skills. Of the 10 articles that combined two methods, the most frequently used combination was questionnaire plus observation ($n = 5$). Only two articles used three methods (questionnaire, observation, and performance task). Of the six articles that used a single method, four used a questionnaire, one observation, and one a performance task. Taken together, the most frequently used methods were the questionnaire ($n = 14$), followed by observation ($n = 9$).

Taken together, most of the articles reported a positive effect of training with digital tools on the development of collaborative skills. However, five of them failed to find any effect on the development of collaborative skills. This lack of effect was particularly noticeable in the articles dealing with various modes of learning, when blended learning (i.e., combination of online and in-person) was compared with more traditional approaches (i.e., either online or in-person) (Burns et al., 2021; Carbonaro et al., 2008; Djukic et al.,

2015; Kraus & Gramopadhye, 2001; Wang et al., 2017). Of the remaining 13 articles, only three compared groups with and without the use of digital tools, showing a positive effect of digital tools on the development of collaborative skills (Brannick et al., 2005; Chen et al., 2020; Lin et al., 2018). Three other studies explored the effects of specific variables in conjunction with the use of digital tools to develop collaborative skills. In two of these studies, video games were used, with results revealing that peer support helped to improve collaborative skills (Chang & Hwang, 2017), and the use of an after-action review procedure (e.g., debriefing) enhanced team performance (Jarrett et al., 2016). In the third study, using the learning-to-collaborate-by-collaborating process improved collaborative skills (Cortez et al., 2009). The seven other articles reported a positive effect of training with digital tools on the development of collaborative skills. More specifically, four studies with a case study design only assessed collaborative skills after the use of digital tools (Baser et al., 2017; Carroll et al., 2015; Riivari et al., 2021; Sancho-Thomas et al., 2009), whereas the other three articles assessed them both before and after a digital tool use (Evans et al., 2016; Lee et al., 2020; Riesen et al., 2012).

4. Discussion

The present systematic review examined how digital tools can be used to train collaborative skills. A search of seven databases allowed us to identify 2475 articles, of which only 18 met our inclusion criteria.

Most of these articles were published in the social sciences area, specifically education and e-learning, followed by medicine and computer science. In fact, 13 of the 18 included articles were primarily conducted among students, though only four of them involved middle- or high-school students. The five remaining articles focused on employees in two vocational fields: aviation and healthcare.

Regarding study design, analysis revealed a high proportion of experimental designs (14/18), although these seldom featured a longitudinal design (4/14). These results are consistent with a recent systematic review in which only one of the 46 selected papers using gamification in education and learning had a longitudinal design (Zainuddin et al., 2020). Moreover, the present review revealed that all the articles in the medical field, contrary to those in other fields, used standardized tools for measuring collaborative skills. More specifically, they were based on one of two systematic intervention programs (i.e., TeamSTTEP or IPE), which provide a framework and tools for developing and assessing collaborative skills. This observation is not surprising, given that the medical field, like the aeronautics field, has pioneered the training of professionals to develop teamwork skills, and is more likely to involve team simulations (e.g., using high-fidelity mannequins) (Fritz et al., 2008). As the growing transformation of work appeals to collaborative skills for teamwork, research on the development of collaborative skills now needs to be extended to other vocational fields (Succi & Canovi, 2020).

The present systematic review also revealed that a wide variety of digital tools were used to develop collaborative

skills, and *immersive environments* were predominant (10/18). Three main types of digital tools were used: video games, sharing platforms, and simulations with scenarios. Although most of the digital tools in the included studies required group activities (13/18), some of them relied on individual activities. It was mainly the scenario-based simulations that involved individual activities, for example when the implementation of a virtual agent simulated an environment that gave individuals the impression of doing group work. These results highlight the importance of working in groups to develop collaborative skills using digital tools, but digital environments simulating group work can also be used individually for this purpose. In the included articles, all the video games that were used had to be played in teams in order for a mission to be accomplished. It was by collaborating that participants could performed a given mission. In other words, in order to develop collaborative skills from video games, they had to collectively take part in the mission, including communicating with each other and/or helping each other.

The present systematic literature review highlighted a diversity of findings about the effects of digital tools on the development of collaborative skills. This diversity can be attributed not only to the variety of digital tools used by researchers, but also to the variety of measures used to assess collaborative skills. Self-report questionnaires were often preferred, and the use of different non standardized instruments without any psychometric validation limited comparisons between studies. When researchers use their own self-report measures, it is difficult to gauge the efficacy of an intervention at both the first (participants' satisfaction) and second (attitudinal or knowledge change) levels identified by Kirkpatrick and Kirkpatrick (2006). To assess this efficacy, and also to improve collaborative skills, future studies should reinforce behavioral and performance measures and used them in addition to self-report measures. Concerning the latter, it would be useful to administer standardized and validated questionnaires measuring collaborative skills, notably in repeated training sessions aimed at improving these skills, as there have so far been very few longitudinal studies (Jarrett et al., 2016; Riesen et al., 2012).

Moreover, analysis revealed that some of the quantitative studies included in the present systematic review had adopted a media comparison approach, assessing the contribution of digital tools compared with more traditional pedagogical situations where they are not used (Brannick et al., 2005; Burns et al., 2021; Carbonaro et al., 2008; Kraus & Gramopadhye, 2001). This is a useful approach for demonstrating the possible effects of digital tool use, but it also has limitations, notably because it focuses on the technology rather than on the learner, and also because it does not help to demonstrate the complementarity of media, or the importance of instructional methods or the features of the digital environment (See Buchner & Kerres, 2023). Other studies varied the pedagogical situations in which one or more digital tools were used, assessing the effects of synchronization-based peer assistance (Chang & Hwang, 2017), a learning-to-collaborate step (Cortez et al., 2009), or the delivery of the same module in versus outside the classroom (Djukic

et al., 2015). Finally, a few studies combined the two approaches, investigating, for example, the effects of augmented reality and competition (Chen et al., 2020) or a web-based collaborative problem-solving system with or without a teacher's guidance. The variety of these pedagogical situations and instructional methods made it difficult to come up with practical recommendations, but nevertheless demonstrated the importance of the pedagogical context in which the digital tool is used.

4.1. Theoretical and practical implications

This systematic analysis of the literature has implications in terms of our original research question. It would seem that we must shift our focus away from the question of which digital tools to use in order to develop collaborative skills to that of how to use them (the value-added approach). In a closely related field of research, Cai et al. (2022) demonstrated in their meta-analysis that adding scaffolding (e.g., feedback, hints, or reflection) to digital game-based learning environments has positive effects on learners' performance. This finding tends to support a value-added approach in which the emphasis is on assessing the characteristics of the learning environment, rather than on actual digital tool (non)use. The necessary development of this value-added approach has been supported in the field of game-based learning (Mayer, 2019), as well as more recently in the field of augmented reality (Buchner & Kerres, 2023).

In terms of recommendations, this systematic review may have implications not only for Human-Computer Interaction researchers, but also for educators aiming to train people to collaborate in teams. Indeed, Human-Computer Interaction researchers need to focus its research on this approach in order to gain a better understanding of how to design useful tools for training collaborative skills. For example, some recent findings have suggested that delivering instructions on how to collaborate during a computer-based collaborative task improves performance and task conflict regulation in online groups (Hémon et al., 2024). This study adopted an approach that we believe should be developed further, in order to better understand how specific features of digital tools can support group activities by enhancing teamwork and collaborative skills. As underscored by Fiore et al. (2018), "students rarely receive meaningful instruction, modelling and feedback on collaboration" (p. 368), which may explain why they overestimate their collaborative skills without necessarily collaborating efficiently. This review also has implications for education and training. Collaborative skills are transversal skills that need to be developed by students, and should be included better in the curriculum in addition to disciplinary contents. Nowadays, immersive and non-immersive digital tools appear to be promising and complementary to traditional non-technological methods based on face-to-face collaboration. Nevertheless, educators need to be vigilant in the way they measure the acquisition of collaborative skills using digital tools. We also recommend organizing a series of training sessions over time, and evaluating their effects using validated metrics.

5. Future research directions

Based on this systematic review, we can propose some ideas for future research.

First, our findings confirm the need to go further in the use of digital tools, and in particular, to continue taking a closer look at the different functionalities offered by digital environments. Future research should apply the value-added approach in order to draw up recommendations for future digital tool development. For example, research should focus on the impact of automatic feedback on self-assessment and/or the use of instruments to guide and facilitate the development of collaborative skills during training sessions.

Furthermore, although a diversity of collaborative skills measures was used, self-report questionnaires are privileged by researchers. It therefore appears necessary to verify the psychometric qualities of the scales used. In addition, future research would benefit from using performance-tasks to evaluate collaborative skills, thus avoiding a potential desirability bias and false memories when measuring these skills by questionnaires. With this perspective, the desire to integrate the development of learners' collaborative skills into their curriculum, notably through the use of digital tools, leads us to reconsider research design. Future research would benefit from the implementation of longitudinal study designs to examine the effects of training over time in ecological contexts.

6. Limitations

The present systematic review had several limitations. First, we focused exclusively on articles published in English peer-reviewed journals, and did not include any gray literature (e.g., white papers, doctoral dissertations, chapters, and articles published in non-peer reviewed journals). Second, although we used expanders proposed by databases to search for terms synonymous with our keywords, we may have missed some articles involving teamwork, collaborative skills or digital tools, as these were not mentioned in the Abstract or keywords. For these reasons, some relevant studies may not have been included in this systematic review. Third, the review failed to yield clear evidence of the effects of digital tools on the development of collaborative skills, owing to the quality of the selected studies. According to the MMAT, just over half our selected studies were of moderate or high quality, depending on their design. There is therefore a need for further high-quality studies to investigate the effects of team training with digital tools on the development of learners' teamwork and collaborative skills. Given the methodological issues we highlighted, and the disparity of the study fields, digital tools, methods and measures used, any attempt to generalize the results reported here must be carried out with caution.

7. Conclusion

One of the main conclusions of the present systematic review is that digital tools have the potential to develop collaborative skills. Integrating digital tools into traditional classrooms or incorporating digital tools for training teams in in-person

courses contributes to the development of these skills. Nevertheless, the mere presence of digital tools does not systematically guarantee an improvement in collaborative skills. Rather, the transformative potential of digital tools lies in their ability to reshape and enhance existing learning modalities through specific interventions. Another important issue is the need for future research to better understand the features of the digital environments that enhance these skills. A further challenge for the future is to embed interventions that use digital tools to develop collaborative skills within the academic curriculum. In order to assess the development of these skills, and the efficacy of the digital tools intended to promote them, standardized measures with good psychometric validity should be used, as well as behavioral and performance measures collected over different training sessions from a longitudinal perspective. To conclude, work on how digital tools contribute to the development of collaborative skills is still in its infancy, and more research based on rigorous methods and measures is needed.

Notes

1. "Interprofessional education occurs when students from two or more professions learn about, from, and with each other to enable effective collaboration and improve health outcomes" World Health Organization (WHO) (2010, p. 7).
2. TeamSTEPPS is an evidence-based set of teamwork tools, aimed at optimizing patient outcomes by improving communication and teamwork skills among healthcare professionals (French Agency for Healthcare Research and Quality).
3. UWEIQ has 35 items belonging to four subscales: communication and teamwork (9 items), interprofessional learning (9 items), interprofessional interaction (9 items), and interprofessional relationships (8 items) (Pollard et al., 2004, 2005).

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Data availability statement

Data and codebook are available on our OSF webpage: <https://osf.io/u2qez/>.

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Appendix A.

Article	Participants	Country	Design	Digital tool	Activity	Metrics	Findings
1. Baser et al. (2017)	N = 15 Seventh grade students	Turkey	Case study Collaborative project-based learning	Nonimmersive environment: forum	Group	Interview <ul style="list-style-type: none"> 15 questions asked by IT teachers (e.g., Do you think three-pupil groups are appropriate for your work? Why? / Do you think collaborative working contributed to your project work? Or would you have preferred individual work rather than collaborative work for this project? Why?) Observation <ul style="list-style-type: none"> Group observation form featuring 19 items, each one scored by the IT teachers 	Participants reported developing collaborative skills
2. Brannick et al. (2005)	N = 96 US Navy pilots	USA	Between-group Training group: received instruction on a PC-based simulator and received feedback Control group: received classic crew resource management (CRM) training	Immersive environment: PC-based simulator as an analog of line-oriented flight training	Group	Observation (5 items) <ul style="list-style-type: none"> Two items assessing coordination between team and air traffic controller were rated by two Navy instructors: behavior observed (1) or not observed (0) Three items assessing technical equipment-related problems were rated by two flight instructors on a Likert scale ranging from 1 (<i>unsatisfactory</i>) to 5 (<i>outstanding</i>) 	Coordination was significantly better in the training group than in the control group No significant difference was observed between the two groups on the three items assessing technical equipment-related problems → CRM training was effective. More specifically, the PC-based flight simulator was useful for training CRM behaviors
3. Burns et al. (2021)	N = 31 Fourth-year medical students	USA	Mixed Comparison of standard education (in-person groups) and novel education intervention (online training) Pre- and postintervention questionnaires	Immersive environment: Storyline e-learning software (Virtual TeamSTEPPS®).	Individual	Questionnaires <ul style="list-style-type: none"> TeamSTEPPS benchmark. 23 items, each with five possible response options, measured teamwork knowledge TeamSTEPPS Teamwork Attitudes Questionnaire (T-TAQ). 30 items measured individuals' attitudes toward teamwork behaviors related to patient care and safety in five core domains (team structure, leadership, situation monitoring, mutual support, and communication), rated on a 5-point Likert scale 	TeamSTEPPS benchmark and T-TAQ scores increased significantly between the pre- and postintervention tests No significant difference was observed on these scores between the two groups (standard education vs. novel education intervention) → Receiving training either in person (including group session) or on line (software-based simulations featuring nonplayer character) did not affect scores on teamwork knowledge and attitudes questionnaires
4. Carbonaro et al. (2008)	N = 44 Health science students	Not indicated	Between-group Comparison of students in traditional learning (face-to-face course) versus blended learning format	Nonimmersive environment: Elluminate (classroom environment designed to support interactions)	Group	Questionnaire <ul style="list-style-type: none"> University of West England Interprofessional Questionnaire (UWEIQ; Pollard et al., 2004). 35 items divided into four subscales 	No significant differences on UWEIQ and TOSCE scores between blended learning and traditional learning groups at either pre- or posttest → No effects of blended learning

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Article	Participants	Country	Design	Digital tool	Activity	Metrics	Findings
			Pre- and postintervention questionnaires			(communication and teamwork, interprofessional learning, interprofessional interaction, and interprofessional relationships) rated on a 5-point Likert scale	versus traditional learning (face-to-face class) on either self-assessed communication and teamwork skills, or attitudes toward interprofessional learning
5. Carroll et al. (2015)	N = 45 Students	USA	Case study Distributed collaborative homework activities. Three successive assignments (HW1, HW2, HW3) started in week 7 of the course. 3 weeks to complete HW1, and 2 weeks to complete HW2 and HW3	Nonimmersive environment: Basic Resources for Integrated Distributed Group Environments (BRIDGE)	Group	<p>Questionnaire</p> <ul style="list-style-type: none"> For HW1 and HW3: six open-ended questions (e.g., how they used the four collaborative facets and identified any strengths and weakness of these facets) For HW2: four closed questions assessing the degree of focus on each facet, rated on a 7-point Likert scale, and 4 open-ended questions eliciting examples <p>Observation</p> <p>Teams were scored on four facets: communication (5 items), planning (4 items), productivity (4 items), and evaluation/negotiation (5 items). Each item was scored on a 3-point scale (0-1-2)</p>	<p>→ Teams were relatively strong on communication, and relatively weak on planning</p> <p>Collaborative performance improved over the semester</p>
6. Chang & Hwang (2017)	N = 65 Seventh graders	Taiwan	Between-group Experimental group: game with a mission synchronization-based peer-assistance approach. Participants needed to complete the mission together without the mission synchronization-based peer-assistance approach. Participants could complete the mission with or without collaboration	Immersive environment Video game on biology	Group	<p>Questionnaire</p> <ul style="list-style-type: none"> Teamwork Skills Questionnaire (Jeng & Tang, 2004). Five items rated on a 5-point Likert scale <p>Observation</p> <ul style="list-style-type: none"> Coding of six interactive student behaviors (video taped): IL (playing games on their own), IH (seeking peers' assistance), IA (actively helping peers solve learning problems), IG (actively helping peers solve gaming problems), IV (voting for or discussing answers), and IO 	<p>Teamwork skills were significantly better in the experimental group than in the control group</p> <p>Coding of interactions revealed that four behaviors (IH, IA, IG, and IV) were observed significantly more in the experimental group than in the control group. The opposite was observed for only one behavior (IO)</p> <p>→ The mission synchronization-based peer-assistance approach appears to be more effective for improving students' collaborative skills → Assistance from peers is</p>

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Article	Participants	Country	Design	Digital tool	Activity	Metrics	Findings
7. Chen et al. (2020)	N = 172 Ninth-grade students	Taiwan	Mixed 2 (augmented reality, AR: presence vs. absence) x 2 (competition: presence vs. absence) during robotic learning activity: 1. AR/COM 2. AR/noCOM 3. noAR/COM 4. noAR/noCOM Two robot car building tasks	Immersive environment: Tablet to scan a zapcode to access AR materials	Group	<p>(chatting or engaging in other learning-unrelated behaviors) Questionnaire</p> <ul style="list-style-type: none"> Collaboration assessed on a scale adapted from Chai et al. (2015) <p>Observation</p> <ul style="list-style-type: none"> Scores on five dimensions: team collaboration, discussion, coherence, organization, and presentation <p>Performance task</p> <ul style="list-style-type: none"> For Task#1: the robot must reach the target position (30 points) For Task#2: knock the bottles over with the robot car (10 points, one per bottle) 	<p>effective for promoting collaborative skills</p> <p>Results on collaboration revealed a significant main effect of augmented reality (AR > no AR), no main effect of competition, and no significant AR x COM interaction</p> <p>Results of observation revealed significant AR x Competition interaction effects on group collaboration, group discussion, and group presentation</p> <p>→ Students who used AR were more engaged in collaboration.</p> <p>Accessing information from AR provided a basis for discussion for team members</p> <p>→ Competition had no impact on group collaboration and collaborative skills</p>
8. Cortez et al. (2009)	N = not indicated Undergraduate engineering students	Chile	Mixed Comparison of two groups: experimental group (learning-to-collaborate-by-collaborating, LCC) process (8 phases) Control group without LCC process: only participated in Phases 3 (Collaborative Activity I) and 6 (Collaborative Activity II) Two collaborative activities: Collaborative Activity I and Collaborative Activity II	Nonimmersive environment: Sharing platforms on pocket PC	Group	<p>Observation</p> <ul style="list-style-type: none"> Teamwork skills: team orientation (TO), team leadership (TL), monitoring (MO), feedback (FE), back-up (BA), and coordination (CO) <p>Performance task</p> <ul style="list-style-type: none"> Activity score corresponding to mean number of correct and incorrect riddles solved 	<p>Teamwork skills and activity score increased significantly between Collaborative Activity I and Collaborative Activity II, but only in the experimental group</p> <p>The experimental group performed better than the control group on Collaborative Activity II</p> <p>→ Using the LCC process improved collaborative skills</p>
9. Djukic et al. (2015)	N = 760 Medical and nursing students	USA	Mixed Comparison of two cohorts: Blended-learning interprofessional education (IPE) intervention: e-learning module in classroom with teammates Virtual IPE intervention: same e-learning	Immersive environment: e-learning modules	Individual	<p>Questionnaire:</p> <ul style="list-style-type: none"> Team Skills Scale (Siegler et al., 1998), 15 items probed students' self-reported ability to perform different team tasks, rated on a 5-point Likert scale Attitudes Toward Health Care Teams Scale (Siegler et al., 1998), 21 items divided into three subscales (team value, team efficiency, and shared 	<p>Team skills improved significantly between pre- and postintervention tests</p> <p>No significant difference between the two cohorts on team skills</p> <p>→ No difference between the virtual IPE intervention and blended-learning IPE intervention</p>

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Article	Participants	Country	Design	Digital tool	Activity	Metrics	Findings
10. Evans et al. (2016)	N = 35 Student dietitians	Australia	module, but not delivered in person in the classroom Questionnaire at 0 month (pre) and 12 months (post) Within-participants Online IPE interprofessional education (IPE) unit with pre- and postunit questionnaire	Nonimmersive environment: Blackboard Collaborate (desktop virtual classroom environment)	Group	Questionnaire <ul style="list-style-type: none"> University of West England Interprofessional Questionnaire (UWEIQ; Pollard et al., 2004): 35 items divided into four subscales (communication and teamwork, interprofessional learning, interprofessional interaction, and interprofessional relationships) rated on a 5-point Likert scale Interview Six questions asking participants to describe the degree of perceived interprofessional learning, and their experiences on the discussion boards	UWEIQ scores revealed a more positive value placed on teamwork after the intervention → Using an online IPE unit improved confidence in understanding the roles of other health professionals, as well as self-assessed collaborative skills
11. Jarrett et al. (2016)	N = 492 Psychology students	Not indicated	Mixed 2 (geographical dispersion: distributed vs. colocated) x 3 (type of after-action review (AAR), also referred to as the after-event review or debriefing: non-AAR vs. objective AAR vs. subjective AAR) x 3 (session: Sessions 1–3) repeated measures	Immersive environment: eSim	Group	Questionnaire Team efficacy (Arthur et al., 2007). Six task-specific items rated by participants on a 5-point Likert scale <ul style="list-style-type: none"> Scores ranged from –50 to 100, with points earned for destroying enemy tanks, and points lost if participants' own tanks were destroyed Performance task	Teams with AAR improved their team performance and efficacy more than teams with no AAR Team performance improved across sessions No significant difference between colocated AAR and distributed AAR teams on team performance and team efficacy No significant differences between objective AAR and subjective AAR on team performance and team efficacy → Using AARs to train geographically dispersed individuals and teams is a good solution
12. Kraus & Gramopadhye (2001)	N = 36 Aircraft maintenance technicians (AMTs)	USA	Between-groups Instructor-based training (IBT): traditional team training Computer-based training (CBT): team training instruction based on multimedia	Nonimmersive environment: Aircraft maintenance team training (AMTT) software	Individual	Questionnaire <ul style="list-style-type: none"> Four self-assessed team skills: communication, decision making, leadership, and interpersonal relationships Observation <ul style="list-style-type: none"> Three instructors completed a questionnaire based on their observations during the two 	No differences between the two groups on either the four team skills or the instructor's assessment → CBT is just as effective in delivering team training instructions as IBT

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Article	Participants	Country	Design	Digital tool	Activity	Metrics	Findings
13. Lee et al. (2020)	N = 61 Caregivers	Korea	Within-participants E-learning program combining online lecture and simulation program Three measurement points: before e- learning (baseline, T1), after online lecture (T2), and after simulation (T3)	Nonimmersive environment: Combined Online Lecture and Simulation Program on Function-Focused Care in Nursing Homes (COLSP FFCNH) system	Individual	<p>tasks</p> <ul style="list-style-type: none"> Performance task Instructors assessed group performance on accuracy, safety, and speed using an assessment grid <p>Questionnaire</p> <p>Korean version of the self-report instrument to assess:</p> <p>(1) team process outcomes with transactional memory system (15 items), knowledge sharing and utilization (5 items), motivation for learning transfer (5 items), self-efficacy (18 items), interpersonal understanding (11 items), and proactivity in problem solving (8 items), rated on a 5-point Likert scale. FFC knowledge assessed with 15 Yes/No items yielding a performance score (1 point for each correct answer)</p> <p>(2) team performance outcomes with four items rated on a 5-point Likert scale</p>	<p>Baseline (T1) ≠ after online lecture (T2)</p> <p>T1, T2 < after simulation (T3)</p> <p>→ The e-learning program combining online lecture and simulation program significantly improved team process and team performance outcomes</p>
14. Lin et al. (2018)	N = 241 Junior high-school students	Taiwan	Mixed Three groups: <ul style="list-style-type: none"> web-based collaborative problem-solving systems (wCPSS)-supported environment without the teacher's guidance wCPSS-supported environment with the teacher's guidance cCHLA (classroom-based collaborative hands-on learning activities)-facilitated environment (control group)	Nonimmersive environment: Collaborative problem solving	Individual	<p>Performance task</p> <ul style="list-style-type: none"> Four problem-solving questions: two at pretest, and two at posttest 	<p>Collaborative problem-solving skills were better in the group with wCPSS-supported environment than in the control group (cCHLA) than with the teacher's guidance performed better than the group without this guidance</p> <p>→ A web-based collaborative problem-solving system should be introduced into the curriculum to develop collaborative problem-solving skills</p> <p>→ Teachers should provide guidance to ensure more effective performance</p>
15. Riesen et al. (2012)	N = 60 Recently graduated students with	Canada	Two measurement points: pre- and post-intervention Within-participants Pretest and posttest interprofessional education (IPE)	Immersive environment: Web.Alive™	Group	<p>Questionnaire</p> <ul style="list-style-type: none"> Interdisciplinary education perception scale (IEPS; Luecht et al., 1990). 18 items probing 	<p>Interprofessional collaborative competencies increased between pretest and posttest. Scores on TOSCE's collaboration items</p>

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Article	Participants	Country	Design	Digital tool	Activity	Metrics	Findings
	Bachelor of Science in nursing, child and youth workers, basic care paramedics and police foundations		workshop with three simulations: (1) initial face-to-face simulation; (2) virtual environment simulation in WebAlive; and (3) final face-to-face simulation			four factors (professional competence and autonomy, perceived need for professional cooperation, perception of actual cooperation and resource sharing within and across professions, and understanding the value and contributions of other professional/professions)	increased across the three simulations → The IPE workshop improved interprofessional competencies
						<ul style="list-style-type: none"> Interprofessional Collaborative Competencies Attainment Survey (ICCAS; MacDonald et al., 2010). 20 items divided into six categories (communication, collaboration, roles and responsibilities, collaborative family-centered approach, conflict management/resolution, and team functioning) 	
						<p>Observation</p> <ul style="list-style-type: none"> Team Objective Standardized Clinical Examination (TOSCE) measuring six competencies: communication, collaboration, roles and responsibilities, collaborative family-centered approach, conflict management/resolution and team functioning. Items rated on a 9-point Likert scale 	
16. Riivari et al. (2021)	N = 309 Undergraduates attending business school	Finland	Case study Using a video game on human resource management (HRM) in the classroom	Immersive environment: NoviCraft	Group	<p>Questionnaire</p> <ul style="list-style-type: none"> Nine open-ended questions: participants analyzed their own perceptions and provided feedback on the gaming experience (e.g., "How would you describe your experiences after the game?") <p>Written reports</p> <p>Approximately one A4 page in length, participants' reports assessed team roles (both their own and those of their team members) and analyzed the team's effectiveness and decision making</p>	<p>→ Results revealed a link between communication and team performance. Participants appreciated <i>forced</i> communication</p> <p>→ Students perceived the importance of team effort and information sharing</p>
17. Sancho-Thomas et al. (2009)	N = 835 Electrical engineering students	Spain	Case study Collaborative project-based learning in two courses on	Immersive environment: NUCLEO	Group	<p>Questionnaire</p> <p>Satisfaction questionnaire with two questions about group management</p>	<p>→ Students rated the game positively, in terms of helping them to develop their teamwork skills</p>

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Article	Participants	Country	Design	Digital tool	Activity	Metrics	Findings
18. Wang et al. (2017)	N = 40 13 registered nurses, 12 radiology residents (Year 2 postgraduate studies), and 15 technologists	USA	programming: either traditional teaching or with NUCLEO video games Mixed 2 groups: • computer-based simulation (CB) • hands-on simulation (HO)Three measures: pretest, immediate posttest, and delayed posttest	Immersive environment	Group	Questionnaire • Written tests with five items probing teamwork skills Observation • Three experts assessed teamwork skills by rating key tasks on a 7-point Likert-like scale	No difference between CB and HO on teamwork skills in either immediate or delayed posttest For CB and HO, performance on team skills in delayed posttest was poorer than in pretest and immediate posttest → Refresher training on teamwork skills seemed necessary