Interreg
2 Seas Mers Zeeën
BHC21
European Regional Development Fund

EUROPEAN UNION

Boosting Human Capital for 21st Century Skills- Literature Review

Auteurs:
Dr. Kamakshi Rajagopal
Dr. Annelies Raes
Berten Hurkmans
Prof. Dr. Fien Depaepe

itec
KU LEUVEN
imec
embracing a better life

1. Introduction

The Boosting Human Capital for the 21st Century (BHC21) project looks at Innovative Learning Technologies (ILTs) to redefine training and recruitment of low-skilled people (LSP) defined as levels 1-4 in the European Qualification framework (reference EQF). Within the context of this Interreg 2 Seas project (2019-2022), we aim to develop a generic 21st-century training model for adult education in technical training which (a) makes use of these technologies and accompanying instructional design, tailored for easy adoption by Small and Medium sized Enterprises (SMEs) and (b) integrates new recruitment and training approaches to increase the success rate of the technical training.

Factsheet on BHC21

Partners:
Provinciale Ontwikkelingsmaatschappij West-Vlaanderen (BE), Vlaamse Dienst voor Arbeidsbemiddeling en Beroepsopleiding (VDAB) (BE), MidKent College (UK), Kent County Council (UK), Skilliant (BE), University of Greenwich (UK), Sirris (BE), The Tavistock Institute of Human Relations (UK), Sud Concept Hauts-de-France (FR), CETIM (FR), Maison pour l'Entreprise l'Emploi et la Formation Santerre Haute Somme (FR), KU Leuven Campus KULAK Kortrijk (BE)

Main Outputs:
- two series of tests to integrate ILTs and modern pedagogical approaches in vocational training for LSP for the manufacturing industry
- Aided by innovative recruitment, these pilots will help to identify and mitigate learning barriers and enhance understanding of the potential of ILTs and pedagogical approaches. Public employment services, LSP and companies suffering skills shortages will all benefit.
- A new training model, including the training of work floor coaches, will be jointly developed, tested, validated & evaluated.

The final output is a feasibility report based on the pilots, demonstrating the economic and sustainable viability of the BHC21 training model. Improved quality of training (from a learner's perspective: increased motivation, less stress, high perceived usefulness) helps SMEs to find/retain qualified personnel and helps LSP to establish sustainable careers.

This document forms part of Output 1 of the BHC21 project. It is organized as follows:

1. Research setting and project requirement
2. Methodology
3. Results
4. Discussion
5. Lessons learnt for project
6. General conclusion

2. Research Setting & Project Requirement

2.1. The BHC21 project and the target group of low-skilled learners

BHC21 addresses a challenge in the manufacturing industry regarding the training and recruitment of low-skilled workers.
In a multitude of studies, this target group has emerged as one struggling with the changes in the manufacturing industry, in particular, the ongoing and increasingly dramatic automatization of manufacturing processes (Dengler & Matthes, 2018; Roos & Shroff, 2017; Veipa et al., 2017). This trend results in the need to develop a workforce that can deal with changing worker behaviour, and continuous training.
However, ongoing efforts to re-train and recruit low-skilled people in the manufacturing industry has hit challenges. One primary challenge is the fact that workers are disengaged with their training process. Outdated teaching practices, non-relevance of material to day-to-day practice and a lack of professional growth all contribute to these high levels of worker disengagement.

The BHC21 project seeks to address these challenges by considering **innovative learning practices, using innovative learning technologies (ILTs).** It looks specifically at the use of robotics, mechatronics, augmented and virtual reality, sensor technology, wearables, simulations and games. Other technologies may be included in this non-exhaustive list, if it is deemed of value.

Low-skilled workers in the manufacturing industry typically perform operational, repetitive jobs, often involving *manual skills*. They form part of a continuous production process, in which their time-bound performance and accuracy are directly related to company productivity.
The commercial move to customization and more variability in the product make production processes more complex and dynamic. This is often a challenge for low-skilled workers, who are not used to adapt their skills flexibly to the demands of a changing industry. For many of them, especially the so-called *soft skills* form a barrier to change. An increased skill demand for communication, alignment and collaborative work often forms a real challenge for low-skilled people, who often – but not always – might also be dealing with learning challenges or lower language proficiency.

Although training has been organized specifically for this target group, previous studies and pilot projects have indicated that low-skilled workers are often less motivated to participate in training sessions, or, if at all enrolled, do not complete them (Gitschthaler & Nairz-Wirth, 2018).

The BHC21 project explores an alternative training method with the use of ILTs, that have the potential specifically to develop their social skills as well as to target their manual skills.

Additionally, the engaging nature of these technologies may also have an effect on low-skilled learners' motivation.

2.2. Technologies of interest

In recent years, certain technologies are being increasingly used in industrial settings for training. For the purposes of this review, we focus on the technologies described and illustrated in Table 1, that create hybrid learning spaces, in the blur between the physical and virtual reality. These technologies were chosen as they afford interesting industrial applications for training. These technologies form the starting point for the literature study in BHC21.

Table 1 Innovative Learning Technologies within the scope of BHC21

technology	definition	references
Augmented Reality (AR)	any case in which an otherwise real environment is "augmented" by means of virtual (computer graphic) objects	Milgram & Kishimo, 1994 Light Guide Systems for assembly operators (Vanneste et al., 2020)
Virtual Reality (VR)	"a reality" one in which the participant-observer is totally immersed in, and able to interact with, a completely synthetic world	Milgram & Kishimo, 1994
Robotics	use of machines to perform complex tasks that are typically done by human beings	Anwar et al., 2019 Siciliano & Khatib, 2016
Wearables	electronic devices that can be worn as an accessory (embedded in clothing, jewelry, or even implanted on a person's body), that collect personal data and provide insight into collected data	Abowd, Dey, Orr & Brotherton, 1998
Sensors	electronic devices that detect physical, chemical, or biological property quantities and convert them into readable signals (some wearables include sensor technology)	Beigl, Krohn, Zimmer & Decker, 2004 use of sensors for maintenance of machinery (Albano at al., 2020).

Mechatronics	synergistic combination of mechanical engineering, electronic control and computer technology. It relates to the design of systems, devices and products with the aim of achieving an ideal balance between basic mechanical structure and its overall control.	Müller, 2005 Bradley et al, 2000 cobots Van Acker et al., in press
Games	software technology that facilitates individual and group activities in the form of games or with gaming patterns	De Vin, Jacobsson and Odhe, 2018
Simulation	environment consisting solely of virtual objects	Milgram & Kishimo, 1994

2.3. Focus of this document and research questions

This output describes the results of a literature review, looking at the design and effectiveness of ILTs in training low-skilled people in the manufacturing industry, on their manual skills and/or so-called soft skills.

The research question of the BHC21 project is:
"Which ILTs and instructional design have proven effectiveness in acquiring competences in technical training programs?"

In line with the project goals, this research question was re-interpreted to scope the review as follows:

A. The literature was selected with a focus on the **target group of low-skilled workers** with a priority for adults. Low-skilled youth were included in a second instance.
B. The primary goal of the review is to elaborate which **technologies and technological designs** are used and have been researched on their effectiveness under which circumstances. This is required for the redesign of industrial training with ILTs within the project in WP2. Additionally, it is also interesting to understand which quantitative measures are used to observe and measure this effectiveness, in light of the project goals to measure the effect of these industrial trainings (both in technical training and vocational training) on learner performance and teaching and coaching strategies.
C. An additional goal of the review is to understand which **instructional design** is prevalent and/or effective in the use of these technologies, as it is a central project aim to design appropriate instructional support for the pilots in WP3.
D. As previously mentioned, our focus is on **manual skills and/or so-called soft skills**.

The research question has been reformulated as follows:

RQ1: Which (combination of) ILTs have proven effectiveness in acquiring competences in technical training programs?

RQ2: What are the related instructional design features (protocols, guidelines and principles) that can support this technological design in achieving effectiveness?

This output describes the results of a literature review, looking at the effectiveness of ILTs in training low-skilled people in the manufacturing industry, on their manual skills and/or so-called soft skills.

3. Methodology

3.1. Selection of articles

Defining the scope of the literature review, we formulated the following **inclusion criteria**:

1. Manufacturing industry: Given the primary focus of the BHC21 project, the literature study focuses on the manufacturing industry, and in particular, on the technical profiles in this industry.
2. Skills: From a technological point of view, priority is given to articles describing technologies that support one or both of two things: "teaching practical manual skills" and/or "practicing so-called soft-skills".
3. Design: The primary focus of this literature review is the (technological) design of training practices using ILTs. Articles describing innovative pedagogies for low-skilled workers that did not use innovative learning technologies, were not included in this study.
4. Target group: Articles dealing with adult low-skilled learners were included in this literature study. If relevant, articles dealing with young low-skilled learners (children and teenagers) were also considered. Articles with typically developing young people were included if the technological or instructional design was deemed of value.
5. Nature of study: empirical studies were of preference, but non-empirical studies and articles were included if the technological or instructional design was deemed of value.

As the description of the target group of low-skilled people is unclear in literature, we used two strings to perform the search. Although more generic descriptions such as "(students-/workers-)at-risk" were used, the search results remained limited. Alternative search strings using the EQF levels 1-4 (not reported here) did not turn up sufficient results.
This scoping resulted in the definition of the following **Boolean strings**, consulted in the databases ERIC, OVID, PsycArticles, SCOPUS and LearnTecLib, which were chosen as they focus on educational research (rather than pure technological design or industrial application):

- Boolean1:
  STRING: "vocational training" AND ("AR/VR" OR "Augmented Reality" OR "Virtual Reality" OR "Robotics" OR "wearables" OR "sensors" OR "mechatronics" OR "games" OR "simulation") AND ("low-skilled" OR ("at-risk") OR ("students-at-risk") OR ("workers-at-risk"))

- Boolean2:
  STRING: "vocational training" AND ("AR/VR" OR "Augmented Reality" OR "Virtual Reality" OR "Robotics" OR "wearables" OR "sensors" OR "mechatronics" OR "games" OR "simulation") AND "low-skilled"

The results were refined on the period of 2014-2019 (taking into account only the recent applications of technology in a fast-developing field.). Table 2 illustrates the numbers of articles collected.

Table 2 Number of articles emerging from search, ordered by database

	Total	2014-2016	Peer-reviewed	
ERIC	161 746	30 96	22 73	Boolean1 Boolean2
Ovid	36 90	17 42	NA NA	Boolean1 Boolean2
PsycArticles	23 2	16 2	16 2	Boolean1 Boolean2
Scopus	69 13	37 6	16 3	Boolean1 Boolean2
LearnTecLib	54	24	23	Boolean = "vocational training" AND "low-skilled"

Excluding duplicates, the literature search (Fig. 1) resulted in 239 articles. A primary screening of the titles and abstracts on the inclusion criteria resulted in:

- 29 non-applicable articles
- 60 articles which were related to the topic, but without an empirical/design focus (inclusion criteria 2, 5)
- 150 relevant articles

As visible in Figure 1, the abstracts of this last group of 150 articles were screened in more detail on their relevance to the target group of low-skilled people. Only 47 articles fulfilled our inclusion criterium concerning the target group of adult low-skilled learners as well as young low-skilled learners (children and teenagers). In the full-text analysis, a further 10 articles did not fulfill the inclusion criteria in sufficient detail and were not taken up in analysis. This resulted in 37 articles that were taken up for full-text analysis.

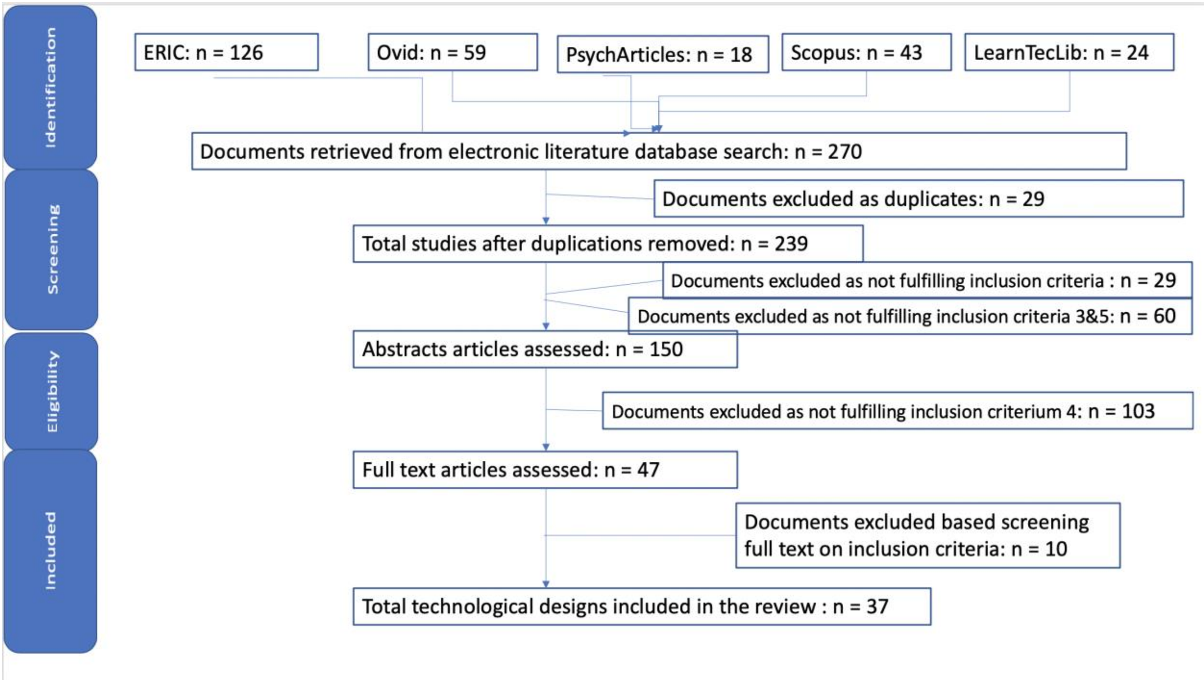

Figure 1 Literature search

3.2. Analysis

In order to answer the two research questions, the full text of each of the 37 articles was coded on four aspects: (a) the technological design, (b) the skills targeted for development, (c) instructional design used and (d) research design, including methodologies used and outcomes obtained. General patterns in the use of technology were then elicited, and linked up to instructional design.

A. Technological design

The technological design was categorised according to our own typology of technological features (including particular software, devices, electronic sensors etc.) (table 3). This typology is organised following the Activity-Centred Analysis and Design (ACAD) framework (Carvalho & Goodyear, 2018), which acknowledges the epistemic, physical and social situatedness of learning. When using ACAD, it is necessary to differentiate between elements that are open to alteration through design and the emergent activity of learners, which is only indirectly influenced through design. ACAD has been used to analyse emergent learning activity in both, online and place-based spaces for learning. It supports this identifying three areas that can be designed by educators or learners themselves: set design (the material entities and spaces within the setting of learning), social design (the roles and relationships in the learning setting) and epistemic design (the knowledge-related tasks that learners engage with).

The technologies in table 3 are not listed in any particular order, nor are they all of the same order (e.g. hardware, software, specific technological features). Although we started with an initial set of technological features (related to table 1), the full-text analyses showed that this set was too limited in actual design. This initial typology was therefore elaborated with technological features emerging from the articles. A technological design can combine multiple features from Table 3.

*Table 3 Typology of technological features (initial set indicated with *)*

Technological design features	Description
Related to the mechanics of the learning environment (set design in ACAD model)	
*Augmented reality	The design features a form of augmented reality (computer graphics overlaying physical reality)
*Virtual reality	The design features a form of virtual reality, in which the learner is immersed in computer graphics environment.
*Mixed reality	The design includes multiple forms of reality, i.e. augmented and virtual
*Virtual Environment	The design is supported by a virtual environment, where the learning activities take place
*Game	The design is a game or features gaming patterns
*Simulation	The design uses a simulated environment consisting of solely computer-generated graphics of existing physical items or environments.
physical (touch) feedback (haptic; vibration)	The design contains technological features that allows the learner to operate (parts of) the environment by touch
wearable / sensors	The design uses sensors (embedded in the environment or in wearables) to capture data about the learner or learning environment
indoor positioning beacons	The design can locate the position of learners within a learning environment using beacon technology
interactive simulation	The design uses a simulated environment consisting of solely computer-generated graphics in which the learner can operate certain aspects of the virtual environment
interactive print	The design features the use of printed information in the physical world that the learners interact with or manipulate using virtual tools
recommendation // Intelligent Tutoring System	The design includes an automated recommendation system (intelligent tutoring system)
*robot	The design features a robot, i.e. an automated machine that can perform activities typically done by human beings
avatar	The design features options for a learner to create a virtual identity within a virtual environment. This virtual identity (avatar) plays a central role in the learning activities.
mobile device	The design allows the learner to work on a mobile device (smartphone, tablet, dedicated device)

smartphone	The design allows the learner to work on a smartphone
Related to the social interactions enabled by technology (social design in ACAD model)	
*Collaboration support technologies	The technology in the design enables collaboration between the learners
storytelling / role-playing	The technology in the design enables the learner to play a particular role or take on particular behavioural patterns in the learning environment
social network (with location)	The design includes a social network, indicating relationships between learners. Sometimes, this network also includes current synchronous location information
competition	The technology in the design enables learners to compete with each other
Related to the instruction enabled by technology (epistemic design in ACAD model)	
textual support	The design features some form of textual support provided in a virtual or physical environment
auditory instructions	The design features some form of auditory instructions
video guide	The design features some form of video-supported guide
accompanying website / e-learning	The design features an accompanying informational website or e-learning modules that support other learning activities
speech recognition software	The design uses technology to capture, recognize and act upon human speech

B. Skills targeted for development

A second level of coding involved the skills targeted for development by the technological design. As with the technological features, we started with two skills (fine manual skills and soft skills of communication) but elaborated this list as the analysis continued. It emerged that ILTs are not only used to develop particular skills, but also abilities, attitudes and behaviours. In this study, we use the general term of *competence* to denote all of these. The final list is organized as a typology in Table 4.

*Table 4 Typology of targeted competences (initial set indicated with *)*

Targeted competences	Description
*fine manual skills	Cognitive skill related to the execution of particular fine manual movements and operations to perform a task
conceptual understanding	Cognitive skill with focus on understanding of concepts
spatial-temporal understanding	Cognitive skill with focus on understanding of spatial-temporal position of concepts, and changes in this position
perceptual understanding	Cognitive skill with focus on understanding of perception of reality
working memory	Cognitive skill with focus on development of working memory
episodic memory	Cognitive skill with focus on development of episodic memory
flow	Non-cognitive ability related to occurrence of a state of flow, i.e. a positive psychological state in which the learner is completely involved in an activity for its own sake, that is challenging, intrinsically rewarding and enjoyable (Csikszentmihalyi, 1996)
decision-making	Non-cognitive ability to make reasoned, argumented decisions using judgement
attitudinal development	Development of a particular attitude relevant for a desired learning behaviour
*soft skill: communication	Non-cognitive skill regarding the ability to communicate in an appropriate and suitable way with someone
soft skill: collaboration	Non-cognitive skill regarding the ability to collaborate effectively with someone
soft skill: language skills	Non-cognitive skill regarding the ability to use language in an appropriate and suitable way with someone
soft skill: engagement and empathy	Non-cognitive skill regarding the ability to engage with someone in an appropriate and suitable way and be empathetic with that person

C. Instructional Approach

In a secondary analysis (and in aid of the second redefined research question), the typology for instructional design (Table 4) was built starting from the innovative pedagogies identified by Ferguson et al. (2019). All pedagogies can be supported by technologies.

Table 5 Innovative pedagogies (following Ferguson et al., 2019)

Innovative pedagogy	Description
Playful learning	Pedagogy that includes playful learning experiences; means to motivate and engage; develops critical thinking, problem solving, analytical and communication skills.
Learning with robots	This includes both using robots for education, as well as the process of creating robots to understand underlying concepts. Advances in Artificial Intelligence have greatly increased the possibilities for learning with robots.
Decolonizing learning	This is a form of critical pedagogy that focusses on the systematic questioning (unsettling) of existing (power) relations. Digital decolonisation questions how power is embedded in the (way) tools are used, and gives learners the means to gain a critical perspective on this.
Drone-based learning	This pedagogy uses drones (small vehicles controlled remotely) as a means to engage learners in the (enriched) exploration of physical environments.
Learning through wonder	This pedagogy starts from the premise that wonder inspires learning, motivates learners and activates seeking out different perspectives. Wonder can be designed for. Wonder can be seen as a series of phases: Anticipation, Encounter, Investigation, Discovery, Propagation (McFall, 2014).
Action learning	This pedagogy combines learning-by-doing with reflective learning and collaborative learning. In an action-learning session, the coach helps learners focus on a problem by asking questions that elicit reflection
Virtual studios	This pedagogy extends the concepts of active and social learning to online learning. The studio focusses on social interaction and collaboration around half-formed ideas, to give learners an experience of practice-oriented community-of-practice learning.
Place-based learning	This pedagogy starts from the contextual (physical/social) setting in which the learning takes place, where new technologies enable rich and inclusive learning opportunities.
Making thinking visible	This pedagogy focusses on the abilities of technology to make visible desired and real (student) thinking processes.
Learning Empathy[1]	This pedagogy focusses on developing learners' attitudes of empathy, by making learners aware of their own behavior or supporting the taking up of various roles.
Behaviour development	This pedagogy focusses on developing a particular desired behavior in learners, by putting them in certain situations.

[1] Adapted from classroom-based method Roots of Empathy from Ferguson et al. (2019)

Drill & Practice	This method focuses on systematic repetition of concepts, examples or practice problems. This exercise can be used to perfect a skill or procedure in a disciplined way.

D. Participants and Research design

Furthermore, the experimental design of each study (where available) was analysed. Following inclusion criterium 5, we primarily focused on empirical studies but non-empirical studies and articles were included if the technological design was deemed of value. In the analysis, particular focus was given to the population of the participants and the measures used to describe the learning outcomes.
The population has been described in the following way:

- Adult low-skilled people (BHC21 target group): adult learners who are low-skilled (due to condition (e.g. Autism Spectrum Disorder) or circumstance (e.g. low language skills))
- Young low-skilled people (relevant for BHC21): young learners (age 0-18) who are low-skilled (due to condition or circumstance).
- Young people (relevant for BHC21): young learners (age 0-18) – as these participants are still at earlier stages of development, the approaches described here will be relevant. (Marco et al, 2013; Richard et al, 2007)

- Not low-skilled: adult learners – if the participants are not low-skilled, further elaboration will be given on why the study is relevant for BHC21.

E. Seeking patterns

After the coding was completed, emerging patterns were identified. In particular, we focused on four phenomena of interest for the immediate goals of the project, i.e. the study design to test the effectiveness of Innovative Learning Technologies and the definition of the measures:

- Recurring combinations of technological design features
- Recurring patterns of pedagogies and technological design
- Recurring patterns of targeted competences and technological design
- Recurring patterns of targeted competences, pedagogies and technological design

Results

Table 6 presents an overview of the 37 articles, including their focus on skills, the technological design they use, the research design, type of study conducted and measures looked at.
Several notes need to be made on the articles presented in table 6.
1. There is only one article dealing with operational fine manual skills (article 11), and only one with an application in the construction industry (13).
2. The analysis shows that several types of low-skilled persons are included, either through personal traits or through circumstance.
Examples of circumstance included in our analysis are:

- adults asked to work within a restricted context, with focus on non-verbal skills (1)
- participants in a restricted physical context (training) (34)
- US soldiers returning with PTSD (30)

3. Low-skilled people on the autism spectrum are the target group in 9 articles (3, 16, 18, 20, 21, 24, 26, 27, 36), with a specific focus on job seekers on the autism spectrum (20) and learners with high-functioning autism (21),
4. The teacher perspective on the use of innovative technologies is discussed in article 28, and article 22 deals with the developmental perspective of learners over a period of time.
5. A comparative research design, primarily between-subjects, is used in 21 of the 37 articles.
6. Only one article presents research with a within-subject design. There are both qualitative, quantitative and mixed method studies. We have also included non-empirical studies when the technological design used is interesting for the project.

Table 6 Articles in Literature Study

	Authors	Technology used	Skills trained	Instructional approach	Population	Sample Description & Size	research design	measures
1	Orman, E. K., Price, H. E., & Russell, C. R. (2017).	AR, VR, virtual environment wearble/sensors	Soft skill: communication	Drill and Practice	Not low-skilled -	10 9M, 1F	expert-novice comparative study with (pre-test/post-test)	(physical) performance (quant.)
2	Yoon, S. A., Anderson, E., Park, M., Elinich, K., & Lin, J. (2018)	AR, collaboration support, textual support,	Conceptual understanding Soft skill: communication Soft skill: collaboration	Learning through wonder	Young people	374 53%M, 47%F	comparative study with 4 conditions	qualitative data
3	Cox, D. J., Brown, T., Ross, V., Moncrief, M., Schmitt, R., Gaffney, G., & Reeve, R. (2017)	AR, VR, virtual environment, simulation, sensors (wearbles), auditory instruction	Spatial-temporal understanding Perceptual understanding	Making thinking visible	Adult low-skilled people	25 (M=17.83y 87.5%M, 12.5%F) 26(M=18.08y,73.1%M, 26.9%F	comparative study (pre-test/ post-test)	performance (quant.)
4	Laine, T. H., Nygren, E., Dirin, A., & Suk, H.-J. (2016)	AR, game, smartphone, recommendation, storytelling.role-playing	Conceptual understanding	Playful learning	Young people	61 52%M, 48%F	survey study mixed method	learner characteristics (quant.) motivation, learner experience (qual.)

5	Chao, J., Chiu, J. L., DeJaegher, C. J., & Pan, E. A. (2015)	AR, MR, virtual environment, simulation, physical (touch) feedback (haptic, vibration), wearables/sensors	Conceptual understanding	Learning through wonder	Young people	30 50.8%M, 49.2%F	comparative study between 2 conditions	knowledge integration (quant.)
6	Chang, H.-Y., Hsu, Y.-S., & Wu, H.-K. (2016)	AR, VR, interactive simulation	Conceptual understanding Attitudinal development	Action learning	Young people	45 53%M, 47%F 15-16y	comparative study (pre-test/ post-test) between 2 conditions	knowledge and attitude (quant.)
7	Abdusselam, M. S., Kilis, S., Sahin Çakir, Ç., & Abdusselam, Z. (2018)	AR, smartphone	Conceptual understanding	Learning through wonder	not available	not available	evaluative study on design	No data

8	Estapa, A., & Nadolny, L. (2015)	AR, mobile device, smartphone, interactive print, accompanying website/e-learning	Conceptual understanding	Learning through wonder	Young people - students	61 56%F, 44%M	comparative study (pretest/posttest/delayed posttest) between 2 conditions	knowledge (quant.)
9	Kapp, S., Thees, M., Strzys, M. P., Beil, F., Kuhn, J., Amiraslanov, O., … Wehn, N. (2019)	AR, MR, physical (touch) feedback (haptic, vibration), wearable/sensors, textual support	Conceptual understanding	Learning through wonder	N.A.	N.A.	technical design	N.A.
10	Korozi, M., Leonidis, A., Ntoa, S., Arampatzis, D., Adami, I., Antona, M., & Stephanidis, C. (2018)	Virtual environment, game, simulation, physical (touch) feedback (haptic, vibration), interactive simulation	Conceptual understanding Spatial-temporal understanding Perceptual understanding	Playful learning	Young people	8 4 (3.5-4.5y) 2 (5-6y) 1 (7.5y) 1 (9y)	iterative design process and user based evaluation	learner engagement with technology (quant.) learner experience (through parents) (qual.)

11	Westerfield, G., Mitrovic, A., & Billinghurst, M. (2015)	AR, MR, physical (touch) feedback (haptic, vibration), wearable/sensors, textual support, recommendation, robot	Conceptual understanding Fine manual skills	Behavioural development	Not low-skilled	16 11M, 5F	comparative study (pretest/posttest) between 2 conditions	knowledge, learner experience, learner satisfaction, mental stress, physical stress (quant.)
12	Han, J., Jo, M., Hyun, E., & So, H. (2015)	AR, VR, MR, wearbles/sensors, storytelling/role-playing, interactive print, robot	Soft skills: engagement and empathy	Empathy in learning	Young people	81 42 5-year old kids 39 6-year old kids 48M, 33F	mixed method comparative study between 2 conditions	learner satisfaction, learner experience and learner engagement (quant.) Qualitative data
13	Pejoska, J., Bauters, M., Purma, J., & Leinonen, T. (2016)	AR, collaboration support, smartphone, interactive simulation, social network (with location)	Soft skills: communication Soft skills: collaboration	Empathy in learning	N.A.	N.A.	design of a social AR prototype	N.A.

14	Civelek, T., Ucar, E., Ustunel, H., & Aydin, M. K. (2014)	Virtual environment, physical (touch) feedback (haptic, vibration), wearable / sensors, interactive simulation	Conceptual understanding	Learning through wonder	Young people	17-18y Experimental: 106 (27F, 79M) control: 109(25F, 84M)	comparative study (posttest) between 2 conditions	attitude and performance (quant.)
15	Cai, S., Chiang, F.-K., Sun, Y., Lin, C., & Lee, J. J. (2017).	AR, simulation, physical (touch) feedback (haptic, vibration), wearbles/sensors, storytelling/roleplaying, interactive simulation	Conceptual understanding	Learning through wonder	Young people	42 Experimental: 5 subgroups with 4 students control: 5 subgroups with 4 students no sig. diff. in achievement pretest	mixed method comparative study (pretest/post-test/delayed post-test) between 2 conditions	knowledge, learner satisfaction and learner acceptance (quant.) Qualitative data

16	Wallace, S., Parsons, S., & Bailey, A. (2017)	VR, virtual environment, simulation, collaboration support, social network (with location), avatar	Soft skills: communication	Empathy in learning	Young Low-skilled people	10(ASD; 12-16y; 9M, 1F) 10 (14-16y; 8M,2F)	comparative study between 2 conditions	sense of presence, social attraction and facial expression recognition (quant.)
17	Zirzow, N. K. (2017).	VR, virtual environment, wearbles/sensors, smartphone, interactive simulation, avatar	Conceptual understanding Soft skills: language skills Working memory	Learning through wonder	N.A.	N.A.	Non-empirical - examples of applications with signing avatars	educational uses of signing avatars for deaf and/or hard-of-hearing learners
18	Fonseca, D., Moreira, F., de Reina, O., de Renteria, I., Navarro, I., & Ferrer, Á. (2017)	VR, mobile device, wearbles/sensors, smartphone, video guide, indoor positioning beacons	Spatial-temporal understanding Perceptual understanding	Place-based learning	Adult low-skilled people Not low-skilled (some ADHD)	Experimental: 15 (8F, 7M; 2 medium level ADH; M= 21,5y) Control: 17 (9F, 8M; 2 30% ADHD; M = 20y)	mixed method comparative study (pretest/posttest) between 2 conditions	performance, learner effort and learner satisfaction (quant.) learner experience and satisfaction (qual.)

19	Guerron, Nancy E; Cobo, Antonio; Serrano, J. J. (2018).	VR, virtual environment, physical (touch) feedback (haptic, vibration), wearbles/sensors, smartphone, auditory instruction, avatar	Spatial-temporal understanding	Place-based learning	Adult low-skilled people)	4 to 20 blind people who participated in the 6 workshops	experimental study consisting of 6 workshops	learner performance, learner engagement and learner satisfaction (quant.)
20	Smith, M. J., Ginger, E. J., Wright, K., Wright, M. A., Taylor, J. L., Humm, L. B., … Fleming, M. F. (2014)	VR, virtual environment, recommendation, storytelling/role-playing, accompanying website/e-learning, avatar, speech recognition software	Soft skills: communication Soft skills: language skills Attitudinal development Soft skills: engagement and empathy	Empathy in learning	Adult low-skilled people	26 18-31y	randomized single-blinded controlled trial between subjects comparative study between 2 conditions	learner characteristics, learner experience, learner satisfaction and learner engagement (quant.) learner performance (quantified qual.) (rating of video data on success factors for job interviews)

21	Ke, F., & Lee, S. (2016)	VR, collaboration support, storytelling/role-playing	Soft skills: collaboration	Action learning	Young low-skilled people	3 (2; 8-11y; with HFA) 1 typically developing learner	qualitative case study and the single-subject research	learner performance and learner engagement (qual.)
22	Picard, L., Abram, M., Orriols, E., & Piolino, P. (2017)	VR, virtual environment, physical (touch) feedback (haptic, vibration), textual support, interactive simulation	Spatial-temporal understanding	Learning through wonder	Young people Not low-skilled	C1: n=125(58M, 67F; 24 6y, 24 7y, 25 8–10y, 15 10–12y, 15 14–16y, 22 18–24y) C2: n= 79(14 6y, 11 7y, 15 8–10y, 15 14–16y, 9 18–24y)	Comparative study between 2 conditions (VR-Episodic Memory tests vs standard episodic memory tests)	learner performance & knowledge retention (quant.)

23	Negen, J., Heywood-Everett, E., Roome, H. E., & Nardini, M. (2018)	VR, physical (touch) feedback (haptic, vibration), wearable/sensors, storytelling/roleplaying, interactive simulation	Spatial-temporal understanding	Place-based learning	Young people Not low-skilled adults	G1: 11 (3.5–4y, M: 3.76, SD: 0.15) G2: 10 (4–4.5, M: 4.35, SD: 0.14) G3: 5 adults	between-subjects comparative study between 3 groups	learner performance (quant.) spatial recall and movement in space using log data (quant.)
24	Bozgeyikli, L., Raij, A., Katkoori, S., & Alqasemi, R. (2018)	VR	Conceptual understanding Soft skills: communication Soft skills: collaboration Soft skills: language skills Soft skills: engagement and empathy	Learning through wonder	N.A.	N.A.	design considerations for VR applications for individuals with ASD	N.A.

25	Yi-Lien, Y., Yu-Ju, L., & Yen-Ting, R. L. (2018).	VR, virtual environment, simulation, collaboration support, textual support, storytelling/role-playing, interactive simulation, avatar	Soft skills: collaboration	Action learning	Young people	65 27M, 38F	qualitative comparative study between 2 conditions (gender)	learner experience and learner satisfaction (qual.)

26	Smith, M. J., Fleming, M., Wright, M., Losh, M., Boteler Humm, L., Olsen, D., & Bell, M. (2015)	VR, virtual environment, recommendation, storytelling/role-playing, accompanying website, avatar, speech recognition software,	Soft skills: communication Soft skills: language skills Attitudinal development Soft skills: engagement and empathy	Empathy in learning	Adult low-skilled people	23 n = 15 VR-JIT trainees n = 8 controls	randomized controlled trial	validated measures and instruments: a) Demographic Characteristics, Vocational History, and Clinical Assessment; b) Neurocognitive and Social Cognitive Measures; c) Feasibility Assessments; d) Primary Efficacy Assessments; e) Process Measure self-confidence at performing job interviews using a 7-point Likert scale Role-play scored by blinded expert HR raters based on the VR-JIT learning obj. Change in VR-JIT performance (quant.) follow-up survey reflection on 6 months (qual.)
27	Politis, Y., Olivia, L., Olivia, T., & Sung, C. (2017	Virtual environment, simulation, textual support, avatar	Soft skills: communication	Empathy in learning	Adult low skilled people Not low-skilled adults	stress test: 15 (8 ASD) usability test: 6 (ASD;2F,4 M;M = 20y)	mixed method Participatory design	

28	Hartley, M. D., Ludlow, B. L., & Duff, M. C. (2017).	VR, virtual environment, simulation, interactive simulation	Teacher training		Not low-skilled	not an empirical study	not an empirical study	not an empirical study
29	Bressler, D. M., Bodzin, A. M., & Tutwiler, M. S. (2019)	VR, game, collaboration support, mobile device, storytelling/role-playing, interactive print	flow	Action learning	Young people	203 (8th-grade; science students; middle schools district)	between-subjects comparative study (gender)	Achievement track. Gender. Group composition

30	Derby, J. (2014).	VR, virtual environment, game, physical (touch) feedback (haptic; vibration), wearables/sensors, storytelling/role-playing, interactive simulation, avatar	Working memory Episodic memory	Action learning	Not low-skilled	not an empirical study	not an empirical study	not an empirical study
31	Misfeldt, M. (2015).	Game, storytelling/role-playing, competition	Soft skills: communication Soft skills: collaboration Attitudinal development	Playful learning	Not low-skilled	9 individuals 3 focus groups	qualitative study: evaluation of 2nd prototype game with students playing the game	student framing of activities in relation to domains of gaming, competing and construction site management (qual.)
32	Wass, S. V, & Porayska-Pomsta, K. (2014)	VR, robot, avatar	Soft skills: language skills		not an empirical study	not an empirical study	not an empirical study	not an empirical study

33	Winkelmann, Z. K., Eberman, L. E., Edler, J. R., Livingston, L. B., & Games, K. E. (2018)	Simulation, collaboration support, physical (touch) feedback (haptic; vibration)	Athletic development		not available	not available	not available	not available
34	Fox, J. L., Stanton, R., & Scanlan, A. T. (2018).	Wearables/sensors,	Spatial-temporal understanding Perceptual understanding	Playful learning	Not low-skilled	15(Age: M = 20.4 ± 4.5y; Stature: M =187.4 ±7.6cm; Body Mass: M = 86.2 ± 12.1kg; Body Fat: M = 11.6 ± 2.1%)	within-subjects comparative study	Int. & ext. measures during physical conditioning training, games-based training, and competitive games during the preseason in male semi-professional basketball players (quant.)
35	Wahyudin, D., Hasegawa, S., & Kamaludin, A. (2017)	Game, simulation, mobile device, storytelling/role-playing	Decision making	Learning Empathy	Young people Not low-skilled	276 (UNIV=65 M, 60F; HS=106M, 45F)	mixed method	demographic data (quant.) Game behavior and preferences (quant.) Participants' viewpoint to computer game for training opinion for general aptitude (qual.) motivation

36	Kaboski, J. R., Diehl, J. J., Beriont, J., Crowell, C. R., Villano, M., Wier, K., & Tang, K. (2015)	robot	Soft skills: communication Soft skills: collaboration	Learning Empathy	Young low skilled people Young people	Pairs of 8 (ASD) and 8 (TD) peers (12–17) matched on age, gender, grade in school, IQ, & language skills	quantitative study on the development of peer intervention skills through collaborative learning on the development of a robot	Social anxiety (quant.) Social skills (quant.) Robotics knowledge (quant.)
37	Ching, C. C., Stewart, M. K., Hagood, D. E., & Rashedi, R. N. (2016)	Game, mobile device, wearables/sensors, smartphone, storytelling/role-playing, competition	Decision making	Behavioural development	Young people Young low-skilled people	26 (21M; 5F)	mixed methods study to understand how youth engage with data from fitbit vs own assessment of data	qualitative data

The analysis shows that the instructional approach is intertwined with the technological design chosen for. There are clear differences in level of instructional support offered to learners (evidenced by the combination of technologies used) and consequently, differences in the extent of learner control given. There are also several technical solutions that can create similar learner experience, so depending on the context (learner needs, desired competence development, etc.), choices can be made on which didactical strategies to employ. In the included articles, there are some patterns to be distinguished. Table 7 shows an overview of the predominant technical solutions, organized per competence developed, and an associated pedagogy. The competences are organized according to the Sector Qualification Framework Structure (Brockmann et al., 2010), with occupational competence (consisting of knowledge and know-how) and personal competence (consisting of social competence and self-competence).

Table 11: A Proposed Revision of the SQF Structure.

Structure of requirements				
Occupational competence			Personal competence	
Knowledge	Know How		Social competence	Self-competence
Tools, equipment, materials Depth and breath, Systematic, Non-systematic	*Skills:* Manual, Intellectual Scope of activities to be undertaken	*Transversal Abilities:* Planning, Organising, Controlling Assessing Scope of activities to be undertaken	Team/leadership skills, involvement and communication	Autonomy/responsibility, achieving results, reflectiveness and learning competence, taking responsibility

Figure 2 Brockmann et al. (2010)'s Sector Qualfication Framework Structure

Table 7 Technological design per competence developed, and associated instructional approach

SQF Structure	*Competence*	*Instructional approach*	*technologies*	*articles*
Know-how	conceptual understanding	learning through wonder	AR + physical feedback + wearables/sensors + interactivity	5, 9, 11, 15, 7, 8, 14, 17, 24
		action learning	AR + interactivity	2, 6
		playful learning		4, 10
	spatial-temporal understanding	place-based learning	VR + wearables/sensors + physical feedback/interactivity	18, 19, 23
		playful learning	wearables/sensors interactivity/physical feedback	34, 11
		making thinking visible	wearables/sensors	3
		learning through wonder	interactivity/physical feedback	22
	perceptual understanding	playful learning	wearables/sensors interactivity/physical feedback	34, 10
		making thinking visible	VR/VE/simulation + wearables/sensors	3
		place-based learning	VR + wearables/sensors	18
	fine manual skills	behaviour development	AR/MR + wearables/sensors + physical feedback + support	11
Self-competence	working memory	learning through wonder	VR/VE + Wearables/sensors/interactivity/avatar	17

		action learning	VR/VE + Wearables/sensors/interactivity/avatar	30
	episodic memory	learning through wonder	VR/VE + Physical feedback + interactivity	22
		action learning	VR/VE + Physical feedback + interactivity	30
	flow	action learning	VR + game + mobile device	29
	decision making	roots of empathy	game + mobile device + storytelling/role playing	35
		behaviour development	game + mobile device + storytelling/role playing	37
	attitudinal development	behavioural learning	VR + storytelling/roleplaying	20, 6
		learning **e**mpathy	VR + storytelling/roleplaying	26
		action learning	game + storytelling/roleplaying	31
Social competence	communication	learning **e**mpathy	VR/VE + avatar	16, 20, 26, 27, 13, 36
		learning through wonder	AR/VR + collaboration support	24, 2
		playful learning	game	31

		behaviour development	VR/VE	1
	collaboration	action learning	VR + collaboration support + storytelling/roleplaying	21, 24, 31
		learning through wonder	AR/VR	2, 24
		learning **e**mpathy	AR; robot	13, 36
	empathy and engagement	learning **e**mpathy	VR + storytelling/roleplaying	12, 26
		behavioural learning	VR + storytelling/roleplaying	20
		learning through wonder	VR	24

In answer of our first research question on the **proven effectiveness of ILTs** in acquiring competences in technical training programs, the articles show that effectiveness of the use of ILTs is difficult to ascertain, as comparative studies do not show conclusive evidence. However, it is possible to say something about the application of these technologies. Firstly, the analysis shows that ILTs are used to develop various skills, and are often used in combinations that support an overall design to develop these skills. Secondly, forms of immersive experiences with Extended Reality technologies (AR/VR) were most prevalent in this analysis, which due to their immersive nature seem to provide suitable learning environments for the target group of low-skilled people. In particular, when these technologies are augmented with sensors and wearables to give feedback on learner activity, they seem to be especially interesting. Examples in our analysis include (i) a driving simulation environment, with physical components such as steering wheel and mirrors, that give feedback (article 14); (ii) a virtual simulation for training assembly of electrical components (article 11) and (iii) virtual reality environment to train physics through allowing experimentation to see “cause and effect” in a physical sense (article 12) Thirdly, game and storytelling techniques seem to be useful in the development of social competence, which is a key need for the target group of low-skilled people. Fourthly, the analysis has shown that there are many validated instruments to measure behaviour, learning and social skills for the specific target group of learners on the autism spectrum.

In answer of our second research question on **instructional design features**, these features depend on the types of skills that are developed and the level of learner control that needs to be given. For know-how related skill development, there seems to be a spectrum of instructional designs, from one extreme where learners are guided step-by-step, to the other extreme where they are encouraged to explore a virtual environment on their own. In both extremes, student activity can be made visible to learners for encouraging active behavioural change (*making thinking visible)*. This information allows teachers to provide relevant timely feedback to support the learning process (although this aspect is not prominent in this analysis). For developing self-competence, immersive environments with immediate feedback (through haptic signals for example) or with forms of role-play and storytelling seem useful. Games can be useful here too. For developing social competence, immersive environments again prove useful learning environments, when they are supported by collaboration support, such as? guided dialogue, role-taking or step-by-step guide. Depending on the type of skills to be developed, games can be appropriate here. Of particular interest in this category are the use of robots for interaction, where learners can interact with embodied agents to develop their social skills.

Discussion and possibilities for the BHC21 project

The results of this literature review are interesting for the aims of the BHC21 project.

Firstly, the skills and competences that emerge from the literature review are relevant for the target group of the BHC21 project. It has been found that occupational competences such as developing knowledge and know-how can be supported with innovative learning technologies. The literature review has shown examples where conceptual, perceptual and spatial-temporal understanding can be developed using these technologies. The literature review has also shown possibilities for developing personal competence. The analysis shows examples of development of self-competence in the forms of judgement or attitude, with the support of innovative learning technologies. Also, the specific needs of developing social competence in the form of communicative and collaborative abilities can also be developed through the use of ILTs. Moreover, the literature review gives insight into the instructional approaches that can support the use of the technology to develop these different competences. These are particularly useful for the choice of ILTs in WP2 and the design of the tests and pilots in the project.

Secondly, the literature review has surprisingly few examples of applications in industry, with the target group of low-skilled people. It is possible that this is due to the period in which the search was conducted (June 2019 at the beginning of the project). For historical context, the term “Industry 4.0” was coined in 2015, the same year the first commercially viable AR headset (Microsoft Hololens) was announced, with Hololens 2 appearing in 2019. In other words, this period may have been too early for significant effectiveness studies on application of ILTs in industry. It is also likely that examples of industrial applications do not appear in academic searches because of the lag in academic research done in this field. A new search may show different results.

Thirdly, the literature review shows that Extended Reality technologies, namely AR and VR, are the most interesting for the project goals. They provide immersive learning experiences that can support the development of very different types of skills, and can be combined with different complementary technologies to achieve suitable learning environments. This technology is therefore very versatile and useful to explore within the project, offering many possibilities for the industry.

Fourthly, although the literature review has not brought up any significant conclusions on the effectiveness of ILTs within the BHC21project, it does give insight into the considerations to develop the methodology for measuring effectiveness within the BHC21 project. For example, this literature review shows many possible avenues for using validated instruments for specific target groups of learners on the autism spectrum. It also brings to the fore the complexity of the design of interventions, that touches on different learning goals. To be able to identify the impact of these complex designs, the research methodology needs to be comprehensive.

Uptake within the BHC21 project

The results of this literature study have been taken up in further work within the BHC21 project. This work has informed the choice of the ILTs in the different regions within the project.

Within WP2, this work feeds into the design of the decision-supporting instrument, an instrument to support companies and trainers in the choice of suitable ILTs for their learning needs. It also feeds into the design of the methodology to measure the effectiveness of the use of ILTS in the tests and pilots.

References

Abdusselam, M. S., Kilis, S., Sahin Çakir, Ç., & Abdusselam, Z. (2018). Examining Microscopic Organisms under Augmented Reality Microscope: A 5E Learning Model Lesson. Science Activities: Classroom Projects and Curriculum Ideas, Vol. 55, pp. 68–74.

Abowd, D., Dey, A. K., Orr, R., & Brotherton, J. (1998). Context-awareness in wearable and ubiquitous computing. Virtual Reality, 3(3), 200-211.

Albano, M., Lino Ferreira, L., Di Orio, G., Maló, P., Webers, G., Jantunen, E., ... & Papa, G. (2020). Advanced sensor-based maintenance in real-world exemplary cases. Automatika, 61(4), 537-553.

Anwar, S., Bascou, N. A., Menekse, M., & Kardgar, A. (2019). A systematic review of studies on educational robotics. Journal of Pre-College Engineering Education Research (J-PEER), 9(2), 2

Beigl, M., Krohn, A., Zimmer, T., & Decker, C. (2004). Typical sensors needed in ubiquitous and pervasive computing. Proceesdings of INSS, 22-23.

Bozgeyikli, L., Raij, A., Katkoori, S., & Alqasemi, R. (2018). A Survey on Virtual Reality for Individuals with Autism Spectrum Disorder: Design Considerations. IEEE Transactions on Learning Technologies, 11(2), 133–151. Retrieved from http://dx.doi.org/10.1109/TLT.2017.2739747

Bradley. D.A., Dawson, D., Burd, N.C, Loader, A.J. (2000): Mechatronics – Electronics in products and processes, Stanley Thornes, 2000.

Bressler, D. M., Bodzin, A. M., & Tutwiler, M. S. (2019). Engaging Middle School Students in Scientific Practice with a Collaborative Mobile Game. Journal of Computer Assisted Learning, 35(2), 197–207.

Brockmann, M., Clarke, L., & Winch, C. (2010) Bricklaying is more than Flemish bond. Bricklaying qualifications in Europe. Leonardo Da Vinci Project. Nazareth, Belgium: CLR publications, 87.

Cai, S., Chiang, F.-K., Sun, Y., Lin, C., & Lee, J. J. (2017). Applications of Augmented Reality-Based Natural Interactive Learning in Magnetic Field Instruction. Interactive Learning Environments, Vol. 25, pp. 778–791.

Carvalho, L., & Goodyear, P. (2018). Design, learning networks and service innovation. Design Studies, 55, 27–53. https://doi.org/10.1016/j.destud.2017.09.003

Chang, H.-Y., Hsu, Y.-S., & Wu, H.-K. (2016). A Comparison Study of Augmented Reality versus Interactive Simulation Technology to Support Student Learning of a Socio-Scientific Issue. Interactive Learning Environments, Vol. 24, pp. 1148–1161.

Chao, J., Chiu, J. L., DeJaegher, C. J., & Pan, E. A. (2015). Sensor-Augmented Virtual Labs: Using Physical Interactions with Science Simulations to Promote Understanding of Gas Behavior. *Journal of Science Education and Technology*, Vol. 25, pp. 16–33.

Ching, C. C., Stewart, M. K., Hagood, D. E., & Rashedi, R. N. (2016). Representing and Reconciling Personal Data and Experience in a Wearable Technology Gaming Project. IEEE Transactions on Learning Technologies, 9(4), 342–353.

Civelek, T., Ucar, E., Ustunel, H., & Aydin, M. K. (2014). Effects of a Haptic Augmented Simulation on K-12 Students' Achievement and Their Attitudes Towards Physics. EURASIA Journal of Mathematics, Science & Technology Education, 10(6), 565–574. Retrieved from http://dx.doi.org/10.12973/eurasia.2014.1122a

Cox, D. J., Brown, T., Ross, V., Moncrief, M., Schmitt, R., Gaffney, G., & Reeve, R. (2017). Can Youth with Autism Spectrum Disorder Use Virtual Reality Driving Simulation Training to Evaluate and Improve Driving Performance? An Exploratory Study. *Journal of Autism and Developmental Disorders*, Vol. 47, pp. 2544–2555.

Csikszentmihalyi, M. (1996). Creativity: Flow and the psychology of discovery and invention. New York: Harper Collins

Dengler, K., & Matthes, B. (2018). The impacts of digital transformation on the labour market: Substitution potentials of occupations in Germany. Technological Forecasting & Social Change, 137, 304–316.

Derby, J. (2014). Violent Video Games and the Military: Recruitment, Training, and Treating Mental Disability. Art Education, 67(3), 19–25. Retrieved from http://www.arteducators.org/research/art-education

De Vin, L. J., Jacobsson, L., & Odhe, J. (2018). Game-based Lean Production training of university students and industrial employees. Procedia Manufacturing, 25, 578–585. https://doi.org/10.1016/j.promfg.2018.06.098

Estapa, A., & Nadolny, L. (2015). The Effect of an Augmented Reality Enhanced Mathematics Lesson on Student Achievement and Motivation. Journal of STEM Education: Innovations and Research, Vol. 16, pp. 40–48.

Ferguson, R., Coughlan, T., Egelandsdal, K., Gaved, M., Herodotou, C., Hillaire, G., Jones, D., Jowers, I., Kukulska-Hulme, A., McAndrew, P., Misiejuk, K., Ness, I. J., Rienties, B., Scanlon, E., Sharples, M., Wasson, B., Weller, M. and Whitelock, D. (2019). Innovating Pedagogy 2019: Open University Innovation Report 7. Milton Keynes: The Open University.

Fonseca, D., Moreira, F., de Reina, O., de Renteria, I., Navarro, I., & Ferrer, Á. (2017). Assessment of Wearable Virtual Reality Technology for Visiting World Heritage Buildings: An Educational Approach. Journal of Educational Computing Research, 56(6), 940–973. https://doi.org/10.1177/0735633117733995

Guerron, Nancy E; Cobo, Antonio; Serrano, J. J. (2018). METHODOLOGY FOR BUILDING VIRTUAL REALITY MOBILE APPLICATIONS FOR BLIND PEOPLE ON ADVANCED VISITS TO UNKNOWN INTERIOR SPACES. IADIS 2018 International Conference, 3–15.

Gitschthaler, M., & Nairz-Wirth, E. (2018). The individual and economic costs of early school leaving. In Comparative Perspectives on Early School Leaving in the European Union (pp. 61–74). https://doi.org/10.4324/9781315170404

Han, J., Jo, M., Hyun, E., & So, H. (2015). Examining Young Children's Perception toward Augmented Reality-Infused Dramatic Play. Educational Technology Research and Development, Vol. 63, pp. 455–474.

Hartley, M. D., Ludlow, B. L., & Duff, M. C. (2017). Second Life®: A 3D Virtual Immersive Environment for Teacher Preparation Courses in a Distance Education Program. Rural Special Education Quarterly, 34(3), 21–25. https://doi.org/10.1177/875687051503400305

Kaboski, J. R., Diehl, J. J., Beriont, J., Crowell, C. R., Villano, M., Wier, K., & Tang, K. (2015). Brief Report: A Pilot Summer Robotics Camp to Reduce Social Anxiety and Improve Social/Vocational Skills in Adolescents with ASD. Journal of Autism and Developmental Disorders, 45(12), 3862–3869. Retrieved from http://dx.doi.org/10.1007/s10803-014-2153-3

Kapp, S., Thees, M., Strzys, M. P., Beil, F., Kuhn, J., Amiraslanov, O., … Wehn, N. (2019). Augmenting Kirchhoff's Laws: Using Augmented Reality and Smartglasses to Enhance Conceptual Electrical Experiments for High School Students. Physics Teacher, 57(1), 52–53. Retrieved from https://doi.org/10.1119/1.5084931

Ke, F., & Lee, S. (2016). Virtual reality based collaborative design by children with high-functioning autism: design-based flexibility, identity, and norm construction. Interactive Learning Environments, 24(7), 1511–1533. https://doi.org/10.1080/10494820.2015.1040421

Korozi, M., Leonidis, A., Ntoa, S., Arampatzis, D., Adami, I., Antona, M., & Stephanidis, C. (2018). Designing an Augmented Tabletop Game for Children with Cognitive Disabilities: The "Home Game" Case. *British Journal of Educational Technology*, Vol. 49, pp. 701–716.

Laine, T. H., Nygren, E., Dirin, A., & Suk, H.-J. (2016). Science Spots AR: A Platform for Science Learning Games with Augmented Reality. *Educational Technology Research and Development*, *64*(3), 507–531. Retrieved from http://dx.doi.org/10.1007/s11423-015-9419-0

Marco, J., Cerezo, E., & Baldassarri, S. (2013). Bringing tabletop technology to all: evaluating a tangible farm game with kindergarten and special needs children. Personal and Ubiquitous Computing, 17, 1577–1591.

McFall, M. (2014). Using Heritages and Practices of Wonder To Design a Primary-School-Based Intervention. Unpublished PhD thesis, University of Nottingham. http://bit.ly/2QY1sp9

Milgram, P., & Kishimo, F. (1994). A taxonomy of mixed reality. IEICE Transactions on Information and Systems, 77(12), 1321–1329.

Misfeldt, M. (2015). Scenario based education as a framework for understanding students engagement and learning in a project management simulation game. Electronic Journal of E-Learning, 13(3), 181–191.

Müller, D. (2005). Mechatronics in Vocational Training. In: Müller, D. (ed.), MARVEL – Mechatronics Training in Real and Virtual Environments, Leonardo Da Vinci, pp. 17-21

Negen, J., Heywood-Everett, E., Roome, H. E., & Nardini, M. (2018). Development of allocentric spatial recall from new viewpoints in virtual reality. Developmental Science, 21(1). https://doi.org/10.1111/desc.12496

Orman, E. K., Price, H. E., & Russell, C. R. (2017). Feasibility of Using an Augmented Immersive Virtual Reality Learning Environment to Enhance Music Conducting Skills. *Journal of Music Teacher Education*, Vol. 27, pp. 24–35.

Pejoska, J., Bauters, M., Purma, J., & Leinonen, T. (2016). Social augmented reality: Enhancing context-dependent communication and informal learning at work. British Journal of Educational Technology, 47(3), 474–483. https://doi.org/10.1111/bjet.12442

Picard, L., Abram, M., Orriols, E., & Piolino, P. (2017). Virtual reality as an ecologically valid tool for assessing multifaceted episodic memory in children and adolescents. International Journal of Behavioral Development, 41(2), 211–219. https://doi.org/10.1177/0165025415616198

Politis, Y., Olivia, L., Olivia, T., & Sung, C. (2017). Involving People with Autism in Development of Virtual World for Provision of Skills Training. International Journal of E-Learning & Distance Education, 32(2).

Richard, E., Billaudeau, V., Richard, P., & Gaudin, G. (2007). Augmented reality for rehabilitation of cognitive disabled children: a preliminary study. In Virtual rehabilitation on IEEE (pp. 102–108), Venice, Italy.

Roos, G., & Shroff, Z. (2017). What will happen to the jobs? Technology-enabled productivity improvement – good for some, bad for others. Labour & Industry: A Journal of the Social and Economic Relations of Work, 27(3), 165–192.

Siciliano, B., & Khatib, O. (Eds.). (2016). Springer handbook of robotics. Springer.

Smith, M. J., Ginger, E. J., Wright, K., Wright, M. A., Taylor, J. L., Humm, L. B., … Fleming, M. F. (2014). Virtual Reality Job Interview Training in Adults with Autism Spectrum Disorder. Journal of Autism and Developmental Disorders, 44(10), 2450–2463. Retrieved from http://dx.doi.org/10.1007/s10803-014-2113-y

Smith, M. J., Fleming, M., Wright, M., Losh, M., Boteler Humm, L., Olsen, D., & Bell, M. (2015). Brief Report: Vocational Outcomes for Young Adults with Autism Spectrum Disorders at Six Months After Virtual Reality Job Interview Training. Journal of Autism and Developmental Disorders, 45(10), 3364–3369. https://doi.org/10.1007/s10803-015-2470-1

Van Acker, B., Conradie, P., Parmentier, D., Joundi, J., Saldien, J., & Vlerick, P. Een exploratief onderzoek naar de accepteerbaarheid van industriële cobots bij (toekomstige) operatoren. (Accepted).

Vanneste, P., Huang, Y., Park, J. Y., Cornillie, F., Decloedt, B., & Van den Noortgate, W. (2020). Cognitive support for assembly operations by means of augmented reality: an exploratory study. *International Journal of Human-Computer Studies*, 102480.

Veipa, I., Jermolajeva, E., & Azena, L. (2017). PROFESSIONAL AND QUALIFIED WORKFORCE FOR THE REGIONS OF LATVIA – THE CHALLENGE OF THE 21ST CENTURY. Reģionālais Ziņojums. Pētījumu Materiāli, (13), 64–86. Retrieved from http://search.proquest.com/docview/2132572289/

Wahyudin, D., Hasegawa, S., & Kamaludin, A. (2017). Students' Viewpoint of Computer Game for Training in Indonesian Universities and High Schools. Education and Information Technologies, 22(4), 1927–1945. Retrieved from http://dx.doi.org/10.1007/s10639-016-9522-9

Wallace, S., Parsons, S., & Bailey, A. (2017). Self-reported sense of presence and responses to social stimuli by adolescents with autism spectrum disorder in a collaborative virtual reality environment. Journal of Intellectual and Developmental Disability, 42(2), 131–141. https://doi.org/10.3109/13668250.2016.1234032

Wass, S. V, & Porayska-Pomsta, K. (2014). The Uses of Cognitive Training Technologies in the Treatment of Autism Spectrum Disorders. Autism: The International Journal of Research and Practice, 18(8), 851–871. Retrieved from http://dx.doi.org/10.1177/1362361313499827

Westerfield, G., Mitrovic, A., & Billinghurst, M. (2015). Intelligent Augmented Reality Training for Motherboard Assembly. International Journal of Artificial Intelligence in Education, 25(1), 157–172. Retrieved from http://dx.doi.org/10.1007/s40593-014-0032-x

Winkelmann, Z. K., Eberman, L. E., Edler, J. R., Livingston, L. B., & Games, K. E. (2018). Curation of a Simulation Experience by the Clinical Scholar: An Educational Technique in

Postprofessional Athletic Training. Athletic Training Education Journal, 13(2), 185–193. Retrieved from http://dx.doi.org/10.4085/1302185

Yi-Lien, Y., Yu-Ju, L., & Yen-Ting, R. L. (2018). Gender-Related Differences in Collaborative Learning in a 3D Virtual Reality Environment by Elementary School Students. Educational Technology & Society, 21(4), 204–216. https://doi.org/10.2307/26511549

Yoon, S. A., Anderson, E., Park, M., Elinich, K., & Lin, J. (2018). How Augmented Reality, Textual, and Collaborative Scaffolds Work Synergistically to Improve Learning in a Science Museum. *Research in Science & Technological Education*, Vol. 36, pp. 261–281.

Zirzow, N. K. (2017). Signing Avatars: Using Virtual Reality to Support Students with Hearing Loss. Rural Special Education Quarterly, 34(3), 33–36. https://doi.org/10.1177/875687051503400307