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Could Vocational Education Benefit From Augmented Reality and Hypervideo Technologies? An Exploratory Interview Study

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Abstract

Context: This study investigates the perspective of vocational educators on the possibility of adopting augmented reality (AR) and hypervideo (HV) technologies to support their teaching practice. Vocational education and training (VET) is particularly concerned with the learning of resources (knowledge, skills and attitudes) that are immediately transposable into conduct and procedures in the workplace. AR and HV can provide means to answer this requirement, but both technological solutions are still not so diffused in VET. The purpose of this study is to inquire into the perception of educators on the main advantages and disadvantages of using AR and HV to support teaching-and-learning.

Methods: A semi-structured interview protocol has been proposed to 73 teachers, inter-company trainers and in-company trainers in 10 professions (at least two per category within each profession). The interview was organized in two main steps: A need analysis, in which the most important and difficult operative skills are identified for the interviewee's profession; and a discussion of advantages and disadvantages of AR and HV. Content analysis was applied to the interview transcriptions.

Results: The results show that the main advantages reported in the literature for the two technologies – such as the ability to switch between 2D and 3D and carry out simulations –

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are also found in the VET context by educators. For HV the main technical advantages (such as the use of active points, and non-linear navigation of video content) were autonomously recognised, while the potential of the instrument to support reflection has not been clearly identified.

Conclusions: AR and HV are considered as tools able to support apprentices' procedural learning especially with regard to the operational skills which were judged by the educators to be most relevant for VET.

Keywords: Augmented Reality, Hypervideo, Dual VET, Semi-Structured Interview, Qualitative Analysis, VET, Vocational Education and Training

1 Introduction

Augmented reality (AR) is increasingly attracting the interest of educational researchers (Garzón et al., 2019; Sirakaya & Sirakaya, 2018, 2020), and one reason for this is because of its growing accessibility through mobile devices like smartphones and tablets (Akçayır & Akçayır, 2017). The distinctive characteristic of AR is that it allows users to see the real world as enriched by superimposed, additional layers of digital information (Azuma, 1997). Within AR technologies, additional distinctions can be done based on two main factors: Use mode and input mode.

As per the use mode, depending if the AR solution requires the user to hold a device – very often a smartphone or a tablet – or not, you can speak respectively about handheld and handfree use. In the latter case, having your hands free also comes with the possibility of seeing through a wearable device such as a Head Mounted Display. For this reason, handfree is often referred to as see-through use mode.

As per the input mode, the presence or absence of markers makes the difference. A marker, usually a QR code, is a trigger allowing the device to recognize the element of reality to which the "augmentation" is associated and to make the augmented elements visible. Beside these usual marker-based solutions, marker-less solutions exist as well. In this case, the device can directly recognize the shape of the object (or use non-visible data provided by GPS, eyetracking, handtracking) to activate the augmented elements. Marker-less solutions are currently still not widely used, for both economic and technical reasons. From the combination of use and input modes we can then identify four main categories: (1) Marker-based handheld; (2) marker-based handfree/see-through; (3) markerless handheld; and (4) markerless handfree/see-through.

The opportunity to receive precise instructions on the execution of a procedure and, consequently, to reduce both the number of errors and execution time has been one of the main features attracting the attention of both researchers and industry, for example, in manufacturing (Forest, 2021; Wang et al., 2016). Time and cost savings, a reduction of error rates and (possibly) a decrease in cognitive load have also been the major benefits identified when it comes to using AR in general (Jetter et al., 2018; Radosavljevic et al., 2020; Sirakaya & Kilic Cakmak, 2018).

Hypervideo (HV, also known as interactive video) is a nonlinear video presenting (1) complex functions to control the navigation of the video stream, (2) hyperlinks giving access to additional information and materials through specific markers or hotspots and (3) annotation features allowing users to integrate their notes in the video and share and discuss them with others (Sauli et al., 2018). Both hyperlinks and annotations are considered additional layers of information that are placed over the video. For this reason, HV can be considered a technologically easier and less-expensive variant compared with AR, being able to integrate in an interactive way to overcome the risk of passivity that video sometimes entails. Moreover, where HV allows interactivity with content in a video, AR offers the same affordance directly in the real world. In other words, AR represents the synchronous and immersive version of HV.

Reduced costs and increased efficiency of AR have attracted the industrial sector. Numerous companies have introduced AR in their production processes (Li et al., 2018). However, few studies have tried to verify its effectiveness in initial VET. The use of HV to support VET has received more attention from the literature in the educational field (e.g., Cattaneo et al., 2016, 2018, 2019), but also in this case no study aimed at capturing the perspective of VET educators. For this reason, the current exploratory study presents the results from 73 semi-structured interviews conducted with teachers, branch course instructors and in-company trainers in the Swiss VET sector, with the aim of collecting the VET educators' perceptions of the advantages and disadvantages of each of the two technologies when applied to sustain learning in initial VET curricula. In doing so, we have attempted to answer the following two research questions:

1. What are the main advantages and disadvantages of using AR and HV as expected by VET educators?

2. What is the relationship between the perceived advantages and disadvantages of AR and HV and the operative skills to be acquired in VET curricula?

2 Theoretical Framework

Below, we present the main advantages and disadvantages of AR and HV as they emerge from the literature. The different states of advancement of the related research has made the presentation of the advantages different for the two cases: In discussing AR, we report as advantages the effects that the introduction of AR has had on the users. In the case of HV, we refer to its affordances. Indeed, AR is a technology that presents numerous modalities of use (e.g., marker-based handheld and see-through, markerless handheld and see-through), several of which still require further research to clearly identify its affordances.

2.1 Augmented Reality (AR) in Education

The literature has extensively investigated the effects of introducing AR in educational contexts. Conventionally, these can be divided into advantages and disadvantages, though the attribution to one of the two categories cannot always be done so neatly. Therefore, we present the advantages and disadvantages of AR as they have emerged from the literature.

2.1.1 AR Main Advantages

AR's main advantages have been widely underlined in the literature. Reviews in the educational field have reported advantages in terms of psychological variables—for example, motivation, engagement and cognitive load—and in terms of learning outcomes—for example, improved academic performances, spatial abilities development and better understanding of learning materials (Akçayır & Akçayır, 2017; Bacca et al., 2014; Chen et al., 2017; Radu, 2014; Sirakaya & Sirakaya, 2020).

Increased motivation and engagement have been widely reported in the literature, though some methodological limitations have reduced the reliability of these results. Indeed, there are still only a few longitudinal studies and research designs that have utilised control groups; moreover, the use of AR—especially in its immersive mode, which is less widespread among the general public—is often subject to the "novelty effect". This phenomenon refers to an increase in motivation or in the perceived usability of a technology because of its novelty (Koch et al., 2018) and has been highlighted by several authors (Hussein & Nätterdal, 2015; Jensen & Konradsen, 2018; Parmar, 2017); however, there are still few studies taking the novelty effect into explicit account in their research design (Huang et al., 2020).

The issue of cognitive load is also discussed in the literature. In most cases, the use of AR has been reported as benefitting the management and control of cognitive load (Avila-Garzon et al., 2021; Lee, 2020; Papakostas et al., 2021). That being said, in some other contexts, AR has been perceived as a source of cognitive overload: When creating a learning environment that is too rich in information, AR risks overloading students (Akçayır & Akçayır, 2017; Cheng & Tsai, 2013; Dunleavy et al., 2009).

Regarding learning outcomes, the literature seems be in agreement that AR can support learning processes and academic achievement. AR can indeed be used to perform simulations (Cuendet et al., 2013; Strada et al., 2019) or visualise normally invisible elements, such as electromagnetic fields (Villanueva et al., 2021). The fact that Sirakaya and Sirakaya (2020) identified an inverse proportionality between students' prior knowledge and the utility produced by AR does not contradict this general verification and is aligned with the famous expertise reversal effect in multimedia learning (Kalyuga, 2014) which states that instructional methods of multimedia instruction that are effective for less experienced learners may not be effective for more experienced learners and vice versa. Hence, the effective introduction of technologies in education cannot be separated from the adoption of an adequate pedagogical design (Avila-Garzon et al., 2021).

In their review of education in the engineering field, Papakostas et al. (2021) explored the issue of spatial abilities. The authors reported that 25 out of the 32 studies found an improvement in spatial abilities following the use of AR. However, a previous review by Voronina et al. (2019) about geometry produced unclear results on the role of AR in supporting spatial abilities. For example, Gün and Atasoy (2017) studied the development of spatial abilities with the support of AR in the context of a geometry course aimed at learning the concept of volume. The research design was based on a pre–post-test measure with a control and an experimental group; the latter group exercised spatial abilities using both AR and real objects, while the control group only used real objects. The results showed significant improvements in spatial abilities and academic performance, but there were no significant differences at the post-test between the two groups. Additionally, the research design was not completely discriminant regarding the role of AR, so it is possible that the experimental group also obtained improvements by the use of real objects.

2.1.2 AR Main Disadvantages

The main disadvantages associated with AR can be categorised into three macro-categories: (1) High costs; (2) usability problems; and (3) technical limitations.

In almost all of the analysed studies, the applications used required an ad hoc development phase to respond to the specific needs of the context, thus significantly increasing the access cost to this type of experience (Bacca et al., 2014). Even though with the increased popularity of smartphones it is no longer essential to purchase expensive devices to deploy an AR solution (Akçayır & Akçayır, 2017), immersive technologies continue to come with high costs.

The macro-category of usability problems encompasses at least two separate aspects: First, it refers to the need to find the time to become familiar with the technology (Wüller et al., 2019) and, second, to the cybersickness phenomenon that makes immersive technologies completely inaccessible for some users (Moro et al., 2019, 2021).

Finally, the technical limitations are the most frequently mentioned, referring to (1) difficulties in maintaining the overlap between real and digital objects (Wang et al., 2016); (2) too high response times in overlaying digital objects, especially for markerless solutions; and (3) an almost total absence of applications able to support collaborative activities (Li et al., 2018).

In addition, many of the advantages of AR have yet to be definitively demonstrated; similarly, almost all the disadvantages of this technology seem likely to be resolved in the coming years (Akçayır & Akçayır, 2017; Papakostas et al., 2021).

AR Advantages and Disadvantages in VET: An Illustrative Example

Despite the paucity of studies stated above, most of the advantages and disadvantages of AR can also be seen when looking at applications within VET. We refer to the experience of Lee (2020) to provide an illustrative example. In the context of the vocational training of carpenters, one of the most complex and central of the professional skills to acquire is that of making wooden joints. Lee's (2020) research was organised on a pre–post-test design with control and experimental groups. In the pre-test, the spatial abilities of all the participants were measured. In the post-test, in addition to spatial abilities, the author also measured the levels of cognitive load while performing the splicing tasks, as well as the final results produced by the students. The splicing tasks to be performed were divided into three difficulty levels (easy, medium and difficult), which were classified in accordance with the teachers, here depending on the complexity of the splicing to be performed. The results showed that there was no significant difference in final performance when looking at both easy- and medium-level splices, while the difference was significant when looking at the 'difficult' splices, where the experimental group reported better results. Analysis of cognitive load is also interesting: When looking at the medium difficulty task, where students had obtained comparable performance in both groups, the cognitive load was found to be significantly higher for those in the control group; it would seem that AR put the students in a position to complete the task and do so while exerting less effort. Finally, from the comparison of spatial abilities in the pre-test and post-test it was found that whereas in the pre-test there were no significant differences between the experimental and control groups, these were observed in favour of the experimental group in the post-test. Despite these positive results, the authors reported a number of limitations related to the fact that difficulties were reported in performing some 3D animations; the participants would have needed more time to become familiar with AR technology; the study was aimed at novices, so it is not known whether it would produce similar results with more advanced participants; the study had a limited duration; and a longitudinal study would be needed to verify that AR can support the learning of this type of skill, which usually takes a long time to master.

2.1.3 HV Main Advantages

Although hypervideo (HV) has been much less investigated than AR, some studies and reviews have examined its use as a cognitive or sociocognitive tool (e.g., Cattaneo et al., 2019; Chambel et al., 2006; Evi-Colombo et al., 2020; Sauli et al., 2018; Zahn, 2017; Zahn et al., 2010). A recent meta-analysis shows that videos that include enhanced interaction features are significantly more effective to foster learning than traditional videos (Ploetzner, 2022). This said, HV itself relies on video. Video-based demonstrations are well suited for sustaining procedural learning (Arguel & Jamet, 2009; Mohd Saiboon et al., 2014; van der Meij & van der Meij, 2016) because they can make both expert and novice behaviour visible and audible (Rosen et al., 2010). However, although such demonstrations are commonly used (Grossman et al., 2013), their effectiveness has been questioned, mainly because of the risk that learners will remain passive. In this respect, on top of the traditional affordances that a video can have, HV integrates interactive features that provide unique opportunities to increase the quality of demonstrations and secure more active engagement from learners. These features are as follows (Sauli et al., 2018): *Extended navigational control options, linkage options, automated feedback options and communication facilities.*

In addition to classic controls (stop, pause and rewind/forward), HV has advanced nonlinear features, such as a table of contents or index (e.g., Meixner et al., 2016; Tiellet et al., 2010), allowing the user to pursue macro-level activities (Merkt et al., 2011). These features enable users to autonomously moderate the information intake against the risk of cognitive overload because of video complexity and transience (e.g., Schwan & Riempp, 2004), as well as to select nonlinear trajectories through the video material (e.g., Girgensohn et al., 2015; Meixner et al., 2016).

Additionally, HV makes it possible to integrate other existing content and media (text, audio, etc.) via hyperlinked markers, here by presenting a spatial and a temporal dimension. These markers can be placed anywhere in a video and have a double function: On the one hand, their spatial dimension allows them to be used as cueing tools (De Koning et al., 2007; van Gog, 2014) to focus the learners' attention on the significant detail of the image, hence playing an attention-directing role (e.g., Merkt & Sochatzy, 2015). On the other hand, they help the learner connect different sources of information (e.g., van der Meij & de Jong, 2006) through additional materials, making the relationship between concrete and abstract, practical and theoretical and particular and general issues explicit and more evident all while exploiting the benefit of using multiple representations.

Further, HV makes it possible to directly embed quizzes in the instructional video, along with automated feedback that can support learners and their self-regulatory mechanisms (e.g., Rice et al., 2019; van der Meij & Böckmann, 2021; Vural, 2013).

Finally, from a technical point of view, this feature could be considered not so different from the above-mentioned markers (e.g., Meixner et al., 2014; Sadallah et al., 2014), yet from a pedagogical point of view, it is possible to add newly created content in the form of textual overlays, creating a very powerful HV tool. We usually refer to this as 'video annotation'. Video annotation can be provided individually or collaboratively, directly by the learner, by peers or by tutors, and it has been shown to be a powerful tool to support reflection processes and self-regulated learning (e.g., Colasante, 2011; Evi-Colombo et al., 2020).

Apart from the advantages directly coming from HV's distinctive features, in previous use cases, HV has also shown some positive impact on learners' motivation (Cattaneo et al., 2018; Sauli et al., 2018), though more research is needed to definitively prove this point.

2.1.4 HV Main Disadvantages

With respect to AR, HV produces fewer disadvantages in terms of its usability because it presents no large differences with respect to traditional video interfaces, with which most users are already very familiar. The same can be said for technical problems because this kind of technology is much less complex than AR. In this respect, some existing problems could deal with the efficiency of IT infrastructure and capacity of the internet connection. That being said, the most important disadvantage of HV is likely in the costs teachers perceive in terms of time to be invested to become competent in the mastery of the pedagogical exploitation of the tool, particularly when HV must be designed from scratch as an instructional material (Cattaneo et al., 2016).

3 Methods

In this section, we outline the methods used for conducting this research. The discussion is divided into three subsections: Context and participants, procedures adopted, and finally, the approach used for data analysis.

3.1 Context

The current study took place in the context of Swiss vocational education and training, where activities are organised according to a dual (trial) model, one in which the learners (apprentices) alternate among three different training locations: (1) The school, where they have lessons with teachers and are exposed to the main theoretical notions useful for carrying out the profession; (2) the intercompany or branch courses, which is led by trainers, where apprentices have the opportunity to learn some professional procedures using machines similar to those they could encounter in the workplace; and (3) the workplace, where they work for most of the week as apprentices and where an in-company trainer follows and supervises their professional activity (for additional details on the Swiss VET model, see Bonoli et al., 2018; Strahm et al., 2016).

3.2 Participants

To bring together all the figures involved in the training process, we listened to the point of view of 73 participants (age range: 25–67; mean age = 42.9; SD = 10.4; female = 7), including 27 teachers (mean age = 43.3), 23 intercompany course trainers (mean age = 42.6) and 23 in-company trainers (mean age = 42.6) from 10 different professions and from two linguistic regions (see Table 1 for details). The choice of occupation was made in three stages: (1) Considering the entire VET/PET spectrum under Lucas et al.'s (2012) classification of VET professions; (2) narrowing the field by considering areas identified as promising in the literature; and (3) testing the availability and interest of trainers of the selected professions in the field.

Table 1: Participant Overview

Profession	Language	Teachers	Inter-company courses trainers	In-company trainers
Informatic	IT	2	0	0
Dental assistant	IT	2	1	1
Woodworker	IT	2	0	1
	DE	2	2	2
Carpenter	IT	1	1	1
	DE	2	2	2
Installer of refrigeration systems	IT	1	2	3
Installer of sanitary facilities	IT	2	3	1
	DE	1	2	2
Heating installer	IT	2	1	2
	DE	1	2	2
Mechatronic	DE	2	1	2
	IT	2	2	2
Gardener	DE	3	2	1
Logistic	DE	2	2	1
Total		**27**	**23**	**23**

3.3 Procedure

Each interview was organised following a protocol carried out in two phases: (1) A need analysis inspired by Hennessy (2011) and (2) a semi-structured interview, in which the main advantages and disadvantages of AR and HV were discussed consecutively.

3.3.1 Need Analysis

A need analysis, which has been inspired by the standardised tool by Hennessy (2011), was carried out starting with the training plan of the profession in which the interviewee is active. The training plan (Figure 1) shows the skills that apprentices are expected to acquire during their curriculum. The plan is usually structured into two sections: Operational skills fields (on the left side of the figure) and operational skills (on the right side of the figure), the latter constituting concrete operationalizations of the former. In other terms, each operational skill field includes two or more operational skills. At the beginning of the interview, each participant was shown her/his training plan and given the following instructions in sequence: (1) To identify the five operational skills that they consider the most important for the profession; (2) to identify the five operational skills that they consider the most difficult while also considering their experience in training; and (3) to identify a podium of the three operational skills that they consider both important and difficult to learn/teach.

The results of the need analysis were used to focus the interviews on the actual needs of the 10 professions considered.

3.3.2 Semi-Structured Interview

Immediately after completing need analysis, a one-minute clip was shown to the participants, in which six examples of see-through handless AR applications in VET contexts were shown. The applications showed different technological solutions of AR, from the use of digital twins to simple signaling, used in different professions like logistics, carpentry, mechanics, plumbing, and other. None of them showed AR applications for real-time support. We tried to include at least one example from each of the professions interviewed. If the participants were already familiar with AR technology, follow-up questions were formulated to check in which context they had been known. The interview protocol asked about the perceived advantages of a possible introduction of AR technology to support students' learning and about the perceived disadvantages as well; to investigate these advantages and disadvantages, a further focus was placed on the operational skills reported during the previous phase. A similar procedure was then followed regarding HV. After showing the functionalities offered by one of the currently available tools for the creation of HVs, the main perceived advantages and disadvantages were investigated, here with particular reference to the operative skills the interviewee placed emphasis on.

3.4 Data Analysis

All interviews were transcribed verbatim and analysed using qualitative content analysis through NVivo software (released in March 2020). The materials have been coded by dividing the text into a unit of analysis, which can be defined as "an idea, argument chain or discussion topic" (Strijbos et al., 2006, pp. 28-46). A first version of the coding scheme was developed, here taking into consideration the AR and HV literature that had analysed the advantages and disadvantages of the two technologies. Complementarily, additional codes were integrated with further advantages and disadvantages mentioned directly by the interviewees. The final coding scheme is reported in Table 2. The coding process was carried out using a non-mutually exclusive approach, whereby each unit of analysis could also be assigned two or more codes. Whenever a code was not treated by educators in an unambiguously positive or negative manner, it was associated with the macro-category "neutral" to which a sentiment (positive or negative) was subsequently assigned, depending on the type of considerations reported. Units of analysis that did not fit into any of the identified codes were not coded. Two different coders used the coding scheme independently to code about 20% of the corpus (Cohen's K = 0.77; agreement 98%). Divergences were solved between the two coders or, if necessary, involving a third coder.

Table 2: Coding Scheme

	Code	Code description	Example	References
Advantages	Simulation	Interviewee describes a procedure in which AR or HV is used to simulate events	Using AR in simulating faults	Cuendet et al. (2013); Strada et al. (2019)
	From 2D to 3D	Interviewee describes situations in which AR or HV is used to display in 3D, 2D elements	Using AR to visualize a 2D project in 3D	Wulandari et al. (2019); Lee (2020) Papakostas et al. 2021
	See through things	Interviewee should be interested in using AR or HV to see through elements	Using AR to see an implant through a wall	
	See invisible elements	Interviewee should be interested in using AR or HV to see invisible elements	Using AR to see electromagnetic fields	Villanueva et al. (2021)
	Imagine future scenarios	Interviewee would use a technology to see future development of her/his project	Using AR to see a complete roof	

	Data recording	Interviewee would use AR or HV to record her/his learning	Using HV as workbook	
	Support in distance teaching	Interviewee should be interested in using AR or HV in distance teaching	Using HV to teach during pandemic	
	Support student motivation	Interviewee suggests that AR or HV could increase students' motivation		Akçayır & Akçayır (2017); Bacca et al. (2014); Chen et al. (2017); Radu, (2014); Sirakaya & Sirakaya (2020)
Disadvantages	Expensive	Interviewee reports that buying devices could be too much expensive	It is difficult to buy these devices for our school	Bacca et al. (2014)
	Hard to use in workplace	Interviewee reports difficulties in using these technologies in workplace	Using AR devices could be difficult with dirty hands	Wüller et al. (2019); Wang et al. (2016); Park et al. (2020); Li et al. (2018)
	Time consuming	Interviewee reports that completing a task using these technologies could require too much time	Using HV could require a lot of time in recording a video	Wüller et al. (2019)
	Deskilling	The interviewee fears that technological support may reduce the skills of operators when they cannot have them	Operators can not complete a task without technological support	
	Do not improve existent solutions	The interviewee describes a situation which the existent solutions offer the same service or better	Operators can already verify implant parameters using a laptop	
Neutral	Support in theory learning	Interviewee describes how AR or HV could support students in learning theory	Using AR to describe volume changes in wood	Akçayır & Akçayır (2017); Villanueva et al. (2021)
	Reflection	Interviewee reports that technologies could affect reflections.		
	Procedural learning support	Interviewee describes procedures in which could be supported by AR or HV	Using AR to assembly elements	Sirakaya & Kilic Cakmac (2018); Bacca et al. (2015); Radosavljvic et al. (2020); Radosavljvic et al. (2020); Wang et al. (2016)
	Attention	Interviewee reports that could affect on student attention	Using AR could be seen as a game	
	Workplace safety	Using AR or HV to Support workplace safety	Using AR to learn safety procedures	Li et al. (2018)
Operative skills	Planning	Interviewee describes an operative skill related to the planification	Drawing up plans, planning activities, designing	
	Assembly	Interviewee describes an operative skill related to the assembly	Assembly elements, Assemble components, mount devices	

	Repairs and Maintenance	Interviewee describes an operative skills related to the maintenance	Repair faults and carry out maintenance operations
	Optimization	Interviewee describes operative skills that requires optimization	Organize the spaces in a warehouse
Technologies	HV	Interviewee discusses about HV	
	AR	Interviewee discusses about AR	

NVivo software was then used to calculate the distribution of categories in the interviews, and the following indices were chosen: (1) Occurrences, that is, the number of times a code was assigned within the interviews, as presented in absolute value and (2) co-occurrences, that is, the number of times that two or more codes were used simultaneously for the same unit of analysis. The results are presented both in absolute value and using the c-coefficient n12/(n1+n2-n12). In the formula, we have the numerator 'n12', which represents the co-occurrences between the two codes (we could also have n12...n, depending on how many codes in the same unit of analysis are searched for). In the denominator, we have 'n1' and 'n2', which represent the number of occurrences for which the co-occurrence is being observed. However, the number of co-occurrences (n12) is subtracted from these two values to avoid adding up the intersection set of the two occurrences twice. As is evident from this formula, when operating with c-coefficient, both occurrences are taken into account at the denominator, thus ensuring the co-occurrence standardisation process. Comparing the co-occurrences in absolute value when there are substantial differences in the number of occurrences cannot provide reliable data about the result and could more easily lead to a misrepresentation of the obtained results, which the standardised c-coefficient should help avoid.

Before proceeding with the results, we give some indications about the interpretative method adopted for the indices used. In assessing the 'strength' of a co-occurrence, we took into account three distinct elements: (1) How much one of the codes co-occurred with the other regarding its own number of occurrences, here by relativising the result for two or more codes; (2) looking at the overall view offered by the c-coefficient (which we recall when integrating at the denominator the occurrences of two or more codes considered in the co-occurrence); and (3) integrating the figure with the percentage of the number of participants who reported that specific co-occurrence. To facilitate the reading of the results, we propose an example of the co-occurrence between the code 'From 2D to 3D' and 'AR'. As a first step, we verified that in 69 out of the 70 total occurrences of the code 'From 2D to 3D' (99%), this code co-occurred with that of AR; then, we carried out the same verification from the point of view of AR, where this represents about 11%. As a second step, we looked at the c-coefficient score (0.11) and, finally, at how many participants had found this advantage in using AR (42%). Here, although the c-coefficient is not very high, also because of the disproportion of the occurrences of the two co-occurring codes— 'From 2D to 3D' (O=70) and 'AR' (O=599)—the possibility to switch from 2D to 3D is perceived as a very relevant advantage by the interviewed educators. When possible and functional to our aims, we also used queries that allow us to have triple or quadruple co-occurrences because these queries provide data that is easier to interpret.

4 Results

In this section, we present the main findings of our research. After describing the outcomes of the needs analysis, we illustrate the perceived advantages and disadvantages for both technologies.

4.1 Need Analysis

During the interviews, only 59 of the 72 participants completed need analysis according to the indications provided. During the interviews, this tool was used to guide the reflective process of the interviewees, and no finicky compilation was required. Among the 59 respondents, five did not identify a complete podium of important and difficult operational competences, which generated six missing values and a total corpus of 171 operational competences. As can be seen from Table 3, assembly procedures (48) have the highest number of occurrences, followed by 'Planning' tasks (38) and 'Repair and maintenance' (32). These are the most frequently discussed topics during the interviews and. Therefore. were included in the coding scheme. Other operational skills emerged, such as 'Diagnostics' (18) and the execution of 'safety protocols' (7). The category 'other' (18) was then used for the operational skills that could not be placed in any of the previously mentioned areas and were mentioned very few times within the analysed corpus; these include the following: 'Administrative tasks' (5), 'software development' (5), 'plant management' (3) and 'specific woodworking' (3).

Table 3: Need Analysis Occurrences

Assembly	Customer relations	Diagnostics	Optimization	Other	Planning	Repair and maintenance	Security protocols
48	6	18	6	16	38	32	7

4.2 Occurrences in the Interviews' Body

As per the number of occurrences (see Table 4), the macro-categories that occurred the most, in decreasing order, are 'Technologies' (O = 870), within which the mainly occurring subcategory is 'AR' (O = 599); 'Neutral' (O = 543) and main subcategory 'Procedural learning support' (O = 289); 'Operative skills' (O = 404) and its main subcategory 'Assembly'; and finally the main categories 'Advantages' (O = 277) and 'Disadvantages' (0 = 220). The prevailing sentiment associated with the occurrences in the category 'Neutral' is 'Positive' (O = 362).

Table 4: Number of Occurrences and Related Participants per Macro-Category and Subcategories

	Codes	*Occurrences*	*Participants*
Advantages	From 2D to 3D	70	30
	Simulation	57	27
	See through things	33	18
	Support in distance teaching	30	15
	Support student motivation	29	19
	Imagine future scenarios	23	16
	Data recording	20	13
	See invisible elements	15	9
Disadvantages	Hard to use in workplace	68	34
	Do not improve existent solutions	40	24
	Deskilling	40	20
	Time consuming	34	19
	Learn how to use	22	16
	Expensive	16	12
Neutral	Procedural learning support	289	66
	Support in theory learning	152	52
	Workplace safety	60	32
	Attention	28	16
	Reflection	14	9
Operative skills	Assembly	171	39
	Repairs and Maintenance	134	28
	Planning	94	33
	Optimization	5	5
Sent Tech	AR	599	72
	HV	271	67
	Positive	362	68
	Negative	72	33

4.3 Perceived Advantages in AR and HV

We identified as perceived advantages both those coded directly in the 'Advantages' category and those in the 'Neutral' category before looking at those associated with a positive 'Sentiment'. In descending order, the most relevant occurrences and co-occurrences among the advantages are as follows: 'From 2D to 3D' and 'AR' (C = 69, c-coefficient = 0.11); 'Simulation' and 'AR' (C = 55, c-coefficient = 0.09); 'See-through things' and 'AR' (C = 32, c-coefficient = 0.05); and 'Support in distance teaching' and 'HV' (C = 13, c-coefficient = 0.05). In the neutral positive category, the categories 'Procedural learning support' stands out both in relation to 'AR' (C = 174, c-coefficient = 0.16) and 'HV' (C = 71, c-coefficient = 0.08) and 'Support in theory learning' in relation to 'AR' (C = 69, c-coefficient = 0.07) and 'HV' (C = 49, c-coefficient = 0.07). The full results can be seen in Tables 5 and 6.

To give voice to the numbers that emerged and understand how the different advantages and disadvantages looked to the participants, we supplemented the quantitative data with contextualised quotes. For example, we did this for a carpenter intercompany course trainer, who—especially considering the difficulties he encountered in his teaching experience—thinks that AR can become a tool to stimulate his students' three-dimensional visualisation. In this view, AR does not only offer a technological solution for solving a technical problem (visualising models in 3D), but it could also become a new tool in the teacher's toolbox:

> *So, for a student who needs to be able to interpret (the plans), it can sometimes be a stimulus to first visualise it in a three-dimensional version. With augmented reality, we can give them this three-dimensionality, even before they have the piece in their hands. One difficulty I have encountered in my years of teaching is the stimulation of three-dimensional vision (Interview 12, line 148).*

An example of the association with the simulation potential of AR is provided by an in-company trainer of heating installers, for whom AR could be useful to display (simulating it) the operation of a heating system. In this case, the in-company trainer would use AR not only to visualise, but also to support the understanding of the consequences of an action by using a simulation: 'What happens if I adjust my pump like this?' He explains that it is not always possible to observe the consequences of poor heat pump regulation in the short term and that AR could help him to do this by overcoming time constraints:

> *Right now, I'm thinking of a hydraulic circuit. If, for example, you set the regulator incorrectly and the pupil could then see, aha, that's not the reason. Or this is the reason, this is the reason. So as seen before, it's the wrong screw. You can actually deal with that. There are some really difficult things. If you can let it run virtually and say, what happens if I don't take it into account? Then that's certainly a good thing. Yes. So, as I said, I see it as another methodological possibility (Interview 47, Line 321).*

Examples of exploiting AR to support the execution of procedures requiring several steps are also reoccurring, as in this excerpt by an intercompany course trainer of sanitary facilities installers:

> *Maybe it's more like an instruction or a checklist. Like a building process. So that you know what you have to do or what you must not forget (Interview 70, Line 199).*

Especially when looking at the professional activity, correctly remembering the execution of a procedure can be a great advantage: From the point of view of the correctness of the execution of the procedure, the time taken and resulting costs for both the company and client. An in-company trainer of refrigeration installers notes the following:

> *So that's a very long procedure. In the end, to change a 10 CHF part a technician is there all day. Empty everything, replace, empty, recharge, try again if that's not the problem, he's gone, all day long. So that's a procedure that everyone dislikes. It doesn't even allow us if we've done something wrong (to be able to recover some of the work done), so we have to reopen the circuit. It means doing the whole procedure again (Interview 17, Line 310).*

Similarly, in case HV is used instead of AR:

> *This kind of video would certainly be useful. You can see how it's done, and then, you can call up the information you need. So, I would see it there. There would be possibilities for the manual part. I would also see that I could film the work processes and fill them with information (Interview 46, Line 300).*

Table 5: Co-Occurrences of the Perceived Advantages and Technologies

			AR		HV	
Perceived advantages	*Occurrences*	*Participants*	*Co-occ.*	*c-coefficient*	*Co-occ.*	*c-coefficient*
From 2D to 3D	70	30	69	0.11	2	0.01
Simulation	57	27	55	0.09	5	0.02
See through things	33	18	32	0.05	1	0.00
Imagine future scenarios	23	16	21	0.03	1	0.00
Support student motivation	29	19	10	0.02	19	0.07
Data recording	20	13	4	0.01	17	0.07
Support in distance teaching	30	15	16	0.03	13	0.05
See invisible elements	15	9	15	0.02	0	0.00

An in-company trainer of woodworkers refers to the importance of the 'workbook' for apprentices. In the first years of training, each student is told the functioning of the different machines, as well as the procedures to be followed for their correct use. Usually, the trainees take notes in their workbook, and years later when they encounter the same machine again, they can use the workbook as a form of support for carrying out the procedure. The participant would gladly use the possibility of chapter navigation offered by HV, combined with the possibility of noting down the details of the individual work step:

> *You could use it as a workbook. (If I were to use it to write down the operation) of this circular machine, then (I would proceed like this) chapter 1: Power button, chapter 2 adjust wedge 0.5 more than blade, chapter 3: Start workpiece. And so on. In the third-year exam, all these notes, this workbook, can be kept, so what we were talking about earlier happens. When the guys arrive in the third year and they have to adjust that machine, they can retrieve their notes; then, it becomes convenient. You can actually travel there with the system you were showing (Interview 18, Line 433).*

Table 6: Triple Co-Occurrences Neutral/Positive and Technologies

Neutral/Positive	Co-Occurrences	c-coefficient	Participants
PLS/AR/Positive	174	0.16	57
PLS/HV/Positive	71	0.08	42
STL/AR/Positive	69	0.07	33
STL/HV/Positive	49	0.07	33
WPS/AR/Positive	21	0.02	16
WPS/HV/Positive	17	0.03	15

PLS= Procedural Learning Support; STL= Support in Theory Learning; WPS= Workplace Safety

4.4 Perceived Disadvantages in AR and HV

Similar to what we did for the advantages, also in the case of disadvantages, we include in the presentation of results both the codings of the category 'Disadvantages' and those of the category 'Neutral', which are associated with the sentiment 'Negative'. In descending order (see Tables 7 and 8), the main perceived disadvantages related to 'AR' are 'Hard to use in workplace' (C = 52, c-coefficient = 0.08), 'Deskilling' (C = 36, c-coefficient = 0.06) and 'Do not improve existing solutions' (C = 32, c-coefficient = 0.05). Regarding 'HV', only 'Time consuming' (C = 23, c-coefficient = 0.08) and 'Hard to use in workplace' (C = 15, c-coefficient = 0.05) stand out. When looking at co-occurrences with the two technologies in the 'Neutral' category with 'Sentiment' 'Negative', no relevant results appear.

Regarding the feasibility of using AR in the workplace, for example, an in-company trainer of refrigeration installers raises questions about the possibility of using these technologies in practice, especially for repairing tasks, which the interviewee considers too heterogeneous. In the interview, the participant reports that even the same model of a heat pump may have been produced by several manufacturers, and this may be enough to radically change the procedures to be followed: *"No, not in our training, not in our repair work, because it often happens that one is not the same as another" (Interview 15, Line 163).*

An intercompany course trainer of the carpenters expresses doubts about providing too much support to the students. His fear is that they would become lazy and that using AR would finally result in deskilling apprentices. To better understand the below quotation, it is important to contextualise the rough theory developed by the participant about the inclination of his students to use cognitive resources. Although not exactly in these terms, we could trace what is reported by the participant back to Kahneman's theory (2002): Humans will always prefer to use 'system 1' (instinctive, based on the use of heuristics and low cognitive expenditure) over 'system 2' (reflexive, basing decisions on exact calculations and the high expenditure of cognitive resources). Hence, a question arises: When AR offers students the opportunity to opt for 'system 1', will they stop using 'system 2' altogether?

> *The disadvantage is that by always having, as I said before, a ready-made meal there, you don't make the effort to try to recreate this thing, and you also slow down a bit. That's my fear: I have more than 10 years of teaching experience, and during these years, I have tried to change the way I provided materials for students to process. I noticed that by providing materials that I more or less preprocessed, the students changed their response: Those who were given a ready-made meal got lazy, while those who had to fend for themselves better learned how to proceed. I also think it is very important to define upstream in which context to introduce augmented reality: If you are having too much difficulty in imagining (the 3D development) a project and it is the only way to make you understand it, then it is fine, but if it has to become a way to avoid straining yourself, getting lazy and not imagining the three-dimensionality of objects, then it is not good (Interview 12 Line 157).*

Table 7: Co-Occurrences of the Perceived Disadvantages and Technologies

	AR		**HV**	
Disadvantages	**Co-occurrences**	**c-coefficient**	**Co-occurrences**	**c-coefficient**
Hard to use in workplace	52	0.08	15	0.05
Deskilling	36	0.06	3	0.01
Do not improve existent solutions	32	0.05	9	0.03
Time consuming	11	0.02	23	0.08
Learn how to use	14	0.02	7	0.02
Expensive	13	0.02	3	0.01

Table 8: Triple Co-Occurrences Neutral/Negative and Technologies

Neutral/Negative	Co-Occurrences	c-coefficient	Participants
PLS/AR/Negative	13	0.01	10
Attention/AR/Negative	11	0.02	9
WPS/AR/Negative	11	0.02	6
Attention/HV/Negative	7	0.02	5
Reflection/AR/Negative	6	0.01	4
SLT/HV/Negative	6	0.01	4
PLS/HV/Negative	5	0.01	4
SLT/AR/Negative	5	0.01	5
Reflection/HV/Negative	3	0.01	2
WPS/HV/Negative	0	0.00	0

4.5 Operative Skills, Advantages and Disadvantages

To verify whether there is a match between the advantages and disadvantages of AR and HV and the operational skills indicated as the most relevant by the trainers, we carried out co-occurrences analysis between 'operational skills' ('Assembly', repair and maintenance and planning) discussed during the interviews and the macro-categories of advantages and disadvantages (see Tables 9 and 10). As before, codes belonging to the neutral macro-category, here associated with a 'Positive' or 'Negative' sentiment, were included in the advantages and disadvantages, respectively. Looking at the results, AR seems to be able to support procedural work in all three operational skills analysed: 'Assembly' (C = 56), 'Repairs and maintenance' (C = 30) and 'Planning' (C = 6). However, AR is also negatively associated with 'Repairs and maintenance' (C = 5); 'From 2D to 3D' is of interest for both 'Planning' (C = 31) and 'Assembly' (C = 8); and 'Deskilling' is associated with 'Assembly' (C = 7). When it comes to HV, 'Assembly' is supported by 'Procedural learning support' (C = 6) and 'Support in theory learning' (C = 6). Finally, 'Procedural learning' for 'Repairs and maintenance' is supported by HV (C = 14). Particularly relevant is the result observed for 'Assembly', 'Procedural learning support' with a 'Positive' sentiment and the use of AR. In fact, this is a co-occurrence with four different codes that emerged on 56 occasions reported by 27 of the 72 educators. Therefore, the data sustain the idea that AR can support procedural learning, especially when looking at assembly procedures, which are the central themes for VET, which also emerged during need analysis. Less pronounced but just as relevant is the result regarding 'Planning' AR and 'From 2D to 3D'. From what the educators have reported, it seems that AR can support planning processes, especially when considering the transition from 2D to 3D. Planning processes are mentioned as crucial by the trainers, even if only informally: Being able to read and adequately create a work plan is the basis for many of the professions.

Table 9: Main Co-Occurrences Between Operative Skills, Advantages and Disadvantages in AR

AR	Co-occ.	Participants
Assembly/AR/Procedural learning support /Positive	56	27
Planning/AR/From 2D to 3D	31	19
Repairs and maintenance/AR/Procedural learning support /Positive	30	15
Assembly/AR/From 2D to 3D	10	8
Planning/AR/Imagine future scenarios	10	7
Repairs and maintenance/AR/See through things	8	5
Assembly/AR/Deskilling	7	6
Planning/AR/Procedural learning support /Positive	6	6
Planning/AR/Support in theory learning/Positive	6	4
Repairs and maintenance/AR/Deskilling	6	4
Repairs and maintenance/AR/Procedural learning support/Negative	5	4

Table 10: Main Co-Occurrences Between Operative Skills, Advantages and Disadvantages in HV

HV	Co-occ.	Participants
Repairs and maintenance/HV/Procedural learning support /Positive	14	10
Assembly/HV/Procedural learning support /Positive	6	5
Assembly/HV/Support in theory learning/Positive	6	4

5 Discussion

R1: What are the Main Advantages and Disadvantages of Using AR and HV as Perceived by VET Educators?

The results show that 89% of the participants perceive that the introduction of AR in VET can support procedural work, hence confirming what has been claimed in the literature (Li et al., 2018; Park et al., 2020; Wang et al., 2016). The ability to make three-dimensional designs (Lee, 2020; Papakostas et al., 2021; Wulandari et al., 2019), to simulate the consequences of a procedure in real time (Cuendet et al., 2013; Strada et al., 2019) and to be able to look through objects are the benefits most often mentioned by the interviewees.

The disadvantages reported by the interviewees, however, differ from what is reported in the literature: Although not having had the opportunity to experience the technologies first-hand is surely a limitation of the current research, which could have influenced the participants' perception of the advantages and disadvantages, in other respects, it is interesting to note that this has raised issues other than technical ones (Wang et al., 2016), specifically those issues connected to usability (Wüller et al., 2019). Except for the difficulty of use in the workplace that has already been reported for construction safety by Li et al. (2018), the concern about deskilling constitutes a novel concept that opens up reflection about the role that these technologies can take on in supporting training. If AR, especially in the work environment, has a clear effectiveness in reducing the number of errors made and the efficiency in the execution of a procedure, from the perspective of some participants, it is not clear what its role could be in training and how much it could even interfere with learning. In part, this result is also reflected in the literature: It is not unequivocal that AR can ensure better learning outcomes, and even the sharper results obtained about motivation could still be flawed by the absence of longitudinal research that would avert the novelty effect. In other words, the role of AR, especially its wearable and markerless version, in supporting VET has yet to be clearly defined. The main prerogative reported by several interviewees, which seems to distinguish AR from VR and from the other technologies included in extended reality (XR), lies in the opportunity to directly handle the materials in the real world and acquire the muscle memory necessary for the correct execution of the procedure while at the same time being supported with additional information layered on top of what is seen in the real world. In thinking to AR, trainers might have identified the disadvantage of "deskilling" also due to the examples shown in the short clip. The short video emphasized activities in the workplace and not in teaching situations. This might have led the trainers to think, that the introduction of AR could be a tool to replace some of the activities currently carried out by the operators, rather than a learning support instrument. In other words, teachers were worried that the professionals of the future may become completely dependent on technology (or on synchronous remote support that AR technology could provide) and gain deep learning of fewer procedures as a result.

The main technical advantages offered by HV have been recognised by educators, such as the possibility of displaying content in a nonlinear way by using segmentation through chapters. In terms of teaching, several educators have reported the potential advantages in using it to support both theoretical and procedural learning. The possibility of annotating video materials is not reported by the trainers, while the literature reports it as an effective tool to foster reflective processes (Colasante, 2011; Evi-Colombo et al., 2020). In terms of the disadvantages, compared with AR, the users report few disadvantages because the user experience does not differ much from that of a traditional video, hence providing a much higher degree of familiarity. Among the few disadvantages reported are the time needed to design, record and subsequently produce an HV. However, these limitations are already known, and several platforms are upgrading to offer the possibility to more quickly make the video interactive.

Finally, it is worth noting that the main result of this research lies in the central role that both AR and HV have in supporting procedural learning: Both in terms of the number of co-occurrences and percentage of participants who reported this advantage, the two technologies can be considered excellent allies for supporting procedural learning, which is a central element in VET programmes.

R2: What is the Relationship Between the Expected Advantages and Disadvantages of AR and HV and the Operative Skills to be Acquired in VET Curricula?

The results clearly report that according to our interviewees, AR can support procedural learning when referring to the operational skills of 'Assembly', 'Repair and maintenance' and 'Planning'. This finding is particularly relevant, especially in view of the results produced by need analysis showing that the two operational skills most supported by AR are also the most important and difficult for most trainers. This could give important hints for developing AR applications supporting these kinds of procedures. Planning could also be significantly supported by introducing AR, especially when looking at the transposition from 2D to 3D. HV is considered a tool capable of supporting procedural work in relation to 'Assembly' and repair and maintenance activities, though it cannot offer real-time support during the performance of procedures. On the other hand, no negative points could be identified from the use of this technology when it came to operational skills. Finally, it is worth mentioning that our data did not mention explicitly one of the possibilities we find in the literature when looking at how to use AR and HV for supporting learning, and namely the possibility to use them collaboratively. Consider, for example, the possibility of receiving AR-based remote assistance while a maintenance procedure is being performed (De Pace et al., 2019) or having the ability to simultaneously view the same augmented world in the planning phase (Nebeling et al., 2020). HV as well can be used collaboratively to support teaching, for example providing students with a raw video and asking them to transform it into a HV (Evi-Colombo et al., 2022) or using video annotation to augment it (Boldrini et al., 2021).

6 Conclusion

According to the interviews we conducted with 73 VET educators, the introduction of both AR and HV tools in VET would mainly produce advantages when applied as a way to support the teaching and learning processes, especially when applied to procedural learning. Procedural learning seems indeed to be the natural target audience for these technologies. The two technologies have aroused different impressions among the trainers: AR creates greater polarisation, raising great enthusiasm among its supporters and scepticism among its detractors, though the balance is strongly in favour of the former; HV, probably because it is not so disruptive regarding other already familiar technologies, is a more consolidated tool, whose benefits are somehow known to the trainers, who sometimes have used it themselves; the points against its use are largely circumscribed. The strong agreement found between the operational skills reported during the need analysis and the affordances found in the two technologies is one of the main results produced by this study. According to educators' expectations, the use of AR and HV could lay the groundwork for teaching more effectively many operational skills considered relevant to the profession. In perspective, the adoption of these technologies could be a means by which to obtain better professionals.

Despite these results, the current research has several limitations. First, it is a pilot, descriptive study in which the participants were not given the opportunity to experience AR solutions directly. All participants were asked if they were already familiar with augmented reality, yet none of them had heard of it. On some occasions, we cannot say with certainty that the participants had a clear understanding of the differences between AR and virtual reality, and in a few cases, it was necessary to intervene to better clarify the differences and be sure about the interviewees' interpretation. Also, probably for the same reason (lack of direct experience), the educators often referred more willingly to professional applications than to educational ones, though these latter applications were the focus of our study. Additionally, although it was meant as an illustration of the possibilities AR provides, the visualisation of the examples within the explanatory video could have induced a priming effect in the participants. Moreover, there was a difference in the time spent discussing the two technologies during the interviews: AR is mentioned more than twice as many times as HV. This was a choice made in advance in view of the different notorieties of the two technologies; AR seems to have been more unfamiliar and partially unknown to almost all the participants, while HV was found to be known to most respondents. Interestingly, some trainers report fears about the possibility of deskilling in relation to AR by future professionals: It is possible that the absence of a pedagogical model that clearly indicates how the technology can be used to support vocational education and training, as also pointed out by Garzón et al. (2019), has raised doubts in some trainers who fear that these technologies may reduce students' problem-solving skills and force them to rely too much on technological support rather than reason with their own capacities. Future research could investigate what role AR can play in supporting VET by trying to clearly identify what advantage it may bring over other immersive technologies, as well as how AR and HV can be combined within a pedagogical model so that the maximum benefit can be derived from the opportunities offered by the two technologies. Furthermore, although the analogy between what happens in AR and HV is clear (in both cases, a layer of information is superimposed on reality), it needs to be clarified what relationship may persist between the two. The two technologies could fulfil each other's desires, and the specific affordances of each of the two could be pedagogically combined to full utilise the technology. This pedagogical empowerment should be investigated more, both at the theoretical and practical levels.

The present study—and in particular its need analysis—also have highlighted which operational skills need more support in VET today. Several educators underlined the usefulness of the first interview phase that allowed them to focus on those skills needing more support than others. The needs reported by the interviewees might be helpful for other educators who want to benefit from the teaching experience reported in these interviews. Further studies are needed for developing applications that meet the needs expressed by the educators, as well as for the development of pedagogical models that maximise the use of the two technologies.

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Ethics Statement

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