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RESEARCH ARTICLE

The more the better? Comparing two SQD-based learning designs in a teacher training on augmented and virtual reality

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Abstract

The purpose of this study was to investigate whether a learning design based entirely on the micro level strategies of the *Synthesis of Qualitative Data* (SQD) model is better suited to promote teachers augmented and virtual reality-related *Will, Skill,* and *Tool* (WST) compared to a learning design based less on the SQD model. To this end, we first developed two learning designs that were randomly distributed across two teacher professional development courses. In one course ($n = 23$), teachers learned according to our developed and fully SQD-based *Tell–Show–Enact–Do* (TSED) learning design; in the other course, teachers ($n = 22$) followed a *Tell–Show–Enact* (TSE) learning design that was less SQD-based. The results of the quasi-experimental field study show that the developed fully SQD-based TSED learning design is better able to promote the elements WST in teachers regarding the integration of augmented and virtual reality in the classroom. The results of the study have implications for theory and practice. For example, the developed TSED learning design can serve as a blueprint for other teacher educators, and the empirical findings support the micro level strategies recommended in the SQD model. Additional findings are discussed.

Keywords: Will–Skill–Tool model, Teacher education, Teacher training, SQD model, Augmented reality, Virtual reality, Learning design, Learning events

Introduction

Augmented reality (AR) and virtual reality (VR) are two contemporary visualization technologies that gained momentum in educational research and practice. AR is defined as the computer-supported extension of reality through digital objects, leading to a situation in which the real world and the virtual world exist simultaneously, interactions happen in real time, and the real and virtual objects align to each other (Azuma et al., 2001). In contrast, VR is defined as a completely computer-generated environment aiming to blend out the real world and allowing natural interactions within the virtual world, or in short: *VR is reality that is virtual* (Slater & Sanchez-Vives, 2016, p. 2). Following Slater and Sanchez-Vives (2016), we use the term VR to refer to immersive VR (iVR) generated through the use of head-mounted displays (HMDs) or CAVE systems. So in our understanding and throughout this paper we do not include virtual worlds, games or simulations viewed on desktop computers when using the term VR (like in Merchant et al., 2014). However, other authors also use the term iVR in their studies when using HMDs (e.g. Parong & Mayer, 2018).

The potential possibilities of AR and VR for use in teaching and learning are manifold. For example, researchers demonstrated that AR can support reading (Yilmaz et al., 2017), fosters skills acquisition in medical and creativity education (Elfeky & Elbyaly, 2018; Meola et al., 2017), promotes deep understanding of science phenomena by making the invisible visible (Altmeyer et al., 2020; Yoon & Wang, 2014), scaffolds learning through immediate feedback and just-in-time information (Kyza & Georgiou, 2018; Loup-Escande et al., 2017; Van Merrienboer & Kester, 2014), reduces cognitive load while enhancing performance (Buchner et al., 2022), and engages learners in immersive learning allowing them to practice authentic tasks in real-world situations (Dede, 2009; Dunleavy & Dede, 2014; Georgiou & Kyza, 2018). For VR, research showed that the technology can be used to practice hazardous lab work (Makransky et al., 2019a, 2019b) or car painting tasks, which without VR would result in a huge consumption of resources (Zender et al., 2020); fosters the acquisition of procedural knowledge and application on real-life tasks (Makransky et al., 2019a; Radianti et al., 2020); and, like AR, promotes affective and motivational learning outcomes like interest or positive emotions toward a subject (Buchner & Kerres, 2021; Makransky et al., 2020a, 2020b; Parong & Mayer, 2018).

However, as for any educational technology and media, the described potentials must be put into practice considering learning goals and learners' needs to provide effective and engaging learning activities that support the achievement of these goals (Kerres & Witt, 2003; Merrill, 2002, 2018; Seufert et al., 2021). As the long history of research on educational technologies has shown, the mere use of a new, supposedly innovative technology does not automatically result in better learning (Clark, 1994; Mishra et al., 2009). Therefore, the role of teachers cannot be overstated, as they are the ones who end up designing and implementing technology-enriched learning environments for their students. The question is, what do teachers need to integrate technologies like AR and VR into their teaching in a meaningful way?

AR and VR classroom integration

For AR and VR, research showed that implementation in the classroom is a complex matter (e.g. Dengel et al., 2021; Southgate et al., 2019). For example, previous studies have clearly shown that without instructional elements, such as learning strategies, VR can even be a hindrance to learning (for overviews see Makransky & Petersen, 2021; Mulders et al., 2020). The same applies to AR, if the focus is on the mere visualization of learning content, but no real learning activities are offered that allow or stimulate deep processing of the content presented via the visualization. As a consequence, learners like the AR-enriched learning environment but compared to control conditions no benefits in terms of learning outcomes occur (Chang et al., 2016; Garzón et al., 2020; Huang et al., 2019).

To better understand what teachers need to integrate AR and VR in the classroom in a meaningful way, we refer to a well-known model for technology integration: The *Will–Skill–Tool* (WST) model (Knezek & Christensen, 2016; Knezek et al., 2003). The

WST model is a technology integration model containing three key elements that predict teachers' use of technology in the classroom. *Will* is defined as positive attitude and belief toward the integration of technology, for example, regarding the benefits of the implemented technology for students' learning (Knezek et al., 2003; Petko, 2012). *Skill* represents teachers' readiness and self-perceived confidence to actually use a certain technology (Knezek & Christensen, 2016). *Tool* is related to the availability of software, applications or devices as well as the opportunity for teachers to access them (Knezek & Christensen, 2016). Many studies proved that the three elements of the WST model can predict teachers use of technology in the classroom. The explained variability of technology integration ranges from 60 to 96% (Farjon et al., 2019; Knezek et al., 2003; Sasota et al., 2021). Testing of the model was done in general for technology use in the classroom. We apply the model to AR/VR classroom integration leading to the following consequences in teacher training and education:

- AR/VR-related *Will*: Originally, both AR and VR were not developed for educational use. This fact is still reflected in the amount of money spent on AR/VR, with gaming and entertainment being the largest area (Martín-Gutiérrez et al., 2017; Statista, 2021). It is therefore not surprising that teachers are skeptical about the use of AR and VR and associate it with many challenges (Alalwan et al., 2020). Research has also shown that AR/VR can be perceived as hedonic technologies (van der Heijden, 2004), meaning they are associated with entertainment but not learning (Makransky et al., 2020a, 2020b). As a consequence, it is important in teacher education and training to provide evidence and *good practice* demonstrating how AR and VR can be used in the classroom to enhance students learning. If done successfully, teachers should be less skeptical about the use of AR/VR and be confident that both technologies can be used for the purpose of learning. This argument corresponds with the definition of *Will* in the WST model: teachers show a positive attitude towards the usefulness of technology in instruction (Knezek & Christensen, 2016, p. 311).
- AR/VR-related *Skill(s)*: As with any technology, AR and VR require a variety of skills so that teachers can competently conduct a deployment. For example, teachers need to be able to install, open, and use applications on a mobile device. They need to know how AR works in its basic features. For example, marker-based AR requires a so-called trigger image that must be scanned with the camera of the mobile device. It becomes even more complex when teachers want to create their own AR/VR content. This requires basic multimedia design skills. For example, Buchner and Zumbach (2018) first produced videos and then augmented them using an online platform. Without prior knowledge of video production, this use would not have been possible. Surveys also show that a lack of skills in AR and VR is the decisive criterion for or against its use (Alalwan et al., 2020; Fransson et al., 2020). As a consequence, teachers need to be trained in how to use AR and VR as well as how to create multimedia content that can subsequently be used in AR/VR platforms like the *Areeka Studio* or *Co-Spaces Edu* (Areeka, 2020; DelighteX, 2021). If done successfully, teachers should be confident in their ability to use AR/VR for the purpose of learning. This argument corresponds with the definition of *Skill* in the WST model: teachers feel ready and confident in their use of technology (Knezek & Christensen, 2016, p. 311).

- AR/VR-related *Tool*: For a long time, the use of AR/VR was coupled with bulky devices that were so expensive that only universities, the military, and the business world could afford to purchase them. With the advent of the smartphone, this changed fundamentally, and today both AR and VR content can be used on mobile devices (Akçayır & Akçayır, 2017; Arth et al., 2015; Cochrane, 2016). HMDs are also becoming increasingly cheaper and smaller. Nevertheless, teachers still say that access to tools and applications that are actually suitable for teaching and learning is massively limited and the applications found are usually not aligned with curricular learning objectives or are not well designed (Alalwan et al., 2020; Fransson et al., 2020). Another issue is the dependence on technology companies, which can charge for previously freely available tools at any time or remove tools from the consumer market altogether. This is what happened with the *HP Reveal* application (previously *Aurasma*), which Buchner and Zumbach (2018), for example, used not only to design AR content for their lessons, but also to teach other teachers how to create AR in many workshops (Buchner & Zumbach, 2020). Today, the teachers who participated in the workshops can no longer use the application because it has been taken off the market, and the created content is lost. As a consequence, teachers need to know where they can find appropriate AR/VR applications and how to use tools (if possible, freely available) that allow designing own AR/VR content. The latter is decisive because creating own content allows teachers to align the AR/VR content to learning goals. If done successfully, teachers should be confident that they can access AR/VR applications and tools for the purpose of learning. This argument corresponds with the definition of *Tool* in the WST model: teachers are aware of availability and accessibility of technology (Knezek & Christensen, 2016, p. 311).

After analyzing *what* is necessary to support teachers AR/VR classroom integration, teacher educators need to know *how* to foster the WST elements.

Strategies to foster AR/VR integration

How can teacher educators and teacher education institutes prepare future teachers and train in-service teachers to integrate technology in the classroom? Tondeur et al. (2012) analyzed qualitative studies to answer this question and synthesized the most effective strategies found resulting in the SQD (*Synthesis of Qualitative Data*) model (see also Tondeur et al., 2019). The model consists of three levels represented as circles. In the inner circle, six micro level strategies are recommended that can foster teachers' technology integration: Role models (i.e., observing other teachers how they use technology in the classroom), Reflection (i.e., discussing a developed learning design with peers), Instructional design (i.e., planning and preparing of technology-enhanced lessons), Collaboration (i.e., sharing of attitudes and abilities; co-designing of lessons and/or instructional materials), Authentic experiences (i.e., seeing and experiencing of technology classroom integration), and Feedback (i.e., getting input from experts on the use of the technology integration). In the second circle, four key themes that are necessary at the institutional level are summarized. These themes should be implemented in the entire teacher education programme leading to the idea of the institution as a *unit of change* (Tondeur et al., 2012, p. 142): Technology planning and leadership, training staff, access to resources, and cooperation within and between the institutions. In the outer third level, two overarching strategies are outlined: Aligning theory and practice, and Systematic and systemic change efforts. These two overarching strategies are important for both the micro level strategies and the institutional level strategies (Tondeur et al., 2012, p. 141). Our study is situated in a teacher training course; hence, we focus in this contribution on the micro level strategies and the strategy of aligning theory and practice.

Recently, Tondeur et al. (2021) reflected on the practicability and fruitfulness of the SQD model. The authors criticize that the described strategies are not clear enough and that SQD might serve more as a *thinking tool* than a practical solution (Tondeur et al., 2021, p. 2197). However, some studies already tried putting the SQD strategies into practice.

Tondeur (2018) linked the SQD strategies to the instructional approach of *teacher design teams* (TDT). In TDT instruction, a group of teachers develops curriculum materials similar to the learning technology by design approach used by Koehler and Mishra (2005) to foster technological pedagogical and content knowledge (like recommended in the TPACK model; Mishra & Köhler, 2006). However, Tondeur (2018) did not report data on the effectiveness of the TDT approach based on SQD.

Hsu and Lin (2020) developed an ICT training course in language teacher education based on the SQD model strategies. The authors call their learning design an integrative approach with *learning through technology* including the aforementioned learning technology by design approach (Hsu & Lin, 2020, p. 4). The authors applied a pretest/posttest research design to explore if their ICT training course can foster TPACK. Results show that the training increased pre-service language teachers TPACK. A limitation of the study is the missing control group making it difficult to attribute the improvement in TPACK scorings entirely to the intervention.

Lachner et al. (2021) designed a *TPACK-module* based on the SQD model and more general principles of teacher education. The module was implemented as an add-on to a regular course in five different subjects in pre-service teacher education. The authors provide a detailed description of the module, the learning activities the students performed, and how these activities are linked to SQD. Furthermore, Lachner et al. (2021) compared the regular course + TPACK-module with the regular course only (called *business-as-usual control condition* by the authors; p. 6). Results provide evidence for the effectiveness of the SQD strategies: the pre-service teachers in the regular course + TPACK-module outperformed the control group students significantly with an effect of medium size regarding TPACK. Overall, the Lachner et al. (2021) study is of high quality informing both theory and practice, among others by providing all the used materials as open educational resources (OER). However, one limitation is the rather "passive" control group in which the pre-service teachers did not engage in any kind of instruction related to TPACK. As Lachner et al. (2021, p. 12) write, their study is a traditional effectiveness study not allowing a *fine-grained* analysis.

In sum, research on the effectiveness of the SQD strategies (Tondeur et al., 2012, 2019) when put into practice is at an early stage: The outlined studies focused only on the promotion of TPACK. According to Petko (2012), TPACK is represented in the *Skill* element of the WST model. Research on the effect of the SQD strategies on the *Will* and *Tool* element when used in a learning design is lacking. Moreover, studies with active

Table 1 Merging of the SQD strategies with the learning events and a detailed description of what the instructors and/or the learners do

SQD strategies	Learning event	Details
Theory	Tell	Instructors present information on AR/VR and instructional design models how to develop meaningful learning environments
Practice and role model	Show	Instructors demonstrate how AR/VR was used in the classroom; the examples are real-world examples planned and implemented by the instructors
Authentic experience	Enact	Learners test AR/VR learning materials and act as if they were students; Learners teach a lesson with AR/VR learning materials
Instructional design, collaboration, feedback and reflection	Do	Learners come together in small groups, design a learning environment, develop the necessary AR/VR learning materials, and present their lesson plan in the whole group afterwards. Additionally, all the groups get feedback from the peers and the instructors

control groups, e.g., learners that also engage in some strategies of the SQD model, are totally missing. According to Tondeur et al., (2021, p. 2197), knowledge on how the strategies come together can help improving the *Consistency* of the SQD model. Finally, no study applied the SQD strategies to foster technology-specific classroom integration. The summarized studies addressed technology in general, hence, we focus in this study on AR/VR contributing to specify the discussion on how and when the SQD strategies are helpful (or not).

The present study: Putting the SQD model strategies into practice to foster AR/VR-related WST

The aim of this study was to investigate whether a learning design fully based on the SQD strategies is more effective to foster AR/VR-related WST in an in-service teacher training compared to a learning design with less strategies incorporated.

Therefore, we first had to develop two comparable learning designs that put the more or less strategies into practice. To do so, we merged the SQD strategies with what Merrill (2002, 2018) calls instructional or learning events. Learning events describe the activities performed by the teacher or the learner. For example, the most frequently used learning event is the *Tell* learning event in which a teacher presents information of a topic to the learners. The *Show* learning event demonstrates the application of the information through examples, and finally in the *Do* learning event, the learners apply their newly acquired knowledge to solve a certain problem (Merrill, 2018). The three learning events *Tell, Show,* and *Do* align with the SQD strategies Theory, Practice, Role model, Instructional design, Collaboration, Feedback, and Reflection (Table 1). However, for gaining Authentic experience we decided to add a new learning event, which we call *Enact* (Table 1). We refer to the work of Gallagher and Lindgren (2015) who describe enacting as a form of role-playing or *acting-as-if* situation. In such situations, learners perform actions as something/someone else. For us, *Enact* represents much better the idea of experiencing an authentic technology-enriched learning environment as a teacher or a learner than, for example, calling this a *Do* learning event. Our *Tell–Show–Enact–Do* (TSED) learning design integrating all of the SQD model strategies is illustrated in Fig. 1. To test the effectiveness of the integrated

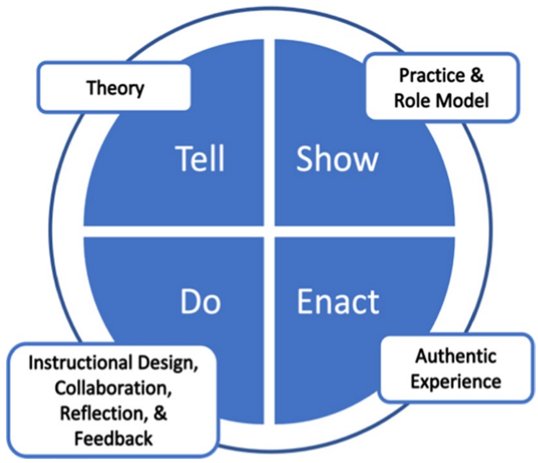

Fig. 1 Illustration of the Tell–Show–Enact–Do learning design based on the micro level strategies of the SQD model

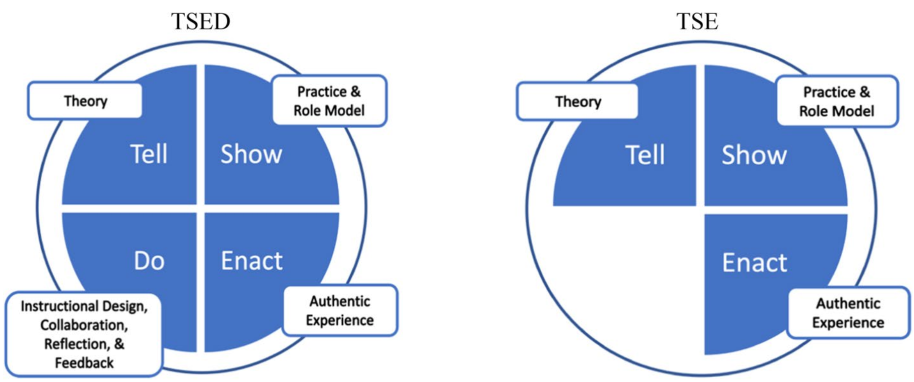

Fig. 2 Overview of the two learning designs with merging of the learning events and the strategies recommended in the SQD model

learning design regarding teachers' WST we compared it to a learning design that incorporated less strategies of the SQD model (see Fig. 2 in the next section).

We explored the following research questions:

> RQ1: Do the participants in the TSED condition show a greater will to integrate AR/VR in the classroom compared to the control condition?
> RQ2: Do the participants in the TSED condition feel better prepared in terms of their skills to integrate AR/VR in the classroom compared to the control condition?
> RQ3: Do the participants in the TSED condition demonstrate greater confidence in accessing AR/VR applications and tools compared to the control condition?

Method

Participants and context

The study was implemented in the in-service teacher training course *Introduction to media didactics* which is part of the professional development program *Media pedagogy* organized cooperatively between St. Gallen University of Teacher Education and the Eastern Switzerland University of Applied Sciences. Teachers participate in this course and program on a voluntary basis. Upon successful completion of all courses, participants receive a certificate. The level of education in which the participants teach, and work varies from elementary school to universities as well as companies in which the teachers are expected to develop new teaching scenarios as instructional designers/didactic professionals. In total, data of 45 participants (23 women; one participant did not choose a gender but wrote *human being* instead) with an average age of 38.9 years ($SD = 7.65$ years) was collected from the courses held in 2019 ($n = 22$) and 2021 ($n = 23$). In the *Introduction to media didactics* course both authors of this research study act as instructors. We teach the fundamentals of using media and technology for the purpose of teaching and learning. In addition, we discuss new innovations in the field of educational technologies with the participants. In the courses of 2019 and 2021 we focused on the educational potentials and challenges of AR and VR as part of the 2-day course.

Design

The study was conducted as a quasi-experimental field study. The assignment of the courses either to the experimental condition following the developed learning design or the control condition was random. The independent variable of the study were the different learning designs (Fig. 2): In the experimental condition ($n = 23$), the participants followed the developed *Tell–Show–Enact–Do* (TSED) learning design that is holistically based on the SQD model. The participants in the active control condition ($n = 22$) learned with a *Tell–Show–Enact* (TSE) learning design, which incorporates fewer strategies from the SQD model. The content taught as well as the examples demonstrated were the same in both conditions.

As dependent variables, we used the three elements defined in the WST model: *Will* (i.e., attitudes and beliefs toward technology), *Skill* (i.e., confidence to use the newly introduced technology), and *Tool* (i.e., access to the technology).

As control variables, we collected age and gender of the participants.

Measures

Data was collected using an online questionnaire that participants completed after finishing the last learning event of each learning design. We measured the three elements of the WST model with adapted items of the *Technology Usage Inventory* (TUI) developed by Kothgassner et al. (2013). The items are well-suited for our purposes because the TUI was specifically developed for research on innovative technologies like AR and VR. To measure *Will*, we used six items of the TUI representing teachers' attitudes toward the usefulness of AR/VR as educational technology. We used three positive items (e.g., "AR/VR can improve my teaching") and three negative items (e.g., "I think the use of AR/VR is risky") that in sum constitute the scale *Will* (Cronbach's alpha = 0.82; six items). To measure *Skill*, we used an adapted version of the usability scale of the TUI. The scale consists of three items, for example, "I find it easy to use AR/VR" (Cronbach' alpha = 0.70; three items). To measure *Tool,* we used the accessibility scale of the TUI. The scale consists of three items, for example, "I think AR/VR is accessible to everyone"

(Cronbach's alpha = 0.75; three items). All items were answered on a Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree).

At the end of the questionnaire, the participants also indicated their gender and age. In the case of gender, participants were also able to give their own answer. As already mentioned, one person chose this option and did not assign himself/herself to a gender but wrote *human being* instead.

Procedure

Both courses started with the *Tell* learning event (30 min), first introducing information about AR and VR as a technology through a lecture supported by a slide show presentation. For example, we summarized the history of AR and VR by presenting the first headset developed by Sutherland (1968), the reality–virtuality continuum (Milgram et al., 1995) and accepted definitions of AR and VR together with some key terms associated with AR/VR technologies, e.g. immersion (e.g. Azuma et al., 2001; Slater & Sanchez-Vives, 2016). Second, we introduced the *framework model of design-oriented media didactics,* which is a well-known framework for designing digital learning and teaching in German speaking countries. The framework combines the German tradition of didactics with the tradition of instructional design originated in English-speaking countries (Kerres, 2018). Subsequently, in the *Show* learning event (30 min), we demonstrated examples of already implemented AR/VR-enriched learning environments of the first author and colleagues together with examples from the literature. For example, we showed how to use VR in science education (Parong & Mayer, 2018) and primary education (Buchner & Aretz, 2020) and how to implement AR as both an instructional technology (Buchner, 2021; Buchner & Zumbach, 2018; Paraschivoiu et al., 2021) and a design technology allowing learners to create their own multimedia artefacts (Buchner & Kerres, 2021; Buchner & Weißenböck, 2019).

After the *Tell* and *Show* learning events, the control group TSE was given time to test the AR/VR learning materials presented. As mentioned earlier, we call this *Enact* in our design (45–60 min). Enacting the materials corresponds to gaining authentic experience from the SQD model. In our learning design, the teachers take on the role of students and tested the materials from that perspective, as learners, so to speak.

In the experimental TSED condition, participants received additional demonstrations of how teachers can create AR and VR content themselves during the *Show* learning event (30 min). To do this, we introduced Areeka Studio,[1] an online tool for designing AR materials, as well as the stories360 website,[2] where VR content can be created based on 360° images. Afterwards, we initiated the *Do* learning event (240 min), where participants planned, designed, and developed their own AR or VR learning environments in small groups (two to four people) using the presented tools and considering the media didactics framework. After completing the AR/VR learning environments, participants presented it and received feedback from colleagues and the two lecturers. Altogether, the TSE learning design took about 2 h, the TSED learning design almost 6 to 7 h.

[1] https://studio.areeka.net

[2] https://stories360.org

Table 2 Means and standard deviations for the dependent variables per condition

Scale	TSED (n = 23)		TSE (n = 22)	
	M	*SD*	*M*	*SD*
Will	5.78	0.46	4.10	0.89
Skill	4.51	0.44	4.03	0.65
Tool	4.33	1.11	3.38	1.04

Table 3 Means, standard deviations, and t-test results

Scale	TSED (*n* = 23)		TSE (*n* = 22)		*t*(43)	*p*	*d*
	M	*SD*	*M*	*SD*			
Will	5.78	0.46	4.10	0.89	7.991	< 0.001	2.383
Skill	4.51	0.44	4.03	0.65	2.902	0.006	.865
Tool	4.33	1.11	3.38	1.04	2.980	0.005	.889

Data analysis

For the purpose of data analysis, the mean values of the individual items were aggregated to their corresponding scales. Negative items were recoded so that high values in each scale represent agreement.

Results

Descriptive statistics and preliminary analysis

In Table 2, the mean values with standard deviations for the three dependent variables for each condition are given. Data reveals that the teachers in the TSED condition show higher *Will, Skill,* and *Tool* scores compared to the control condition.

To account for a possible influence of age and gender (like mentioned in Sasota et al., 2021), we first test for differences in these factors. Results of an independent *t*-test show that the age of the participants in the TSED condition ($M = 38.70$, $SD = 8.27$) and the TSE condition ($M = 39.14$, $SD = 7.10$) do not differ significantly, $t(42) = -0.19$, $p = 0.85$. The same is true for gender, χ^2 (2) = 0.09, $p = 0.76$ (TSED condition: 12 women, 10 men, one person wrote human being instead; TSE condition: 11 women, 11 men).

RQ1: Do the participants in the TSED condition show a greater will to integrate AR/VR in the classroom?

Descriptive data in Table 2 shows that the participants of the TSED condition report higher scorings in the *Will* scale compared to the participants of the TSE condition. An independent *t*-tests reveals that the difference between the conditions is significant, $t(43) = 7.99$, $p < 0.001$, $d = 2.38$ (see also Table 3). Hence, we conclude that the TSED learning design incorporating all strategies recommended in the SQD model was better able to enhance teachers' willingness of AR/VR classroom integration than the TSE learning design incorporating fewer strategies. The corresponding effect size is large.

RQ2: Do the participants in the TSED condition feel better prepared in terms of their skills to integrate AR/VR in the classroom?

As can be seen in Table 2, the participants of the TSED condition scored higher in the *Skill* scale than the participants of the TSE condition. The difference between the conditions is significant and the effect is of large size, $t(43) = 2.90$, $p < 0.01$, $d = 0.87$ (see also Table 3). Therefore, we conclude that the TSED learning design incorporating all strategies recommended in the SQD model was better able to enhance teachers' skills on how to use AR/VR in the classroom than the TSE learning design incorporating fewer strategies.

RQ3: Do the participants in the TSED condition demonstrate greater confidence in accessing AR/VR applications and tools?

Descriptive date in Table 2 displays that the participants of the TSED condition rated their confidence in accessing AR/VR applications and tools higher compared to the participants of the TSE condition. An independent *t*-tests reveals that the difference between the conditions is significant, $t(43) = 2.98$, $p < 0.01$, $d = 0.89$ (see also Table 3). Hence, we conclude that the TSED learning design incorporating all strategies recommended in the SQD model was better able to enhance teachers' confidence in accessing AR/VR applications and tools for classroom use than the TSE learning design incorporating fewer strategies. The corresponding effect size is large.

Discussion

The aim of this study was to investigate whether a learning design, holistically based on the SQD micro level strategies, is more effective in promoting AR/VR-related *Will, Skill,* and *Tool* (WST) than a learning design that is less based on SQD. To allow this detailed analysis, we developed two learning designs using Merrill (2002, 2018)'s learning events and merged them with the SQD strategies. The results show that our developed *Tell–Show–Enact–Do* (TSED) learning design fully based on the SQD strategies is better able to foster teachers' AR/VR-related WST than the *Tell–Show–Enact* (TSE) learning design in the control condition incorporating less strategies of the SQD model. The results have implications for research and practice, which we discuss in more detail below.

Theoretical contributions

The results of this study support the SQD model by showing that the micro level strategies are effective instructional recommendations to foster teachers' technology integration. In our case, we provide evidence for the usefulness of the strategies when teaching about specific technologies like AR and VR. Furthermore, we extend the knowledge base by demonstrating that the strategies work beyond the acquisition of skills (or knowledge about technology, pedagogy, and content). In this study, we showed that our integrated TSED approach also fosters teachers' willingness to use AR/VR in the classroom and strengthens teachers' confidence in accessing tools that allow AR/VR use for the purpose of teaching and learning. By investigating the SQD model in combination with the WST model, the study contributes to a better understanding of how the SQD model aligns with other conceptual models. According to Tondeur et al. (2021), exploring such connections can help to improve the quality of the SQD model (in terms of

Consistency). Moreover, Tondeur et al. (2021) mentioned that little is known about how the SQD strategies come together. We contribute to this issue by demonstrating that an integrated learning design using all of the micro level strategies is more effective than a learning design incorporating fewer strategies of the SQD model. However, it is important to note that our study, like others, focused on the micro level, which has also been criticized in Tondeur et al. (2021). In addition, we combined several of the micro-level strategies in the *Do* learning event, while the *Enact* learning event only consists of one strategy (authentic experiences). It is conceivable that other combinations of the strategies reveal similar results. With this in mind, we can show with our study that integrating a *Do* phase is particularly essential to foster teachers' WST.

Empirical contributions

Research on the effectiveness of the SQD strategies is largely based on correlational studies that do not allow conclusions about causality (Lachner et al., 2021). Hence, with this study we contribute to the still limited empirical basis in which the strategies have been examined in comparative studies. Additionally, our study extends previous empirical investigations (e.g., Lachner et al., 2021) by adding an active control group in which the aim of the instructors was to foster technology classroom integration too. Regarding the question, how the integration of AR/VR can best be supported in teacher education, this research provides the first empirical evidence showing that a learning design based on SQD is effective in promoting teachers' classroom integration of these two contemporary technologies.

Practical contributions

A major concern expressed in Tondeur et al. (2021) is the *fruitfulness* of the SQD model for practice. Due the conceptual character of the model it is not clear how teacher educators and teacher education institutions should implement the recommended strategies. We merged the (micro level) strategies with learning events leading to a blueprint that can be used by other practitioners. The combination of *Tell–Show–Enact–Do* learning events based on SQD has proven to be an effective learning design to foster teachers' WST of AR/VR classroom integration. Furthermore, compared to other SQD-based practical solutions (e.g., Hsu & Lin, 2020; Lachner et al., 2021), the TSED approach is employable in 1-to-2-day courses as well as in 1-day workshops. However, it is important to note that for a successful implementation of the TSED learning design about 6 to 7 h must be scheduled.

Limitations and future directions

A limitation of the study is the measurement of the dependent variables based on self-reporting scales. While this might be very reliable for the *Will* and *Tool* scale, the *Skill* scale should be expanded by including other survey methods in a future study. For example, it would be conceivable to divide *Skill* into technological, pedagogical, and content knowledge (TPACK) as suggested by Petko (2012) and to use a survey instrument developed to measure these three aspects. It is also necessary in a future study to obtain qualitative data in addition to quantitative data. For example, one approach could be contacting the participating teachers after a certain period of time and asking them whether they have actually used AR/VR in their lessons or not.

Another open question is how the developed TSED learning design compares to other learning designs that are even more strongly oriented towards the SQD model. For example, it would be quite conceivable that the learning technology by design approach based on SQD (Hsu & Lin, 2020; Koehler & Mishra, 2005) would lead to similar results. Furthermore, it is possible that the *Do* learning event is the most important one to foster teachers' *Will, Skill,* and *Tool*. To investigate this question, it is necessary to compare the TSED learning design to other combinations in future studies. For example, instead of removing the *Do* learning event, researchers might remove the *Enact* learning event. It is possible that a *Tell–Show–Do* (TSD) approach is as effective as the TSED learning design tested in this study. Comparing a TSD learning design with the TSED learning design also addresses another limitation of this study: A closer look on the two designs investigated in this study reveals that the participants in the TSE condition received less training time than the participants in the TSED condition. Therefore, it is possible that time is a decisive factor affecting the results. The comparison of TSD and TSED can overcome this issue because the training time will be much more balanced.

Further, it must be noted that we cannot generalize our results to other educational technologies and media. Further research is therefore necessary to determine whether the TSED learning design is also suitable for the design of learning environments incorporating educational videos, games, or other digital learning materials. A further testing of the learning design with pre-service teachers is also necessary, as our study is situated in in-service teacher training.

Conclusions

In this research, we provide evidence that our *Tell–Show–Enact–Do* (TSED) learning design integrating the micro level strategies of the SQD model is more effective to promote teachers' *Will, Skill,* and *Tool* regarding the use of AR and VR technologies in the classroom than a learning design less based on SQD. However, the developed design is still time-consuming when implemented in practice. Therefore, it must be investigated whether time can be saved by applying other combinations with the same effectiveness. As the results of this study show, using the *Do* learning event seems to be crucial. In combination with *Tell, Show,* and *Enact* learning events, the developed learning design proved to be effective. Therefore, the developed TSED learning design can serve as a blueprint for practitioners by showing how the SQD strategies can be implemented in teacher education and training practice. Furthermore, the research helps to raise the quality of the SQD model by showing how the strategies come together in a learning design and by connecting the SQD model to the *Will, Skill, Tool* (WST) model of technology integration. Further research is necessary to test if the developed TSED learning design also works in general or for other contemporary educational technologies to foster teachers' technology integration.

Abbreviations
AR: Augmented reality; VR: Virtual reality; SQD: Synthesis of Qualitative Data; WST: Will, Skill, Tool; HMD: Head-mounted display; TSED: Tell–Show–Enact–Do; TSE: Tell–Show–Enact; TPACK: Technological, pedagogical, and content knowledge; TUI: Technology Usage Inventory.

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Authors' contributions
Both JB and MH made substantial contributions to the conception and design of the work. JB analyzed the data and wrote the first draft of the manuscript. JB and MH interpretated the data. JB and MH revised the first draft and finally both authors read and approved the final manuscript.

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Availability of data and materials
The dataset analyzed during the current study and other materials used in this research project are available via the following link: https://osf.io/gfmdx/.

Declarations

Competing interests
The authors declare that they have no competing interests.

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