Guidelines for Playful Learning Design in VR/AR: Insights From Student Productions

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Abstract: The paper presents three perspectives on virtual reality (VR) and augmented reality (AR) as educational technology: one on the learning attributes of VR and AR, the second on practical issues and problems, and the third on learning design guidelines. The perspectives are explained through text, tables, and examples from engineering students' productions. The paper will be of interest to students, designers, and researchers of VR and AR for training and learning.

Keywords: Virtual reality, Augmented reality, Learning design, Playful design, Game-based learning, Educational technology

1. Introduction

VR and AR are collectively referred to as XR. The paper introduces three perspectives on XR as educational technology: one about the learning attributes of XR, the second about practical issues/problems, and the third about learning design guidelines and recommendations. The perspectives are explained in text and tables, and they are also illustrated by examples from students' productions.

Regarding the technology, AR and VR blend the physical and virtual environments (Klopfer 2008; Kerawalla 2006; Cheng & Tsai 2013; Dunleavy 2014). In VR, the user typically wears a head-mounted display that provides a virtual 3D world experience. AR overlays a virtual layer on top of the physical environment, with the most popular example being PokemonGo.

The student productions were from the fourth semester 15 ECTS course, Learning Technology 2, from the software engineering program titled Bachelor's in Game Development and Learning Technology. The course aimed to teach academic learning theory, motivational theory, and applied programming for external devices such as VR headsets and smartphones. The students were expected to apply their prior knowledge in 3D game engine programming, sensor technology, and game design to create these prototypes. The student productions are from the spring semesters of 2022 and 2023.

The students conceptualized a range of themes for their projects, including health promotion, first aid training, civil firefighting, diver training, and more. The goal of the prototypes was to provide engaging and interactive training experiences that would be more effective than traditional training methods. The prototypes were developed using Unity, a popular game engine, and tested on the Oculus Quest 1, a standalone VR headset. The development process was iterative, with the students receiving feedback and making improvements along the way. Formative evaluations were conducted in class four times to ensure that the prototypes were meeting the learning goals and objectives of the course. Additionally, some of the groups had expert consultants who provided domain knowledge and feedback.

Our approach to learning and teaching is grounded in social constructivism, which focuses on the collaborative nature of development. Vygotsky (1978; in Cooper et al. 2021) is famous for defining the zone of proximal development (ZPD) as the difference between actual development, as determined by a learner's independent problem solving, and potential development, as determined by problem-solving under adult guidance. In his view, guided activity done in the ZPD was the essence of teaching and learning. We expand the adult's role in the ZPD to include a teacher and educational technology perspective. Vygotsky himself also expands the concept to include play, games, and peers. In summary, teachers, play, games, educational technology, and peers can all bring the learner into the ZPD. The designer's challenge is to guide this process and guide the student into her personal ZPD while using the system. Below is a figure of the ZPD.

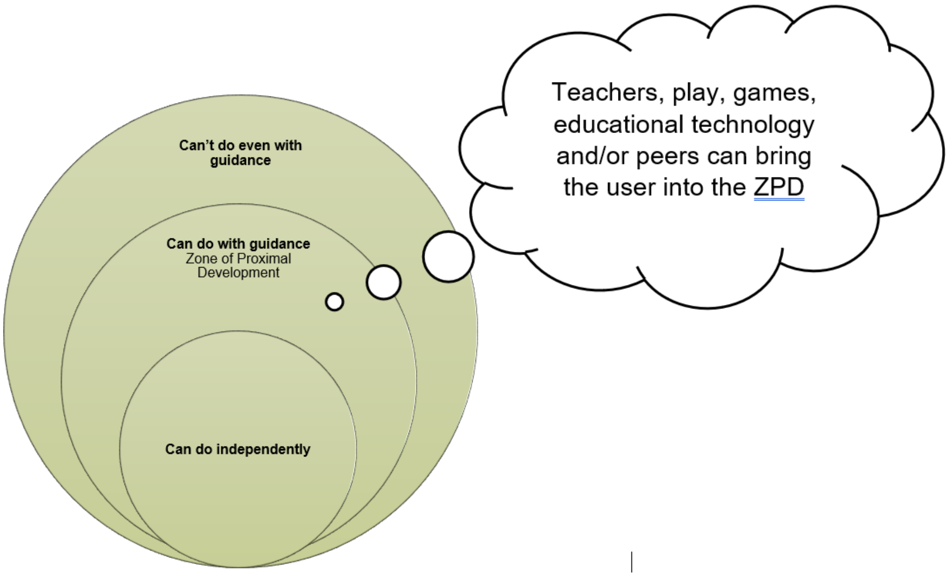

Figure 1: Teachers, peers, play, games, and educational technology can all facilitate the user's entry into the Zone of Proximal Development (ZPD)

In game-based learning, and educational technology, the idea is to alleviate and support the teacher by developing assistive digital applications (Cooper et al. 2021). The goal for the designer is to shape the system to support the ZPD, which can be achieved in various ways that will be discussed in the coming sections.

Organization of the paper: The paper is divided into three core sections that discuss the three perspectives on XR as educational technology: learning attributes of XR, practical issues and problems, and learning design guidelines, see the figure below. These sections are followed by illustrative examples from the students' productions. Finally, a summary of the paper is presented.

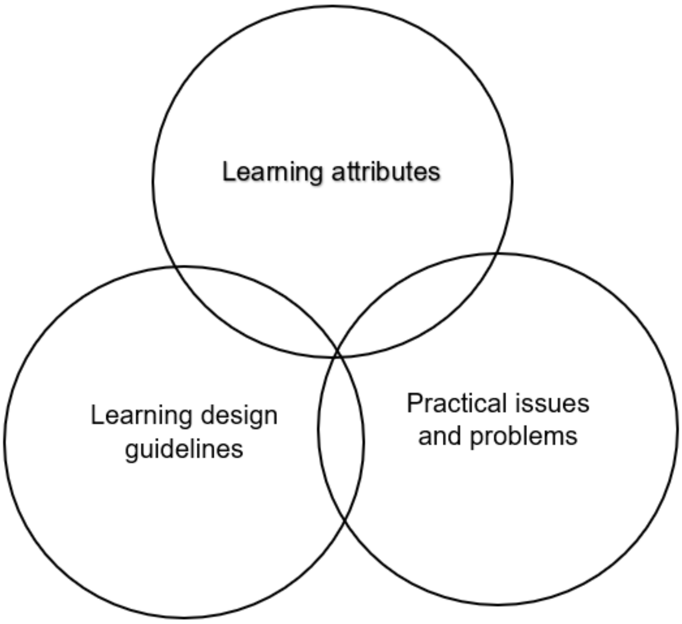

Figure 2: Three perspectives on designing educational technology for XR

2. Overview of Learning Attributes of XR

A lot of the potentials and challenges are similar in VR and AR as educational tools, so in this paper, we will assume similar affordances. XR are rapidly developing technologies that are being increasingly used in educational settings.

Immersion in the learning process is the most well-known argument for applying VR in teaching, training or psychiatric therapy (in the table 1 below). The intense feeling of being there, even though it's a simulation, has been noted by several studies (Calleja 2007; Kerawalla et al. 2006; Majgaard et al. 2017; Murray 1997; Waterworth 2014; McGonigal 2011). The environment can provide a *safe* real-life simulation without real-life consequences, for example, jumping off a roof in VR without sustaining injuries. Another compelling argument for the use of VR is its ability to create convincing simulations of real-life scenarios. Simulation and play have several overlapping characteristics such as context markers framing the scenario, actions without real-life consequences and make believe (Bateson 2000). Play and game characteristics in a simulation might engage the learner. An example of context markers could be a defibrillator, stretcher, band aid, people in white clothes in a first aid scenario in a simulated hospital. The learner will immediately understand what this is all about. The designer should introduce simple and understandable context markers to frame the scenario and engage the learner. *Playful learning* applies inspiration from the world of computer games.

Learning often takes place when the learner is actively participating and exploring the subject matter. The learner interacts, reflects, and forms experiences this is ascribed as *experiential learning* (Kolb 1984; Kolb et al. 2011; Majgaard et al. 2020). The learning environment should be designed to be interactive to support experiential learning and *interactive learning* processes. It should be noted that interactions should be meaningful and closely related to the subject matter (Gee 2004). Repetitive, meaningless, interactive micromanagement will not support the learning process; on the contrary, it will bore the learner. Designing educational tools is a delicate balance between repeating what the learner already knows and gradually introducing new challenges. *Practice learning* is supported by simulations of complex real-life situations, for example, providing first aid in the middle of a crowd. The simulations could also support the practice of, for example, the order of lifesaving procedures or other medical procedures in VR or AR.

XR allow for personalized learning processes. The learner can train at their own pace and repeat the subject matter as many times as needed without the system losing patience. The system can be tailored to *individual learning* styles (Gee 2004). The learning process is often individual and solitary. *Social learning* elements in XR are in their infancy, but soon, we will explore social spaces where learners can discuss and interact meaningfully[1]. XR technology can make learning *accessible* to learners with disabilities who might otherwise struggle with traditional teaching methods.

Learners in XR are often unfamiliar with the interaction method. In most VR applications, the controllers are invisible while wearing the headset. Therefore, the designer often needs to start with a tutorial scene to teach the use of the controllers. Often, the designers provide visual guidance because text is considered clumsier from an affordance perspective and long text sections are also difficult to read in VR (Norman 2002).

XR technology can effectively *visualize 3D* models and add a new dimension to the physical surroundings, such as revealing hidden clues or information on real-life maps or details in the solar system that cannot be seen with the naked eye. This attribute can be described as seen the unseen (Dunleavy 2014; Majgaard et al. 2017; Nørgaard et al. 2019; Mantovani 2003; Martín-Gutiérrez 2010).

Below are some potential benefits and challenges of XR technology for learning. The table is divided into attributes, with the potential benefits and challenges outlined for each. While the table covers a comprehensive set of aspects, it is not exhaustive, and additional themes/attributes could be considered.

Table 1: Overview of learning attributes and their potentials and challenges in VR/AR

	Attributes	Potentials and challenges
	Immersive Learning.	Potential XR technology provide an immersive learning experience that engages students in a way that traditional teaching methods cannot. Potential: Students with attention issues can easier concentrate in VR because of the limited number of distractions Challenge: The immersive nature of AR technology can

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[1] Social networking https://allvirtualreality.com/review/best-social-networking-apps-vr-oculus-quest.html

	Attributes	Potentials and challenges
		be distracting and may interfere with learning, especially for students with attention issues.
2	Playful learning	Engaging learning environment inspired by the world of computer games
3	Safe Learning Environment	Potential: XR technology provide a safe learning environment where students can explore and experiment without the risk of real-world consequences.
4	*Experiential learning*	Potential: Provide the learner with new activities and experiences that encourage reflection and foster learning
5	*Interactive learning: Learning by active participation*	Potential: interacting centered around academic learning goals Potential: XR technology allow for interactive learning experiences that facilitate active participation and feedback. Potential: Actions instead of text and words Challenge: Reading and writing in VR
6	Practice learning: Simulations in real-life context	Potential: AR and VR can provide surroundings which emulate complex real-life situations. Potential: Learning new practices by training in VR simulations
7	Individual Learning processes	Potential: XR technology allow for individual and personalized learning experiences that can be tailored to each student's needs and learning style.
8	Social Learning processes	Potential: In the future we might sed more social spaces where user can meet in VR/AR and learn together Challenge: XR technology can be isolating and may not provide the same level of social interaction as traditional learning methods.
9	Accessible Learning	Potential: XR technology can make learning accessible to students with disabilities, who might otherwise struggle with traditional teaching methods.
10	Learning by imitation or practice learning	Potential: The learner imitates steps in a complex procedure for example steps in an epidural procedure in a health context.
11	Visualizing and/or coupling of 2D and 3D objects	Potential: Visualizing and inspecting 3D objects from all sides Potential: Coupling of 2D and 3D models are often difficult in book but easier in XR
12	Seeing the unseen	The technology can add a lens to the physical surrounding e.g. see hidden clues or written information on real-life objects

3. Overview of Practical Issues Using XR

The XR interfaces are in their infancy. There are not a lot of applications, the development of new applications is expensive, new versions of headsets are surfacing every year, and the headsets are expensive in a school setting. In combination with smartphones, the technology is more accessible (Issue 1 and 3, see the table below).

Motion sickness is a well-known phenomenon in VR because there might be a small delay or difference between head movements and movements seen in the headset (Issue 2). Motion sickness happens when the movement you see is different from what your inner ear senses. The sensitivity to motion sickness differs from person to person. Designers use all kinds of tricks to minimize the sickness, for example, providing a windshield frame when simulating driving cars or flights. Another trick could be to minimize multiple objects in the periphery of the eyes (LaViola 2000). Too much immersion can also cause dangerous situation where users fall or run into walls (Issue 4).

Table 2: Practical issues using XR

	Issue	Potentials and/or challenges
1	Cost-effective?	Potential: XR technology can be more cost-effective than traditional learning methods, especially for hands-on, experiential learning. Challenge: The availability of educational XR content is limited, and creating high-quality content can be time-consuming and expensive.
2	Cyber sickness - motion sickness	Challenge: XR technology can be disorienting, and in some cases, can cause motion sickness, which can be a safety concern. Prevention: The designer can design to reduce the potential cyber sickness e.g. by reducing mismatch between user movements in the simulation and the physical environment
3	Technical Issues and immature technology	Challenge: XR technology require high-performance hardware and software, which can be costly and difficult to set up and maintain.
4	Immersion issues	Challenge: Users might also fall or run into wall, so beginners should be watched.

4. Overview of Playful Learning Design Guidelines of XR

Learning design involves planning, facilitating, and conducting teaching, in this case, involving educational technology. It focuses on the activities that learners need to undertake to achieve the learning goals (Weitze 2015). How is learning design activities designed into XR applications? And how is the learner guided to reach the learning goals? When using digital technology in education, there will be two types of didactic learning designs: the automated and the teacher-led teaching activities. The teacher-led activities take place before and after the use of digital technology. Before XR, there will typically be an introduction to the academic field and the digital application. Then, students will work with the application, and finally, there will be an academic debriefing (Majgaard 2020). This means that in the design of learning technology, both an automated guidance for use in the system and a concrete proposal for how the technology can be incorporated into teaching must be developed, see the figure below.

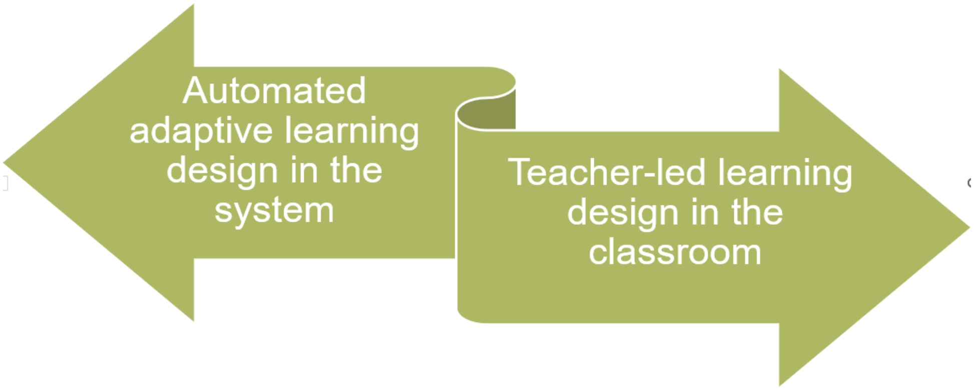

Figure 3: Overview of the learning designs: The automated built in learning design and the teacher-led learning design

In the table three we provide an overview of well-known playful learning design guidelines inspired by Gee (2004), Fan (2012), Habgood (2007) and Dunleavy (2014). The table covers ideas for the built in adaptive automated learning design. The learning design elements should provide the learner with user guidance without introducing heavy tutorials (Fan 2012; Curtis 2012; and Majgaard 2015).

Fan (2012) the creator of "Plant vs zombies" outlined several tips for making tutorials more effective and smoother (Curtis 2012; Majgaard 2015). According to Fan there should be no tutorial page, the tutorial is seamlessly blended into the playful application. The learner doesn't have to read about specific actions. The learner is to be lured into doing a specific action just once. "Once they see the results of their action, that's often all it takes for them to understand that action," Fan said (Curtis 2012). Furthermore, the use of text messages should be minimised. The messaging should be adaptive and if the learner understands the mechanics no messages or arrows are displayed. The designer should prefer to use visuals to teach, e.g. an arrow, or just showing how interactive objects work. Too much information creates noise, e.g. messaging on things the learner already knows. See more in theme 3, 4, 5, 6 in the table below.

Gee (2004) provides a long list of elements from the world of computer games which can be applied in educational technology. In the table below we chose the elements from problem solving which are the most applicable for designers of XR. See more in guideline 2, 8-12 in the table below.

When the learner has become familiar with the controllers, the designer can introduce the subject matter without inducing cognitive overload (Dunleavy 2014). See more in guideline 1 in the table below.

The core game mechanics are where user interactivity takes place (Fullerton 2019; Habgood 2007). In educational tools, the designer should integrate learning goals with the core mechanics (Habgood 2007). Habgood (2007) developed a division game where the core mechanics revolved around finding the correct divisor (guideline 14).

Table 3: Overview of playful learning design guidelines to implement in VR/AR

	Guidelines for designing playful learning experiences	**About the guidelines**
1	Cognitive overload for beginners – complex interaction	The user interface / controller is often difficult to use. XR technology require a significant learning curve, which can be a challenge for both students and teachers who are not familiar with the technology. The learner should exercise using the controllers before introducing hardcore academic learning activities.
2	Elements for guiding the learner	The learner might not know what to do in VR/AR and what the overall purpose is. Introduce the learner to the learning activity.
3	Blend in the tutorial	Spread out the teaching of the mechanics.
4	Better to have the learner do than read	The learner remembers better when an action is performed. Just get the learner to do it once.
5	Use visuals to teach	Hint the user with arrows, movements or simulate the wanted action.
6	Use fewer words	Use fewer words (max. 8) Use unobtrusive messaging if possible. Use adaptive messaging. If the user is familiar with the activity skip the message.
7	Framing and context markers	Context markers can ease the understanding of the scenario. In a classroom, context markers are the blackboard, tables and chairs arranged in school setting. Don't create noise by adding random objects.
8	Pleasantly frustrating activities	If the challenge is too hard or two simple the learner will become frustrated and leave the simulation too soon. The design should balance skills and challenges in the learning activity.

	Guidelines for designing playful learning experiences	About the guidelines
9	Well-ordered problem and challenges	The learner should have well sized problems – simple in the beginning and more complex later. Problems in the beginning should lead to more complex and harder problems later.
10	Cycles of expertise	The learners should practice and repeat skills until they are nearly automatic.
11	Information on demand or just in time	Information should be presented when it is useful in the simulation. Spread out the teaching of simulation mechanics.
12	Sandboxes	Potential: a place to experiment practice without restrictions.
13	Asymmetrical VR	One user in VR and another in front of a computer
14	Core mechanics and interaction should relate to the learning goals	The core of the user activity should relate closely to the learning goals. It should not be about playing irrelevant mini-games in the systems.

5. Illustrative Examples From Student

In the following we will introduce selected illustrative examples from student projects from spring 2022-2023. The students' projects will illustrate examples of learning approaches, practical issues and learning design approaches. The learning attributes mentioned in Table 1, the practical issues outlined in Table 2, and the learning design guidelines specified in Table 3 form the key components for consideration.

Fear of flying

The *Fear of Flying* application is a VR simulation of a flight that goes through the safety instructions given to passengers at the beginning of a flight route. The app aims to help individuals who experience mild fear of flying to become more knowledgeable and comfortable with flying. This is done though providing an immersive (attribute 1, see table 1) and safe environment (attribute 3) that enables users to learn about the safety instructions giving during a flight in an interactive (attribute 5) and experiential manner (attribute 4). Though interactive learning, the user can participate actively in the learning process, interacting with different objects and performing tasks to progress though the simulation (guideline 4: Better to have the learner do than read). The simulation is divided into sections, and the user is presented with one problem at a time (guideline 9: Well-ordered problem of challenges) to avoid cognitive overload. The application also highlights key elements of the safety instructions at specific times (guideline 5: Use visual to teach), aiding users in seeing the unseen (attribute 12) and framing and contextualizing the information. The group was particularly attentive to cybersickness (Table 2) as turbulence was simulated, which required taking away user viewpoint control by "shaking" the surroundings – just like in the real world.

Asymmetric Mathematics

The game *Asymmetric Mathematics* provides a good example of how social learning (guideline 7) can be achieved through asymmetric VR (guideline 13). The game is an immersive VR learning application (guideline 1) that introduces playful game-like elements (attribute 2) to math learning in high school. The game is played in co-op mode, where one student is immersed in a VR classroom environment, using a classic representation of classroom, to provide a clear understanding of the game's setting (guideline 15) while the other player sits in the same (physical) room. They are required to collaboratively solve a series of mathematical tasks, which are presented to the player in VR. The player(s) in the physical room are provided with a special calculator that is connected to the VR simulation, which functions as a means of communications and serves as a formal collection of responses. The player in VR can observe a "bomb", which exhibits the time, number of strikes, and enables the selections of the questions to be answered. The application encourages interactive learning (guideline 4) though active participation and takes cognitive overload for beginners (guideline 9) into account, as the users are provided with a guide, step by step as the game unfolds. To address the issue of cybersickness (Table 2) the players are seated, limiting their movement to only their head.

H.C. Adventures

H.C. Adventures is an interactive, location-based AR application aimed at enhancing children's (in first and second grade) comprehension and learning of fairytales by Hans Christian Andersen. By collection location-based data from the user, the app generates routes around the user's actual surroundings. The user will along the route encounter segments of fairytale narrated by a talking hat inspired by H.C. Andersen. In addition, the talking hat acts as a supportive guide for the children, providing step-by-step instructions as necessary (guideline 11) to mitigate the risk of cognitive overload (guideline 1 and 2). Additionally, the child can follow along and read the fairy tale in a 3D AR book.

The app uses game elements and playful learning (attribute 2) to motivate children to read more and spend more time outside by providing a treasure hunt-like storytelling experience. Learning occurs through active participations (attribute 5) in three types of AR challenges, including a "collecting" task (coins and other assets from the fairytale), a picture puzzle, and a location-based task, where the user has to choose the correct destination among three options to proceed to the next scene. Additionally, users are able to interact with characters from the fairytale, affording experiential learning (attribute 4).

Moreover, the application promotes social learning as children can engage in group play and learning.

Fire simulation

The developed fire simulation application exemplifies the attribute of a safe environment (attribute 3). The application simulates a burning building, where the user is required to perform smoke diving and locate a series of objects. The usage of the application requires two individuals, one who is immersed in the virtual burning building, acting as the smoke diver, and another outside of the virtual environment, guiding the smoke diver. The application utilizes asynchronous VR (guideline 13), which affords social learning (guideline 9).

The application was designed in collaboration with firefighters to simulate the experience of how firefighters work in the real world. Through the application, users are expected to gain an understanding of the firefighting profession. This is achieved through interactive learning (attribute 5), practice learning (attribute 6), and experiential learning (attribute 4), where the user gains a first-hand experience of acting as a firefighter and searching for a series of objects in a burning building. The group encountered technical issues and immature technology (issue 3), which resulted in having to streamline the 3D content in the application to avoid excessive resource consumption. To minimize the risk of cybersickness, a teleportation system was implemented to restrict movement within the virtual environment to occur synchronous with the user's body.

We are in space

The VR application *We are in space* takes middle school students (7th to 9th grade) on a spaceship journey through the solar system, providing a dynamic and interactive (attribute 5) experience of discovery and theory as a supplement to physics education, particularly focusing on the attribute Seeing the unseen (attribute 12).

The app enables users to travel to different planets, explore them, cut them open (attribute 4), as well as view various information about them.

The user is provided with various means of interacting with and manipulating their environment, including buttons and handles to change planets or the starry sky. Users are presented with different missions, guided by the spaceships navigation system, which introduces information step by step to avoid cognitive overload (guideline 1) and guides the user (guideline 2). Through this, the user gradually acquires relevant knowledge about the planets, when necessary to complete a given mission illustrating the Information on demand guideline (11).

6. Summery and Conclusion

In the article, we presented three approaches to the development of educational tools in XR. The three approaches were: one on the learning attributes of XR, the second on practical issues and problems, and the third on learning design guidelines. The tables are a work in progress. In the illustrative examples, we related selected student prototypes to elements in the tables. This puts flesh and blood on the concepts in the tables. And it also gives readers an idea of the variation in the students' products.

In the LT2 course in 2023, students were asked to relate the tables to their development of educational tools in AR or VR. The students have not yet submitted their projects and reports by the deadline of this article. They were particularly discussing learning design guidelines, such as pleasantly frustrating activities. In user tests (especially on younger students), they received a lot of feedback on whether the learners understand the intentions of the prototypes and whether they could figure out what to do in the simulations. Additionally, there were discussions about cybersickness and how to avoid it, such as teleporting within the application.

Based on the illustrative examples provided, the three tables have demonstrated their practical utility in designing and developing XR learning experiences. For instance, the Fear of Flying project demonstrated the implementation of an immersive and safe learning environment (attribute 1 and 2) designed to facilitate learning about safety instructions through an experiential and interactive learning (attribute 4 and 5) approach. To enhance user guidance and user experience, challenges were presented one at a time (guideline 9) and visual effects such as highlighting of relevant objects (guideline 5) were employed.

In the Fire simulation project, a safe learning environment (attribute 2) was also created, allowing users to experience firsthand smoke diving through experiential learning (attribute 4).

The utilization of the social learning guideline (guideline 7) was effectively demonstrated in both the Asymmetric Mathematics project and the Fire simulation project, wherein asymmetric VR (guideline 13) was employed. Furthermore, the Asymmetric Mathematics exemplified the playful learning attribute (2) by integrating game-like elements. Similar utilization of game elements was observed in the AR project, H.C. Adventures, where the game elements were used to enhance children’s motivation to read more.

The We are in space project particularly illustrates the attribute of seeing the unseen (attribute 12) and the guideline information on demand (guideline 11). In this simulation, users have the opportunity to explore planets up close, including the ability to split them in half to view their interiors. Additionally, the students in this project focused on introducing information in a step-by-step manner (guideline 1) and only providing information when necessary (guideline 11).

To conclude, the tables are an operational and practical step towards developing XR systems for learning and training. It is also clear that more evaluation is needed on the students' use of the tables.

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