electronics

MDPI

Article

Creating an Immersive XR Learning Experience: A Roadmap for Educators

Maram Meccawy

Faculty of Computing and Information Technology, King Abdulaziz University, Jeddah 22254, Saudi Arabia; mmeccawy@kau.edu.sa

Abstract: The use of extended reality (XR) technologies, namely Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR) in education, has attracted much attention in recent years. Many educators have described how XR benefits learners and how useful AR and VR technologies are in the classroom. However, creating AR and VR educational tools, apps or learning environments is a complex process, hence providing an immersive learning experience using these technologies is not a straightforward journey. As a result, the adoption of these emerging technologies in education might be delayed or halted despite their reported benefits to today's learners. In this paper, websites, technical articles, academic journals, reports and mobile app stores, relating to the use of XR technologies in education, have been examined. A number of themes have emerged and been reported in this paper, which provides a roadmap for those who would like to create XR experiences for learning and training purposes. The paper also describes the factors that should be considered when selecting an option to follow to introduce such immersive learning experiences.

Keywords: XR; VR; AR; MR; immersive learning environment; content creation; educational technologies

check for updates

Citation: Meccawy, M. Creating an Immersive XR Learning Experience: A Roadmap for Educators. *Electronics* **2022**, *11*, 3547. https://doi.org/10.3390/electronics11213547

Academic Editor: Ioannis Paliokas

Received: 20 September 2022
Accepted: 27 October 2022
Published: 30 October 2022

1. Introduction

One of the main challenges of the COVID-19 pandemic (2020–2022) was the social distancing rules that forced people to study and work from home, mostly in isolation. The majority of interactions between people took place online through video-conferencing tools such as Zoom, which, despite its effectiveness in allowing people to communicate for educational and work purposes, had a drawback that some have referred to as Zoom fatigue [1]. This fatigue resulted in an increase in the demand for reduced digital distances between people, as well as for richer visual environments for online communications, which emerging technologies, including extended reality (XR), promise to achieve [2]. XR, also referred to as cross-reality (CR), includes a number of immersive technologies, such as Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR) and any other future realities that may emerge. AR provides an of experience the real environment with an overlay of computer-generated data. Two examples of AR devices are Microsoft's HoloLens and Magic Leap. However, most users experience AR through the cameras on their smartphones or tablets. In terms of VR, it encapsulates a user in a fully simulated environment that replaces the real physical world. Using VR devices like the HTC VIVE, Oculus Quest, or even a simpler form via mobile phones with Google's Cardboard, users can experience, view, interact and move around virtual artificial worlds. Moreover, 360° media, which consists of 360° images and videos, can also be viewed in VR and are often used by developers to provide immersive content. As for MR, it provides an integration of real and virtual environments using tools such as Microsoft's HoloLens, hence the user can interact with physical and digital objects in the real world. Figure 1 below shows those realities in relation to the real environment as described by Paul Milgram and Fumio Kishino [3].

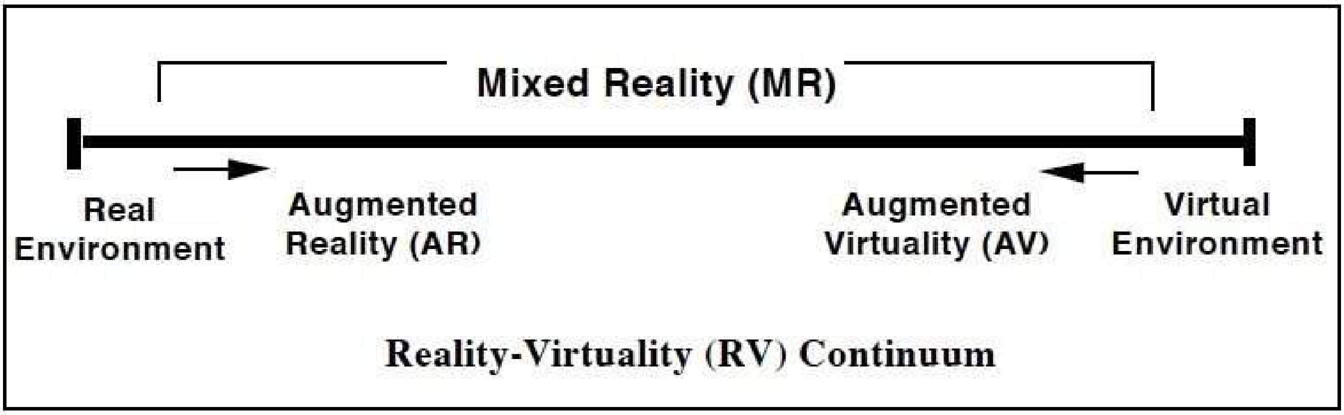

Figure 1. Reality–Virtuality [3].

In terms of the level or degree of immersion offered by XR technologies, there are three types [4]: fully immersive, semi-immersive and non-immersive. Fully immersive content requires special devices, such as VR HMDs (Head-Mounted Displays), that allow users to be part of the virtual environment by cutting out all outside information. On the other hand, non-immersive content does not require any special devices to interact with the user; it uses mobile and desktop screens and is considered the lowest type of immersion. Finally, semi-immersive falls between the two types; it uses a real environment or equipment that is compatible with and connected to a desktop screen to increase the level of immersion without cutting out all outside information.

The market for XR is expected to reach USD 397.81 billion by 2026 [5]. One of the sectors in which XR is expected to show rapid growth in the next few years is the education sector. Over the last decade, a number of studies have shown that these virtual tools and platforms can greatly enhance learning experiences [6–14]. It has also been used during the pandemic to aid language learners during the lockdown, with no possibility of practicing their speaking skills in the real world [15]. Moreover, they have been used to teach learners with special needs how to deal with issues both in and out of the classroom. One example is using VR to help autistic children learn vital life skills, such as how to cross a street [16].

Authoring rich, interactive educational content, such as adaptive or intelligent learning systems, has always had its challenges [17]. Moreover, those systems have interoperability issues [18] and, hence, remain an area of active research. As with other rich, interactive, intelligent educational content, XR educational content can be challenging to develop. VR requires intensive graphics capabilities to achieve smooth implementation and worth [19]. Many teachers have stated that they face limited availability of instructional designs when it comes to applying VR/AR content in the classroom. This refers to the limited materials offered in VR/AR with no guarantees that these materials would suit the students' learning goals [20]. Moreover, the interoperability of VR content across platforms is also hard to achieve, and, hence, VR is often delivered as a proprietary solution [19], that is created or owned by an organisation or an individual.

The cost, management/administration agreements, support and complex content creation process—which includes equipment, maintenance and staffing—of XR have been listed as the top concerns of small- to medium-sized public institutions looking to deploy educational VR [21]. The main challenge that has been highlighted by teachers is the lack of financial resources to purchase the necessary VR hardware and software [22]. Cost being a major barrier in this area was echoed by another study [23], which pointed out that this obstacle must be overcome to experience an extensive application of VR in the educational field. The high cost of design and implementation, in particular, does slow down the process of using these XR tools for learning purposes.

Teachers and educators who are eager to try new technologies in the classroom and who have learned about the potential benefits of VR or AR are faced with a challenging task: where to start? What tools to use? What platforms could they subscribe to? How long would it take? How much would it cost? Provided that this is a solo effort, as it often is, the task becomes overwhelming to the extent that it might result in dismissing their attempts to experiment with XR technologies. Therefore, this paper aims to provide a roadmap that would help pave the way for the adoption of these emerging technologies. It provides an overview of the approaches available to institutions and individual educators who would like to provide a form of immersive learning experience to their learners. Learning institutions vary in size, population, financial and technical resources, infrastructure, management mindset and flexibility. Moreover, they vary in the level of immersion they would like to apply or achieve. Each available approach has both advantages and disadvantages; for example, one option might be cost-effective but has a steep learning curve or would require extended periods of time to develop. Hence, there might not be one single solution or development approach to create or acquire an XR learning system that would suit the needs of all. Nevertheless, showing what possibilities are available would help educators choose what best serves their requirements.

The paper proceeds as follows: the Section 2 gives a brief background to the XR development cycle. It is followed by Section 3 which reviews relevant studies from the literature. After that, Section 4 presents the research methodology. In Section 5, the results are described. Section 6 discusses the factors that need to be taken into consideration in order to determine the most suitable approach, and finally, Section 7 concludes this paper.

2. Extended Reality System and Development Cycles

2.1. An Extended Reality System

An extended reality system consists of the application, interaction, processing and rendering and feedback, as seen in Figure 2 [24].

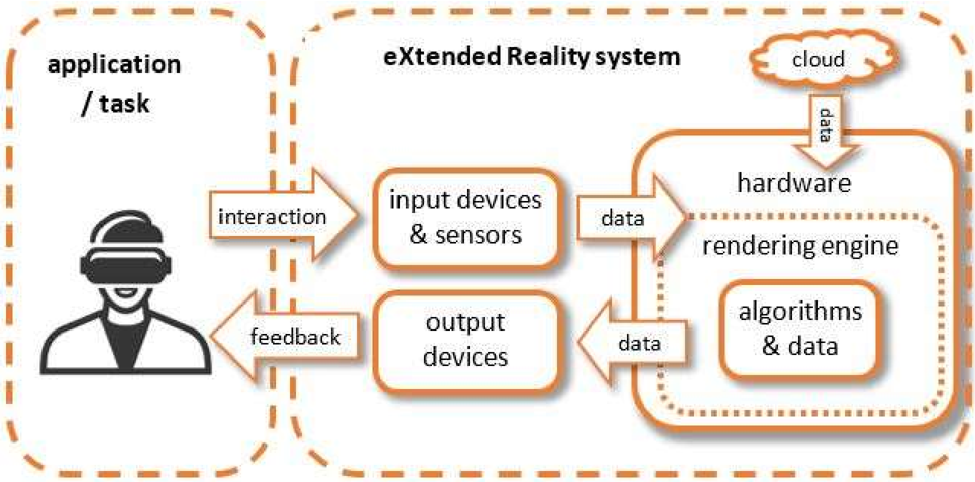

Figure 2. Major Components of an Extended Reality System [24].

The XR system can include many different applications, such as social, medical, educational and cultural, and can also involve themes around advertising, entertainment, the military, tourism and heritage. When using this application, the user will be presented with a scene and will then interact with it. His or her interaction is captured via a range of visual, audio, or motion input devices and sensors.

The data from this interaction will be passed as input (in addition to other data from the environment if necessary) to the XR hardware devices, where further processing and rendering will be applied to create the desired output. The rendered scene(s) will be delivered as feedback to the user.

2.2. XR Development and 3D Modelling

In general, software creation is a skill that requires time and dedication to master. Software development becomes even more challenging when XR applications and platforms are to be created, as they can be as complex to create as a movie, involving directing actors, scenes and stories. XR content needs to be designed and developed to produce an experience that is safe and accessible and fulfils the needs of all intended users. In VR, the user is in a completely virtual environment that may not relate to the physical world in which they live. On the other hand, in AR, the physical environment needs to be read and then meaningfully augmented with virtual content.

The development of XR content involves the following:

1. Creating 3D models and animations as well as adding lights and shadows, then ground and align all these objects around physics, spatial sound, menus and heads-up displays.
2. Designing implicit and/or explicit interactions between the user and the physical environment (as in the case of AR) or virtual environment (as in the case of VR).
3. Adapting to a number of different output devices and platforms: desktops, mobile devices (smartphones and tablets), VR headsets, such as Meta's Oculus (Go, Rift and Quest) and HTC Vive, or AR headsets, such as Microsoft's HoloLens and Magic Leap.
4. Additional requirements, including social, legal and ethical concerns, health and safety, accessibility and equity, as well as security and privacy, need to be taken into account.

Designing for XR applications is a complex task that requires knowledge from multiple disciplines in terms of interaction design, user experience, programming and content creation. This complexity increases for educational XR, as it requires additional competencies in learning objectives because the activities designed need to fit the objectives that are to be achieved [25].

3. Literature Review

As mentioned earlier, many studies have indicated XR technologies' potential benefits in education, whether it is by applying AR [26], MR [27], or VR [28]. However, the presence of these technologies in mainstream education remains limited, with many challenges reported [19–21,23]. One of the main challenges is creating or acquiring XR educational content. Authoring 3D content is a major component in all XR systems, and although it might have become easier, it is still not easy enough for fast production by faculty and teachers [29]. Some teachers have stated that they would face limited instructional design when it comes to applying VR/AR content in the classroom [20]. XR application developers need professional skills for content generation, full immersion, interactivity, programming and implementation [30]. There is still a demand for AR development tools that empower instructors to create AR experiences without technical backgrounds as designing AR applications remains a complicated and time-consuming task for beginners [31]. Creating an XR lesson requires technical skills and pedagogical storytelling that are most probably challenging for the majority of teachers and educators [32]. Moreover, XR educational software usability is another challenge that has been highlighted in the literature alongside the cost of XR [33]. Therefore, despite years of XR technologies being introduced in education, they have not gained widespread use in schools due to challenges related to pedagogical content, expertise, digital infrastructure, funding, and a lack of universal design [34].

Educators who want to venture into applying XR technologies in education might not know where and how to begin. They might not realise what is available in order to start experimenting with these immersive technologies. Indeed, there are plenty of resources in terms of tools, platforms and applications, in addition to many academic and non-academic articles, reports and reviews, but educators who are often struggling with the high demands of their jobs within a limited time frame would most likely find it difficult to find the right direction to follow. There have been many studies and reviews of the educational use of XR technologies in the literature, but the majority, if not all, are not set out to show what different approaches are available to create XR educational materials by the average teacher. For example, the research presented by Luo et al. [35] provides a literature analysis that emphasised four interrelated aspects of VR-based instruction: instructional context, instructional design, technological affordances and research findings. Although it provides good findings for teachers and developers alike, it does not review the actual technical tools used for content creation. Another study [36] evaluated seven aspects of the immersive learning experiences including the educational field, type of immersive technology, role of technology in education, pedagogical strategies, interaction techniques, evaluation methods and challenges. It stated that most studies, including 42 reviewed papers, presented programming tools and development platforms in addition to 3D creation modelling tools, which are only accessible to programmers and developers. Furthermore, it mentioned a few commercial tools which tend to be limited to creating immersive 360-degree videos.

Medicine is one of the domains where researchers have experimented with XR technologies for a considerable period of time, hence some mature solutions have emerged. Research presented in [37] reviews a number of virtual and augmented reality applications for biomedical science. It lists three types of biomedical educational applications, with a focus on cost and complexity, presenting the software, hardware and platform, for each category. These categories are the low-cost or no-cost solutions that were created through development platforms such as unity, the prosumer solutions and commercial solutions. It gives a good insight to educators who want to integrate XR technologies in the teaching and learning process in higher education. However, it is limited to the biomedical domain. Moreover, a non-systematic literature assessment has been conducted in order to provide a better understanding of the current extended reality (XR) modalities in another medical domain which is cardiothoracic surgery [38]. It presented the three areas of cardiothoracic surgery: preoperative planning, intraoperative guidance, postoperative management, and explained which XR technology (AR, VR, or MR) was used in relation to certain topics under each of those areas. Nevertheless, there was no review of how the educational content was created.

An additional study [39] reviewed the VR market for educational and training across several domains between 2019–2021 through the online store of one of the main players of the VR HMD, Oculus. The results showed that more than half of the available applications are available free of charge, mostly in English, and the best rated applications came from the nature, space, medicine, art and history domains. The study, however, did not review any development tools or platforms. On the other hand, the study presented by Dengel et al. [40] reviews AR authoring toolkits for education, it identified “easy access”, “GUI-based design”, and “interactive contents” as needs of teachers for designing AR content for the classroom. The results listed five toolkits that address the need for teachers for designing interactive AR learning experiences without the need for extensive programming knowledge. These toolkits still involved teachers developing their content from scratch either by coding using the available 3D models, or by using a minimal coding drop and drop toolkits.

The following studies [30,33,41,42] have also reviewed the use of XR technologies in education, however, none of them show the various educational content development approaches or draw a comparison between them.

It can be concluded that most reviews in the literature focus on other aspects of XR in education than content creation approaches. They mostly compare case studies in terms of their learning impact or outcomes, the learning domain, the teaching and learning strategies, the study level, or the hardware involved (output devices). Whenever the development tool, software, or platform is described, they provide details regarding that certain tool. There are limited studies, if any, that provide an overview of the various possible approaches rather than a single tool or technology. Therefore, this paper aims to bridge this gap by providing a twofold solution: (1) explaining the different approaches to creating an XR learning experience that is available for teachers at the start of their XR journey, highlighting the advantages and disadvantages of each approach, and (2) describing a number of programming languages, development tools, market platforms and applications under each approach, listing examples of how each approach has been applied, when available. Nevertheless, the educational instructional design and user experience aspects of this process is another task that educators will have to carefully consider, and which is out of the scope of this paper, although selecting a readily available educational market solution would most likely address this matter.

4. Research Methodology

4.1. Research Questions

This research aims to provide a non-systematic overview of the current approaches for creating XR learning experiences. This paper addresses the following questions:

1. What are the available software tools, platforms and applications that educators can utilise when looking to introduce XR learning experiences into the classroom?
2. What factors need to be considered before selecting one of these options?

In order to address these two questions, an extensive search has been conducted as will be described in the subsequent sections.

4.2. Search Process

The search for the different available tools and approaches to create an immersive XR learning experience involved searching three different types of databases and repositories: academic/research databases, educational as well as technical reports, articles and websites. Applications' stores will also be described.

4.3. Inclusion Criteria

The search criteria applied through the search process are as follows:

- The platform, tool, application, or learning content has to be related to AR, VR, or MR.
- The platform, tool, application, or learning content has to be either used within an educational context or could be utilised for educational purposes. Training, such as in post-secondary education, has also been considered.
- The platform, tool, application, or learning content has to have an English interface, in order to be accessible to a wider range of users.
- The platform, tool, application, or learning content can have any degree of immersion: fully immersive, semi-immersive, or non-immersive.

4.4. Research/Academic Databases

The starting point was to look into the latest research activities in this area, to learn what approaches have they followed and what possible tools have been applied. This would highlight tools and platforms that have been used and are mostly validated through empirical studies. This search was conducted using the following databases: Google Scholar, IEEE Xplore, Springer Link, ACM Library and Science Direct. The focus was on finding empirical experiments and case studies where XR technologies have been used within a learning or training context.

The majority of research projects that have applied VR or AR in an educational setting have used proprietary software that has been developed by the research team using common programming platforms. This is understandable, as research experiments would have predefined constraints and would most likely want to test or evaluate a certain aspect of the learning content or experience. There is a great need to be in control and hence developing their own solution would be the better-suited approach here. However, some other research projects opted to use over-the-shelf market solutions. This could be either to save time and effort or simply because the goal was to test that particular XR environment within an educational context.

4.5. Technical and Educational Reports, Articles and Websites

The results of the first approach were mostly developed by the researchers as mentioned earlier, hence in order to find other available tools, there was a need to search other educational resources, which are neither research nor academic resources but which, nevertheless, served educational purposes. These included online reports and articles as well as websites dedicated to teaching and learning. To find those resources, multiple Google searches were performed, which yielded either resources that reviewed a number of XR educational tools or presented the platforms' websites.

4.6. App Stores

Many immersive experiences involve the use of portable devices, with the majority running on Apple's iOS or Android platforms, or on the higher-end VR headsets such as Meta's Oculus. Therefore, searches for educational tools and content were performed using Apple's App Store, Google's Play Store and Oculus's Quest Store.

4.7. Data Analysis

As a result of the aforementioned search process, a number of themes and options emerged from the analyses of information taken from websites, technical articles, journal articles, reports and mobile apps related to the use of XR technologies in education between the autumn of 2021 and the spring of 2022.

This research followed an inductive approach where the data determine our themes or approaches. Hence, the objective was not to list all the tools or platforms under a given approach but rather to give enough examples for a better understanding of each one. Therefore, there are likely other programming toolkits, development tools and platforms that are not mentioned in this paper.

5. Results

5.1. Programming Platforms

Educators with solid technical backgrounds, such as computer scientists or game developers, might want to venture into XR using their own applications. This is also the case for those who have access to technical development resources onsite. In either case, developers would most probably use game development engines, such as Unity and Unreal, or web applications development platforms, such as WebXR.

This approach might be time-consuming, but it allows for more control and flexibility over the system and would most likely be cost-effective compared to other approaches. However, it has been widely reported that developing XR applications from scratch has a steep learning curve, similar to developing games in general and creating 3D models, as said by [43]: "The cost of Unity is its complexity". Below is a list of the three most popular tools for software developers who want to venture into XR.

Unity [44] is a cross-platform game engine with a built-in integrated development environment (IDE) developed by Unity. Traditionally, it has been used for developing digital games for web plug-ins, desktop platforms and mobile devices. It is also used for developing VR, AR and MR applications and platforms. For example, Maroon [45] is a Unity-built interactive physics laboratory and experiment environment designed to teach physics in an immersive and engaging way.

Unreal Engine (UE) [46] is a game engine used for developing interactive digital games; it is capable of creating immersive worlds that cater to the VR experience. An educational research project developed using UE is presented in [47].

WebXR [48] is a group of standards used together to support the rendering of 3D scenes on hardware designed to present virtual worlds (VR) or to add graphic images to the real world (AR). Examples of WebXR frameworks are *A-Frame*, *Three.js*, *Babylon.js* and *PlayCanvas*. An example of an educational project developed using WebXR technologies is found in [49].

Google ARCore [50] is a software development kit developed by Google that allows for AR applications to be built using a set of application programming interfaces and extensions. It works with Unity, Unreal, Android and iOS platforms.

Apple ARKit [51] is Apple's equivalent of Google's AR development kit for iOS devices.

5.2. Development Tools and Platforms (Minimal Coding)

This is an approach that could be used by educators with some IT skills or even by experienced programmers who are looking for a shorter development cycle. This approach allows users to develop their own XR applications and preserve full control of the flexibility of their XR educational system. These types of software tools and platforms were developed to cater to novice users with minimal or no coding skills. The development process usually consists of drag-and-drop activities or inserting or modifying a very limited number of code lines. Many of them, however, require good design skills in terms of usability and user acceptance. As a result of the limited coding, they might provide more limited functionality and options compared to the previous approach of building the XR experience from scratch. Nevertheless, they do allow educators to overcome the programming learning curve, such as in the case of Unity, and hence preserve time and effort. Many view this option as a good starting point for anyone who wants to venture into XR development. Examples are presented below.

XR. + [52] is an AR studio that allows users to create AR applications without any coding. It has a number of pricing options as well as a free version with limited capacity and features. All examples presented on the provider's website are from the business and advertisement sectors. However, XR. + can also be used to build educational XR applications.

PlugXR [53] is a cloud-based AR platform for creating and publishing advanced AR applications and experiences. It has a number of pricing options as well as a free version with limited capacity and features. One example that illustrates its usage in creating an educational experience is that of the periodic table [54].

Adobe Aero [55] is an AR authoring and publishing tool by Adobe. It is currently available for iOS, but there are versions for MacOS and Windows. It requires no coding and allows designers to see immediate results in real time. It is available free of charge.

Amazon Sumerian [56] is a VR engine from Amazon Web Services; users are not required to have 3D graphics skills or VR programming skills to use it. Sumerian works with all popular VR platforms and offers a 12-month free tier to help users start using the platform.

InstaVR [57] is an interactive VR authoring tool that allows users to rapidly make interactive 360° image/video-based VR experiences. It is web browser-based and requires no coding; development is, rather, achieved through drag-and-drop activities. It allows the products to be packaged into different formats to be viewed on different output devices ranging from desktop/mobile browsers, Android and iOS devices, Cardboards, Oculus VR headsets and VIVE VR headsets. Examples of educational customers, as listed on its website, include the University of South Wales and the University of Birmingham. It offers a limited free version alongside other paid option.

Smart VR Lab CMS [58] is a content management system for VR devices. Smart VR Lab provides an easy solution for uploading and managing VR apps, 360° videos and 360° photos on VR devices. It gives access to a rich digital library of content and enables users to share content as well. It produces software applications that can run on multiple output devices. It provides a one-month free trial, followed by a few paid options.

CoSpaces Edu [59] is a child-friendly creation application that allows users to easily create their own virtual content. It can work on a website inside a browser and as a mobile or tablet application. CoSpaces Edu enables learners to build, code and explore their own creations in VR or AR while learning essential digital skills. Creating in CoSpaces Edu involves a drag-and-drop process using a variety of creative features, including a 3D object, building blocks, multimedia upload and block-based coding. It has a visual block-based coding language known as *CoBlocks*. This platform is focused on making children contribute to creating VR worlds rather than being on the receiving end. It has two main plans. The free basic plan comes with basic features, and the pro plan offers a wide selection of annual payments depending on the number of users.

Enduvo [60] is an online learning platform that allows users to create and share immersive training experiences anytime and anywhere. It applies a no-code approach to authoring and delivering AR/VR learning content that can be shared and accessed through VR headsets or on PCs, laptops, or tablets. It provides three plans: basic (free), standard and extra.

5.3. Subscribing to Educational XR Environments

An educational institution or an individual teacher/college professor might want to have a readily available solution that requires no or minimal configuration effort when it comes to deploying XR in the classroom. They would look for a solution that is ready and easy to use, similar to what they have been experiencing for the last 20+ years with learning management systems (LMS). In this case, the following available immersive learning environments might suit their needs, but the financial cost might be more affordable to some than others. Another downside is that those platforms might not be customisable to the desired extent in order to meet students' needs or learning objectives. Examples are described below.

Virbela [61] is a virtual office or cloud-based platform that connects teams in one online space. It could be used for creating private worlds or event spaces. Hence, it is possible to create an educational platform or an online school, college, or a complete 3D university campus. It can also be educational and research events such as conferences; for example, Virbela was used to host the virtual format of the IEEE VR 2022 [62]. It offers free trials as well as paid solutions. Virbela seems to be popular among academic researchers, as it has been used in a number of studies [63–65].

Kai XR [66] introduces itself as a platform "built by educators for educators." Kai XR's digital learning platform leverages 360° virtual field trips, allowing children to explore the world from the classroom. Kai XR virtual field trips are diverse 360°/VR content highlighting locations around the world; it aims to create child-friendly immersive content. The platform is built on four main principles: safety, education, inclusion and engagement. It follows VR standards and regulations that VR headsets should only be used by children 13 and above. Therefore, it recommends the use of Kai XR's Exploration Mode for younger children. This mode will give them a non-immersive and safe pathway to VR. The platform can be accessed using a wide range of devices such as smart TVs, tablets, smartphones, laptops, desktops, or the all-in-one VR headsets, such as Oculus Quest. Similar to other platforms, in addition to a short free-trial period, it offers paid options that vary according to the number of users and frequency of payment.

5.4. Subscribing to Educational Discipline-Specific XR Environments (Medicine)

At higher education levels in particular, some disciplines or fields of study, such as medicine, dentistry and nursing, have been experimenting and applying XR in their teaching and learning processes for some time. This has resulted in a market that offers both mature products as well as research solutions. Such solutions might be more desirable by educators in those fields as they will be more aligned with the learning objectives or expected outcomes. A number of examples are listed and explained below.

UbiSim [67] (nursing) is a platform that claims to be the world's first immersive VR training platform for nurses. It has a completely virtual simulation lab that allows students to be immersed in an environment where they can interact with lifelike patients. It aims to help them better engage with patients and improve their clinical reasoning, decision-making and communication skills. It consists of many possible scenarios where nursing students, either individually or in groups, can learn about real-life situations such as emergencies, child care and pregnancy. It requires a subscription.

PeriopSim VR [68] (surgery) has been developed in collaboration with different types of medical professionals to ensure accuracy and realistic outcomes. It wants to bridge the gap between the classroom and the operation room. Its portal allows educators to create, manage and track learners' understanding as well as assign them simulation work and monitor their competency. This solution has two versions: one is a simulation accessed through computers, laptops and mobile devices, while the other is a VR simulation version. It provides a free demo, but it is a paid solution.

OSSO VR [69] (surgery) is a surgical training and assessment platform that allows medical device companies and healthcare professionals to share, practise and learn new surgical skills and procedures. This platform focuses on training rather than learning and on professionals rather than new medical students. However, it can be tailored to different needs and might be of great use in postgraduate training as well.

Oxford Medical Simulation [70] (medical and nursing) delivers medical and nursing VR simulations that can be utilised for teaching and training purposes. The content can be accessed using either VR headsets or standard computers. It applies a learner-centred approach where learners can learn how to care for unwell patients, collaborate with colleagues and engage with other interdisciplinary teams in scenarios that simulate real-life situations. The listed solutions that this platform provides include nursing simulation, medical simulation, interprofessional simulation, skills and procedures, mental health simulation, paediatric simulation, distance learning and assessment. The website lists a number of reputable universities that use this platform, such as Oxford University, Manchester University, Sheffield Hallam University and Edinburgh University, among others.

5.5. Subscribing to Non-Educational XR Environments

Similar to the XR learning environments mentioned in the two previous sections, this section lists a number of ready XR environments (mainly VR) that offer subscriptions. However, the main difference is that these environments were not solely created for educational purposes but could still be adapted by educators to suit learners' needs. However, it seems that their functionality and usability have made them popular among educators and academic researchers that they have chosen them over purposely-built educational XR platforms.

Engage [71] is a spatial network solution that lets users play the role of a first-person human character in any given environment such as education, military, business or entertainment. Engage can be deployed as a trainee simulator, a role-player station, an instructor aid, a desktop simulation game, or a VR headset experience. It offers *MetaWorlds*, which are virtual-persistent locations that can be tailored to customers' needs. They can also be connected to create what is known as *Engage Oasis*. Similar to other virtual platforms on the market, Engage offers a range of price plans to suit different requirements. The platform also provides a free guest account that allows the user to explore and attend events in this metaverse world. Moreover, a guest can host a room with a maximum of four guests and has access to demo creation tools.

AltspaceVR [72] has been acquired by Microsoft. It is a virtual space that allows users to attend live events, meetups, and more with other users for free, regardless of geographical location. It can be used with a number of VR headsets, such as HTC VIVE, Oculus Quest and Windows Mixed Reality. Moreover, a user can access the 2D mode on a PC/Mac to receive a feel for a social VR experience without a headset. A number of studies have shown how AltspaceVR can be utilised for educational and training purposes [73–75].

Spatial [76] is an AR/VR collaboration platform that turns any room into a 3D workspace as it offers customisable 3D spaces. Users can join from the web, mobile, and VR devices. It offers both free and paid plans.

Mozilla Hubs [77] is a virtual place where users can meet with friends online in a virtual social space. Users can create a virtual 3D space and invite others to join them using a URL. Hubs is a VR chatroom designed for a wide range of headsets and browsers. It was also designed with the aim of preserving privacy in mixed reality (MR) and allowing for scalability. Moreover, this platform is free; anyone who is interested in hosting an event can create a private room and invite others to join. This feature has resulted in the wide use of Mozilla for educational and research papers, as can be found in the following studies [78–81].

5.6. Complete XR Solutions

Some learning institutions might want to go a step further and purchase a complete hardware and software XR educational package that can be deployed immediately in the classroom. As both the hardware and software were provided together, they will be easily set up; headsets would be preloaded with educational content. However, the cost is expected to be considerably higher and user scalability might be an issue as the number of headsets are predefined at the time of purchase. Below are some examples of companies that provide complete XR educational packages.

ClassVR [82]: ClassVR is a full-service immersive educational platform from educational technology provider Avantis. It includes both the hardware (VR headsets) and a library of curriculum-aligned immersive educational content, which teachers can control from a centralised management system on a single computer. The XR learning content is known as *Avanti's World* [83]. Avanti's World, which could also be accessed or purchased without VR headsets, is a virtual learning platform that allows students to explore hundreds of educational VR experiences, all in one theme park. The park contains six educational virtual reality *lands*, covering different areas of the educational curriculum. Avanti's World offers a free teacher pass that allows teachers to a one-ticket park (a teacher can set up an account to view a selection of showcases for free), and limited park access (lifetime free access to limited activities, quizzes and assignments). In addition, this limited pass provides community support to any user. Paid subscriptions include an individual classroom pass as well as a multiclass room pass. Avanti's World provides a full VR solution for those wishing to provide VR learning experiences in school in addition to LMS-like management solutions, including student management, progress tracking, marking and grading and comprehensive reporting. The three most important Avanti's World features are: (1) it supports classroom, hybrid, or remote teaching and learning; (2) it allows access from any VR device: a ClassVR headset, a laptop, tablet, or a mobile phone; and (3) it provides flexibility in the way the lesson is delivered. Students can experience Avanti's World alone (solo) or within a group (share). Moreover, teachers can set up the environment in a way that allows guided learning (focused and controlled by the teacher) or explorable learning (students are free to explore the learning environment as they like).

zSpace [84] is a combined AR/VR software and hardware solution for immersive and interactive learning experiences. Students can view virtual models in 3D using a special lightweight glass, examine those models in detail and manipulate them using a stylus pen. It provides educational content on a variety of subjects, including across multiple educational levels such as in STEM (science, technology, engineering and mathematics) and STEAM (science, technology, engineering, the arts and mathematics), from K-8 and American high school's math, science, biology, physics and chemistry, as well as subjects relating to careers and technical education, such as health science, manufacturing and agriculture. It provides a number of hardware and software products that can be purchased and customised by a learning institute. Research work that involves using zSpace experiences is found in [85].

VictoryXR [86] states its goal is to build the education metaverse. Its website claims to have created over 240 VR experiences spanning over 50 different learning units. It provides a number of AR/VR solutions for K-12, which vary in contracts and prices; a number of bundles include selling the hardware headsets pre-loaded with their curricula, and other solutions only provide the XR software products, such as the VR STEAM simulation labs (for example, the cadaver lab, chemistry labs and art rooms). Some solutions offer both synchronous and asynchronous learning experiences.

5.7. Educational XR Mobile Applications and XR Educational Content

Many developers of educational XR apps have made them available to download via Apple's App Store or Google's Play Store. Examples are Human Anatomy Atlas (AR), Catchy Words (AR) and Ancient Egypt (VR). Moreover, many VR headset vendors, like Oculus Quest, have a number of educational VR applications that can be purchased through their own platforms, such as Mondly (languages), Star Chart (space) and Painting VR (the arts).

Given the popularity of both STEM and STEAM approaches to education, a number of well-known cultural and scientific institutes have realised the importance of XR in engaging audience minds and attracting young people to the arts and science, and have been offering rich XR content for free to the public. Examples include the Smithsonian, NASA, BBC, National Geographic and Google Art & Culture. Accessing such content has been made as simple and affordable as possible through desktops, smartphones and tablets, as well as high-end VR headsets. If an educator or a learning institute does not have the means to provide a fully immersive learning environment, their learners can still be offered a taste of XR by integrating freely available high-quality XR educational content into their lesson plans or lectures.

This is the cheapest and easiest approach in terms of both software or hardware as it requires no technical expertise and can be accessed from a web browser with minimal or no cost. A study that reviewed VR educational and training applications in the Oculus store has found that more than half of the applications were available free of charge [1]. However, it is more likely to have limited functionality and alignment with learning objectives. The following table summarises the main advantages and disadvantages of each of the aforementioned approaches.

6. Discussion

Once the decision has been made by educators to provide XR educational experiences to students, two main questions will arise: which XR learning content creation or acquiring approaches are available? Which approach should be used to create an immersive learning environment that suits our needs?

The results section has provided answers to the first question. A number of options that vary in time, effort and cost as shown in Table 1, exist. They include creating your own solution, subscribing to an educational or non-educational market XR platform, or downloading an application from a digital store.

As for the second question, selecting a certain approach depends on a number of factors that should be considered. These factors are technical expertise, time, budget, scalability, level of control, configuration and maintenance, availability of suitable XR learning content, pedagogical alignment, security and privacy, output tools and finally the degree of immersion that is to be achieved. These factors are described in detail in the sections below:

1. Technical Expertise: How technical are the team members? How fast could they learn a new programming language or navigate a new developing environment? If the answers are positive and the technical aspects are not of great concern, then developing a proprietary immersive learning solution using popular vendor-independent game engines, such as Unity, might be the best option. This approach would allow for a great degree of flexibility and control, leading to the creation of a learning environment that satisfies students' needs, learning goals as well as cultural aspects. However, if an educator faces a shortage of technical skills but still wants to develop a proprietary XR application, then XR development platforms that require minimal coding, such as XRplus for AR or InstaVR for VR, can be chosen if there is a will to compromise on some of the more advanced features.
2. Time: How quickly is this immersive learning environment needed? Starting XR development from scratch will usually take longer than subscribing to an off-the-shelf market solution. If time is an important factor in terms of wanting to start

experimenting with XR technologies in the classroom, then subscribing to Virbela, for example, might be the best option here.

3. Budget: How much is management willing to invest in creating an immersive learning environment? Would creating an in-house solution be cheaper than subscribing to a readily available solution? Educational institutes differ in size, funding, geographical location and technical and management support. A small primary school in a rural area will most likely have fewer options than a well-funded private academy in the capital. Learners in both situations can still enjoy and benefit from XR learning environments while using different tools and approaches.
4. Scalability (number of participants): Some of the off-the-shelf market platforms charge customers per user or classroom. Therefore, scalability could increase the cost of the subscription. Moreover, some options might have a maximum capacity of users that cannot be exceeded or upgraded even with a higher budget.
5. Level of Control: There is always a trade-off when using an off-the-shelf solution in comparison to developing an in-house system. Using an available immersive XR learning environment might take only a few minutes, hours, days, or a couple of weeks to have it set up and available for use. However, it might come with limited features and less control over the learning environment. On the other hand, creating your own solution would require weeks, months, or perhaps a year to develop and needs to be planned well ahead to allow for the software's full development and testing cycle.
6. Configuration and Maintenance: Buying a product or subscribing to a service or platform comes with a full package, which includes continuous maintenance and support. These products have been through rigorous cycles of testing, bug fixing and upgrades. They are deployed on multiple servers and have backups. Hence, there are fewer concerns about technical issues and future upgrades.
7. Availability of Suitable XR Learning Content: The majority of international companies that provide XR learning content are based in English-speaking countries: the United States, the United Kingdom, Canada, Australia and New Zealand. Most of the available learning XR content is in English or a few European languages such as French or German. This makes the content, app, or system only accessible to learners, especially school pupils, in English-speaking countries or to international schools that follow an English-speaking curriculum. A recent study [39] that analysed the VR market for educational and training applications found that in 2021 there have been 233 VR applications in English, followed by 21 in French and 20 in Spanish. On the other hand, there were only four applications in Arabic and three in Turkish. Therefore, if you need XR content that is not in English, you will most probably have to develop it in-house through one of the first two approaches.
8. Pedagogical Alignment: One of the most difficult aspects of introducing any new technology to the classroom is how to align it with the existing curriculum. How do you make sure that applying VR or AR is going to yield the desired learning outcome? Designing the educational element of the software requires a great depth of knowledge of the subject matter in addition to software design and development. In this case, designing the product from scratch would put the instructor in charge of this important aspect during development. This also applies, to a certain extent, when subscribing to an XR platform that was intended for educational purposes, as learning and education were part of its core design and not a new feature or plug-in that was added as an afterthought, especially if this XR educational platform was created for your certain domain, such as medicine.
9. Security and Privacy: Educational systems are full of sensitive personal data that needs to be adequately secured to maintain users' privacy on the one hand and prevent any tampering (exam marks or progress assessment) on the other. Most market solutions provide security and privacy restrictions that be controlled by the educator or institute. Moreover, immersive platforms collect enormous amounts of

personal and behavioural data [87], which results in more privacy concerns regarding who owns the data and how it can be used. If subscribing to a market solution, these aspects need to be clear.

10. Output tools: The selected option, specifically when subscribing to readily available XR learning solutions, has to be compatible with the output channels/headsets available to the students.
11. Degree of Immersion: Achieving a fully immersive learning experience requires the use of more advanced tools such as VR Oculus headsets. On the other hand, non-immersive experiences can be completed using desktops that are most likely available in most schools' computer labs.

Table 1. The main advantages and disadvantages of each of XR Educational Creation Approaches.

XR Content Development Approach	Example	Pros	Cons
Programming Platforms	Unity	• Allows more control and flexibility over the system • System design meets requirement and learning goals • Cost-effective	• Time Consuming • Steep Learning Curve • Requires advanced IT, programming and designing skills • Maintenance • Limited/No interoperability
Development Tools and Platforms (Minimal Coding)	InstaVR	• Shorter development cycle • Some control and flexibility • Design meets requirement • Mostly drag-and-drop	• Requires good design skills • Limited functionality and options • Maintenance
Subscription to Educational Platforms	Virbela	• No technical expertise required • Designed for learning purposes • No/minimal configuration required • Maintenance	• Financial Cost • Less flexibility than developing your own solution
Subscription to Non-Educational Platforms	Engage	• No technical expertise required • No or minimal configuration • Maintenance	• Financial Cost • Less flexibility than developing your own solution • Not purposely created for education
Complete XR Solution	ClassVR and Avanti's World	• No technical expertise required • No or minimal configuration • Maintenance • Fully immersed and integrated • Preloaded learning content	• High cost • Predefined number of users according to number of headsets (scalability)
XR Learning Apps and Educational Content	Catchy Words, NASA	• No technical expertise required • No configuration required • Minimal or no cost • Automatic fixes and updates	• Limited functionality and alignment with learning objectives

Prior to making a selection, educators and learning institutes are advised to take into consideration all those factors and assess their current situation in order to make an informed decision.

7. Conclusions

XR has shown great promise in improving teaching and learning methods, particularly in a post-COVID-19 world, where there has been a wide application and acceptance of technology in learning, even in less privileged countries and societies. As was mentioned in previous sections of this paper, many empirical studies have reported XR's positive impact on education across various subjects and at different levels of study, including both K-12 and higher education. However, authoring XR learning content is not an easy task; creating 3D models and providing an immersive learning experience is a complex process.

There is not a single path to follow when it comes to creating immersive learning environments using XR technologies. Many options, most of which were inspected and reported in this paper, are available, from creating one's own proprietary solution that would allow for flexibility but has a steep learning curve and requires a longer time to develop to compromising on flexibility in favour of the time by choosing development platforms that require minimal or no coding. On the other hand, XR off-the-shelf market solutions are available for a subscription, with some specifically tailored for learning and training (generic as well as discipline-specific), while others were created for generic XR uses but can still be tailored for educational purposes. These solutions mostly provide full packages, including setting up, maintenance and technical support. However, they come with costs that not all teachers, instructors, or educational institutes can afford. Hence, many teachers who are eager to use VR or AR in the classroom might end up resorting to the easiest and cheapest option, which is to download freely available applications or tools, of which most are available in Android or Apple stores. However, as these are very generic apps and tools, they might not align well with the curriculum in terms of goals or learners' language.

This paper believes in the value of XR in education while realising the hurdles blocking these emerging technologies from being part of mainstream educational tools. It recognises that with educational XR, the challenges faced by educators come from multiple perspectives: technical, educational and social. Therefore, it presents varied available solutions that would allow institutions to choose a suitable route, with, hopefully, few technical challenges, in order to focus their attention on both the educational and social aspects of an immersive learning experience. The result should be a learning experience that is an integrated and integral part of the overall learning process. It should have correctly defined learning objectives that can be realised through matching learning activities to produce learning outcomes that can be clearly measured and assessed.

This paper has presented a non-systematic overview that would serve as a good starting point for educators and educational organisations who wish to implement an XR strategy.

Future research involves conducting a qualitative research study with teachers and faculty members to investigate their opinions regarding the XR approaches that have been mentioned in this paper.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Wiederhold, B.K. *Connecting through Technology during the Coronavirus Disease 2019 Pandemic: Avoiding "Zoom Fatigue"*; Mary Ann Liebert, Inc.: New Palt, NY, USA, 2020; pp. 437–438.
2. Chen, P.; Griswol, M.; Li, H.; Lopez, S.; Norouzi, N.; Welch, G. Immersive Media Technologies: The Acceleration of Augmented and Virtual Reality in the Wake of COVID-19; World Economic Forum White Paper. 2022. Available online: https://www.weforum.org/reports/immersive-media-technologies-the-acceleration-of-augmented-and-virtual-reality-in-the-wake-of-covid-19 (accessed on 26 October 2022).
3. Milgram, P.; Kishino, F. A taxonomy of mixed reality visual displays. *IEICE Trans. Inf. Syst.* **1994**, *77*, 1321–1329.
4. Alqahtani, A.S.; Daghestani, L.F.; Ibrahim, L.F. Environments and system types of virtual reality technology in STEM: A survey. *Int. J. Adv. Comput. Sci. Appl. IJACSA* **2017**, *8*, 77–89.

5. Mordor-Intelligence. Extended Reality (XR) Market-Growth, Trends, COVID-19 Impact, and Forecasts (2022–2027). Available online: https://www.mordorintelligence.com/industry-reports/extended-reality-xr-market (accessed on 26 October 2022).
6. Messner, J.; Yerrapathruni, S.; Baratta, A.; Whisker, V. Using virtual reality to improve construction engineering education. In Proceedings of the 2003 Annual Conference, Phoenix, AZ, USA, 15–21 November 2003.
7. Allcoat, D.; von Mühlenen, A. Learning in virtual reality: Effects on performance, emotion and engagement. *Res. Learn. Technol.* **2018**, *26*, 2140. [CrossRef]
8. Pottle, J. Virtual reality and the transformation of medical education. *Future Healthc. J.* **2019**, *6*, 181. [CrossRef] [PubMed]
9. Vasilevski, N.; Birt, J. Analysing construction student experiences of mobile mixed reality enhanced learning in virtual and augmented reality environments. *Res. Learn. Technol.* **2020**, 28. [CrossRef]
10. Lomicka, L. Creating and sustaining virtual language communities. *Foreign Lang. Ann.* **2020**, *53*, 306–313. [CrossRef]
11. Wu, J.; Guo, R.; Wang, Z.; Zeng, R. Integrating spherical video-based virtual reality into elementary school students' scientific inquiry instruction: Effects on their problem-solving performance. *Interact. Learn. Environ.* **2021**, *29*, 496–509. [CrossRef]
12. Moro, C.; Birt, J.; Stromberga, Z.; Phelps, C.; Clark, J.; Glasziou, P.; Scott, A.M. Virtual and augmented reality enhancements to medical and science student physiology and anatomy test performance: A systematic review and meta-analysis. *Anat. Sci. Educ.* **2021**, *14*, 368–376. [CrossRef]
13. Araiza-Alba, P.; Keane, T.; Chen, W.S.; Kaufman, J. Immersive virtual reality as a tool to learn problem-solving skills. *Comput. Educ.* **2021**, *164*, 104121. [CrossRef]
14. Rahman, M.H.A.; Yahaya, N.; Abd Halim, N.D. Virtual world for collaborative learning: A review. In Proceedings of the 2014 International Conference on Teaching and Learning in Computing and Engineering, Kuching, Malaysia, 11–13 April 2014; IEEE: Piscataway, NJ, USA, 2014.
15. Alwafi, G.A.; Almalki, S.; Alrougi, M.; Meccawy, M.; Meccawy, Z. A Social Virtual Reality Mobile Application for Learning and Practicing English. *Int. J. Interact. Mob. Technol.* **2022**, *66*, 55–74. [CrossRef]
16. Alharbi, A.; Aloufi, S.; Assar, R.; Meccawy, M. Virtual Reality Street-Crossing Training for Children with Autism in Arabic Language. In Proceedings of the 2020 International Conference on Innovation and Intelligence for Informatics, Computing and Technologies (3ICT), Sakheer, Bahrain, 20–21 December 2020; IEEE: Piscataway, NJ, USA, 2020.
17. Obeidat, H.; Meccawy, M.; Blanchfield, P. *Authoring for Adaptive Web-Based Learning Systems: A Case Study*; International Journal of Emerging Technology in Learning: Kassel, Germany, 2009.
18. Rey-López, M.; Brusilovsky, P.; Meccawy, M.; Díaz-Redondo, R.; Fernández-Vilas, A.; Ashman, H. Resolving the problem of intelligent learning content in learning management systems. *Int. J. E-Learn.* **2008**, *7*, 363–381.
19. Velev, D.; Zlateva, P. Virtual reality challenges in education and training. *Int. J. Learn. Teach.* **2017**, *3*, 33–37. [CrossRef]
20. Alalwan, N.; Cheng, L.; Al-Samarraie, H.; Yousef, R.; Alzahrani, A.I.; Sarsam, S. Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: A developing country perspective. *Stud. Educ. Eval.* **2020**, *66*, 100876. [CrossRef]
21. Cook, M.; Lischer-Katz, Z.; Hall, N.; Hardesty, J.; Johnson, J.; McDonald, R.; Carlisle, T. Challenges and strategies for educational virtual reality. *Inf. Technol. Libr.* **2019**, *38*, 25–48. [CrossRef]
22. Fransson, G.; Holmberg, J.; Westelius, C. The challenges of using head mounted virtual reality in K-12 schools from a teacher perspective. *Educ. Inf. Technol.* **2020**, *25*, 3383–3404. [CrossRef]
23. Baniasadi, T.; Ayyoubzadeh, S.M.; Mohammadzadeh, N. Challenges and practical considerations in applying virtual reality in medical education and treatment. *Oman Med. J.* **2020**, *35*, e125. [CrossRef]
24. Schreer, O.; Pelivan, I.; Schäfer, R.; Sabbah, Y.; Royan, J.; Deschanel, M.; Verly, J.; Gallez, A.; Grain, S.; Gérard, A.; et al. XR4all: Moving The European XR Tech Industry Forward: Final Research Agenda 2020. Available online: https://xr4all.eu/wp-content/uploads/xr4all_finalresearchagenda_2020_public.pdf (accessed on 26 October 2022).
25. Gilardi, M.; Hainey, T.; Bakhshi, A.; Rodriguez, C.; Walker, A. XR Maths: Designing a Collaborative Extended Realities lab for Teaching Mathematics. In Proceedings of the European Conference on Games Based Learning, Brigton, UK, 23–24 September 2021; Academic Conferences International Limited: Oxfordshire, UK, 2021.
26. Ibáñez, M.B.; Portillo, A.U.; Cabada, R.Z.; Barrón, M.L. Impact of augmented reality technology on academic achievement and motivation of students from public and private Mexican schools. A case study in a middle-school geometry course. *Comput. Educ.* **2020**, *145*, 103734. [CrossRef]
27. Birt, J.; Stromberga, Z.; Cowling, M.; Moro, C. Mobile mixed reality for experiential learning and simulation in medical and health sciences education. *Information* **2018**, *9*, 31. [CrossRef]
28. Vergara, D.; Extremera, J.; Rubio, M.P.; Dávila, L.P. Meaningful learning through virtual reality learning environments: A case study in materials engineering. *Appl. Sci.* **2019**, *9*, 4625. [CrossRef]
29. Ziker, C.; Truman, B.; Dodds, H. Cross reality (XR): Challenges and opportunities across the spectrum. In *Innovative Learning Environments in STEM Higher Education: Opportunities, Challenges, and Looking Forward*; Springer Nature: Berlin, Germany, 2021; pp. 55–77.
30. Doolani, S.; Wessels, C.; Kanal, V.; Sevastopoulos, C.; Jaiswal, A.; Nambiappan, H.; Makedon, F. A review of extended reality (XR) technologies for manufacturing training. *Technologies* **2020**, *8*, 77. [CrossRef]
31. Rajaram, S.; Nebeling, M. Paper Trail: An Immersive Authoring System for Augmented Reality Instructional Experiences. In Proceedings of the CHI Conference on Human Factors in Computing Systems, New Orleans, LA, USA, 30 April–5 May 2022.

32. Thanyadit, S.; Heintz, M.; Law, E.L.; Mangina, E. *How Easy Is It to eXtend Reality? A Usability Study of Authoring Toolkits*; AHFE International: San Francisco, CA, USA, 2022.
33. Kavanagh, S.; Luxton-Reilly, A.; Wuensche, B.; Plimmer, B. A systematic review of virtual reality in education. *Themes Sci. Technol. Educ.* **2017**, *10*, 85–119.
34. Simon-Liedtke, J.T.; Baraas, R.; Regnesentral, N. The Future of eXtended Reality in Primary and Secondary Education. *Stud. Health Technol. Inform.* **2022**, *297*, 549–556. [PubMed]
35. Luo, H.; Li, G.; Feng, Q.; Yang, Y.; Zuo, M. Virtual reality in K-12 and higher education: A systematic review of the literature from 2000 to 2019. *J. Comput. Assist. Learn.* **2021**, *37*, 887–901. [CrossRef]
36. Kuhail, M.A.; ElSayary, A.; Farooq, S.; Alghamdi, A. Exploring Immersive Learning Experiences: A Survey. *Informatics* **2022**, *9*, 75. [CrossRef]
37. Venkatesan, M.; Mohan, H.; Ryan, J.R.; Schürch, C.M.; Nolan, G.P.; Frakes, D.H.; Coskun, A.F. Virtual and augmented reality for biomedical applications. *Cell Rep. Med.* **2021**, *2*, 100348. [CrossRef]
38. Sadeghi, A.H.; el Mathari, S.; Abjigitova, D.; Maat, A.P.M.; Taverne, Y.J.J.; Bogers, A.J.C.; Mahtab, E.A. Current and future applications of virtual, augmented, and mixed reality in cardiothoracic surgery. *Ann. Thorac. Surg.* **2020**, *113*, 681–691. [CrossRef]
39. Smutny, P. Learning with virtual reality: A market analysis of educational and training applications. *Interact. Learn. Environ.* **2022**, 1–14. [CrossRef]
40. Dengel, A.; Iqbal, M.Z.; Grafe, S.; Mangina, E. A Review on Augmented Reality Authoring Toolkits for Education. *Front. Virtual Real.* **2022**, *3*, 798032. [CrossRef]
41. Tang, Y.M.; Chau, K.Y.; Kwok AP, K.; Zhu, T.; Ma, X. A systematic review of immersive technology applications for medical practice and education-trends, application areas, recipients, teaching contents, evaluation methods, and performance. *Educ. Res. Rev.* **2021**, *35*, 100429. [CrossRef]
42. Alnagrat, A.; Ismail, R.C.; Idrus, S.Z.S.; Alfaqi, R.M.A. A Review of Extended Reality (XR) Technologies in the Future of Human Education: Current Trend and Future Opportunity. *J. Hum. Cent. Technol.* **2022**, *1*, 81–96. [CrossRef]
43. Comber, O.; Motschnig, R.; Mayer, H.; Haselberger, D. Engaging students in computer science education through game development with unity. In Proceedings of the 2019 IEEE Global Engineering Education Conference (Educon), Dubai, United Arab Emirates, 8–11 April 2019; IEEE: Piscataway, NJ, USA, 2019.
44. Unity. Available online: https://unity.com/ (accessed on 26 October 2022).
45. Holly, M.; Johanna, P.; Sebastian, R.; Sandra, B.; Christian, G. Designing VR Experiences–Expectations for Teaching and Learning in VR. *Educ. Technol. Soc.* **2021**, *24*, 107–119.
46. Unreal. Available online: https://www.unrealengine.com/ (accessed on 26 October 2022).
47. Němec, M.; Radoslav, F.; Jan, T.; Jan, K. Using virtual reality in education. In Proceedings of the 2017 15th International Conference on Emerging eLearning Technologies and Applications (ICETA), Stary Smokovec, Slovakia, 26–27 October 2017; IEEE: Piscataway, NJ, USA, 2019.
48. WebXR. Available online: https://www.w3.org/TR/webxr/ (accessed on 26 October 2022).
49. Rodríguez, F.C.; Peraro, M.D.; Abriata, L.A. Democratizing interactive, immersive experiences for science education with WebXR. *Nat. Comput. Sci.* **2021**, *1*, 631–632. [CrossRef]
50. Google ARCore. Available online: https://developers.google.com/ar (accessed on 26 October 2022).
51. Apple ARKit. Available online: https://developer.apple.com/augmented-reality/ (accessed on 26 October 2022).
52. XR. +. Available online: https://xr.plus/ (accessed on 26 October 2022).
53. PlugXR. Available online: https://creator.plugxr.com/ (accessed on 26 October 2022).
54. PlugXR, Learning with Augmented Reality Can Be Fun and Engaging. 2020. Available online: https://youtu.be/FBpBO8p0Aa8 (accessed on 26 October 2022).
55. Adobe Aero. Available online: https://www.adobe.com/uk/products/aero.html (accessed on 26 October 2022).
56. Amazon Sumerian. Available online: https://aws.amazon.com/sumerian/ (accessed on 26 October 2022).
57. InstaVR. Available online: https://www.instavr.co/ (accessed on 26 October 2022).
58. Smart VR Lab CMS. Available online: https://www.smartvrlab.nl/ (accessed on 26 October 2022).
59. CoSpaces Edu. Available online: https://cospaces.io/edu/ (accessed on 26 October 2022).
60. Enduvo. Available online: https://enduvo.com/ (accessed on 26 October 2022).
61. Virbela. Available online: https://www.virbela.com/ (accessed on 26 October 2022).
62. IEEE VR 2022. Available online: https://ieeevr.org/2022/ (accessed on 26 October 2022).
63. Mora-Beltrán, C.E.; Rojas, A.E.; Mejía-Moncayo, C. An Immersive Experience in the Virtual 3D VirBELA Environment for Leadership Development in Undergraduate Students during the COVID-19 Quarantine. *Learning* **2020**, *6*, 7.
64. Jauhiainen, J.S. Entrepreneurship and Innovation Events during the COVID-19 Pandemic: The User Preferences of VirBELA Virtual 3D Platform at the SHIFT Event Organized in Finland. *Sustainability* **2021**, *13*, 3802. [CrossRef]
65. Depp, C.A.; Howland, A.; Dumbauld, J.; Fontanesi, J.; Firestein, D.; Firestein, G.S. Development of a game-based learning tool for applied team science communication in a virtual clinical trial. *J. Clin. Transl. Sci.* **2018**, *2*, 169–172. [CrossRef]
66. Kai XR. Available online: https://www.kaixr.com/ (accessed on 26 October 2022).
67. UbiSim. Available online: https://www.ubisimvr.com/ (accessed on 26 October 2022).
68. PeriopSim VR. Available online: https://periopsim.com/ (accessed on 26 October 2022).

69. OSSO VR. Available online: https://www.ossovr.com/ (accessed on 26 October 2022).
70. Oxford Medical Simulation. Available online: https://oxfordmedicalsimulation.com/ (accessed on 26 October 2022).
71. Engage. Available online: https://engagevr.io/ (accessed on 26 October 2022).
72. AltspaceVR. Available online: https://altvr.com/ (accessed on 26 October 2022).
73. Martos, S.; Klymovych, S.; Karabuta, O. *AltspaceVR in Distance Education of Philology Students*; Publishing House "Baltija Publishing": Riga, Latvia, 2021.
74. Jauregi-Ondarra, K.; Gruber, A.; Canto, S. Pedagogical experiences in a virtual exchange project using high-immersion virtual reality for intercultural language learning. In Proceedings of the CALL and Professionalisation: Short Papers from EUROCALL 2021, Paris, France, 26-27 August 2021; Volume 155.
75. Orel, M. The potentials of virtual reality in entrepreneurship education. In *New Perspectives on Virtual and Augmented Reality*; Routledge: Abingdon, UK, 2020; pp. 38–48.
76. Spatial. Available online: https://spatial.io/ (accessed on 26 October 2022).
77. Mozilla Hubs. Available online: https://hubs.mozilla.com/ (accessed on 26 October 2022).
78. Yoshimura, A.; Borst, C.W. Evaluation and comparison of desktop viewing and headset viewing of remote lectures in vr with mozilla hubs. In Proceedings of the International Conference on Artificial Reality and Telexistence, and Eurographics Symposium on Virtual Environments (ICAT-EGVE), Orlando, FL, USA, 2–4 December 2020.
79. Prasolova-Førland, E.; Estrada, J.G. Towards increasing adoption of online VR in higher education. In Proceedings of the 2021 International Conference on Cyberworlds (CW), Caen, France, 28–30 September 2021; IEEE: Piscataway, NJ, USA, 2021.
80. Barrett, A.; Pack, A.; Guo, Y.; Wang, N. Technology acceptance model and multi-user virtual reality learning environments for Chinese language education. *Interact. Learn. Environ.* **2020**, 1–18. [CrossRef]
81. Hopp, M.; Pfiel, S.; Schuster, R.M.; Tiefenbacher, F.; Reiner, M. A debate about implementing immersive technology for higher education: Pre-study examining the usability of virtual reality for lectures. *Hum. Syst. Manag.* **2020**, *39*, 565–571. [CrossRef]
82. ClassVR. Available online: https://www.classvr.com/ (accessed on 26 October 2022).
83. Avanti's World. Available online: https://www.avantisworld.com/ (accessed on 26 October 2022).
84. zSpace. Available online: https://zspace.com/ (accessed on 26 October 2022).
85. Hite, R.; Jones, M.G.; Childers, G.M.; Ennes, M.; Chesnutt, K.; Pereyra, M.; Cayton, E. Investigating potential relationships between adolescents' cognitive development and perceptions of presence in 3-D, haptic-enabled, virtual reality science instruction. *J. Sci. Educ. Technol.* **2019**, *28*, 265–284. [CrossRef]
86. VictoryXR. Available online: https://www.victoryxr.com/ (accessed on 26 October 2022).
87. Karutz, C.O.; Bailenson, J.N. Immersive virtual environments and the classrooms of tomorrow. In *The Handbook of the Psychology of Communication Technology*; John Wiley & Sons: Hoboken, NJ, USA, 2015; pp. 290–310.