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Augmented Reality Applications in the Classroom: Teachers' Experience

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Abstract: Augmented Reality is overlaying three-dimensional images or videos on a surrounding physical environment. Many studies have proven that Augmented Reality (AR) can enhance users' learning experience and promote their engagement and excitement. There are also studies showing that teachers have a positive attitude towards using AR as an educational tool in the classroom. However, there is a lack of AR applications implemented in schools and there is limited research examining K-12 teachers' use of AR applications. Hence, this study followed a qualitative approach by conducting in-depth interviews to understand the experiences of six K-12 teachers in Australian schools that had used and implemented AR in their classrooms. This research aimed at uncovering the underlying advantages and challenges teachers and their students have faced when working with AR in the classroom, and the teachers' intentions for future use. Our findings show that the teachers believed AR is a valuable learning experience, and they would use it in the classroom if it served their needs. Teachers also believed AR provided new ways for children to express learning and enhanced school and community engagement. They listed curriculum, time constraints and support, followed by students' ages, space, equipment, and technical issues as challenges for AR use. The most emphasized challenges were curriculum fit and mapping AR applications with curriculum, as well as lack of educational AR applications and applications that are co-designed with educators and students. We believe our findings will help designers, researchers, and schools to better understand teachers' requirements which can be used to inform the design of more efficient and effective AR applications that will serve the needs of its users and minimize the disruption on the classroom environment.

Keywords: Augmented Reality, AR, Implementation, K-12 Education, Advantages, Challenges, Teachers, Teacher's Experiences, Future Attitudes, Student Experiences

1. Introduction

Advancements in technology are continuously bringing opportunities for new ways of supporting learning. Evolutions in technology have allowed virtual illustrations to be in 3D which can promote excitement and engagement (Irshad and Rambli 2016). One such technology is Augmented Reality (AR) where computer-generated 3D images, videos and sometimes audio are presented on a surrounding physical environment. This emerging technology is still trying to find its place in education despite significant evidence indicating its potential as a valuable teaching and learning tool. According to the review held by Chen et al. (2017), AR's main advantages in education are: better learning performance, increased learning motivation, deeper engagement of students, perceived enjoyment, and positive attitudes. Yet, little is known about why current AR applications have not been adopted and retained successfully in the 'Kindergarten to 12th grade' educational environment. Although the concept of AR initiated in the 1990s, there is still a lack of AR applications implemented in the educational sector (Radu 2014). According to Lee (2012), this could be due to their perceived incompatibility with the traditional learning methods, the costs incurred for developing and maintaining AR, and general resistance to new technology. Akçayır and Akçayır (2017) pointed out two major challenges facing educational AR applications that involve usability and technical issues.

Existing literature have focused on the short-term effect of AR on students' learning as well as the emotional states of students when interacting with AR in schools (Ibáñez and Delgado-Kloos 2018), while few focus on the longer-term effects of using the technology, after the temporary "wow" moment

of any novel technology. Also, several studies have explored teachers' intentions for adopting AR in the classroom and they have shown that teachers had positive acceptance rates for using AR in the classroom (Alkhattabi 2017; Banerjee and Walunj 2019; Ozdamli and Karagozlu 2018). However, more research is needed on how teachers have implemented AR and their experiences in their classrooms. Hence, there is an absence of studies that investigate the experiences of the users of educational AR applications in the longer-term of using it, especially in the context of K-12 education.

This study aimed to interview teachers currently using AR in their classroom and understand what is working, what is not and what they think about using AR in the future. While not neglecting the importance of students input for understanding these concerns in the future, teachers' opinions are required as they play a key role in the adoption of these technologies. In addition, teachers from diverse backgrounds and specialties may have different views on their experiences with AR. Understanding the existing experiences of K-12 school teachers who have initiated the use of AR in their classrooms, will aid in understanding the needs of the users and what challenges they face during implementation.

2. Literature Review

It is common to hear the terms Augmented Reality (AR) and Virtual Reality (VR) together, which is not wrong as they are both under the genetic term Mixed Reality, however, they have different degrees of reality. VR is when someone is immersed in an entirely virtual environment where there is no connection to the real world. Whereas AR is like a middle point that connects what is completely real (e.g. a physical table that you can touch) with completely virtual objects (e.g. a 3-D image of a synthetic lamp) and aligns them with each other interactively (Azuma 1997).

In recent years, there has been an upsurge of published papers regarding AR in education. A dramatic increase started in 2011 and escalated in 2013 to 2017 (Akçayır and Akçayır 2017). It is believed that the spread of mobile devices and AR development tools, even in developing countries, increased the use and study of AR (Akçayır and Akçayır 2017; Garzón, Pavón, and Baldiris 2019).

AR enriches individuals' understanding of the real world through virtual aspects that cannot be easily detected by their senses (Azuma 1997). While using AR in education, it can help students gain deeper understandings of the human anatomy (Fuchsova and Korenova 2019), learn the English vocabulary in an attractive and interactive manner (Lee et al. 2017) or even introduce animals in early childhood education (Nainggolan et al. 2018). AR can serve students with different learning abilities to *understand spatial data* and *improve reading comprehension* (Billinghurst and Duenser 2012). Also, AR aids the future direction of *individual learning* (Pence 2010).

Many reviews have collected the advantages of AR in education, and similarly they found that the top two are "Learning Gains" and "Motivation" (Akçayır and Akçayır 2017; Altinpulluk 2019; Bacca et al. 2014; Chen et al. 2017; Garzón et al. 2019; Radu 2014). *Learning gains* is where students show higher learning performance and achievement. This was proven through studies that adopted a pre-test - post-test approach on every experimental (with AR) and control (traditional teaching) groups of students. While *motivation* is where students feel more motivated to learn compared to traditional learning methods. Garzón et al. (2019), believed that this motivation is driven by *sensory engagement*, where students use more than one of their senses to learn. Since AR is a representation of 3D elements, it helps in *visualizing abstract concepts* that are difficult for students to grasp with traditional teaching methods which eventually may help in greater *memory retention* (Garzón et al. 2019; Radu 2014). Another advantage of AR in learning is that it may promote students' *self-learning* (Papanastasiou et al. 2019; Pence 2010), or even providing means for *collaboration* between students in cases like in-formal learning where students team up to solve an outdoor mission (Chang, Chung, and Huang 2016; Chiang, Yang, and Hwang 2014).

Despite the great evidence that prove AR's potential as an effective learning tool, there are some challenges that had been reported. Usability and technical drawbacks are the most reported issues, as AR is still an emerging technology. While AR can be in many types, the technical issues may differ. A *Marker-based AR* tracks a marker which may be interrupted if the marker is out of camera's sight and cause students' confusion (Dalim et al. 2016). Also, if the marker is disturbed by light and pointing angles, this may cause identification failure (Chang and Hwang 2018). Using a *Marker-less AR* may solve those problems; however, this type is still evolving as the tracking work is much harder in this type (Bacca et al. 2014). For *Location-based* AR, GPS signals would sometimes be inaccurate in locating a specific learning target (Chiang et al. 2014; Dunleavy and Dede 2014).

In regards of interaction design, students' *cognitive overload* was a common reported issue, due to difficult tasks, app-related *technical issues,* and *teacher's inadequate training* (Papanastasiou et al. 2019). Studies have already proposed to solve this through simplistic and enhanced design (Dunleavy and Dede 2014), however, more usability studies are needed that consider the state-of-art characteristics with an educational environment (Akçayır and Akçayır 2017). This is important to understand user preferences and establish suitable design principles and evaluation criteria for AR use in education to deliver AR to its full potential (Billinghurst and Duenser 2012). Additionally, curriculum was considered as a challenge that may limit teachers' adoption and use of AR applications. Tzima et al. (2019) surveyed teachers and curriculum was found to be the major restricting factor. Other teachers pointed out that they lack the knowledge and training of how to map curriculum contents to AR applications (Oliveira da Silva et al. 2019).

School's Support was mentioned as well in the literature, and this can be considered as a general challenge with the adoption of new technology. In order for teachers to adopt new technology in teaching, school administrators need to effectively offer implementation support (Sugar, Crawley, and Fine 2004; Tondeur et al. 2017). In schools where devices are not available, hard to get due to financial reasons and school policies restrict students to bring their own devices are challenges for teachers to implement AR (Alalwan et al. 2020). Moreover, applying AR in a lesson may take more *time* than a usual lesson. This may be due to the need of training for teachers and students, the complexity of the application or because of the novelty of AR (Cheng and Tsai 2013). Oliveira da Silva et al. (2019) surveyed teachers and found that time was a factor that prevented teachers from implementing AR more often as more planning and class time is needed. Lack of time was also an AR challenge mentioned by teachers (Alalwan et al., 2020).

3. Methodology

The aim of this research was to examine K-12 teacher's experience with AR in the classroom, we did a qualitative study, and conducted semi-structured interviews. The method was chosen as it offers deeper insights on the entire experience rather than a specific part or aspect of an experience as with quantitative methods (Moustakas 1994).

Due to the closure of schools during the pandemic of COVID-19, alternative ways of contacting teachers were through social media platforms (such as Twitter, Facebook, Instagram), by attending an online STEM conference, dedicated online AR websites, through school homepages and participants in this study nominating colleagues that are familiar with using AR. There were no incentives offered to the participants. Due to the difficulty in recruiting teachers that are familiar with the use of AR in the classroom and the low response rate in the circumstances of COVID-19, this study has a limited set of 6 teachers where one is an educational technologies advisor as well. While Creswell et al. (2007) inferred that recruiting 5-25 participants is recommended for phenomenal studies to explore individual experiences with a certain phenomenon, this study is in the recommended range. All participating teachers in this study teach in Australian schools. Where two teach in primary school, two teach secondary school students and two teach in high school. Further details about their backgrounds are in the results section.

Data was collected after an ethics approval was obtained. Prior to the interview, the participants were initially asked to read the plain language statement that had information about the research and purpose of the study. Then they were asked to fill in an online pre-questionnaire through Qualtrics that requested their consent to gather data and audio-record the interview. The responses were stored by the Qualtrics platform that was secured through an official username and password. The interviews were held through an online meeting room via *Zoom*. The interviews lasted for about 50 minutes on average. After the interview, the audio-recordings were transferred from the recorder to the researcher's laptop and then transcribed and stored safely.

All six participants completed the pre-questionnaire and only five had the time to proceed with the interview. The pre-questionnaire was initiated by collecting demographics about the teachers, followed by teacher's familiarity with the use of technology in the classroom and particularly AR. For example, their age, teaching period, what subjects they teach, which grade levels…etc. The final section of the pre-questionnaire was a Likert scale about teacher's experience with AR in the classroom. This scale was inspired from a study held by Santos et al. (2014) that was aimed for hand-held AR

applications. Noting that on initial planning of testing, the aim was to focus on Handheld AR, however due to the difficulty of finding teachers that only use this type, the scope was expanded. Results of the usability scale were not analysed quantitatively because teachers' AR application methods were different.

Interview questions were based on the following four themes: *1)* Motivations for AR Use; *2)* Planning Strategies; *3)* Positive and Negative Usability Aspects; 4*)* Future Use Attitudes. After data was collected, the data was analysed thematically following the six stages proposed by Braun and Clarke (2006). Thematic analysis is suitable for the research in-place because it can be a "realist method, which reports experiences, meanings and the reality of participants" (Braun and Clarke 2006), uncovering teacher's real experiences and attitudes with the implementation of AR in the classroom.

4. Findings

The findings are organized based on the themes extracted from the data collected. Beginning with teachers' biographical backgrounds, followed by their current use of AR and finally their attitudes towards future use. The participants were teachers in Australian schools, three males and three females with diverse age ranges (Table 1). As for their educational background, three had a bachelor's degree, one had a master's degree and two had a master's degree with an in-progress PhD degree.

Table 1. *Age Distribution of Teachers*

Age	20-29	30-39	40-49	50-59
Count	1	1	3	1

According to teaching periods, one had been a teacher for less than 5 years, three teachers had 7 years of experience on average, whereas two had been teachers for about 23 years. In terms of subjects, majority teach Digital Technologies or STEAM (Science, Technology, Engineering, Arts and Math) (5 teachers), Science and Humanities & Social Sciences (3 teachers each), Arts (2 teachers), Mathematics, Future Literacies, Religion & Values and ESL (English as a second language) (1 teacher each). As most of the teachers teach digital technologies or STEAM, they all frequently use technology in their lessons and say they have school's support to use it as well. The responses from the six teachers have been annotated here in the findings as T1-T6. All teachers had used AR in their classes; however, their use was limited. Five teachers applied AR occasionally and some very rarely. While one teacher used AR frequently as in almost every week. They had used different AR applications, 5 used *"Merge",* one had used *"Aurasma"* (Hp Reveal), *"Artivive"*, *"SolarSystems"*, *"Metaverse"*, *"Adobe Aero"* and *"CoSpaces*".

It is important to note that learning with AR can be by creating AR content and viewing AR content. A couple of teachers found it relevant to share their experience with VR as well. There were different methods of how the participated teachers implemented AR or VR with their students:

- Individually in class, each student created their own AR content using a desktop computer and then their work was viewed out of class in a school art exhibition by iPads (T4).
- Individually in class, each student had their own Google Cardboard and inserted their own mobile phones to view VR content (T3).
- Individually at home as assignments for students, each student created a 3D model of their "Minecraft" world and then uploaded their model in "Adobe Aero" to be able to overly their virtual Minecraft world on their real world (T2).
- Individually at home as a virtual art exhibition, students could walk through their artwork (This method was adopted when schools were closed during the COVID-19 pandemic) (T4).
- Collaboratively in class, where two students took turns to use a headset to view AR or VR Google Expeditions content (T1).
- Collaboratively in class, using an iPad to view AR content from a Merge cube (T1, T2).

4.1 Motivational Factors

There were several reasons why participants considered adopting AR in their lessons. This study divided these motivational factors into three main categories; (1) Enhancing Students' Learning, (2) Technology Capabilities, (3) Extending Teacher's Education (see *Table 2*).

Table 2. *Teachers' Motivational Factors for Using AR*

Enhancing Students' Learning	*Technology Capabilities*	*Extending Teacher's Education*
Learning to code	Bringing things to life	Conducting a PhD study on AR
Exposure to new technology	Immersive	Learning new ways of teaching
Creating AR content	Novel	
New ICT skills		
Spatial ability		

Four teachers were motivated to use AR because it enhances students' learning. Two teachers chose it to teach students about coding and gain new skills, the teacher explains: "*...we need to teach students how coding works. There's a little bit of coding in AR, not very much, it is more ICT skills."* (T1). They also expressed that they wanted to teach students how to create 3D content. T1 also believed that primary students should get exposed to AR as a technology, T1 states: *"…the creation really should be taught in years 8,9,10...but I think if children are already going to be using it, they should learn how it works, so they can have a better understanding of it".*

The second motivational factor was the special technological capabilities that AR has to offer. Two teachers had used AR because it could transform static work into an interactive live piece of work. Teachers also saw that it helped students understand spatial ability. T2 had used AR to transform students Minecraft Worlds into a 3D image that is overlaid on their school desks, the teacher illustrated how this was a motive: *"if I didn't it was just going to stay there, when I transformed it into 3D, I'm able to print that picture in the school newsletter, and students could give each student to do a selfie with their own world that they built. I can send it to students, I can be more proud of the work that they've done. Furthermore, we do it for them to see the world in three dimensions in a bigger way. So, it's quite interactive for them."*

In addition, findings showed that AR may increase students' attention and maintain focus in a subject that is usually not that engaging, due to its novelty and immersive nature. Two teachers had commented on these factors: *"So, the immersive nature was the main reason that I wanted to use it because I thought it would attract students and it would keep them focused on the task. They would actually be having fun I thought that while they're having fun, it may be easier for them to learn."* (T3, ESL class), *"So, I was kind of motivated to just make my subject a bit more engaging, because a lot of the time, because it's not one of the mainstream subjects, kids tend to take it and think they can slack off, they're on computers, you know, I'll do whatever I want kind of thing. And I want to just get them a bit more engaged in the technology aspect of the subject."* (T4, Art Class)

The third factor is extending teacher's education where teachers state that they learnt more about AR and its capabilities in the classroom. T2 and T3 are conducting scientific research about AR to complete a PhD degree. Where others seek new ways to teach in the classroom and pass the experience to other colleagues to try. T4 was recommended by another teacher to use AR in her subject: *"'Teacher X' actually suggested that I should do something with augmented reality and at first, I was quite resistant because it seemed like a big learning curve, and when I looked into the applications of it in an art context, I realized it could really, really pay off for the students just a really cool thing"* (T4)

4.2 Teachers' Positive Experiences

The participants expressed positive experiences that they and their students faced when AR was implemented in their lessons. In this study, the positive experiences were divided into two main themes: (1) Engagement, and (2) Interactivity.

All teachers strongly agreed that using AR in the classroom is engaging. T1 says that students sometimes needed to be *"tricked"* to learn something new. Another teacher found students appreciating learning in a new method such as creating AR content, "*It's beyond, you know, getting them just to*

watch a video, they're really engaged in the process" (T4). Two teachers also mentioned that engagement is not just for students of the subject, but engagement of the school as well with their projects. T2 could take selfies of the students with their Minecraft worlds and posted it in the school newsletter. The teacher also introduced "Aurasma" in a STEM fest for the whole school community to be exposed to AR. While the other teacher's great experience was in a school art exhibition where students of all ages and staff engaged with the artworks: *"…and it was just, you know, really excellent at the end, watching all of the kids that weren't even in that class, just engaging with the artworks and just really engaging with the art exhibition, which was, it's actually quite rare."* (T4). This teacher also had another engagement experience during COVID-19, where a student's whole family could visit a virtual AR art gallery of the students' artworks. The teachers also agreed that using AR in the classroom is fun and exciting. One teacher said students expressed AR as "magic," *"I found kids saying this a lot with augmented reality, like it's like magic, you know, because they can see their world through the lens of the camera as well and their world is being changed"* (T4). It wasn't just exciting for the students but for the teachers as well, "*The positive part was hearing the students saying, wow, this is amazing! ... That's what got me excited as a teacher to say that they're actually focused on the tasks, and they are enjoying their classes"* (T3).

In addition, learning by AR can be more interactive than a traditional taught lesson. A teacher commented that if complicated concepts can be explained through AR, *"it is a lot more fun way than listening to a teacher."* (T1). It is not just fun but can be a more effective way of learning certain concepts as well, "*Love seeing their work in AR out in the real world - helps put learning into context for them"* (T5). Five teachers strongly agreed that when using AR, it is possible to describe concepts that are difficult to explain without it. Teachers explained how students can manipulate AR objects and feel more in control of their learning, *"…with Merge Cube, we were looking at the flower, how a bee pollinates a flower, and we rotated it around in our hands, and can look at different steps, we're looking at the plant cell cytoplasm, and from mitochondrion, all those things, it's quite interactive. So, when you just have a potential draw diagram on the board, or even if you show a power point slide show, it's quite different for them. It involves for interactivity and self-exploration; the student can go over with in their own time later on."* (T2). Another teacher adds that AR could give an opportunity for students to express their learning when sometimes they were not good at expressing their learning in a traditional classroom, "*So, that's what drives me to students sometimes they're not very good at showing their knowledge in traditional ways and an opportunity to show knowledge in non-traditional ways,"* (T1).

4.3 Teachers' Challenging Experiences

Even though five teachers in the pre-questionnaire stated that the AR applications were easy to use in class, they expressed their experiences in the interviews more differently. The following derived themes were the challenging experiences that teachers had faced when they implemented AR in their lessons.

Curriculum: The most frequent challenges mentioned by the teachers were related to curriculum. Some refer to it as the most difficult aspect to consider when thinking about using AR in class. One participating teacher said that it is hard to link between the technology and the learning area, "*The hardest thing is to relate the use of the technology into another, we call them KLA's or Key Learning Areas"* (T1). Teachers explained that AR content must fit very well in the curriculum, or it will be difficult to justify its use, "…*certain activities won't be at a simple level, it may not directly map with the curriculum that I'm teaching to the students at that stage, so I'll have to map that out properly as well."* (T2). While teachers believed that content fit was the most important, they acknowledged that using AR would make students engage better with the content even if it didn't map perfectly to the curriculum. It was easy for the STEAM teacher to use AR as the focus was the skill of using the technology. Other teachers found it challenging to find AR applications with content that is related to the curriculum or even for general educational purposes, *"…I was not able to find a lot of appropriate games for educational purposes or .. related to the curriculum .. related to general lack of values or sustainability,…"* (T3).

Time Constraint: Four teachers agreed that using AR in the classroom is time consuming. Before using AR in the classroom, the teachers needed to understand how AR worked and sometimes they just didn't have the time, two teachers expressed this: "*it's quite a learning curve to begin with to implement augmented reality and a lot of times it you know, teachers will have to do that in their own time.*" (T4). Teachers found that students must learn the skill of using the technology before being able

to comprehend any content from it, which requires more class time, *"... if you're trying to fit augmented reality into, say a HASS subject and then with all the skills, you have to teach the kids to be able to function the augmented reality, it takes away a lot of time from the actual content that you're required to learn."* (T4). In addition, as with using something new like AR in class, more time was needed to solve unexpected problems and issues with technology.

Support, Space and Equipment: The findings showed that support was an important factor that affected teachers' use of AR in the classroom. Different forms of support were school support, teachers' support, and companies' support. All teachers agreed that they are more likely to use AR if they have school support. A teacher commented that schools need to be willing to try new technologies, "*…you need to have a school that's really forward thinking or really wants to approach new technologies…. if the schools were able to take into account and support teachers, by giving them like, extra time or extra support, um, that would really help as well"* (T4). Technical support from school was also named as important for teachers to use AR. Teachers had experienced issues such as logins, file sizes and licenses. One teacher said, "*If they're going to have any negatives, it will probably be on the technical side where getting the app installed that would be one thing, would the app be free or not, available to sign in with their school credentials or the school email like some that might have single sign on with Google or single sign on with Microsoft."* (T2). Other than school's support, support from colleagues was another aspect that had been articulated by the teachers, *"'Teacher X' was willing to help, so I think having the support of like, the other teachers really kind of helped it work, I think without that it never would have got off the ground."* (T4). Access to space and equipment were also mentioned as an important factor for teachers to use AR. Some teachers said that a regular classroom with desks and chairs worked fine with AR, however, younger students needed more space. One teacher stated: "*They were able to actually control themselves while they would play because they had some space in between desks and that Blackboard or the whiteboards, they were good. But with the younger ones, the year sevens and eights, they were more mobile while they were actually playing the game."* (T3).
The findings of teachers' current experiences with AR in the classroom are summarized in *Figure 1*.

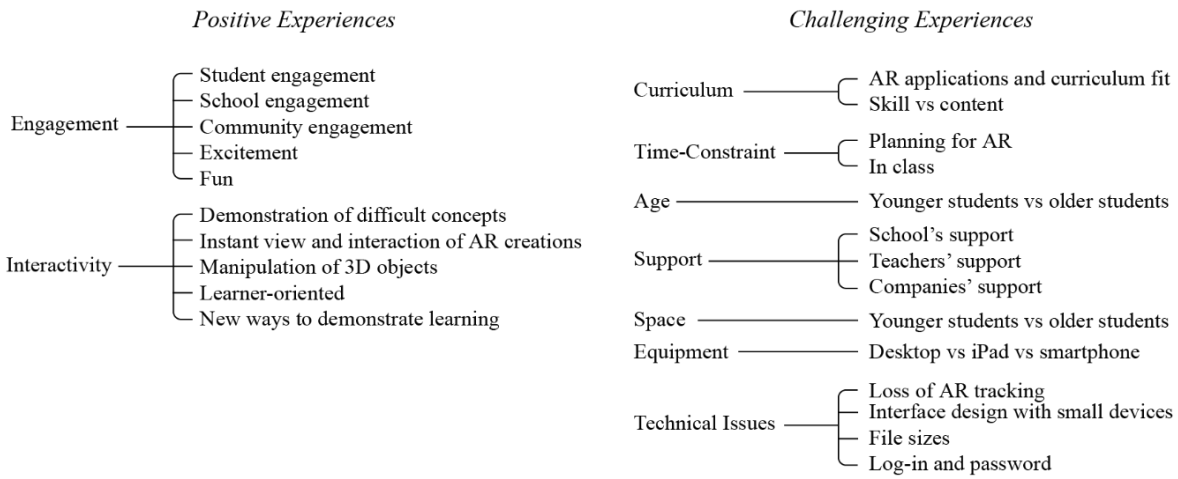

Figure 1. Summary of Teachers' Experiences with AR

4.4 Teacher's Future Use of AR

Teachers were asked about their attitudes toward future use of AR in the classroom. Teachers' replies were positive, and they would recommend other colleagues to use AR in their lessons, "*Yes, I would and I'm actually going to demonstrate merge cube to my other colleagues so they could use it in their science lessons, because that's when it's going to really make an impact"* (T2). Though, one teacher added that teachers believe it's difficult. A teacher said that she would recommend teachers, however caution them about the time and effort that needs to be put in, *"I would because of how engaging it is for the students but I would also caution them as to how much time it does take to set up and we had a lot of great payoff for it…It definitely has a good payoff, but it requires an extra effort."* (T4).

Teacher's confidence and mind-set were also factors related to teachers' use of AR, *"The biggest problem primary teachers have is when technology doesn't work, they don't feel confident, and they are losing that confidence."* (T1). While the other teacher explained, if a teacher implemented methods of independent learning, the adoption of AR would fit seamlessly, *"I believe, that would go back to their teaching practices because in a traditional setting when they place themselves at the center and they just ask the students to listen to themselves and follow their instructions all the time, where there is a lack of independent learning skills, I believe that's when it could be problematic is when they could have that kind of fear. But in a classroom where a teacher sets their routines well from the beginning and if students are learning independently, then I believe the transition would be much smoother."* (T2).

Frequency of AR use varied between teachers from once a week to as often as there was a use for it or the equipment was available, *"…as long as I find more links more relevant content to use it, I would make effort to implement it."* (T2), *"I think any innovation in a classroom should be tried as long as you can find a use for it"* (T1). Teachers had many recommendations for improving educational AR applications. First, developing more AR applications for educational purposes, where AR content is related to curriculum, "*The game designs that I think are essential. So, the games that are going to be designed need to actually meet the needs of the curriculum"* (T3). Second, developing AR applications that are co-designed with educators, *"I would like more applications made by educators or made for education, that were more like easily accessible"* (T4). Third, demonstrating and training how an AR application can directly map with the curriculum may encourage more educators to use it, *"Oh definitely if it was PDS about particular augmented reality and how they could work, how they could fit into curriculum in an easy way that would definitely help a lot of educators approach it, I think."* (T4). Fourth, companies should pilot there products as soon as possible to get more people involved in using the application, *"with new technologies like AR and VR, the companies that design it really need to try and pilot it, get it out to classrooms and educational facilities and universities and just promote its use and try getting a whole lot of people using something new rather than wasting so much time developing instructions how to use it."* (T1). Fifth, educational institutions should release products as soon as possible and not worry so much about the rules of using it, as this limits creativity, *"…education is too concerned about this will affect a child. The main problem is we have to write all these rules about how we can use something before we use it, and the rules stop us from using it in a creative way. It's not always about being safe, sometimes the education departments want to make sure they cover every base before they release a product and sometimes, they just need to release it."* (T1). Sixth, one teacher believed that school culture can restrict the use of AR, she compares between a "teach to test" culture vs an "open approach learning" culture, *"…teachers tend to fall back on the common more rote learning models to really get specific facts across. I think it's because of the teach to test culture that a lot of schools have where we just want them to know the answer to the test like, so they test well, and test scores are all it's important, I think, perhaps in somewhere more open like a Montessori school or school kind of like ballpark where they are approaching learning in a different way that it could possibly flourish a lot more."* (T4).

5. Discussion and Conclusions

In this study we have explored K-12 teachers' opinions on their current experiences with AR in the classroom. The aim was to find out how AR is currently being adopted and what advantages and challenges are present with the implementation. Through a qualitative study, with six participants we found teachers believed that AR is a valuable learning experience, and they will continue to use it as long as there is a purpose for it.

In this paper we found that majority of the advantages that the teachers mentioned comply with existing literature. Further, we found that AR provided new ways to express learning and AR provided means for school and community engagement such as a school art exhibition where students of all ages and staff engaged with the artworks.

While the teachers believed that more AR and 3D content creation will be used widely in the future, our findings show that teachers current use of AR and 3D content was limited due to challenges, that involve curriculum preparation that align with using such technologies; the lack of time to learn and use them to build curriculum; and the lack of support provided to teachers to trial such new ways to design curriculum. Further, students' age and the lack of space, equipment, and technical issues

restricted use of the technology. In particular, the most emphasized challenges were curriculum fit and how to map the AR application with curriculum. Suggestions to solve the challenge of curriculum fit could be articulated from different viewpoints. For example, (1) developing more educational AR applications that fit the curriculum, (2) developing AR applications that are co-designed with educators and students, (3) Training and demonstrating how AR maps with curriculum. These suggestions from the teachers comply with the suggestions found in previous literature, however, this indicates the importance of these aspects and the absence of strong solutions in place.

Teachers' future use highly depends on the purposefulness design of AR applications. Teachers' recommendations fall under this umbrella and suggest: (1) More AR applications developed for educational purposes, (2) Co-designed educational AR applications, (3) Training and demonstrating mapping to curriculum and (4) Considering an open approach learning culture to harness students self-learning. These recommendations are complimentary to previous studies. While, other recommendations were targeted to companies and educational institutions respectively, (5) Conducting pilot studies rapidly to involve as much users as possible with the application and (6) Less restricting rules of how to use a technology as rules usually limit creativity.

The results of this study can help schools understand what challenges teachers have faced with AR and provide more support throughout the implementation. Nevertheless, it showed how vital it is for companies, designers, and developers to work close with teachers and students to develop efficient educational AR applications that line seamlessly in the classroom environment considering the challenges that they may face. This study was the first step towards a larger study where we will co-design an AR application with teachers and implement and test it with the students. This will help us understand how to serve the curriculum and find subjects or concepts that are usually difficult for teachers to deliver and examine whether the AR technology can resolve that difficulty.

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