Why Don't We See More of Augmented Reality in Schools?

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ABSTRACT

Previous research has shown the potential of Augmented Reality (AR) in education, however, its use is still not widespread in the classroom setting. This study aims to understand what is the current maturity level regarding AR use in schools, as well as what is preventing schools to reach higher levels of maturity. We aim to discuss the current use of AR in schools and reflect on ways AR technology can evolve and adapt to support more meaningful and effective learning practices. 106 teachers answered an online survey in order to help us understand those issues. Results have shown that lack of infrastructure and authoring tools are the two biggest problems hindering AR use in classrooms. Evidence suggests the need to focus on authoring tools that support collaboration and creativity in the educational settings, thus, enabling schools to use AR technology in more effective ways and achieving higher levels of maturity. We conclude by listing features for designing AR applications in relation to the maturity levels identified.

1 INTRODUCTION

Augmented Reality (AR) consists of adding virtual elements to a real scene coherently so that users cannot differentiate them from the real scene [2]. It has been long since its potential in education has been investigated. AR can aid learning and make the overall process more interesting and pleasant [11]. *Billinghurst et al. 2012* [3] explain that unlike other computer interfaces that draw users away from the real world and onto the screen, AR enhance the real world experience. They also highlight some reasons why AR educational experiences are different: (a) support of seamless interaction between real and virtual environments, (b) use of a tangible interface metaphor for object manipulation, and (c) ability to transition smoothly between reality and virtuality.

Coexistence of virtual and real information allows learners to visualize complex spatial relationships and abstract concepts [22]. There are applications that explore this characteristic to leverage chemistry [1] and physics [18] understanding. Other key capabilities of AR that can be explored in education are its ability to improve how users receive and follow instructions as well as its capacity to transform the way users interact with and control the product themselves [13].

Those educational possibilities have been increasingly recognized by researchers who have been developing a variety of AR applications aimed at education. Previous research has shown that the number of works investigating and evaluating AR in education has been increasing [6]. Many studies have shown that AR has a positive impact on students' motivation [17, 21] and cognitive performance [23]. AR can be used to leverage learning of different contents from math and science to human and arts. AR applications can aid varied age levels ranging from young children [16] to university students [4, 19].

At the same time, we have seen an increasing interest in AR from big companies, such as Google [9]. Investors are also funding research into wearables development, predicting that the screens in consumers' pockets will be replaced by AR interfaces. Examples of such efforts are Microsoft Hololens [14] and Magic Leap [12].

Nevertheless, the use of AR is still far from widespread in education. There are many factors that may influence teachers' technology adoption, such as their own technology skills and educational beliefs. Social learning and support in workplace environments, the tools available as well as the possibility of customization of educational experiences are also factors that play a role in teachers' adoption of this technology.

In our increasingly connected world, the use of technology is important as it allows new possibilities of learning and collaboration, and empowers both students and teachers. The Future Classroom Lab has proposed a maturity model in order to understand how mature and advanced is the level of technology innovation in schools. They propose a reference guide for the maturity model [8], in which they acknowledge five levels of technology use.

Thus, the goal of this present study is to identify the current maturity of AR adoption in schools as well as what is preventing them to reach higher levels of maturity. Moreover, we aim to discuss the current use of AR in schools and reflect on ways AR technology can evolve and adapt to support more meaningful and effective learning practices. The main research questions are:

RQ1. What is the current maturity level of AR adoption in schools?

RQ2. What are the constraints blocking AR to be used in the classrooms?

To conclude, we will provide some perspective on AR use and integration in the classrooms, harnessing teachers' knowledge to improve the design of tools and lower the barriers to successful classroom use. Thus, the main contributions of this paper are twofold: (a) to point out schools' current level of maturity concerning AR; and (b) reflect on the constraints preventing teachers to reach higher levels of maturity regarding AR use.

2 INNOVATION IN EDUCATION

Innovation is usually defined as the introduction of something new that supports a change in social practice [10]. Studies have shown that the perception of an innovation is crucial to its success. One of the most popular models is Roger's diffusion of innovation theory [20], which is broadly used in the area of technology diffusion and adoption. The author defines adoption as a decision to fully use an innovation as the best course of action available, whereas, rejection is a decision of not to adopt an innovation. He defines diffusion as the process in which an innovation is communicated through certain channels over time among the members of a social system [20]. Through this theory, we can understand the importance of the social system in the adoption and diffusion of innovation.

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Higher levels of innovation can not be achieved in isolation, but, as a social process that involves different stakeholders.

The Future Classroom Lab has proposed a maturity model in order to understand how mature and advanced is the level of innovation in the schools [8]. This model also explores the importance of the social system in innovation adoption. The Future Classroom Lab proposes a reference guide for the maturity model, in which they acknowledge five levels of use and have detailed explanation on how they are expressed concerning five dimensions: (a) teachers' and (b) learners' roles, (c) learning objectives and assessment, (d) school capacity to support innovation in the classroom as well as (e) tools and resources. These levels are explained below:

1. **Exchange:** this level corresponds to isolation of teaching and learning, with technology used as a substitute for traditional methods:
   (a) *Teachers' Roles:* teachers choose the format, approach and digital resources for learners to use;
   (b) *Learners' Roles:* learners use digital learning materials occasionally (usually alone) provided or presented by the teacher;
   (c) *Learning Assessment:* teachers set the learning goals and carry out the assessment using traditional approaches.;
   (d) *School Support:* little or no training and support for teachers regarding digital learning;
   (e) *Tools and Resources:* a narrow range of technology is effectively used in less than 5% of lessons.
2. **Enrich:** here, the learner becomes the user of digital technology, which improves learning and teaching practices:
   (a) *Teachers' Roles:* teachers use technology as a way to enrich their current approaches;
   (b) *Learners' Roles:* they use digital resources a few times and are able to use it both individually and in collaboration in a pre-defined task. They are able to communicate clearly using technology to present ideas;
   (c) *Learning Assessment:* assessment encourages active learning and students have the opportunity to use feedback and assessment evidence to improve performance. Technology is used for assessment purposes;
   (d) *School Support:* Schools encourage technology use, but, school leaders are commonly reactive to change;
   (e) *Tools and Resources:* technology is effectively used in 5-25% of lessons. It sometimes replaces more traditional approaches for learning and teaching.
3. **Enhance:** in the third level, the learner is able to learn more independently and be creative, supported by technology providing new ways to learn through collaboration:
   (a) *Teachers' Roles:* teachers are comfortable with re-organising classroom layout as part of technology use and help students incorporate technologies into their projects;
   (b) *Learners' Roles:* learners are able to choose the technology application and use it to work independently and engaged in collaborative problem-solving or research activities;
   (c) *Learning Assessment:* learners are involved in deciding learning objectives, which include higher order thinking skills. Progress through the task is tracked;
   (d) *School Support:* the school encourages teachers to experiment with new approaches to learning and teaching and they receive appropriate training and pedagogical support;
   (e) *Tools and Resources:* technology is effectively used in 25-50% of lessons for collaboration, communication, and real-world problem solving.
4. **Extend:** in this level, connected technology and progress data extends learning and allows learners greater control on how, what and where they learn:
   (a) *Teachers' Roles:* teachers design activities using technology to empower students to manage their own learning;
   (b) *Learners' Roles:* learners are able to manage their own learning using technology. They make decisions on what, how and when they learn;
   (c) *Learning Assessment:* there is a range of assessment approaches including self- and peer assessment. Assessment goes beyond traditional subject boundaries to include inter-disciplinary skills.;
   (d) *School Support:* the school has a clear vision and strategy for digital learning that addresses key barriers to innovation;
   (e) *Tools and Resources:* teachers and students identify and use new technologies, which are used effectively in 50-75% of lessons.
5. **Empower:** this level concerns the capacity to extend learning and teaching through ongoing whole school innovation, with teachers and learners empowered to adapt and adopt new approaches and tools:
   (a) *Teachers' Roles:* teachers spend most time designing collaborative problem-solving or research and independent learning activities;
   (b) *Learners' Roles:* are connected to others and are able to use a range of technology. They are able to decide what, where, how and when to learn;
   (c) *Learning Assessment:* learners negotiate the learning objectives, which are continuously reviewed and revised. Students receive feedback quickly, usually instantaneously;
   (d) *School Support:* leaders encourage a whole school approach to supporting innovation in learning and teaching;
   (e) *Tools and Resources:* technology is effectively used in more than 75% of lessons. Teachers use a wide range of technologies to support change in the learning process.

According to this model, from the third level onward, the learner can work more independently and creatively supported by technology. The Future Classroom model is a self-review tool that enables schools to reflect on their teaching and learning and their capacity for technology-supported innovation. As a school moves from one level to the next, its capacity to be innovative in technology-supported learning and teaching increases.

In this work, we adapted this model to understand how the schools are currently using AR to support learning. Thus, we would like to know how teachers assess their AR use in the dimensions proposed in the model. It is important to note, though, that good practices and effective learning can happen at all levels, and that level five does not mean that further innovation is not possible.

2.1 Factors that Influence Teachers' Adoption of Technology.

Studies have shown that there are many factors impacting teachers' technology adoption in the classroom. Some of these aspects are: (a) **teachers' confidence and computer self-efficacy**; (b) **their educational beliefs and attitudes concerning technology**; (c) **their personal skills and experience with technology**; and finally (d) **the circumstances at their workplace**, such as access to up-to-date infrastructure and a supportive work culture.

These aspects play an important role whenever teachers select and decide to use technology. Level of experience in using technology is demonstrated to influence an individual's attitude to computers and, thus, their computer self-efficacy. Thus, a strong sense of computer self-efficacy of school teachers can impact the extent and the way technology can be used in everyday practice, significantly changing both teachers' and students' roles [15]. Self-efficacy can be developed through positive experiences with technology [7]. This helps to illustrate the importance of teachers' personal skills and experience with technology. However, *Ertmer et al. 2010* [7] explain that these experiences do not have to be personally experienced by the teacher. Vicarious experiences is also known to have the potential to develop teacher self-efficacy.

Other important aspects to be considered are teachers' educational beliefs and attitudes concerning technology. There is a correlation between teachers' beliefs and their subsequent classroom activities [7]. Also, evidence shows that teachers with more traditional beliefs will implement more traditional or "low-level" technology uses, whereas teachers with more constructivist beliefs will implement more student-centered or "high-level" technology uses.

Vermette et al. 2019 [24] emphasizes the importance of teachers' social fabric in personalizing digital classroom ecosystems. In this study, authors showed that even the tech enthusiasts teachers face a myriad of barriers when trying to integrate new digital classroom tools, such as keeping up with new requirements for learning and troubleshooting hardware and software. They point out that although informal social learning is helpful, it is often not enough. They explain that it is important to have institutional support for integration of digital classroom tools.

3 Methodology

We used an online structured survey to gather information about our research questions. These questions were related to schools' current maturity level regarding AR use in education; and what are the constraints blocking AR to be used in the classrooms. Based on the Future Classroom model, we have designed four questions to assess the levels on the dimensions described in the model. Other questions were related to their experience using and creating AR content. These questions aimed to capture some of the factors identified above in subsection 2.1.

We aimed to recruit participants that represented a broad cross-section across teaching levels and subjects. Thus, this form was shared with English and Portuguese speaking teachers from different countries, levels and areas of expertise as well as to mailing lists and social media groups of teachers interested in innovation and AR use in education.

Participants were requested to fill out the form and share it with their colleagues. After the end of the research, they were entered in a draw for the chance to win a US$ 5.00 (five dollars) Amazon gift card. All the answers were provided in June, 2019.

4 Results and Discussion

We have collected 106 responses from this form and we analyzed them in order to answer the research questions. The preliminary results are presented and discussed in this section.

4.1 Teachers' Profile

Most of the teachers who participated in this research were female. On average, they are 41.1 $\pm$ 10.6 years old, have been teaching for 15.5 $\pm$ 10.0 years and 78% of them know what is AR. As regards to their education, the majority of teachers have a master degree or a specialization course. These results show that most of these teachers are relatively older and have more teaching experience and education. No correlation was found between their age or teaching experience and the use of AR.

Most of them teach in regular public schools, followed by universities and regular private schools. Although we have a limited sample, this result suggests that we are going towards inclusion of students through the use of new technologies, such as AR. As regards to their teaching segment, the data show that most of them teach in the graduation level, followed by high school and middle school teachers. Post-graduation, pre-school and technical school were the segment with the least number of teachers.

When we consider the teachers who have used AR, we observe that half of the subjects taught are STEM related, followed by humanities and multidisciplinary contents as can be seen in Figure 1. It is important to note that one participant can teach more than one subject. Only one teacher used AR to teach medicine and health topics. This result corroborates existing literature, which shows that teachers usually find more abundant AR applications related to STEM subjects [5].

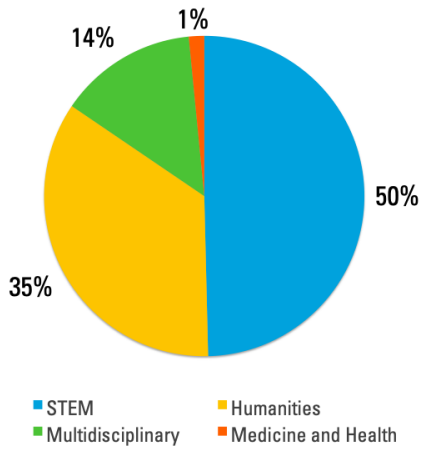

Figure 1: Subjects taught for each area by teachers that used AR.

4.2 Teachers' Knowledge of AR and Barriers to AR Adoption

Figure 2 shows that 54% of the teachers have never used AR. However, from this group, most teachers claimed that they have considered using it. This group of teachers were asked what they would like to know before using AR in their lessons. Most of them claimed they would like to learn more about pedagogic strategies. As one teacher put it, he would like to *"determine if it is pertinent or not"*. Secondly, they would like to learn more about tools available, and, moreover, which tools are accessible in their particular context. This is exemplified in this speech of a teacher who wants to *"learn more about it as there are very limited resources for adult students who are English Language Learners"*. Also, they would like to make sure they have technical support to use AR. These results suggest that teachers still need more time, training and support to feel more confident to use AR.

21 teachers argue that they used AR in classroom more than one time, but, not much. Followed by teachers who used AR in many of their lessons. In this research, we considered it to be more than five

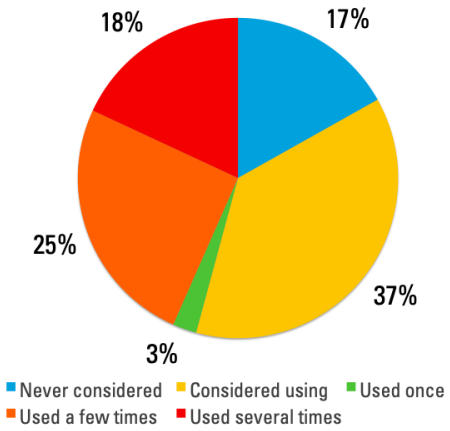

Figure 2: Distribution of teachers according to the use of AR.

uses. Only 2 teachers used AR just once. This result evidences that most of the teachers who used AR are still in an exploratory phase as they claimed to have used it less than five times.

4.3 Teachers' Maturity Level Regarding AR

As previously explained, in the form, we have four questions that intend to assess schools' use of AR technology as previously explained in section 2. These questions consider four of the five dimensions: (a) teachers' and (b) learners' role, (c) learning assessment, and (d) school support. We are not focusing on tools and resources because we are interested on AR as a tool.

As regards to the teachers, most of them classify themselves as levels 4 (extend), 2 (enrich) and 3 (enhance). The same number of teachers were classified as levels 1 (exchange) and 5 (empower), as illustrated in Figure 3. When it comes to all other dimensions, most of them classify themselves more in levels 1 (exchange) and 2 (enrich). However, there are some particularities. 6 teachers considered that students use the technology in level 5 (empower) and 5 see the school support in the same level.

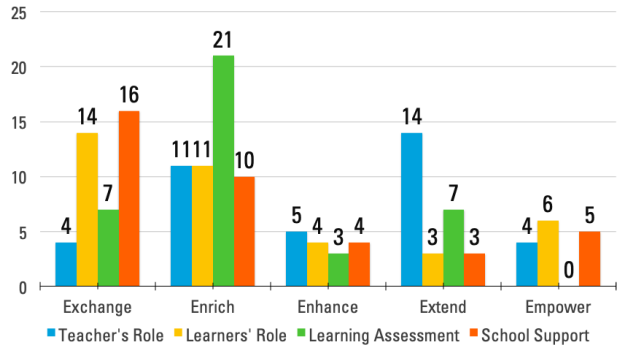

Figure 3: Distribution of teachers over the five maturity levels grouped by dimensions.

The Future Classroom toolkit shows that innovation in a school usually starts as an initiative of one or more individual teachers. However, in order to upscale the innovation process, we need to involve different stakeholders. Thus, school involvement is very important not only to provide infrastructure, but to provide support and promote a culture of innovation and collaboration.

Concerning assessment, they classify themselves in level 4 (extend) as much as in level 1 (exchange) and no one were considered as experiencing level 5 (empower) in that dimension. This result evidences that there is still some difficulties to incorporate new forms of assessment in school. This might happen due to many reasons such as fixed models of assessment or even lack of technology tools that support more innovative forms of assessment. For instance, *Silva et al. 2018* [5] show that teachers consider multiple choice questions as a limited way to evaluate students in AR tools. Thus, it is noticeable that time is needed to integrate AR into the curriculum and develop alternative forms of assessment.

4.4 AR Content Creation

55% of the teachers did not experience AR content creation. From the teachers who created AR content, most of them did it by themselves (24%), as depicted in Figure 4. In only 3 cases, the students were the ones responsible for content creation. Five cases were classified as others. This means that 4 teachers reported AR content creation in partnership with the students; and one teacher created it with the help of a colleague.

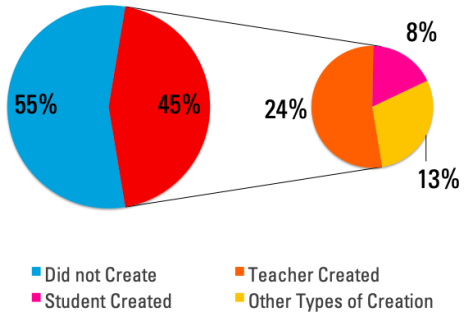

Figure 4: Distribution of teachers according to the creation of AR content and who created it.

4.5 Factors Blocking Teachers to Use AR More Effectively

Participants reported many factors that hinder their ability to use AR more effectively in their classrooms. These factors are illustrated in Figure 5. The most critical is poor infrastructure, which encompasses a variety of issues, such as poor internet connection and lack of devices. Besides, problems related to compatibility among devices were also mentioned.

When asked about the biggest problems faced when using AR, one teacher answered as follows: *"The type of devices of my students that sometimes didn't let them access the content"*.

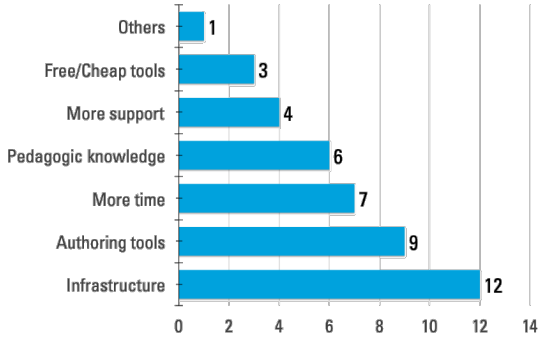

Figure 5: Factors that prevent teachers from using AR in the classroom more often.

The second most mentioned problem by the teachers is the lack of authoring tools as illustrated in this statement: *"I prefer that my students create AR rather than use pre-created programs"*. This

problem evidences that the technology itself needs to become flexible by allowing teachers and students to create appropriate learning content that is aligned with the pedagogic goals for the lessons. This is an important factor if we want schools to progress to higher levels of maturity regarding AR use. The Future Classroom model shows that, from the third level onward, *"technologies are used for collaboration, communication, to solve real-world problems and creativity (authoring tools, creating games, modelling and making)"*.

Teachers also pointed out the lack of pedagogic knowledge or AR applications. Pedagogic knowledge, in this context, means the knowledge of how to integrate AR effectively into teaching and learning. As can be illustrate by this statement: *"I would use AR more if I received more training and could use AR to redefine my lessons"*. Also, two teachers reported students got distracted with AR use. This indicates they had difficulties to coordinate the use of AR to achieve their learning objectives. In other words, data indicate that teachers need more guidance for using AR purposefully in the classrooms as can be seen in these words: *"I would use AR more if I saw other example lessons to get new ideas"*.

The absence of support from school, the lack of time for planning the lessons using AR and also to use in the classroom are other important factors preventing teachers to use AR more often.

The lack of these important aspects may lead to a decrease in teachers' confidence to explore this new technology as can be seen in this statement: *"I am not trained enough to feel confident using AR"*.

Another aspect mentioned is the cost involved in AR adoption. This is an important factor since without support it is difficult for teachers to adopt a new technology such as AR. One teacher reported that he tried to use AR, but,*"it still did not work, because I had to use my own materials"*. Other teacher reported to have used his own device and internet connection.

To sum up, these results evidence that although teachers are interested and eager to learn more about AR technology, its use is still incipient. Most of the teachers have been experimenting with it in their classrooms, but, they still need things like better infrastructure, tools that support content creation, and time to adopt it more effectively for learning. As one teacher put it: *"learners are not used to the technology so they have trouble getting used to it. After 3-4 lesson they become more competent in using the equipment which facilitates learning"*. In other words, they need to explore this technology much more in order to feel confident in using it.

5 Implications

From the identified aspects that are currently hindering AR adoption in classrooms, we believe some of the most interesting for the AR community are: (a) the need to be careful to avoid a lot of effort and frustration for teachers since they are still getting used to this technology. Excessive effort or frustration might hinder their confidence, and prevent future uses; (b) the need for authoring tools, since, these tools would allow more flexible and innovative exploration of AR content in the classroom; (c) the need to support compatibility to many types of devices which may be present in various classrooms; (d) the need to provide collaboration channels among students and also among teachers. It would be beneficial for AR technology platforms to stimulate cooperation among professionals, thus, building a sense of community and helping them advance in terms of maturity regarding AR use.

As regards to authoring tools, some valuable features might be: (a) not relying on internet connection for the AR experience; (b) possibility to create experiences compatible with a variety of devices; (c) possibility to share and reuse content created; (d) possibility to create content collaboratively.

Finally, although it is not in AR designers' hands, it is important to understand aspects such as access to infrastructure and teaching support, as well as learning what kinds of resources are usually available in typical classrooms. For instance, it is noticeable that internet connection is not always available as well as also access to 1:1 devices. Thus, it is important to design tools that work around such limitations.

5.1 Relationship Between AR Application Features and the Maturity Model

Based on our understanding of the maturity model, we point out some aspects that might be considered when developing AR applications.

1. **Exchange:** in this level, students usually work individually and activities and assessment are usually carried out by the teacher. It is interesting for the tool to enable assessment (usually done in more traditional ways at this stage) of students. It does not necessarily need to enable collaboration;

2. **Enrich:** in this level, there is some sharing of useful apps and tools between teachers and technology sometimes replaces more traditional approaches for learning and teaching. Thus, we might infer that tools might need to enable some collaboration and it might also allow more innovative experiences;

3. **Enhance:** in the third level, learning objectives are more personalised. Teachers work with a range of assessment approaches. Students receive quality feedback and their progress is tracked through the task. The need for authoring tools start to appear at this level because technology should enable personalization and intelligent content. It would also be interesting if the tool allows different assessment approaches to be used and progress track throughout the task.

4. **Extend:** in this level, besides the other aspects previously mentioned, tools might enable collaboration beyond traditional subject boundaries, thus, including interdisciplinary skills and collaborative problem-solving.

5. **Empower:** in addition to the aspects previously mentioned, learning objectives are continually reviewed and revised, are wide-ranging, ambitious, and balance the needs of assessment with the importance of developing skills, which are less easily or not formally assessed. Hence, it might be interesting the combination of AR and sensors that could help teachers to assess students more holistically. Learners receive feedback quickly, usually instantaneously.

6 Limitations

As limitations of this study, we point out the number of answers received in the form. The teachers who used AR might be considered in a way pioneers in the use of technology and may not represent the general population. Therefore, this sample may not represent the entire teaching community. Finally, it is important to point out that solving the problems discussed in this work might not directly cause teachers to use AR in more advanced levels. Results evidence that the effective use of AR depend on different aspects and stakeholders. Each of them play an important part in the process. As evidenced in subsection 2.1, many behavioral elements regarding the teacher play an important part in this process. These traits take time to be developed. Moreover, circumstances at workplace also play a significant role in adoption. Aspects such as these are not in direct control of developers.

7 Conclusion

Based on this research, we understand that although teachers seem interested and eager to learn about AR, its use have not reached higher levels of maturity in schools yet. Different aspects are related

to that, such as lack of infrastructure, authoring tools and time. Results have also shown that teachers need more guidance and support in order to better connect AR use with their pedagogic goals. Price of the tools are also a concern for them.

Additionally, the need for AR tools to support collaboration, creativity through content creation (authoring tools) and ability to assess students in more flexible ways are also related to more mature uses of technology. Thus, these would be interesting features to be provided by AR tools.

It is important to address as much of these issues as possible so teachers can be more confident in AR use and feel confident enough to explore this technology in the classrooms and promote effective learning. To conclude, it is important to mention that the goal is not just to use more of AR, but use it effectively, connected to the learning objectives and integrated to other technologies available in schools as advocated in the maturity model. As future works, we will continue analyzing the results to find correlations in this data set.

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