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Towards a Teachers' Augmented Reality Competencies (TARC) framework

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Abstract. Augmented reality, the technology that augments real environments with virtual components, is constantly evolving. Augmented reality (AR) has the potential to offer immersive, authentic, and meaningful learning experiences to students and therefore enhance learning. However, the effective integration of augmented reality into teaching requires from teachers to master a special set of digital competencies. The current study proposes a framework that defines the augmented reality competencies that teachers should have in order to effectively integrate augmented reality into their teaching. The framework comprises four dimensions: basic augmented reality literacies, create, use, and manage augmented reality learning resources. Based on the proposed framework, the study introduces also the Teachers' Augmented Reality Competencies (TARC) questionnaire that can help educators to self-assess and develop their AR competencies in order to integrate augmented reality in their practice.

Keywords: augmented reality, framework, TARC, teachers' digital competencies, teachers' digital skills.

1 Introduction

Augmented Reality is an emerging educational technology that bridges the gap between the virtual and physical world by incorporating virtual components in real environments. The rapid growth of mobile and wireless technologies and other technologies such as motion tracking and sensors has facilitated the wider adoption of AR. AR (as being not fully immersive) is in the one end of the eXtended Reality (XR) or Mixed Reality (MX) spectrum, with the Virtual Reality (VR) to be in the other end (as being fully immersive). In AR, the physical world is linked with the virtual content through various triggers such as physical location triggers (e.g., latitude and longitude), application pre-defined triggers (e.g., an image or a QR code) or Artificial Intelligence services [1]. Therefore, users can navigate in the real world and through these triggers and can have augmented experiences with various overplayed digital assets. These assets can be text, 2D or 3D images, videos or other digital artefacts (e.g., holograms). The navigation is through either dedicated hardware or mobile devices loaded with appropriate AR apps.

2 Augmented Reality in Education

AR provides new possibilities for the educational domain and is a promising tool for teachers and learners. Studies have shown that there are many advantages associated with the use of AR in educational settings. AR enables visualization of invisible and abstract concepts, can provide interaction opportunities for students, increases student interest enhancing their satisfaction and engagement [2]. Moreover, AR enhances leaning achievement favouring long-term knowledge retention and increases learning motivation [3]. Despite the reported positive outcomes of AR in education, AR is still at an early stage and teachers are still hesitant to use AR. Asking educators to develop or use an augmented reality learning experience "might still illicit a questioning expression on their faces" [4]. One reason for this is the lack of AR competencies. Existing teachers' ICT competencies frameworks such as the UNESCO ICT Competency Framework for Teachers (ICT CFT) [5], the European Framework for the Digital Competence of Educators [6] and different technology integration frameworks provide only general guidelines. AR technology involves a wide range of elements that teachers need to master in order to make an effective use of it.

3 Teachers' AR Competencies Framework

The Association for Educational Communications and Technology defined Educational Technology as the "the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources" [7]. Augmented reality, as an emerging educational technology can also be seen under the lens of this definition. "Creation" refers to the "research, theory, and practice involved in the generation of learning environments" [8]. The creation of augmented learning environments can involve the full instructional cycle of the analysis, design, development, implementation and evaluation. "Using" refers to "the theories and practices related to bringing learners into contact with learning conditions and resources" [8]. Using AR involves the deployment of augment learning experiences in the teaching practice. "Managing" AR involves both creation and using [8] as well other administrative tasks such as locating, classifying, evaluating or regulating. The current study proposes a framework that defines a set of competencies that teachers need to have in order to effectively integrate AR into their professional practice and enhance their teaching offering engaging and effective learning experiences. The proposed framework defines three main competency areas: *Create, Use* and *Manage* Augmented Reality Learning Experiences (Fig. 1). We have also defined sub-dimensions for each of these areas. *Creation* involves the capacity to design and develop or modify augmented reality learning experiences. *Use* involves the capacity to *employ various pedagogies*, *teach (face-to-face or online), assess and provide feedback and communicate and collaborate* using augmented reality. *Management* involves the capacity to *find,* *classify and evaluate* augmented reality learning experiences as well as to consider *ethical implications (e.g., copyrights, privacy)* as well as *safety and security issues* with their use.

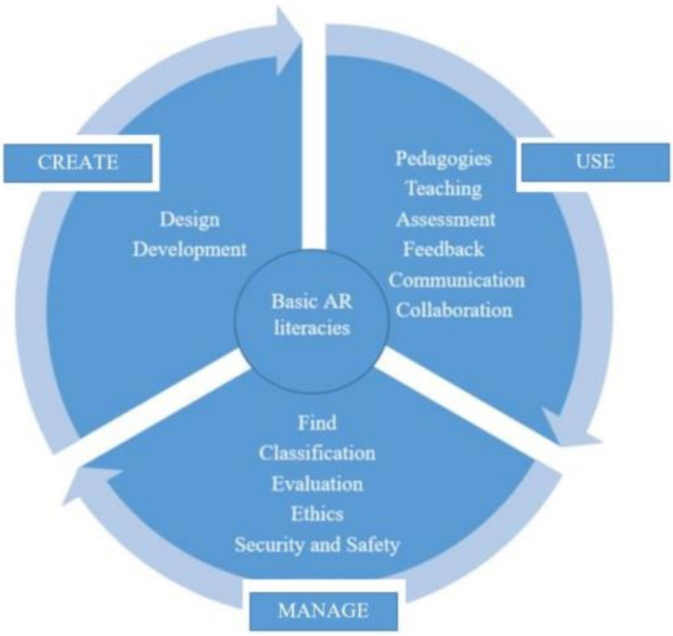

Fig. 1. Teachers' AR competencies (TARC) framework.

3.1 Basic Augmented Reality Literacies

Teachers should have the skills to use Augmented Reality and integrate it into teaching. There is no need for teachers to become experts in Augmented Reality. It is not required to have skills in tracking technologies, display technologies, image processing, computer vision, stereo rendering, etc. Without going too much into programming and software development details, teachers should have basic descriptive knowledge of the following areas: (i) basic understanding of AR definitions, terminology, functionalities as well as advantages and disadvantages, (ii) software needed to operate AR resources, (iii) available tools to create web-based and mobile-based AR off-the-self applications and the differences among these, (ii) required hardware and devices (e.g., headsets, smart-glasses, 360 cameras).

3.2 Creating AR

Design.

Various issues need to be considered when designing AR learning experiences. The existence of many heterogeneous activities that can be integrated in AR design may result in an increased student cognitive load. Therefore, learning scenarios should allow a level of flexibility to accommodate unforeseen events and adapt to student needs [9]. Selecting the appropriate type of digital media is also important to avoid cognitive overload [10]. Most existing applications use only one type of digital element with the majority of them to use text and 2D images while animations, 3D objects and videos are used less frequently [11]. Educators should have the ability to design digital elements as overlay information to augment the digital world. Motivation design should be relevant, trigger students' attention, support their confidence and improve their satisfaction levels [12]. Educators should also consider accessibility features related to social inclusion. Following the Universal Design Principles [13], providing multiple means of representation, engagement, action and expression is recommended.

Development.
Developing AR applications usually requires advanced digital skills and competencies (such as programming, tracking technologies, display technologies, image processing, computer vision, stereo rendering, etc.) that normally go beyond the basic AR literacy skills that have been previously discussed. *ARCore* for Android and *ARKit* for iOS are the most widely used frameworks in developing interactive AR. However, these frameworks require a rather specialised experience in software development, which most teachers do not currently have. This can keep teachers away from AR development resulting in AR experiences without clear learning objectives and curriculum integration [14]. However, there exists a range of closed end-user development tools (e.g., *BlippAR, Metaverse, ARCreator*) with easy-to-use templates and asset libraries, that teachers can use to create their own AR learning experiences. Usually, these tools do not require development of algorithms but only development of AR resources to be linked with objects or locations [15]. Teachers who want to start explore AR development should consider to use these tools to build AR experiences that are aligned with their own with instructional practices.

3.3 Use AR

Pedagogies.
Deciding on the appropriate pedagogy that informs the instructional practices to be implemented when designing AR environments is important. AR learning experiences usually draw upon constructivism and situated learning theories and can support contextualized and student-centered learning [16]. Related literature suggests that the most common pedagogical approaches in AR interventions are collaborative learning, inquiry-based learning, situated learning, and project- based learning [17]. Studies have shown that while situated learning is the most common pedagogical approach, collaborative learning has the greatest impact on students' learning [18]. When designing three-dimensional (3-D) virtual learning environments, there are several contextual var-

iables that need to be considered such as locus of control, class dynamics, level of interactivity, source of information [19]. Providing learning experiences that can be teacher or student controlled, have an appropriate level of interaction and scaffolding while being focused on the learning objectives is a matter of adopting each time the appropriate pedagogy. However, researchers agree that there is a lack of clear guidelines describing pedagogical considerations regarding the development and use of augmented reality environments [20]. Educators, who develop, modify or simply use AR applications should be aware of this and try not to simply use the technology but better integrate pedagogical strategies in their AR interventions.

Teaching.

Teachers can always take advantage of the superiority of AR learning environments not only by developing new AR resources but also by using existing AR resources. There are many AR applications readily available that teachers can use to harness AR content. These applications can facilitate the representation of abstract information in an interactive way by allowing teachers/students to create AR content in different subject areas. AR applications such as *Google Expeditions* or *Thinglink* empower teachers and students to create their own AR experiences and can offer authentic and contextualized learning directly connected to the real-world contexts. Despite the extra workload required, the educational benefit of these AR apps can be rewarding [21].

Assessment.

Learning assessment is an important part of the educational process. Learning outcomes can be evaluated by assessing cognitive (acquisition of knowledge and information and intellectual skills), behavioural (engaging with the learning activities) or affective outcomes (learners' perceptions of their learning) [22]. The ongoing evolution of educational technologies allow the use of new assessment types. The new modes of information representation made available through educational technologies allow innovative digital classroom assessments types. There is a variety of assessment elements that can be incorporated in AR such as game elements or multimodal assessment types. Multimodal assessment can go beyond the conventional paper-based/digital text assessments and require students to combine two or more representational modes using digital technologies [23]. AR technologies can successfully enrich low-stake assessment practices such as formative assessment [24], peer-assessment [25] and self-assessment [26] with impact on learning performance and learning motivation. Simulation-based assessment can be effectively used in assessing problem-solving skills [27]. Medical students assess their clinical skills using AR simulated environments [28].

Feedback.

It is very well known that timely informative feedback enhances learning outcomes [29]. However, providing instant individual feedback to students especially in complex learning tasks such as project-based learning activities can be a challenge for teachers. AR learning environments can provide automated meaningful real-time feedback making a significant difference in terms of learning benefits. This is due to its timeliness and support for visualization [30]. AR interfaces can provide multimodal feedback ranging from visual and auditory to haptic feedback through sensors and control devices. Since feedback can be timely and interactive, learners can be immersed in the learning experience. A properly configured AR-based feedback strategy can help students to better understand the learning tasks. For example, studies have shown that in virtual simulations the provision of explanation type feedback can be more appropriate for declarative tasks whereas for procedural tasks knowledge of correct response feedback is suitable [14]. AR-facilitated feedback can be helpful for teachers as well to identify students' misunderstandings and weaknesses. For example, through an AR interface, teachers receive immediate, private and individualized feedback for each student as well as aggregated feedback for the whole class [31].

Communication.

Communication in virtual environments can involve a variety of activities: creation of digital and virtual artefacts in various forms to convey ideas, verbal or text communication with peers and teachers, interactions through avatars, role playing, visiting each other's' virtual spaces while working in the process of solving a problem or navigating through augmented and virtual spaces. Users can have multiple choices to make connections using interactive interfaces [32] and communicate in group tasks [33]. Emerging assistive technologies, such as smart glasses, facilitate social communications among learners with autism spectrum disorder addressing such the problem of communication deficiencies [34]. Studies have shown that AR facilitates the development of communication competencies [35] and therefore teachers should be able to take advantage of the enhanced interactions offered in virtual environments to build connections and to develop students' communication skills.

Collaboration.

Augmented and virtual reality environments provide a wide range of opportunities for cooperative and collaborative work. Collaboration can include group work, peer review and social negotiation during the development of AR resources or other community-based learning and teaching activities; this works well especially in location-based AR environments [36]. Moreover, in cloud collaboration platforms, learners can also share their local environment remotely in order to collaborate on spatial tasks in shared virtual spaces [37]. AR technologies can enhance non-virtual or virtual collaborative tasks and teachers face the challenge to be able to support and take advantage of these kind of interactions.

3.4 Manage AR

Find.

The capacity to find the appropriate AR educational resources that can be used in specific learning scenarios aiming to address specific learning objectives is fundamental. Teachers are not always in position to develop their own applications and should be able to find ready applications that are stored in various AR repositories (e.g., *GitHub*). Usually, AR software keeps on a library of apps that have been developed with the specific software and teachers can re-use these resources by modifying them according to their needs (e.g., *Google expeditions*).

Classification.

It would be useful for educators to be able to classify different AR resources based on different criteria on order to be able to effectively use them in class. We would argue that a meaningful classification should be based on the curriculum content knowledge that AR resources can offer and support: declarative, procedural or conceptual. According to [38], educational resources can be: information display and presentation (declarative knowledge), practice resources (procedural knowledge) as well as concept representation and data display resources (conceptual knowledge). Similarly, AR resources can be classified with respect to the above criteria.

Evaluation.

Teachers to know how to evaluate AR educational resources with respect to usability, usefulness, credibility, appropriateness/suitability, enjoyment, safety, mobility, educational outcomes/students' performance. Most importantly, teachers should be able to evaluate the feasibility of integrating AR resources in their teaching (e.g. usability) and their educational impact (e.g. knowledge retention, cognitive skills, motivation) as well [39].

Ethics.

There may be several ethical challenges arising from the use of AR in Education. For example, in in pervasive mobile augmented reality the users' private space can be exposed to the outer world [40]. Moreover, facial recognition or geolocation feature can put learners' privacy at risk. Sometimes also, AR and MR application can manipulate emotions and create unrealistic expectations [41] that can have negative mental and social negative effects. Ethical challenges associated with the use of AR should always be taken into consideration especially for minor learners who are more vulnerable.

Security and Safety.

Educators should be aware that augmented reality application could put learners at physical or mental risk [41]. The use of AR devices such as headsets should be avoided to be used outdoors (e.g. in the street) because of their immersive nature. Educators should always promote safe and healthy behaviours.

4 Conclusions and Future Work

Considering the increased potential of AR, previous research indicated the need to focus on the development of AR related skills and competencies [42]. The current study proposes a framework that defines a set of competencies that teachers need to have in order to effectively integrate AR into their teaching. Based on the aforementioned dimensions (Create, Use, Manage) of the proposed framework, the Teachers' AR Competencies (TARC) Questionnaire has been developed (Appendix). In line with our previous efforts to define specific actions someone needs to do in order to improve their digital competencies [43] and introducing a progression model with different levels of expertise [44], our future research aims to further improve the granularity of the proposed framework and validate it. It is in our research plans to organize a large-scale survey among European teachers using the proposed framework and questionnaire and analyze our findings based on gender, educational level (primary, secondary, tertiary, adult education), countries and other factors, elaborating more on the next steps of this promising work.

Appendix

Teachers' AR Competencies (TARC) Questionnaire

How confident are you in doing the following (1 – "Not confident at all" to 5 – Very confident"

CREATE:

DESIGN: I can design AR educational experiences using AR applications and tools to meet specific educational objectives.

DEVELOPMENT: I can develop AR educational resources using easy-to-use AR templates and asset libraries. I can adapt AR educational resources to my teaching goals.

USE:

PEDAGOGIES: I can use/adapt AR educational resources employing various pedagogies and teaching methods.

TEACHING: I can use AR educational resources to teach (e.g., present, demonstrate, explain) my students.

ASSESSMENT: I can use AR educational resources (e.g., AR and multimodal game-based and simulation-based assessments) to assess the students' progress.

FEEDBACK: I can use AR educational resources (e.g., avatars, multimodal interfaces) to guide, feedback, advise, support, and inspire students.

COMMUNICATION: I can use AR educational resources (e.g., avatars, AR spaces) to interact and communicate with students and enable students' interactions and communication.
COLLABORATION: I can use AR educational resources (e.g., avatars, AR spaces) to collaborate with students and enable students' collaboration.

MANAGE:
FIND: I can use search engines, digital repositories, and databases to find existing AR educational resources using appropriate criteria, metadata filters, and recommender systems.
EVALUATION: I can evaluate AR educational resources using appropriate criteria.
CLASSIFICATION/ORGANIZATION/SCHEDULING: I can classify the AR educational resources to information display and presentation, practice resources as well as concept representation and data display resources. I can organize and schedule the most appropriate AR educational resources for achieving specific educational objectives.
ETHICS: I can control the ethical and responsible use of AR resources by all participating in the educational activities (e.g., respecting participants' personality, privacy, rights).
SECURITY & SAFETY: I can secure the safe use of AR resources by all participating in the educational activities (e.g., securing participants' resources, safety, health).

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