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# Educators' ability to use Augmented Reality (AR) for teaching based on the TARC framework: Evidence from an international study

Stavros A. Nikou<sup>1</sup>[0000-0001-9941-2125] Maria Perifanou<sup>2</sup>[0000-0002-9874-8417] and  
Anastasios A. Economides<sup>2</sup>[0000-0001-8056-1024]

<sup>1</sup> University of Strathclyde, Glasgow, UK  
stavros.nikou@strath.ac.uk

<sup>2</sup> University of Macedonia, Thessaloniki, Greece

**Abstract.** Augmented Reality (AR) can enhance learning experience by offering various benefits to learners. However, its integration in classroom practice remains challenging and one reason of this is the lack of teachers' AR competences. The Teachers' AR Competences (TARC) framework defines the main AR competences that educators should have in order to successfully employ AR in their teaching: Creating, Using and Managing AR resources. The current study, building upon the TARC framework, aims to examine the effect of the TARC components of Creation and Management to the educators' ability to Use AR in class. It is the first study that investigates the impact of the educators' AR competences on their ability to use AR in classes. Moreover, while studies for primary and secondary teachers' AR skills exist, this is the first study that explores also university lecturers'/professors' ability to use AR in classes. A survey was conducted with 150 educators around the globe. Regression analysis revealed that the Creation and the Management competences significantly predict university lecturers'/professors' and primary/secondary school teachers' ability to Use AR in their classes. Study findings deemed important for educators and education administration and implications are discussed.

**Keywords:** Augmented Reality, Educators' Competences, Educators' Skills, Higher Education, Primary education, Secondary Education, Teachers' Competences, Teachers' Skills, Teaching with AR

## 1 Introduction

Augmented Reality (AR) is a technology that overlays virtual elements onto the real world, allowing users to perceive and interact with a digitally enhanced environment [1]. AR provides users with an enhanced perception of reality and enables them to interact with both virtual objects and physical surroundings as well as other users in real-time [2], [3]. AR has been used in a variety of industries and services including education [4], [5].

AR enables students to visualize abstract and complex concepts or phenomena, virtual artefacts or environments, and inaccessible places enabling students to better understand and learn [6], [7], [8]. AR enhances students' interest [9], [3], engagement [6], [10], motivation [7], [11], [3] and enjoyment [6], [7], [12]. AR provides collaboration opportunities [13], [2], [7], [14], [3] and enhanced learning experiences [15], [6], [3]. Despite the increasing use of augmented reality (AR) in education and its positive outcomes, integrating it into classroom practices remains challenging [16]. Several barriers exist such as limited digital infrastructure (e.g., tools, equipment/devices, networking) [17], [8], [18], [3], cost [15], [17], [13], [7], [18], [14], [3], complexity of AR and AR applications for educators and students [15], [13], [5], [3] as well as educators' low digital competence [17], [3], [19] and lack of educators' AR competence [15], [13], [2], [7], [18], [5], [20], [3], [19]. Educators constitute one of the key elements to effectively integrate AR into class. However, they usually lack the appropriate AR competences. Existing studies indicate that teachers lack the necessary skills to develop AR applications [2], [7], [19]. Successful implementation of AR in education depends on educators' AR skills and competences.

Despite previous studies on AR in education, to the best of our knowledge, only one study [21] has examined and explored teachers' AR competences, formally defining the necessary AR competence components needed for AR classroom integration. Furthermore, while most previous studies investigated teachers in primary and secondary education [16], [17], [6], [18] or even pre-service (students) candidate teachers [7], there is hardly any research to investigate the AR competence of educators in higher or tertiary education. So, the current study also investigates the AR competence of educators in higher education. Building upon the Teachers' AR Competences (TARC) framework developed in the study by [21], the current study aims to examine the effect of the educators' AR competence components (according to the TARC framework) to the educators' ability to use AR in class.

## **2 Theoretical Background**

### **2.1 Teachers' Augmented Reality Competences (TARC) framework**

The study uses the Teachers' Augmented Reality Competences (TARC) framework [21] as its theoretical background. The framework defines AR competence components that are important for educators to use AR in their teaching. According to the framework, educators should be able to create, i.e., design, develop, and modify AR learning scenarios and digital media to overlay information to the physical worlds. Educators should be able to use AR, i.e., employ proper pedagogies in order to teach and assess in AR learning environments providing meaningful AR-based scaffolding and feedback as well as communicate and collaborate in AR-enhanced virtual worlds (e.g., through avatars). Educators should be able to manage AR resources, i.e., search and find the appropriate AR educational resources, evaluate and classify them based on different criteria for an effective classroom use and deal and overcome several ethical (e.g.,

privacy) as well as security and safety (e.g., physical or mental risks) challenges arising from the use of AR in education. Therefore, the TARC framework comprises the following three components: AR Creation (Design/Develop/Modify, DDM), AR Usage (Pedagogy/Teaching/Assessment/Feedback/Communication/Collaboration, PTAFCC) and AR Management (Search/Evaluate/Organise/Ethics/Safety&Security, SEOES). Based on TARC, the aforementioned study [21] developed the Teachers' AR Competences (TARC) questionnaire used in the current study as well.

## 2.2 Hypotheses

Based on the TARC framework and questionnaire the present study aims to test the following hypotheses:

1. The AR Creation (Design/Develop/Modify) and AR Management (Search/Evaluate/Organise, Ethics/Safety&Security) competences significantly and positively predict higher education lecturers' ability to use AR (Pedagogy/Teaching/Assessment/Feedback/Communication/Collaboration) in class.
2. The AR Creation (Design/Develop/Modify) and AR Management (Search/Evaluate/Organise, Ethics/Safety&Security) competences significantly and positively predict primary and secondary teachers' ability to use AR (Pedagogy/Teaching/Assessment/Feedback/Communication/Collaboration) in class.

## 3 Methodology

### 3.1 Participants, Instruments and Procedure

The study has been conducted from May to June 2022. Researchers distributed a survey among educators internationally through emails, discussion lists, and social media channels. Participation in the study was voluntary and anonymous. 150 valid responses from 35 different countries were collected. 37% of the participants were primary/secondary school teachers and 63% were higher education lecturers/professors. Participants were 49.9% female, 46.6% male, and 3.6% preferred to self-describe/not say. 11.3% of the participants were 21-30 years old, 17.2% were 31-40 years old, 37.1% were 41-50 years old, 26.3% were 51-60 years old, 5.4% were 61-70 years old and 2.7% other/prefer not to say. In terms of their general digital skills level, 9.7% of the participants had basic digital skills, 43% had intermediate digital skills and 47.3% had advanced digital skills. Participants' teaching experience in years was varied as follows: 28% with 1-10 years, 33.2% with 11-20 years, 24.7% with 21-30 years, and 10.2% with more than 31 years. Half of the participants were teaching Informatics/Engineering/Technology (50%) while science (19.3%), Languages/Literature (6.7%), Economics/Social Sciences (4.8%) and others (16.1%) to follow. The socio-demographic characteristics of the participants are presented in Table 1.

The questionnaire on AR competences has been adopted from [21]. Questions were 5-point Likert-type, ranging from "Strongly disagree (1) to "Strongly agree" (5). The

Cronbach's alpha reliability coefficient of internal consistency for all scale items was calculate ensuring that all Cronbach's  $\alpha$  values were greater than 0.7 demonstrating internal consistency [22], [23].

**Table 1.** Socio-demographic characteristics of the participants

Variables	Categories	%
Gender	Female	49.9
	Male	46.6
Age	Self-describe /not say	3.6
	21-30 years old	11.3
	31-40 years old	17.2
	41-50 years old	37.1
	51-60 years old	26.3
	61-70 years old	5.4
	Not say	2.7
General digital skills level	Basic	9.7
	Intermediate	43.0
	Advanced	47.3
Teaching level	Primary and Secondary	37.0
	Higher	63.0
Teaching Experience (in years)	1-10	28
	11-20	33.2
	21-30	24.7
	>31	10.2
	other/prefer not to say	3.2
Teaching Subject/Discipline	Informatics/Engineering/Technology	50
	Science	19.3
	Languages/Literature	6.7
	Economics/Social Sciences	4.8
	Other	16.1

#### 4 Data Analysis and results

The data collected has been analysed using IBM SPSS v.28. To test our hypotheses, we have conducted multiple regression analysis in order to determine the extent to which the AR Creation (Design/Develop/Modify) and AR Management (Search/Evaluate/Organise, Ethics/Safety&Security) educators' competences can predict their ability to use AR (Pedagogy/Teaching/Assesemnt/Feedback/Communication/Collaboration) in class. We have performed multiple regression analyses for two separate group of educators, i.e., Higher Education (HE) lecturers/professors (Hypothesis 1) and Primary/Secondary (P/S) teachers (Hypothesis 2). Data has met the assumptions required for multiple regression. Skewness values for all items were not higher than 3 and kurtosis values for all items were not higher than 8 indicating that data is considered to be normally distributed [24]. The slight deviations from the assumption of homoscedasticity that were observed, do not pose major problems [25], [26]. The values of the Variance Inflator Factors (VIFs) are between 2.25 and 4.01 (less than 10) indicating that there is no multicollinearity [27].

Descriptive statistical values and correlation coefficients are presented in tables 2 and 3 respectively. Generally, educators reported low to medium levels of AR competences with the primary and secondary level teachers to self-report lower competence levels compared to the university lecturers/professors. There were significant and positive correlations between the four independent variables and the ability to teach with AR.

**Table 2.** Mean and standard deviations of the TARC variables

TPACK components	Higher Education (N=95)		Primary/Secondary (N=55)	
	Mean	SD	Mean	SD
AR Usage (PTAFCC)	2.93	1.12	2.74	1.26
AR Creation (DDM)	3.09	1.16	2.56	1.25
AR Management (SEOES)	3.15	1.16	2.81	1.30

**Table 3.** Intercorrelations between the TARC variables

		PTAFCC	DDM	SEOES
AR Usage (PTAFCC)	HE	-		
	P/S	-		
AR Creation (DDM)	HE	.78***	-	
	P/S	.76***	-	
AR Management (SEOES)	HE	.72***	.72***	-
	P/S	.78***	.65***	-

\*\*\* $p < 0.001$

Table 4 presents the results of the multiple linear regression analysis predicting University lecturers' ability to use AR for teaching. The Design/Develop/Modify (DDM), competences were found to be significant predictors of university lecturers' ability to use AR for teaching with  $\beta = 0.47$ ,  $t = 5.75$ ,  $p < 0.001$ . The Search/Organise/Evaluate/Ethics/Safety&Security (SEOES) competences were also found to be significant predictors of university lecturers' ability to use AR for teaching with  $\beta = 0.43$ ,  $t = 5.19$ ,  $p < 0.001$ . The results also indicated that the two variables together, as expressed in the R-square, explained 70% of the total variance in lecturers' ability to use AR for teaching ( $R^2 = 0.703$ ). Of these two variables, the design (DDM) competence makes the largest unique contribution ( $\beta = 0.47$ ).

Table 5 presents the results of the multiple linear regression analysis predicting University lecturers' ability to use AR for teaching. The Design/Develop/Modify (DDM), competences were found to be significant predictors of university lecturers' ability to use AR for teaching with  $\beta = 0.43$ ,  $t = 4.48$ ,  $p < 0.001$ . The Search/Organise/Evaluate/Ethics/Safety&Security (SEOES) competences were also found to be significant predictors of university lecturers' ability to use AR for teaching with  $\beta = 0.49$ ,  $t = 5.14$ ,  $p < 0.001$ . The results also indicated that the two variables together, as expressed in

the R-square, explained 72% of the total variance in lecturers' ability to use AR for teaching ( $R^2 = 0.717$ ). Of these two variables, the management (SEOES) competence makes the largest unique contribution ( $\beta = 0.49$ ).

**Table 4.** Results of the multiple linear regression analysis predicting **HE** educators' ability to use AR for teaching based on the TARC constructs.

Variable	R <sup>2</sup>	Adj. R <sup>2</sup>	F	B	SE	$\beta$	t	p
	0.703	0.697	F (2, 92) = 109.070***					
(Constant)				.21	.19		1.19	.270
DDM				.46	.08	.47	5.75	<.001
SEOES				.41	.08	.43	5.19	<.001

\*\*\*F-Value is significant at the  $p < .001$ .

**Table 5.** Results of the multiple linear regression analysis predicting **Primary/Secondary** educators' ability to use AR for teaching based on TARC constructs

Variable	R <sup>2</sup>	Adj. R <sup>2</sup>	F	B	SE	$\beta$	t	p
	.717	0.706	F (2,52) = 65.942***					
(Constant)				.27	.23		1.17	.248
DDM				.49	.09	.43	4.48	<.001
SEOES				.48	.09	.49	5.14	<.001

\*\*\*F-Value is significant at the  $p < .001$ .

## 5 Discussions – Conclusion

The purpose of the current study was to explore educators' AR competence levels identifying the extent to which the Creation, i.e., Design/Develop/Modify (DDM), and Management, i.e., Searching/Evaluation/Organization/Ethics/Safety&Security (SEOES), components of the TARC framework can predict educators' ability to use AR in class for Pedagogy/Teaching/Assessment/Feedback/Communication/Collaboration (PTAFCC). The study is one of the first that considers AR competence components for educators.

Results revealed low to medium levels of AR competences for the primary, secondary and higher education level educators. Higher education lecturers and professors self-reported slightly higher AR competence levels compared to the primary and secondary school teachers.

Multiple regression analyses conducted for two separate group of educators, i.e., university lecturers/professors and primary/secondary school teachers. Design/Develop/Modify (DDM) and Searching/Evaluation/Organization/Ethics/Safety&Security (SEOES) competences were found to be significant predictors of both university lecturers' and primary/secondary school teachers' ability to use AR in their classes (PTAFCC). The DDM competences refer to the ability of educators to create and edit new digital content. The ability to develop or restructure AR digital content can be a

significant predictor of the ability to actually use AR in teaching. Educators who feel confident in designing, developing, and modifying AR content are more likely to have higher ability in using AR in teaching. The importance of these digital competences has been highlighted in previous studies as well [28], [29]. Existing research conceptualised also the skills of searching, finding an accessing digital resource [28] or managing and evaluating digital information [30]. The importance of ethics and safety/security also has been highlighted in previous research on teachers' digital literacy [31]. Similarly, our study provided evidence that the searching, evaluating, and organising AR content abilities facilitate AR teaching ability for educators. Moreover, the ability to deal and overcome issues related to ethics and safety and security found also to be an important factor to teach with AR and this needs to be carefully considered.

Based on the above, the ability of educators to effectively deliver pedagogically meaningful AR-based lessons relies on their ability to create and manage AR resources. Therefore, amplifying the abilities of educators to create AR content, and manage AR content can enhance their ability to teach with AR. All above AR competences also have been highlighted in "The Digital Competence Framework for Citizens" [32] and the European Framework for the Digital Competence of Educators: DigCompEdu [33]. The study can be helpful for instructional designers, education practitioners and teacher training institutions to gain a better understanding on the AR competence components that are important to be considered when designing instructional practices and teacher AR development programmes.

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