Journal of Computers in Education (2024) 11(4):1041–1060
https://doi.org/10.1007/s40692-023-00288-6

Development and validation of the teachers' augmented reality competences (TARC) scale

Stavros A. Nikou[1] · Maria Perifanou[2] · Anastasios A. Economides[2]

Received: 5 April 2023 / Revised: 15 June 2023 / Accepted: 4 July 2023 /
Published online: 14 July 2023

Abstract
While augmented reality (AR) can offer many advantages in education, one reason for the difficulty of integrating it in instructional practices is the lack of teachers' AR competences. Therefore, there is an increasing need to address the required competences needed by teachers to effectively integrate augmented reality (AR) in their teaching. This study develops and validates a comprehensive augmented reality competences scale for teachers. The suggested instrument encompasses skills related to the creation, use and management of augment reality resources for teaching. The scale was validated on a sample of 150 educators from 45 countries teaching in primary, secondary or tertiary levels. Confirmatory factor analysis demonstrated valid results in terms of model fit criteria, factor loadings, validity, and reliability. The final scale is composed of 11 items and 4 competence components. Teaching subject, general digital skills and previous AR class experience revealed significant differences across the scale components, while gender and age did not reveal any significant associations. Educators in higher education institutions self-reported higher competence level for designing, developing, and modifying AR resources compared to secondary and primary levels. The scale can be used by educators to self-assess their AR competences, teacher professional development institutions and policy makers to develop training programs in AR and software companies to develop AR experiences that can empower educators.

Keywords Augmented reality · Digital competence · Scale development · TARC · Teachers' competences

✉ Stavros A. Nikou
stavros.nikou@strath.ac.uk

Maria Perifanou
mariaperif@gmail.com

Anastasios A. Economides
economid@uom.gr

[1] School of Education, University of Strathclyde, 141 St James Road, Glasgow G4 0LT, UK

[2] SMILE Lab, University of Macedonia, Egnatia 156, 54636 Thessaloniki, Greece

Introduction

Teachers' actual and perceived digital competences are very important determinants for the successful integration of digital technologies in teaching and learning (Knezek et al., 2019; Petko et al., 2018; Rubach & Lazarides, 2021). Digital competences are defined as "the confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society" (Directorate-General for Education, 2019, p. 12) and in the context of education they can be understood as the set of abilities to use digital technologies to optimize teaching and learning effectively. International frameworks such as the UNESCO ICT Competency Framework for Teachers (UNESCO, 2018), and the European Framework for the Digital Competence of Educators (DigCompEdu: European Commission, 2017) have highlighted the importance of teachers' digital competences and research studies examined different areas of teachers' digital competences (e.g., Perifanou & Economides, 2019; Rubach & Lazarides, 2021; Tzafilkou et al., 2022) showing that they constitute an important factor for the successful integration of digital technologies in educational practice (Mishra & Koehler, 2006; Tondeur et al., 2017). However, despite the large number of studies on teachers' digital skills and competences, to the best of our knowledge, no study exists that specifically addresses teachers' competences in using augment reality (AR) in their teaching.

Augmented reality (AR) is a technology which, by incorporating computer-generated virtual information in real environments, can extend/augment users' reality. AR has many benefits in education: it can provide enhanced interaction opportunities, can enable visualization of invisible elements and abstract concepts, can increase student interest, motivation and engagement (Akçayır & Akçayır, 2017) and enhance leaning achievement favouring long-term knowledge retention (Radu, 2014). However, despite the growing trend of introducing AR learning experiences in education and AR's positive educational outcomes it is still difficult to be integrated in classroom practices and a main reason for this is the lack of teachers' AR competences (Tinti-Kane & Vahey, 2018). Usually, teachers lack skills for developing AR applications (Bacca et al., 2014; Belda-Medina & Calvo-Ferrer, 2022; Manuri & Sanna, 2016; Palamar et al., 2021; Tzima et al., 2019; Saforrudin et al., 2011). More specifically, Saforrudin et al. (2011) as well as Bacca et al. (2014) found that most teachers cannot create AR applications. Also, recently, Tzima et al. (2019) observed that most teachers did not use AR applications in teaching and never created any AR application. Similarly, Palamar et al. (2021) discovered that most future teachers (students) had a medium and low level of readiness of using AR in the educational process. Finally, Belda-Medina and Calvo-Ferrer (2022) found that pre-service language teachers lacked knowledge for creating AR applications and integrating them in real classes. Successful implementation of AR in educational practice largely depends on teachers' AR skills and competences. While there is a variety of existing frameworks that address main dimensions of digital competences (e.g., information and data literacy), latest developments have increased the digital skills requirements for teachers. New and emerging technologies introduced new challenges and opportunities. One of the frameworks that have been recently updated to incorporate new and emerging technologies such as systems driven by Artificial Intelligence, is Version 2.2 of the Digital Competence Framework for Citizens (Vuorikari et al., 2022). However, this framework is applicable to a heterogeneous group of people without focusing on education and it defines general (not AR-specific) digital skills. Augmented Reality introduces new interactions with the physical and virtual worlds (Akçayır & Akçayır, 2017) and enables individuals to accomplish increasingly complex tasks (Vrontis et al., 2021) allowing thus learning spaces to be explored in different ways. Therefore, there is an increasing need to address the required knowledge, skills and attitudes needed by teachers to integrate AR in their teaching. AR competences constitute a specialization of advanced digital competences and digital competences should now encompass AR competences. Despite numerous previous studies on AR in education, there is only one study (Nikou et al., 2022), to the best of our knowledge, that examines and explores the AR competences of teachers. Based on that teachers' AR competences (TARC) framework, the current study aims to develop a scale for teachers to self-assess their competences with respect to exploiting AR in education. It is important to investigate the AR specific competences that teachers should have in order to be able to offer AR-supported learning experiences to their students. The current study is the first one to develop and validate a scale for the augmented reality competences of teachers.

Towards this goal, the present study has the following research objectives:

(i) to develop and validate an instrument (scale) on teachers' AR competences,
(ii) to explore potential differences across the proposed instrument (scale) dimensions among different groups of teachers.

Therefore, the study is aiming to increase the understanding of the teachers' continuing professional development needs related to AR so that they can effectively integrate AR into their professional practice.

Methods

Instrument

The initial instrument of the study is based on the Teachers' Augmented Reality Competencies (TARC) framework proposed by Nikou et al. (2022). The framework introduced a questionnaire of fourteen items defining the following three AR competence areas namely Create, Use, and Manage AR learning experiences. The aforementioned competence areas originate from the Educational Technology definition by the Association for Educational Communications and Technology as "the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources" (Januszewski & Molenda, 2008). Nikou et al. (2022) referred to *creation* as the capacity to design, develop and modify augmented reality learning experiences; *use* as the capacity to teach, assess/provide feedback and communicate and collaborate using augmented reality; and *management* as the capacity to find, classify and evaluate augmented reality learning resources as well as considering ethical, safety, and security issues related to the integration of augmented reality into teaching. After an evaluation of the original questionnaire and consultation with experts in the field of Augmented Reality, the initial three dimensions were adjusted to four and the initial number of fourteen items was reduced to eleven, as Fig. 1 shows. The four dimensions of the modified instrument along with their items are: (i) DDM: Design, Develop and Modify, (ii) PTAF: Pedagogy, Teaching, Assessment and Feedback, (iii) SEO: Search, Evaluate and Organise, and (iv) ES: Ethics and Safety. DDM corresponds to the *Creation,* PTAF corresponds to *Use.* Finally, SEO and ES correspond to the *Manage* competence areas named before. The questionnaire about the AR teachers' competences can be found in the Appendix. All items were assessed using a 5-point Likert scale ranging from "Strongly disagree (1) to "Strongly agree" (5).

Participants and data collection

Once ethical approval was granted by the University [details are omitted for review] ethical committee, researchers distributed the questionnaire internationally through emails, discussion lists, and social media channels during the period from May to June 2022. Participation in the study was voluntary and anonymous. A total of 176

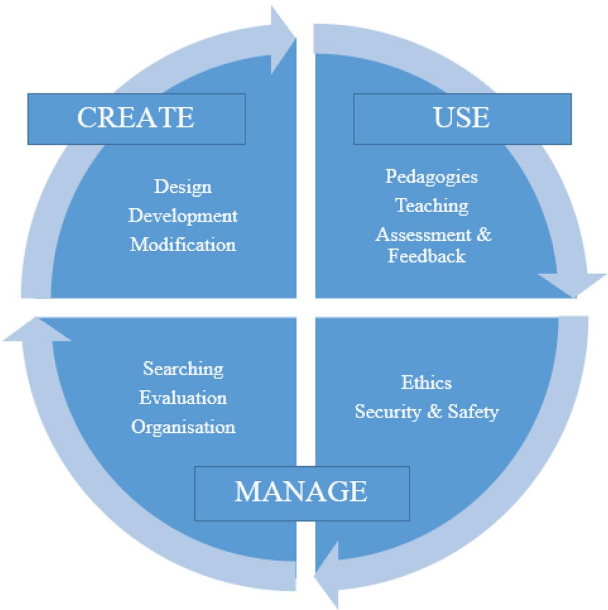

Fig. 1 The proposed framework

responses were collected via Qualtrics. Several responses have been eliminated (as not being complete) and the final sample was 150 which is considered sufficient for Confirmatory Factor Analysis (Tabachnick & Fidell, 2013). Participants were 49.9% female, 46.6% male, 1.2% preferred to self-describe while 2.4% preferred not to say. Their distribution in terms of their age was, in descending order, 41–50 years old (37.1%), 51–60 years old (26.3%), 31–40 years old (17.2%), 21–30 years old (11.3%), 61–70 years old (5.4%), and other/prefer not to say (2.7%).

Participants were from UK (17.5%), Greece (16.2%), Malta (12.3%), USA (7.2%), India (5.5%), Portugal (3.8%), Canada (2.5%), Australia (2.5%), Malaysia (2.1%), and a number of 37 other countries with lower participation as well (30.4%). In terms of their general digital skills level, 9.7% of the participants had basic digital skills (use of a basic range of software such as office; and devices such as computer, tablet), 43% had intermediate digital skills (use of a big variety of software such as Screencastify, Audacity; and devices such as smart interactive whiteboards), and 47.3% had advanced digital skills (use of highly innovative and complex digital and communication technologies such as programming, software development, network management). Most of the participants were teaching in tertiary education (45.7%) with the secondary education (28.5%) and primary education (10.7%) to follow, while 15% of the participants described the education level they were teaching as other. Their teaching experience in years was varied with 23.1% to have 16–20 years teaching experience, 15.6% with 21–25 years, 15.6% with 6–10 years, 12.4% with 1–5 years, and with the ranges of 11–15, 31–35, and 26–30 to be similar namely 10.1%, 10.2%, and 9.1% respectively. The distribution of the participants in terms of the subject they were teaching was Informatics/Engineering/Technology (50%), Science (Math, Physics, Chemistry, Biology) (19.3%), Languages/Literature (6.7%), Economics/Social Sciences (4.8%), Arts (3.2%) and other (12.9%). Finally, regarding the previous use of AR in class, 36% replied that they had used AR in class before while 64% said they had not. The respondents' socio-demographic and teaching related characteristics are presented in Tables 1 and 2 respectively.

Table 1 Participants socio-demographic characteristics (N = 150)

Gender	%	Age	%	Country	%	General digital skills level	%
Female	49.9	21–30 years old	11.3	UK	17.5	Basic	9.7
Male	46.6	31–40 years old	17.2	Greece	16.2	Intermediate	43.0
Prefer to self-describe	1.2	41–50 years old	37.1	Malta	12.3	Advanced	47.3
Preferred not to say	2.4	51–60 years old	26.3	USA	7.2		
		61–70 years old	5.4	India	5.5		
		Other/prefer not to say	2.7	Portugal	3.8		
				Canada	2.5		
				Australia	2.5		
				Malaysia	2.1		
				37 other	30.4		

Table 2 Participants teaching related characteristics (N = 150)

Teaching level	%	Teaching experience (#in years)	%	Teaching subject/discipline	%	Previous AR use in class	%
Primary	10.7	1–5	12.4	Science (Math, Physics, Chemistry, Biology)	19.3	Yes	36.0
Secondary	28.5	6–10	15.6	Informatics/Engineering/Technology	50.0	No	64.0
Tertiary	45.7	11–15	10.1	Economics/Social Sciences	4.8		
Other	15.0	16–20	23.1	Languages/Literature	6.7		
		21–25	15.6	Arts	3.2		
		26–30	9.1	Other	12.9		
		31–35	10.2				
		Other/prefer not to say	3.2				

Data analysis

Data were analysed using IBM SPSS v.28 and IBM Amos v.5. We used a Confirmatory Factor Analysis (CFA) to estimate the structure of teachers' AR competences (MacKenzie et al., 2011). To ensure the suitability of the data for the factor analysis we conducted a principal components analysis estimating the Bartlett's Test of Sphericity to be statistically significant (Byrne, 2010). For the normality of the data, we used the skewness and kurtosis values to be not higher than 3 and not higher than 8 respectively (Hair et al., 2010). To ensure the quality of the model, we have verified all criteria for convergent and discriminant validity. For convergent validity, all factor loadings on their relative construct to exceed 0.70, composite reliability of each construct to exceed 0.70 and all average variance extracted (AVE) values to be greater than 0.50 exceeding the variance due to measurement error for that construct. Discriminant validity should also be supported with the square root of the average variance extracted (AVE) of a construct is higher than any correlation with another construct (Hair et al., 2010).

For the CFA we followed the guidelines and recommendations provided in Brown (2015) for the acceptable fit values for the standard fit criteria, namely: the incremental fit index (IFI), the Tucker-Lewis index (TLI), the comparative fit index (CFI) and the goodness-of-fit index (GFI) should be greater than or equal to 0.90, the fraction chi-squared (χ^2)/degrees of freedom (df) should be less than 3.00 and the root mean square error of approximation (RMSEA) should be less than or equal to 0.08.

Finally, to identify any significant differences among the teachers' groups (according to their (i) gender, (ii) age, (iii) teaching level, (iv) teaching subject/discipline, (v) teaching experience, (vi) general digital skills, and (vii) previous use of AR in the class) across the various components of the proposed instrument we conducted Kruskal–Wallis non-parametric tests that do not require any distributional assumption.

Results

Assumptions of CFA

Principal components analysis conducted on all items of the instrument indicated that the Kaiser–Meyer–Olkin value was 0.934 and that Bartlett's Test of Sphericity was statistically significant ($p < 0.5$). Most of the item coefficients in the correlation matrix were 0.3 and above indicating that the data was suitable for factor analysis (Byrne, 2010; Hair et al., 2010). 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 (Byrne, 2010; Hair et al., 2010; Kline, 2005), as Table 3 depicts.

Construct validity and reliability

To ensure the quality of the model, we have verified the internal consistency, convergent and discriminant validity of the proposed research model, as depicted in Table 4. The criteria of Cronbach's alpha (α), composite reliability (CR) and average variance extracted (AVE) have been considered to ensure the construct validity and reliability of the model (Bagozzi & Yi, 1988; Fornell et al., 1981; Gefen et al., 2000; Hair et al., 2010). All Cronbach's α values are greater than 0.7 demonstrating internal consistency (Hair et al., 2010). All calculated Composite Reliability (CR) values are greater than 0.70 indicating satisfactory construct reliability (Gefen et al., 2000). All factor loadings from the four factors are greater than 0.70 indicating that all items are loaded sufficiently on the corresponding factors ensuring high convergent validity as suggested by Hair et al. (2010). Average variance extracted (AVE) values range between 0.619 (ES) to 0.820 (PTAF) which are all above 0.5 indicating high convergent reliability as suggested by Hair et al. (2010).

Discriminant validity is also supported since the square root of the average variance extracted (AVE) of a construct is higher than any correlation with another construct (Table 5). Thus, both convergent and discriminant validity for the proposed research model are verified (Hair et al., 2010).

After the reliability and validity analysis, we performed a confirmatory factor analysis (CFA) to test the hypothesized factor structure as derived from the theoretical model proposed.

Table 3 Descriptive statistics of the measurement items

Construct		Mean	Std. deviation	Skewness	Kurtosis
DDM	DDM1	2.84	1.33	.081	− 1.113
	DDM2	2.94	1.28	−.100	−.994
	DDM3	2.90	1.28	−.062	− 1.094
PTAF	PTAF1	3.03	1.28	−.005	− 1.034
	PTAF2	3.20	1.32	−.198	− 1.039
	PTAF3	2.86	1.24	.078	−.909
SEO	SEO1	3.32	1.32	−.398	−.897
	SEO2	3.06	1.36	−.126	− 1.100
	SEO3	2.88	1.29	.019	− 1.020
ES	ES1	2.98	1.32	−.150	− 1.066
	ES2	2.94	1.30	−.089	− 1.072

Confirmatory factor analysis

Our model has been evaluated against the aforementioned fit indices and the values were as follows. The χ^2 was 69.757, with degrees of freedom (df) = 36 and p-value < 0.001, which were significant. The ratio χ^2/df = 1.93 is below three, indicating a good fit (Kline, 2016). Moreover, the following fit indices have been identified: CFI = 0.983, TLI = 0.973, IFI = 0.983, GFI = 0.922, and RMSEA = 0.079).

Table 4 Results for convergent validity for the measurement model (acceptable threshold values in parentheses)

Construct items	Factor loading (> 0.70)	Cronbach's alpha (> 0.70)	Composite reliability (> 0.70)	Average variance extracted (> 0.50)
Design, develop, modify (DDM)		0.929	0.930	0.817
DDM1	0.909			
DDM2	0.917			
DDM3	0.885			
Pedagogy, teaching, assessment and feedback (PTAF)		0.944	0.932	0.820
PTAF1	0.944			
PTAF2	0.926			
PTAF3	0.844			
Search, evaluate and organise (SEO)		0.962	0.942	0.845
SEO1	0.832			
SEO2	0.971			
SEO3	0.950			
Ethics and safety (ES)		0.963	0.963	0.619
ES1	0.957			
ES2	0.971			

The CFI, TLI and IFI values are considered excellent fit for the model as being ≥ 0.95 (West et al., 2012). The Goodness of Fit Index (GFI) is very close to 1 which is considered a perfect fit (Tanaka & Huba, 1985). The RMSEA value found is considered to be acceptable as being between 0.05 and 0.08 (MacCallum et al., 1996). In summary, all aforementioned values of CFI, TLI, IFI, GFI and RMSEA indicate an acceptable fit for the model (Brown, 2015; Hu & Bentler, 1999). Therefore, the CFA results demonstrated a relatively adequate model fit.

Teacher differences across the TARC components

With respect to the second research objective, the study examined the differences in teachers; self-reported AR competences in different groups according to (i) gender, (ii) age, (iii) teaching level, (iv) teaching subject/discipline, (v) teaching experience, (vi) general digital skills, and (vii) previous use of AR in the class. Table 6 shows the results on all teachers' groups across the four components of TARC instrument.

The results did not reveal any *gender and age* differences in the teachers' self-reported level of AR competences. *Teaching level* showed significant differences only for the DDM dimension of the instrument ($p < 0.05$) with teachers in higher education to self-report better skills in creating AR resources. *Teaching experience* revealed significant correlations ($p < 0.05$) with the factors of SEO and ES. There is a tendency for positive correlation between teaching experience in years and competence to manage AR resources including ethical and safety aspects. *Teaching subject* showed significant correlations in all components of the instruments, especially for the DDM, PTAF, and SEO factors ($p < 0.001$) following by ES ($p < 0.05$) in favour of the Informatics/Engineering/Technology followed by Science (Maths, Physics, Chemistry, Biology), and Languages/Literature teaching disciplines. *General digital skills and previous use of AR* in class also showed significant differences ($p < 0.001$) in all components of the instrument as well, as it would normally be expected.

Discussions and conclusion

The current study developed and evaluated a self-reporting instrument (scale) for teachers' AR competences and investigated various factors contributing to the various areas of the instrument. Teachers' competences to integrate AR in their teaching is an area that has not received much attention in the literature so far. Therefore, the current study aims to shed some light on the set of competences that teachers need

Table 5 Discriminant validity for the measurement model (values in bold: the square root of the average variance extracted for each construct)

	DDM	PTAF	SEO	ES
DDM	**0.903**			
PTAF	0.843	**0.906**		
SEO	0.733	0.802	**0.920**	
ES	0.689	0.788	0.880	**0.787**

to master in order to effectively integrate AR into their teaching enhancing the learning experience offered to students. The first research objective was to develop and validate an instrument on teachers' AR competences and the second was to explore, among different groups of teachers, potential differences across the proposed instrument dimensions.

Regarding the first research objective, the main components of the proposed instrument are: (i) Design, Develop and Modify (DDM), (ii) Pedagogy, Teaching, Assessment and Feedback (PTAF), (iii) Search, Evaluate and Organise (SEO), and (iv) Ethics and Safety (ES). Confirmatory analysis successfully confirmed the

Table 6 Kruskal Wallis tests on teachers' groups across the four components of TARC instrument competence scale

	DDM	PTAF	SEO	ES
Grouping variable: gender				
Chi-square	7.395	5.384	4.603	6.206
df	3	3	3	3
Asymp. sig	0.286	0.496	0.596	0.401
Grouping variable: age				
Chi-square	7.573	7.145	6.041	4.767
df	5	5	5	5
Asymp. sig	0.181	0.210	0.302	0.445
Grouping variable: teaching level				
Chi-square	7.813	1.361	2.611	4.701
df	3	3	3	3
Asymp. sig	0.050*	0.715	0.456	0.195
Grouping variable: teaching subject				
Chi-square	18.816	17.960	16.110	14.576
df	5	5	5	5
Asymp. sig	.002**	.003**	.007**	.012*
Grouping variable: teaching experience				
Chi-square	11.939	9.595	14.878	16.430
df	7	7	7	7
Asymp. sig	0.103	0.213	0.038*	0.021*
Grouping variable: general digital skills				
Chi-square	35.930	23.771	22.251	21.163
df	2	2	2	2
Asymp. sig	< 0.001***	< 0.001***	< 0.001***	< 0.001***
Grouping variable: previous AR in class				
Chi-square	22.548	31.505	14.633	18.939
df	1	1	1	1
Asymp. sig	< 0.001***	< 0.001***	< 0.001***	< 0.001***

*Correlation is significant at the 0.05 level

**Correlation is significant at the 0.01 level

***Correlation is significant at the 0.001 level, (all above are 2-tailed) proposed instrument on a sample of 150 teachers from 46 countries with different demographic characteristics, teaching disciplines and experience. The instrument's reliability and validity were also confirmed since all reliability related measurements exceeded the minimum value of 0.7 and all items have been sufficiently loaded on the corresponding factors. The proposed modelling of teachers' competences in AR, elaborating mainly in the *Creation* (DDM), *Use* (PTAF), and *Management* (SEO and ES) dimensions of AR specific digital skills, reflects existing validated digital competence scales. The proposed AR competences suggest an AR-oriented approach for the "digital resources" and "teaching and learning" areas of the European Framework for the Digital Competence of Educators (European Commission, 2017). Similarly, our DDM dimension is in line with the "designing, developing and delivering digital content" dimension of the Digital Competency Framework for Digital Teaching and Learning proposed by Lameras and Moumoutzis (2021). The same holds for the "digital content creation" and "safety and security" dimensions of the instrument developed by Rubach and Lazarides (2021) to measure teachers' basic ICT competence beliefs. Similarly, our proposed instrument further elaborates on the dimensions of the Students' Digital Competence Scale (SDiCoS) by Tzafilkou et al. (2022) focusing on AR.

The descriptive statistics presented in Table 3 indicate that teachers' AR competences are at low to medium levels across most components. The lowest mean scores were for the "creation" component" and the medium mean scores were for the "use" component. The mean of the total AR competences score was at a medium level (2.99/5.00). This is in line with previous research reporting intermediate levels of teachers' digital competences (Cabero-Almenara et al., 2021) or even teachers' inefficiencies in digital skills (e.g., Fernandez-Batanero et al., 2020; Ottenbreit-Leftwich et al., 2018).

Regarding the second research objective, the results did not reveal any *gender* differences in the teachers' self-reported level of AR competences. Results on gender differences in teachers' perceived digital skills reported from previous studies are rather contradictory (Esteve-Mon et al., 2020). While studies exist providing evidence for significant gender differences in perception (European Institute for Gender Equality, 2021; Grande-de-Prado et al., 2020; Tzafilkou et al., 2016), other studies reported no significant differences in digital skills in terms of gender (e.g., Badiozaman et al., 2021; Ertl et al., 2020; European Commission, 2018; Tzafilkou et al., 2022). Our study agrees with the latter, showing that digital skills between the genders in the teaching profession are roughly equal. Teacher training institutions foster both men's and women's digital upskilling and therefore both genders are capable of integrating technology in their classes (OECD, 2018).

The results did not reveal *age* differences in the teachers' self-reported level of AR competences. Related literature again reports contradictory evidence regarding age differences in digital skills. Age is usually negatively corelated to teachers' digital skills (Garzon et al., 2020; Saikkonen, & Kaarakainen, 2021) with the older teachers to seem less likely to use ICT in their classrooms (Scherer et al., 2015) while the intermediate age groups to self-report higher competence levels in the pedagogical use of technologies (Rodríguez-García et al., 2019). Our findings, aligning with other studies (Benali et al., 2018; Tondeur et al., 2021) revealed no significant age difference. While younger teachers would normally be expected to be more competent in using digital technologies (Tzafilkou et al., 2023), our findings suggest that digital skills among age groups do not seem to differ significantly. This is encouraging from the perspective of eliminating the gap in the use of digital technologies for teaching among age groups. One reason for this might be that teachers' engagement in delivering online teaching during the pandemic accelerated their digital competencies and their dispositions towards digital education post-pandemic (González et al., 2023; Myyry et al., 2022). Again, the results suggest that teacher training programs should be focused to genders and age groups as well (Sánchez-Cruzado et al., 2021).

Teaching level did not show any significant differences for all dimensions of the instrument but the DDM level ($p < 0.05$). Educators employed in higher education institutions self-reported higher competence level for designing, developing and modifying AR resources, while for the areas of using and managing AR no significant differences were reported. This result can further support the evidence provided by other studies reporting that better digital skills are often associated to higher education (Kaarakainen et al., 2018). The specific result would normally be expected considering the fact that Informatics/Engineering/Technology following by Science were the main teaching disciplines among participants. Higher education science and engineering staff members are more likely to design immersive resources which when coupled with appropriate instructional principles can be used for teaching specific types of learning content (Merchant et al., 2014).

Teaching experience revealed significant correlations ($p < 0.05$) with the factors of SEO and ES. While no significant difference found for the factors of DDM and PTAF, teachers with longer teaching experience can better manage AR resources being more confident to search, evaluate, organise and most importantly to handle ethical and safety related issues for their students. Similarly, studies have found that teachers with more years of experience in using technologies in teaching report higher scores of digital competences (Ghomi & Redecker, 2019). In contrast, other studies have reported that teachers with longer teaching experience demonstrate lower levels of digital skills (Lucas et al., 2021), but this may be due to the fact that more teaching experience is usually related to older teachers and therefore more reluctance in using digital technologies.

Teaching subject showed significant correlations in all components of the instrument, especially for the DDM, PTAF and SEO factors ($p < 0.001$) following by the ES factor ($p < 0.05$) in favour of the Informatics/Engineering/Technology teachers followed by Science (Maths, Physics, Chemistry, Biology), and Languages/Literature teachers. Teaching subject is an important contextual factor that affects teachers' perceptions and use of digital technologies (Hennessy et al., 2005). Not many studies exist exploring digital skills across subjects (Schmid et al., 2021). Our study is in line with previous findings suggesting that teaching subject indicates significant differences across various professional and pedagogical components (Tzafilkou et al., 2023). Existing evidence suggests that Science, Technology, Engineering, and Mathematics (STEM) teachers value more the importance of integrating ICT in education and they usually benefit more from it; therefore, they are more positive towards using it (Siddiq et al., 2016) and more competent in their use (Altun &

Akyıldız, 2017). This is in agreement with our findings revealing that STEM teachers self-reported more competence in creating, using, and managing AR resources.

General digital skills and previous use of AR in class showed significant differences ($p < 0.001$) in all components of the instrument as well. Teachers who have higher general digital skills and teachers who have already used AR in their classrooms self-reported higher level of AR competences. This result agrees with previous findings indicating that previous use of digital technology in teaching is a predictor of teachers' digital competence (Lucas et al., 2021).

Implications

The proposed TARC instrument is specifically focused on the AR competences that teachers need to have in order to appropriately integrate AR in educational practice. It could be used by teachers, educational organizations, educational policy makers, software companies, and other researchers.

The proposed instrument addresses a methodological and theoretical gap in the current literature (Nikou et al., 2022): the development and validation of an instrument that can evaluate teachers' competences in AR. This work is a step forward in establishing a basic understanding of the AR competencies that are important for teaching and learning providing a theoretical basis for other studies exploring teachers' digital competencies in AR. Moreover, researchers would replicate this study with different samples. They would also be inspired by the TARC scale and develop new scales. Furthermore, the study has implications on instructional practices and professional development of teachers.

Recent studies (e.g., Fernandez-Batanero et al., 2020; Ottenbreit-Leftwich et al., 2018) highlighted teachers' inefficiencies in digital skills and a lack of teachers' training (e.g., Perez-Navio et al., 2021; Yoon, 2022). Using our proposed instrument for self-assessing their AR competences, teachers could become aware of their strengths and weaknesses and reflect with regard to AR in teaching. After identifying their competences' levels, they may also take appropriate training in order to develop their AR competence and integrate AR in their teaching practice. For example, teachers may need knowledge and skills with regard to developing AR-based educational applications suitable for their specific teaching subjects. It seems that STEM teachers may be more competent in creating, using, and managing AR resources. Moreover, STEM academic staff are more confident and capable in designing and developing AR resources. Also, teachers with high digital skills may also have high AR competences. These teachers would help their colleagues in selecting, using and even creating appropriate AR applications for their specific teaching subjects.

Educational organizations could use the scale for hiring new teachers with AR expertise as well as for training in-service teachers. They can also design, develop, and implement staff professional development programs on the topics of the TARC scale; provide incentives to their teaching staff in order to improve their AR competences; measure the progress of the AR competences of their teaching staff and the integration of AR in the teaching; and more. Based on the TARC scale, universities could design appropriate programs and courses for teaching pre-service (students) teachers on the integration of AR in education.

Educational policy makers could decide on the areas and levels of introducing and adopting AR in education as well as implementing teachers' professional development programs on integrating AR in education.

Software companies could develop educational AR software at the various dimensions of the TARC scale that will empower teachers. Researchers would replicate this study with different sample. They would also be inspired by the TARC scale and develop new scales.

Limitations and future directions

The present study has some limitations that need to be addressed in future research. First, the sample was not representative of teachers in all countries, subjects/disciplines, education level etc. Future research could replicate this study by considering larger and differentiated sample with respect to teachers' countries, general digital skills, teaching level, teaching subject, previous AR use in class, and more.

Second, respondents were only teachers who were reached via our online survey dissemination efforts and voluntarily answered the questions. Probably, these teachers were interested in AR. Future research could recruit teachers via other methods and persuade them to answer the questionnaire.

Third, the survey instrument collected only the teachers' perceptions with regard to AR in education. Future research could measure the actual teachers' performance in completing specific tasks, creating e-portfolios, solving problems, etc. across the TARC dimensions. Future research also can extent the Ethics and Safety subscale to be tested with three items at least.

Fourth, the current study investigated the teachers AR competences at a specific time. Future longitudinal studies could investigate the evolution of teachers' AR competences over time.

Fifth, this study examined any differences in teachers' AR competences with respect to gender, age, teaching level, teaching experience, teaching subject, general digital skills and previous use of AR. Future researcher could investigate other factors (e.g., personality) that may also affect teachers' AR competence.

Appendix

See Table 7.

Table 7 Teachers' Augmented Reality Competences (TARC) scale

Component	Acronym	Items	Acronym
Design, Develop, Modify	DDM	I can design AR educational experiences using AR applications and tools to meet specific educational objectives	DDM1
		I can develop AR educational resources using easy-to-use AR templates and asset libraries	DDM2
		I can modify and adapt AR educational resources to my teaching goals	DDM3
Pedagogy, Teaching, Assessment and Feedback	PTAF	I can use AR educational resources and tools employing various pedagogies and teaching methods	PTAF1
		I can use AR educational resources and tools to teach (e.g., present, demonstrate, explain the educational content) my students	PTAF2
		I can use AR educational resources and tools (e.g., AR and multimodal game-based and/or simulation-based assessments) to assess the students' progress and provide feedback	PTAF3
Search, Evaluate and Organise	SEO	I can use search engines, digital repositories, and databases to find existing AR educational resources and tools using appropriate criteria, metadata filters, and recommender systems	SEO1
		I can evaluate AR educational resources and tools using appropriate criteria	SEO2
		I can organize and schedule the most appropriate AR educational resources and tools for achieving specific educational objectives	SEO3
Ethics and Safety	ES	I can ensure and control the ethical and responsible use of AR resources and tools by all participating in the educational activities (e.g., respecting participants' personality, privacy, rights)	ES1
		I can secure the safe use of AR resources and tools by all participating in the educational activities (e.g., securing participants' resources, safety, health)	ES2

Funding No funding was received.

Data availability The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethical approval The study received ethical approval by the University of Strathclyde School of Education Ethics Committee.

References

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review, 20*, 1–11. https://doi.org/10.1016/j.edurev.2016.11.002

Altun, T., & Akyıldız, S. (2017). Investigating student teachers' technological pedagogical content knowledge (TPACK) levels based on some variables. *European Journal of Education Studies, 3*(5), 467–485. https://doi.org/10.5281/zenodo.555996

Bacca, J., Baldiris, S., Fabregat, R., & Graf, S. (2014). Augmented reality trends in education: A systematic review of research and applications. *Educational Technology & Society, 17*(4), 133–149.

Badiozaman, I. F. A., Segar, A. R., & Iah, D. (2021). Examining faculty's online teaching competence during crisis: One semester on. *Journal of Applied Research in Higher Education*. https://doi.org/10.1108/JARHE-11-2020-0381

Bagozzi, R., & Yi, Y. (1988). On the evaluation of structural equation models. *Journal of the Academy of Marketing Sciences, 16*, 74–94. https://doi.org/10.1007/BF02723327

Belda-Medina, J., & Calvo-Ferrer, J. R. (2022). Integrating augmented reality in language learning: Pre-service teachers' digital competence and attitudes through the TPACK framework. *Education and Information Technologies*. https://doi.org/10.1007/s10639-022-11123-3

Benali, M., Kaddouri, M., & Azzimani, T. (2018). Digital competence of Moroccan teachers of English. *International Journal of Education and Development using Information and Communication Technology, 14*(2), 99–120.

Brown, T. A. (2015). Confirmatory factor analysis for applied research. In T. A. Brown (Ed.), *Methodology in the social sciences* (2nd ed.). The Guilford Press.

Byrne, B. (2010). *Structural equation modeling with AMOS: Basic concepts, applications and programming* (6th ed.). Taylor & Francis Group.

Cabero-Almenara, J., Guillen-Gamez, F. D., Ruiz-Palmero, J., & Palacios-Rodriguez, A. (2021). Digital competence of higher education professor according to DigCompEdu Statistical research methods with ANOVA between fields of knowledge in different age ranges. *Education and Information Technologies, 26*(4), 4691–4708. https://doi.org/10.1007/s10639-021-10476-5

Directorate-General for Education, Youth, Sports and Culture. (2019). *Key competences for lifelong learning*. Publications Office of the European Union.

Ertl, B., Csanadi, A., & Tarnai, C. (2020). Getting closer to the digital divide: An analysis of impacts on digital competencies based on the German PIAAC sample. *International Journal of Educational Development, 78*, 102259. https://doi.org/10.1016/j.ijedudev.2020.102259

Esteve-Mon, F. M., Llopis-Nebot, M. A., & Adell-Segura, J. (2020). Digital teaching competence of university teachers: A systematic review of the literature. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje, 15*(4), 399–406. https://doi.org/10.1109/RITA.2020.3033225

European Commission. (2017). *Digital competence framework for educators (DigCompEdu)*. Retrieved from https://ec.europa.eu/jrc/en/digcompedu

European Commission. (2018). *Increase in gender gap in the digital sector—Study on women in the digital age*. Retrieved September 29, 2022, from https://ec.europa.eu/digital-single-market/en/news/increase-gender-gap-digital-sectorstudy-women-digital-age

European Institute for Gender Equality. (2021). *Gender equality index 2020—Key findings for the EU*. Publications Office of the European Union.

Fernandez-Batanero, J. M., Montenegro-Rueda, M., Fernandez-Cerero, J., & Garcia-Martinez, I. (2020). Digital competences for teacher professional development. Systematic review. *European Journal of Teacher Education*. https://doi.org/10.1080/02619768.2020.1827389

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39–50. https://doi.org/10.1177/002224378101800104

Garzón, E., Sola, T., Ortega, J., Marín, J., & Gómez, G. (2020). Teacher training in lifelong learning. The importance of digital competence in the encouragement of teaching innovation. *Sustainability, 12*, 28–52. https://doi.org/10.3390/su12072852

Gefen, D., Straub, D. W., & Boudreau, M.-C. (2000). Structural equation modeling and regression guidelines for research practice. *Communications of the Association for Information Systems, 4*(7), 2–77. https://doi.org/10.17705/1CAIS.00407

Ghomi, M., & Redecker, C. (2019). Digital competence of educators (DigCompedu): Development and evaluation of a self-assessment instrument for teachers' digital competence. In *CSEDU 2019—Proceedings of the 11th international conference on computer supported education* (Vol. 1, pp. 541–548). https://doi.org/10.5220/0007679005410548.

González, C., Ponce, D., & Fernández, V. (2023). Teachers' experiences of teaching online during COVID-19: Implications for post pandemic professional development. *Education Technology Research Development, 71*, 55–78. https://doi.org/10.1007/s11423-023-10200-9

Grande-de-Prado, M., Cañón, R., García-Martín, S., & Cantón, I. (2020). Digital competence and gender: Teachers in training. A case study. *Future Internet, 12*(11), 204. https://doi.org/10.3390/fi12110204

Hair, J. F., Jr., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: A global perspective* (7th ed.). Pearson Education International.

Hennessy, S., Ruthven, K., & Brindley, S. (2005). Teacher perspectives on integrating ICT into subject teaching: commitment, constraints, caution, and change. *Journal of Curriculum Studies, 37*, 155–192. https://doi.org/10.1080/0022027032000276961

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Januszewski, A., & Molenda, M. (2008). Definition. In A. Januszewski & M. Molenda (Eds.), *Educational technology: A definition with commentary* (pp. 1–14). Routledge.

Kaarakainen, M.-T., Saikkonen, L., & Savela, J. (2018). Information skills of Finnish basic and secondary education students: The role of age, gender, education level, self-efficacy and technology usage. *Nordic Journal of Digital Literacy, 13*(4), 56–72. https://doi.org/10.18261/issn.1891-943x-2018-04-0

Kline, R. B. (2005). *Principles and practice of structural equation modelling*. The Guilford Press.

Knezek, G., Christensen, R., & Furuta, T. (2019). Validation of a teacher educator technology competencies survey. *Journal of Technology and Teacher Education, 27*(4), 465–498.

Lameras, P., & Moumoutzis, N. (2021). Towards the development of a digital competency framework for digital teaching and learning. In *2021 IEEE global engineering education conference (EDUCON), 21–23 April, Vienna, Austria* (pp. 1226–1232). https://doi.org/10.1109/EDUCON46332.2021.9454027

Lucas, M., Bem-Haja, P., Siddiq, F., Moreira, A., & Redecker, C. (2021). The relation between in-service teachers' digital competence and personal and contextual factors: What matters most? *Computers & Education, 160*, 104052. https://doi.org/10.1016/j.compedu.2020.104052

MacCallum, R. C., Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of sample size for covariance structure modeling. *Psychological Methods, 1*(2), 130–149. https://doi.org/10.1037/1082-989X.1.2.130

MacKenzie, S. B., Podsakoff, P. M., & Podsakoff, N. P. (2011). Construct measurement and validation procedures in MIS and behavioral research: Integrating new and existing techniques. *MIS Quarterly, 35*(2), 293–334. https://doi.org/10.2307/23044045

Manuri, F., & Sanna, A. (2016). A survey on applications of augmented reality. *ACSIJ Advances in Computer Science: An International Journal, 5*(1), 18–27.

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in k-12 and higher education: A meta-analysis. *Computers & Education, 70*, 29–40. https://doi.org/10.1016/j.compedu.2013.07.033

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A new framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.0068

Myyry, L., Kallunki, V., Katajavuori, N., Repo, S., Tuononen, T., Anttila, H., Kinnunen, P., Haarala-Muhonen, A., & Pyörälä, E. (2022). COVID-19 accelerating academic teachers' digital competence in distance teaching. *Frontiers in Education, 7*, 770094. https://doi.org/10.3389/feduc.2022.770094

Nikou, S., Perifanou, M., & Economides, A. A. (2022). Towards a teachers' augmented reality competencies (TARC) framework. In Auer, M. E., & Tsiatsos, T. (eds) *New realities, mobile systems and applications*, *proceedings of international conference on interactive mobile and communication technologies and learning (IMCL) 2021. Lecture notes in networks and systems* (Vol. 411, pp. 203–212). Springer. https://doi.org/10.1007/978-3-030-96296-8_19

OECD. (2018). *Bringing the digital gender divide: include, upskill, innovate*. Retrieved from https://www.oecd.org/digital/bridging-the-digital-gender-divide.pdf

Ottenbreit-Leftwich, A., Liao, J. Y. C., Sadik, O., & Ertmer, P. (2018). Evolution of teachers' technology integration knowledge, beliefs, and practices: How can we support beginning teachers use of technology? *Journal of Research on Technology in Education, 50*(4), 282–304. https://doi.org/10.1080/15391523.2018.1487350

Palamar, S. P., Bielienka, G. V., Ponomarenko, T. O., Kozak, L. V., Nezhyva, L. L., & Voznyak, A. V. (2021). Formation of readiness of future teachers to use augmented reality in the educational process of preschool and primary education. In *Proceedings of the 4th international workshop on augmented reality in education (AREdu 2021), Kryvyi Rih, Ukraine, CEUR workshop proceedings* (Vol. 2898, pp. 334–350). Retrieved from http://ceur-ws.org/Vol-2898/paper18.pdf

Perez-Navio, E., Ocana-Moral, M. T., & Martinez-Serrano, M. D. C. (2021). University graduate students and digital competence: Are future secondary school teachers digitally competent? *Sustainability, 13*(15), 1–14. https://doi.org/10.3390/su13158519

Perifanou, M., & Economides, A. A. (2019). The digital competence actions framework. In *Proceedings of ICERI2019, the 12th annual international conference of education, research and innovation, Seville (Spain)* (pp. 11–13). https://doi.org/10.21125/iceri.2019.2743

Petko, D., Prasse, D., & Cantieni, A. (2018). The interplay of school readiness and teacher readiness for educational technology integration: A structural equation model. *Computers in the Schools, 35*(1), 1–18. https://doi.org/10.1080/07380569.2018.1428007

Radu, I. (2014). Augmented reality in education: A meta-review and cross-media analysis. *Personal and Ubiquitous Computing, 18*, 1533–1543. https://doi.org/10.1007/s00779-013-0747-y

Rodríguez-García, A., Sánchez, M. F. R., & Ruiz-Palmero, J. (2019). Competencia digital, educación superior y formación del profesorado: Un estudio de meta—Análisis en la Web of science. *Pixel-Bit, Revista De Medios y Educación, 54*, 65–82.

Rubach, C., & Lazarides, R. (2021). Addressing 21st-century digital skills in schools—Development and validation of an instrument to measure teachers' basic ICT competence beliefs. *Computers in Human Behavior, 118*, 106636. https://doi.org/10.1016/j.chb.2020.106636

Saforrudin, N., Badioze Zaman, H., & Ahmad, A., et al. (2011). Technical skills in developing augmented reality application: Teachers' readiness. In H. BadiozeZaman (Ed.), *International visual informatics conference (IVIC). LNCS 7067* (pp. 360–370). Springer.

Saikkonen, L., & Kaarakainen, M. T. (2021). Multivariate analysis of teachers' digital information skills—The importance of available resources. *Computers & Education, 168*, 104206. https://doi.org/10.1016/j.compedu.2021.104206

Sánchez-Cruzado, C., Santiago Campión, R., & Sánchez-Compaña, M. T. (2021). Teacher digital literacy: The indisputable challenge after COVID-19. *Sustainability, 13*, 1858. https://doi.org/10.3390/su13041858

Scherer, R., Siddiq, F., & Teo, T. (2015). Becoming more specific: Measuring and modelling teachers' perceived usefulness of ICT in the context of teaching and learning. *Computers & Education, 88*, 202–214. https://doi.org/10.1016/j.compedu.2015.05.005

Schmid, M., Brianza, E., & Petko, D. (2021). Self-reported technological pedagogical content knowledge (TPACK) of pre-service teachers in relation to digital technology use in lesson plans. *Computers in Human Behavior, 115*, 106586. https://doi.org/10.1016/j.chb.2020.106586

Siddiq, F., Scherer, R., & Tondeur, J. (2016). Teachers' emphasis on developing students' digital information and communication skills (TEDDICS): A new construct in 21st century education. *Computers & Education, 92–93*, 1–14. https://doi.org/10.1016/j.compedu.2015.10.006

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Pearson Education Limited.

Tanaka, J. S., & Huba, G. J. (1985). A fit index for covariance structure models under arbitrary GLS estimation. *British Journal of Mathematical and Statistical Psychology, 38*(2), 197–201. https://doi.org/10.1111/j.2044-8317.1985.tb00834.x

Tinti-Kane, H., & Vahey, P. (2018). *xR in EDU survey 2018: benchmarking adoption trends in K12 and higher education. Report series*. EdTech Times.

Tondeur, J., Aesaert, K., Pynoo, B., van Braak, J., Fraeyman, N., & Erstad, O. (2017). Developing a validated instrument to measure preservice teachers' ICT competencies: Meeting the demands of the 21st century. *British Journal of Educational Technology, 48*(2), 462–472. https://doi.org/10.1111/bjet.12380

Tondeur, J., Howard, S. K., & Yang, J. (2021). One-size does not fit all: Towards an adaptive model to develop preservice teachers' digital competencies. *Computers in Human Behavior, 116*, 106659. https://doi.org/10.1016/j.chb.2020.106659

Tzafilkou, K., Perifanou, M., & Economides, A. A. (2022). Development and validation of students' digital competence scale (SDiCoS). *International Journal of Educational Technology in Higher Education, 19*, 30. https://doi.org/10.1186/s41239-022-00330-0

Tzafilkou, K., Perifanou, M., & Economides, A. A. (2023). Assessing teachers' digital competence in primary and secondary education: Applying a new instrument to integrate pedagogical and professional elements for digital education. *Education Information Technologies*. https://doi.org/10.1007/s10639-023-11848-9

Tzafilkou, K., Protogeros, N., Charagiannidis, C., & Koumpis, A. (2016). Gender-based behavioral analysis for end-user development and the 'RULES' attributes. *Education and Information Technologies, 22*, 1–42. https://doi.org/10.1007/s10639-016-9519-4

Tzima, S., Styliaras, G., & Bassounas, A. (2019). Augmented reality applications in education: Teachers point of view. *Education Sciences, 9*(2), 99. https://doi.org/10.3390/educsci9020099

UNESCO. (2018). *UNESCO ICT competency framework for teachers, version 3*. United Nations Educational, Scientific and Cultural Organization. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000265721

Vrontis, D., Christofi, M., Pereira, V., Tarba, S., Makrides, A., & Trichina, E. (2021). Artificial intelligence, robotics, advanced technologies and human resource management: A systematic review. *International Journal of Human Resource Management*. https://doi.org/10.1080/09585192.2020.1871398

Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2,2: The digital competence framework for citizens, EUR 31006 EN*. Publications Office of the European Union.

West, R. F., Meserve, R. J., & Stanovich, K. E. (2012). Cognitive sophistication does not attenuate the bias blind spot. *Journal of Personality and Social Psychology, 103*(3), 506–519. https://doi.org/10.1037/a0028857

Yoon, S. H. (2022). Gender and digital competence: Analysis of pre-service teachers' educational needs and its implications. *International Journal of Educational Research, 114*, 101989. https://doi.org/10.1016/j.ijer.2022.101989

Stavros A. Nikou is Lecturer in Digital Education and Course Leader of the PGCert in Technology Enhanced Teaching and Learning at the School of Education, University of Strathclyde, UK.

Maria Perifanou is Lecturer and Technology Enhanced Learning Researcher (SMILE Lab), University of Macedonia, Greece.

Anastasios A. Economides is the Director of the Smart Mobile Interactive Learning Environments (SMILE) Lab, University of Macedonia, Greece.