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Mapping Educators' Knowledge, Perceptions, and Readiness (KPR) towards the Adoption of Extended Reality (XR) Technologies in the Classroom (KPR-XR): Scale Development and Validation

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Abstract: This research endeavor aimed to develop and validate a comprehensive scale to assess educators' knowledge, perceptions, and readiness (KPR) towards the adoption of Extended Reality (XR) technologies in classroom settings. XR (Virtual Reality -VR, Augmented Reality-AR, and Mixed Reality-MR) has transpired as a ground-breaking tool within the educational landscape, but its effective integration completely relies on educators. Grounded in three theoretical frameworks- Technological Pedagogical Content Knowledge (TPACK) for Knowledge, Technology Acceptance Model (TAM) for Perception, and Unified Theory of Acceptance and Use of Technology (UTAUT) for Readiness- the initial scale included 41 items that were drawn/inspired from different papers published in international journals. After this, expert reviews and Content Validity Index (CVI) calculation wereundertaken, which resulted in three items being removed, resulting in a 38-item scale. The scale was then administered to 700 University educators across India in the mid of 2024. Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) validated the scale structure, confirming three distinct dimensions (KPR) with strong internal consistency (> 0.90). The KPR-XR scale offers a reliable means to examine the critical factors (KPR) that influence educators' adoption of XR technologies, providing important implications for educational practice and policy.

Introduction

SDGs and the Shift Towards Technology in Education

Education systems around the world are evolving more towards the 2030 Agenda for Sustainable Development Goal 4, which is to *"ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"* (*UNESCO: Education for Sustainable Development Goals*). This goal acknowledges that access to high-quality education is a means of achieving social equality and economic advancement in addition to being a fundamental right (United Nations, 2015). However, how can the challenges of educational inequity, unequal educational resources, citizens' right to an education, and related societal problems in resource-constrained environments be addressed? The popularisation of Extended Reality (XR) and other examples of how contemporary technology within education exists might very well aid in solving these issues, thus fostering the sustainable development of education (Guo et al., 2021; Malhotra et al., 2023; Mittal and Jora, 2023).

Since technology showcases versatile solutions to persistent educational problems, its application in the classroom has increased dramatically (Selwyn, 2021). Its quick development has completely changed the educational landscape, creating with new opportunities to improve student access, engagement, and personalized learning (Schleicher, 2018). Specifically, immersive and interactive learning experiences have been brought about by Extended Reality (XR) technologies, such as Virtual Reality-VR, Augmented Reality-AR, and Mixed Reality-

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MR, which can make abstract concepts practical and comprehensible (Alnagrat et al., 2022; Johnson, 2016; Pomerantz, 2019; Pregowska et al., 2024). In ways that were previously unattainable with traditional pedagogical methods, these technologies enable students to interact with instructional materials, visualise intricate processes, and even participate in simulations (*The Future of Jobs Report 2020 | World Economic Forum*, 2020).

Moreover, the vast majority of students today belong to the group known as "digital natives," which is by definition those who have grown up surrounded by digital technology from birth (Prensky, 2001; Zwoliński et al., 2022). It's fascinating to note how their learning process differs greatly from that of previous generations, who took written notes and paid close attention to the teachers as they delivered the subject matter to them. Rather, they learn multidimensionally, and they frequently gain information through social networks and online forums in pursuit of answers (Downes and Bishop, 2012). Technology can also help close educational gaps by giving students in underprivileged areas or marginalised populations access to high-quality resources and guidance (Schleicher, 2018). Hence, a unique need for educational systems that complement these digital experiences has been brought about by this generational change (Reimers and Schleicher, 2020). Therefore, in order to meet students' changing requirements and also make education relevant to the modern workforce and society, technology integration in the classroom is therefore becoming more of a need rather than just an improvement (Selwyn, 2021).

Definitions and Applications of XR Technology

Virtual Reality (VR)

VR is defined by Kiryakova et al. (2018) as *"the entire replacement of the real world with a digitally recreated one"*. Liu et al. (2017) described VR in education as *"a collection of diverse technology while it is more likely an immersion experience with the sense of presence in learning"*. In simple terms, it is a virtual setting that could mimic the real world or be entirely distinct from it. Research has shown that there are a number of advantages to utilising virtual reality in educational settings (Cheng and Tsai, 2013; Schott and Marshall, 2018). Its uses have been demonstrated to improve students' attitudes towards learning (Goldin and Katz, 2007; Hõrak, 2019; Lazar and Panisoara, 2018), improve their comprehension of the subject matter, boost their engagement in learning, encourages student-focused pedagogy and active learning, enhance memorisation (Krokos et al., 2019), creates pleasant classroom environments (Kaplan-Rakowski and Wojdynski, 2018; Chen et al., 2022), and lowers anxiety (Gruber and Kaplan-Rakowski, 2020; Kaplan-Rakowski and Gruber, 2022). On the whole, it results in better educational outcomes.

Augmented Reality (AR)

Augmented Reality (AR) is defined as *"the technology in which virtual objects are interactively overlaid on real time images* (Azuma et al., 2001)". In a likewise definition, Milgram and Kishino (1994) stated "*AR is an active and interactive environment generated by adding virtual data over real time images"*. It refers to a 2D or 3D virtual interface that increases reality by implanting digital elements into the real world (Ispir et al., 2024). It draws students attention to class (Tomi and Rambli, 2013; Delello, 2014), boosts motivation (Perez-Lopez and Contero, 2013; Kerawalla et al., 2006), concretises non-representational concepts (Abdüsselam and Karal, 2012), makes complex topics easy to understand (Kaufmann, 2003; Yen et al., 2013; Shelton and Hedley, 2002), permits the instruction of topics that would be unfeasible to make in a classroom setting (Shelton and Hedley, 2002; Kerawalla et al., 2006; Yuen et al., 2011), warrants the harmless undertaking of risky experiments (Wojciechowski and Cellary, 2013), fosters learners creativity and imagination (Klopfer and Yoon, 2005), supports accurate learning (Yuen et al., 2011; Wu et al., 2013), to name a few.

Mixed Reality (MR)

By allowing users to interact with both digital and physical aspects at the same time in a shared environment, MR goes one step further (Speicher et al., 2019). MR overlays virtual items onto the actual environment by fusing elements of AR and VR (Sugimoto, 2021). This aids educators and professionals across a range of disciplines in imparting professional skills to students in a setting that seems realistic. In specialised fields including medicine (Burke et al., 2017; Hayes and Hughes, 2016), industry (Sautter and Daling, 2021), humanitarian security (Guo et al., 2021) and the military, MR technology is crucial for professional skill training.

Extended Reality (XR)

As defined by Fast-Berglund et al., (2018), XR is *"all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables"*. It blends real and virtual environments for human-computer interaction through wearable electronic devices with computational applications. Observational learning, operational learning, social learning, and academic research are the four categories into which some scholars divide the use of XR technology in education (Liu et al., 2017). By converting passive learning into active, hands-on involvement, XR technologies have special advantages in education by allowing students to visualise difficult concepts and take part in simulations that would be challenging to experience in other ways (Johnson, 2016). Also, by giving students more active control over their learning methods, XR improves communication and engagement between teachers and students (Kuleto et al., 2021). XR also aids in bridging the gap between theory and practical knowledge by offering realistic, immersive simulations, preparing students for real-world situations in disciplines like physics, engineering, healthcare, etc (Gavish et al., 2015).

With all these benefits and applications in place, it comes down to the educators for the successful execution of their pedagogy. They serve as intermediaries in the introduction and effective use of XR tools in the classroom, leading to the transformative potential of XR in education.

Educators as Mediators in XR Technology Adoption

Educators serve as facilitators who may integrate XR tools into their teaching process to meet different learning requirements, helping students understand and relate to difficult material (Kaplan-Rakowski et al., 2022; Pomerantz, 2019). They must have a specialized understanding of XR technologies, a favorable view of their potential, and the willingness to incorporate them into their teaching methods in order for them to be used in the classroom. This successful integration of XR technologies in the classroom is largely dependent on teachers' knowledge (K) about these technologies, says Milgram and Kishino (1994). To use XR in ways that improve learning, teachers must be aware of the distinct uses and potentials of each type of device. For instance, in order to support interactive learning experiences, educators who possess the knowledge and who are familiar with AR can overlay virtual objects onto real-world settings, while those with VR can create immersive environments that make historical incidents or scientific phenomena apparent to students (Maeng et al., 2013; Wang et al., 2018). Teachers can create classes that complement curricular objectives and give students more in-depth, interesting methods to examine materials by becoming proficient with these technologies.

Further, in addition to their level of knowledge, the adoption of XR in the classroom is greatly influenced by teachers' perceptions (P) of its value. Teachers would choose to use XR because of positive perceptions, which are based on the idea that it can enhance learning retention, enable differentiated instruction, and boost student engagement (Meccawy, 2023). Furthermore, educators' readiness (R) to embrace XR depends on both internal (like their comfort level with new technologies) and external (like proper training, resource availability, and administrative assistance) support systems (Schleicher, 2018). A teacher's capacity to solve possible issues that may develop, as well as their openness to change and desire to experiment with XR, are all components of their readiness. In a nutshell, educators are better positioned to realize XR's full educational potential when they are knowledgeable, have a positive perception of XR, and are ready to put it into practice (Kumar et al., 2008). Realising the transformative power of XR in contemporary classrooms and opening the door to creative, interactive learning environments that meet a wide range of student requirements requires supporting educators in these areas.

Need for Scale Development

In order to elicit the educators' KPR towards XR, a scale that measures the three dimensions is crucial. Currently, there is a lack of a tool to measure these three dimensions together (KPR-XR) as far as the two researchers' knowledge. A comprehensive scale to assess educators' KPR to use innovative XR tools is necessary because they are key players in the effective adoption and execution of XR technologies in the classroom (Ibili et al., 2019; Markowitz et al., 2018). By developing a verified and trustworthy tool, academicians, researchers, and policymakers would be better able to comprehend the elements that affect teachers' capacity to include XR into their teaching methods. By developing a robust measurement scale, researchers can gain valuable insights into the explicit knowledge gaps, perceptual biases, and level of readiness of teachers, for the implementation of tailored interventions and the endowment of necessary support to equip them in their XR technology adoption endeavour (Bower et al., 2015; Luo et al., 2019).

Purpose of the Study

To develop and validate a comprehensive scale that assesses educators' knowledge, perceptions, and readiness (KPR) towards the adoption of Extended Reality (XR) technologies in the classroom.

Review of Literature

Significance of XR in Education

The educational landscape could be completely transformed by the incorporation of XR technologies (Radianti et al., 2020; Jee and Kim, 2018). XR can improve students' comprehension, motivation, and retention of information by offering immersive,

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interactive, and captivating learning experiences (Chen et al., 2017; Freina and Ott, 2015). Through XR-based simulations and simulated environments, students can practice skills in safe and regulated surroundings, visualise abstract ideas, and explore complex subjects (Akçayır and Akçayır, 2017; Bacca Acosta et al., 2014). For example, medical students can practise surgery, science and engineering students can perform virtual experiments, and language learners can participate in role-playing exercises in virtual environments that are culturally relevant (Hsu, 2017; Minocha et al., 2017). Additionally, XR technologies' adaptability allows for customised and adaptive learning experiences that accommodate a range of learning requirements and styles (Rodrigues et al., 2019). In order to create a more engaging and productive learning environment, educators can use XR to measure student progress, produce personalised content, and give feedback (Bacca Acosta et al., 2014). To ensure the successful and long-term use of these cutting-edge tools, researchers and practitioners must address issues with technology integration and training for educators as the field of XR in education develops further (Bower et al., 2020; Radianti et al., 2020). This compels the need to have a measurement of their knowledge, perception and readiness.

Existing Scales on XR as an Educational Technology- Research Gap

Teachers' attitudes and preparedness to use XR technologies in the classroom have been the subject of recent research. Meccawy (2023) highlighted both desire and concerns among Saudi educators by identifying themes such XR awareness, content acquisition, and preparedness. Language teachers' opinions of XR were examined by Kaplan-Rakowski et al., (2022), who found both possible advantages and implementation challenges. Gandolfi et al., (2020) developed the Extended Reality Presence Scale (XRPS) inspired by the Multimodal Presence Scale for virtual reality, and was built on three constructs such as physical, social and self-presence. Hogarty et al. (2003) created and validated a survey instrument that took into account both online and printed versions in order to gauge the use of technology in schools. The three-factor structure (attitude, usage, and belief) of a scale developed by Baş et al. (2016) to evaluate teachers' views on ICTs in teaching-learning processes also showed excellent reliability. All of these research stress how crucial it is to comprehend instructors' knowledge, perceptions, and readiness about XR, but none have gauged the three components together due to the lack of a scale.

Conceptual Framework and Adoption of Theories

The conceptual framework for KPR-XR fuses three concrete theoretical models to exhaustively examine the key factors influencing educators' adoption and integration of XR technologies in their pedagogy (Figure 1). For the Knowledge (K) dimension, the framework was drawn from the Technological Pedagogical Content Knowledge (TPACK) model developed by Koehler and Mishra (2009) that accentuates that successful technology integration in teaching requires educators to have a synergistic understanding of technological knowledge (T), content knowledge (C) and pedagogical knowledge (P). In this context of XR adoption, it translates to educators posing the essential knowledge about XR tools and applications i.e., XR integrated-TK (technological knowledge), besides knowing how to effectively feature these technologies into their pedagogical approaches i.e., XR integrated-TPK (pedagogical knowledge) to aid student learning in specific subject areas i.e., XR integrated TCK (content knowledge).

The Technology Acceptance Model (TAM), developed by Davis (1989), provided a solid foundation for the Perception (P) dimension. As per this model, a person's desire to apply technology is largely affected by its perceived usefulness (the extent to which it is thought to improve performance) and perceived ease of use (the extent to which it is thought to be effort-free). Teachers' beliefs and attitudes about integrating XR technologies into their teaching practices are greatly influenced by these notions. The next framework used was the Unified Theory of Acceptance and Use of Technology (UTAUT) for the Readiness (R) dimension by Venkatesh et al. (2003). Performance expectancy, effort expectancy, social influence, and facilitating conditions are some of the major factors that UTAUT identifies as influencing the acceptance and use of technology. Since TAM has a comparable component, the second component in UTAUT- effort expectancy- was disregarded in this case. This readiness criteria are essential for figuring out and forecasting educators' capacity and motivation to integrate XR technologies into their teaching.

Materials and Methods

Scale development

Step 1: Item Pulling and Developing Questionnaire

The initial step was to identify and select items for each dimension (K, P, R) based on the three theories mentioned earlier and then by referring to articles published in international journals As a result of this step, the initial version of the KPR-XR questionnaire with 41 items was formulated, including 21 items on the knowledge dimension, 12 on perception, and 8 on readiness. All three dimensions of the scale were gauged on a five-point Likert scale, with 1 = strongly disagree to 5 = strongly agree to 5=strongly agree.

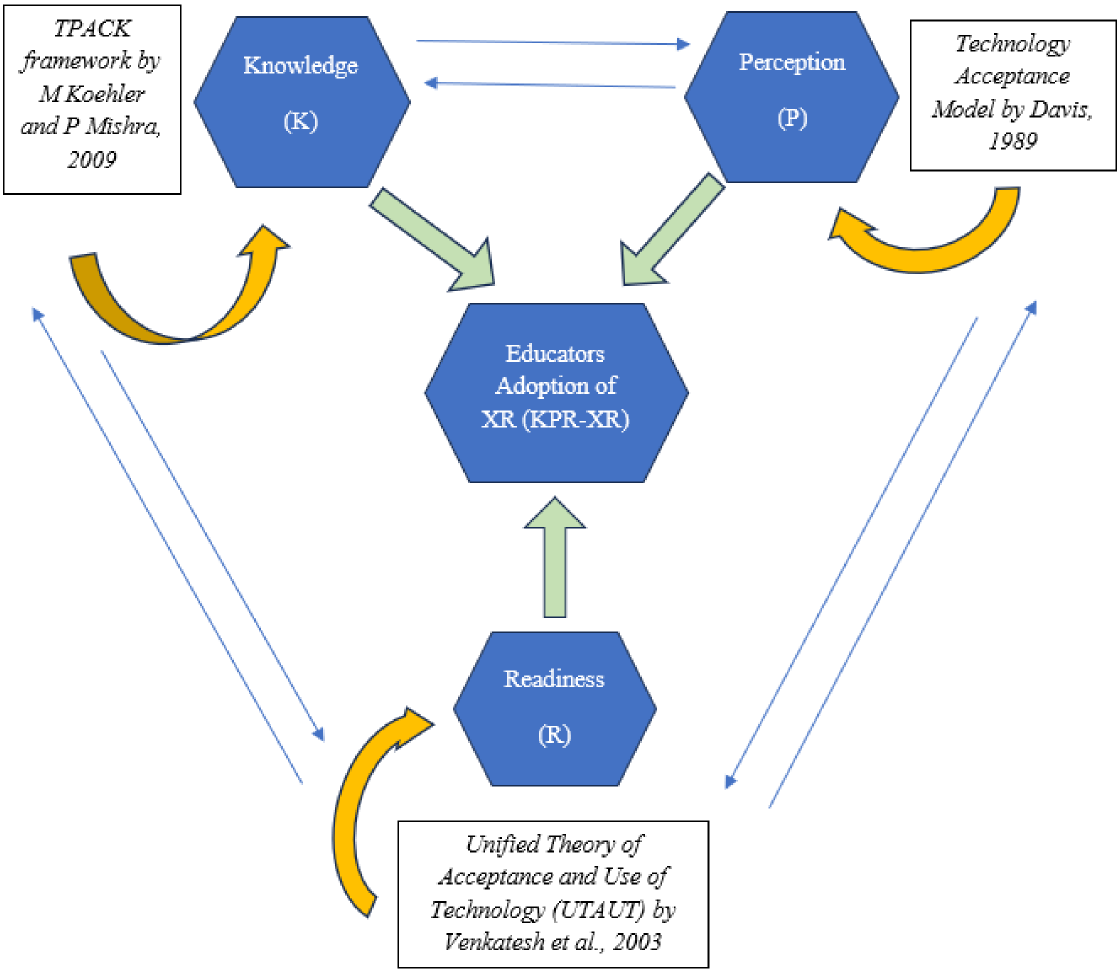

Figure 1. Conceptual Framework Based on Theories and Dimensions.

Once the KPR-TP scale with 41 items was developed, two language experts were consulted and the clarity of the language used was verified. Further, the face and content validity of the scale was examined with a board of six subject experts with varied designations (Lecturers, Assistant professors, Associate professors and Professors) and from different educational institutions. The panel was given the 41 items across three dimensions and was asked to rate the items based on appropriateness to the domains, clarity and also interpretability. The panel furthermore abetted in identifying and estimating the content validity (relevance, coverage, and representativeness) of the items selected. Content Validity Index (CVI) is defined as *"the degree to which an instrument has an appropriate sample of items for the construct being measured* (Polit and Beck, 2004)*"*. They were asked to rate each item using a four-point Likert rating scale (1= Not relevant; 2= Somewhat relevant; 3= Quite relevant; 4= Highly relevant).

Step 2: CVI Calculation Method

The CVI method was employed to elicit the experts' views on the content validity of the questionnaire which was assessed by means of the item-level CVI (I-CVI) and scale-level CVI (S-CVI) approaches (Ayre and Scally, 2014; Zamanzadeh et al., 2015). The I-CVI was calculated by dividing the total amount of experts who were assigned a rating of 3 or 4 (relevant) by the total number of experts. The S-CVI/average (Ave) of 0.9 is indicative of an excellent content validity; whereas, I-CVI of a minimum of 0.83 from six experts is satisfactory (Lynn, 1986). In our calculation, the S-CVI/average was 0.955 and I-CVI of three items were less than 0.83 and thus were deleted (Items 18, 27 and 36). The Initial number of items was 41 and final number of items was 38 and spread across the three dimensions and 14 sub-dimensions i.e., knowledge (seven sub dimensions and 20 items), perception (four sub dimensions and 11 items), and readiness (three sub dimensions and 7 items).

Design, Participants and Data Collection

A non-experimental research design, more specifically a descriptive study based on quantitative data collection was carried out among educators working in universities across India. In order to choose the samples, Lecturers, Assistant professors, Associate professors and Professors from seventeen states of India were randomly chosen via email invitations in the mid of 2024. The respondents

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were informed about the objective of the survey and those who were willing to take part voluntarily were encouraged to respond to the best of their honesty

ranking each item on a five-point Likert scale ranging from 1=strongly disagree to 5=strongly agree. The researchers provided a link to the Google form for completing the questionnaire. The survey was open for participation for three months before closing on reaching the desired sample size of 700. There were no incentives for participating in the survey.

Table 1. Educators' KPR-XR Scale with 38 Items.

Dimension	Item no.	Question
Knowledge (K)	K1	I possess a strong understanding of the concepts and principles within my discipline (CK)
	K2	I am knowledgeable about how the subject matter I teach can be applied in everyday life (CK)
	K3	I have various ways and strategies for developing my understanding of the subject matter I teach (CK)
	K4	I can select appropriate teaching methods based on the instructional content (PK)
	K5	I can adjust my teaching methods based on the performance or feedback of the students (PK)
	K6	I am proficient in using multiple assessment methods to evaluate students' learning outcomes (PK)
	K7	I am familiar with commonly encountered XR (AR + VR+ Mixed) technologies in the educational environment (Technology Knowledge - XR integrated- TK)
	K8	I am proficient in using XR technologies to enhance teaching outcomes (Technology Knowledge - XR integrated- TK)
	K9	I know how to solve (troubleshoot) XR-related technical problems independently (Technology Knowledge: XR integrated- TK)
	K10	I am proficient in formulating curriculum plans with ease (PCK)
	K11	I can select effective teaching approaches to guide students' thinking and learning in subject matter (PCK)
	K12	I can assist students in correcting the learning errors they often commit (PCK)
	K13	I can select appropriate XR tools based on the subject matter I am teaching (XR integrated- TCK)
	K14	I am capable of effortlessly using XR in the subject I teach (XR integrated- TCK)
	K15	I am proficient in using XR to update my knowledge base in my areas of academic interest (XR integrated- TCK)
	K16	I am capable of using XR to enhance the range of the pedagogy I use for teaching (XR integrated- TPK)
	K17	I can choose XR technologies that enhance students' learning for a lesson (XR integrated- TPK)
	K18	I am knowledgeable in integrating XR with educational content and pedagogical methods to improve efficiency and effectiveness of classroom teaching (XR integrated- TPACK)
	K19	I can choose XR technologies that enhance the efficacy of content for a lesson (XR integrated- TPACK)
	K20	I can provide leadership in helping others to coordinate the use of content, teaching approaches and XR technologies at my institution (XR integrated- TPACK)
Perception (P)	P1	I find XR to be useful to my job (PU)
	P2	Using XR can improve my teaching performance (PU)
	P3	Using XR will increase my productivity (PU)
	P4	I will find XR to be very convenient to use (PEU)
	P5	I find it easy to get XR to do what I want it to do (PEU)
	P6	I plan to use XR in the future (BIU)

	P7	I expect that I would use XR in the future (BIU)
	P8	I intend to use the functions and content of XR as often as possible (BIU)
	P9	I think it is worthwhile to use XR in teaching (ATU)
	P10	I think working with XR is fun (ATU)
	P11	I look forward to those aspects of my job that require me to use XR (ATU)
Readiness (R)	R1	Using XR will assist me to accomplish teaching tasks more quickly (PE)
	R2	XR usage will better my teaching quality (PE)
	R3	People significant to me advise XR technology use (SI)
	R4	People who influence my behavior think that I should use the XR technology (SI)
	R5	In general, the institution backs XR technology use (SI)
	R6	I have the resources necessary to use the XR system (FC)
	R7	I can reach out to a person/ group for support in case I face XR tech-related problems (FC)

Data Analysis

The responses that were obtained were uploaded to IBM SPSS v29 and AMOS v26. Two equal and homogeneous subsets (n = 350 each) of the total sample (n = 700) were randomly generated to allow both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). As in Phase 1, EFA was achieved in SPSS v29 in the first half of the sample (n = 350) to investigate the underlying psychometric structure among each of the 38 items. Two preliminary tests were carried out to determine whether the sample was adequate for factor analysis, such as The Kaiser-Meyer-Olkin (KMO) Test of Sampling Adequacy and Bartlett's Test of Sphericity (BTS). According to Tabachnick and Fidell (2007), the latter test examines the hypothesis that the correlation matrix is an identity matrix that will ultimately suggest that the variables are independent of each other, while the former test assesses the sample adequacy as per Hutcheson and Sofroniou (1999). Subsequently, as a commonly advised technique in scale validation methods, principal component analysis with varimax rotation was employed (Costello and Osborne, 2019). As Phase 2, to confirm if the factor structure produced by the EFA procedure was compatible with the data, it was subsequently checked again using CFA on the second half of the sample (n=350) in AMOS. Finally, the scale was then investigated for its reliability by measuring its Internal Consistency using Cronbach's alpha coefficient for each of its dimension.

Scale Validation and Results

1. Exploratory Factor Analysis (EFA)

Suitability of Data

The primary goal of EFA is to discover common components in a dataset and assess the construct validity of a scale (Costello and Osborne, 2019). Importantly, this procedure establishes the basis for structural equation modelling by condensing a collection of elements into a smaller set of combination factors with the least amount of information loss (Hair et al., 2010). To confirm the validity of EFA, it was imperative to ascertain if the data gathered was sufficient for the analysis (Conway and Huffcutt, 2003). Therefore, two tests (Table 3) were conducted to ascertain whether the data were appropriate:

i) The Kaiser-Meyer-Olkin (KMO) Sampling Adequacy Measure: The KMO value obtained was 0.932, which is excellent as it is well above the minimum threshold value of 0.60 as suggested by Awang (2012) for factor analysis (Table 3). ii). Bartletts Sphericity Test: This is crucial since it demonstrates the validity and applicability of the responses gathered to the subject matter the study is trying to achieve. For the factor analysis to be deemed satisfactory, the significance value of Bartlett's Test of Sphericity must be less than 0.05. Table 3 displays a Bartlett's Test significance value of 0.000 which satisfies the necessary significance value of less than 0.05 (Zainudin, 2012). Thus, the results proved the data to be sufficient and suitable to move forward with the reduction process.

Table 2. KMO and Bartlett's Test of Sphericity.

KMO Measure of Sampling Adequacy.		.932
Bartlett's Test of Sphericity	Approx. Chi-Square	9671.874
	df	703
	Sig.	.000

Total Variance Explained

Total variance explained is critical for determining the number of factors that must be retained for subsequent investigations by decreasing them to a reasonable size. The three factors accounted for 60.205% of the variance in the data. This is a good degree of explained variance, implying that these three factors account for a considerable proportion of the data. The following are the individual factor contributions: 29.067% of the variance was explained by factor 1, 19.079% by factor 2, 12.058% by factor 3, and the rest contributed progressively less to this total variance explained. This is a good outcome, displaying that the items were capturing unique and significant aspects of the KPR-XR scale.

Rotated Component Matrix

In the subsequent step, EFA (n=350) in the form of a Rotated Component Matrix (Principal component analysis = extraction method; Varimax with Kaiser normalization = rotation method) was analyzed to elicit underlying factor structure. Principal Component Analysis (PCA) is the most commonly utilised factor extraction technique in SPSS software. Rotations can be performed in a variety of statistical methods, and the varimax rotation method was chosen here (Williams et al., 2010).

Item selection in EFA is guided by these principles: removing items with factor loadings less than 0.5 (Kaiser, 1960), removing items with similar loadings on two factors, removing incorrectly classified items based on specified conceptual factors, and removing items and repeating EFA until a more distinct factor structure appears (Costello and Osborne, 2019; Ferguson and Cox, 1993; Hair, 2009). The factor loadings as seen in Table 2 ranged between .882 ≥ λ ≥ .616 which are all ≥ .50 and are considered appropriate as per the benchmark (Hair et al., 2006). Infact, we noticed that each item is considered excellent, since the item loadings were all greater than 0.60 (Hair et al., 2010). Furthermore, there appeared to be no significant cross-loadings, implying that the variables have strong discriminant validity. Thus, all 38 items across three dimensions were preserved and included to the construct underlying the factor.

2. Confirmatory Factor Analysis (CFA)

CFA was implemented to evaluate the adequacy of the measurement aspects of the proposed model with the second half of the sample (n=350). It is a statistical test designed to assess the scale's discriminant and convergent validity after it has been through EFA. Figure 2 shows that the standardized loadings of all the items range from 0.60 to 0.89. Thus, strong correlations between the items and the corresponding factors are seen here, indicating good convergent validity (Hair et al., 2018). The EFA's three-component structure with 38 was confirmed by the CFA. The construct validity of the scale is strengthened by the congruence between the EFA and CFA scores.

Table 3. Rotated Component Matrix of EFA.

	Component		
	1	2	3
K19	.797		
K7	.787		
K9	.774		
K18	.767		
K20	.767		
K6	.765		
K10	.757		
K14	.755		
K8	.753		
K16	.751		
K5	.746		
K11	.745		
K13	.737		
K1	.731		
K17	.725		
K2	.721		
K15	.691		
K4	.679		
K12	.674		
K3	.616		
P7		.835	
P8		.827	
P11		.822	
P2		.819	
P10		.815	
P5		.803	
P3		.798	
P9		.792	
P1		.789	
P4		.784	
P6		.751	
R4			.882
R2			.880
R5			.858
R1			.815
R6			.773
R7			.764
R3			.750

Finally, the three factors with 38 items were retained and the model fit indices were examined (Table 4). This comprised of the p- value 0.000, which is highly

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significant ($p<0.05$) and CMIN/DF (X^2/df) is 2.689 (below 3), which is also indicative of an excellent fit between hypothetical model and the sample here (Kline, 2023). RMR shows 0.031 (less than 0.08) and falls into the acceptable model fit (Hu and Bentler, 1999). Other indices such as RMSEA= 0.070 (<0.08), GFI = 0.800 (< 0.9), AGFI=0.776 (< 0.8) and lastly the CFI =0.879 (< 0.9 which is not ideal, yet acceptable) (Hu and Bentler, 1999) are all indicative of a good model–data fit in general (Ding and Ng, 2008).

3. Reliability Analysis

Internal consistency reliability was assessed using Cronbach's alpha for all the 38 items individually across the three dimensions. Values above 0.70 are generally considered acceptable, above 0.80 is indicative of good, whereas above 0.90 is considered excellent (DeVellis, 2003; Nunnally and Bernstein, 1994). Looking at the dimension-wise reliability, the Cronbach's alpha value are all above 0.90 (Table 5) (Nunnally and Bernstein, 1994).

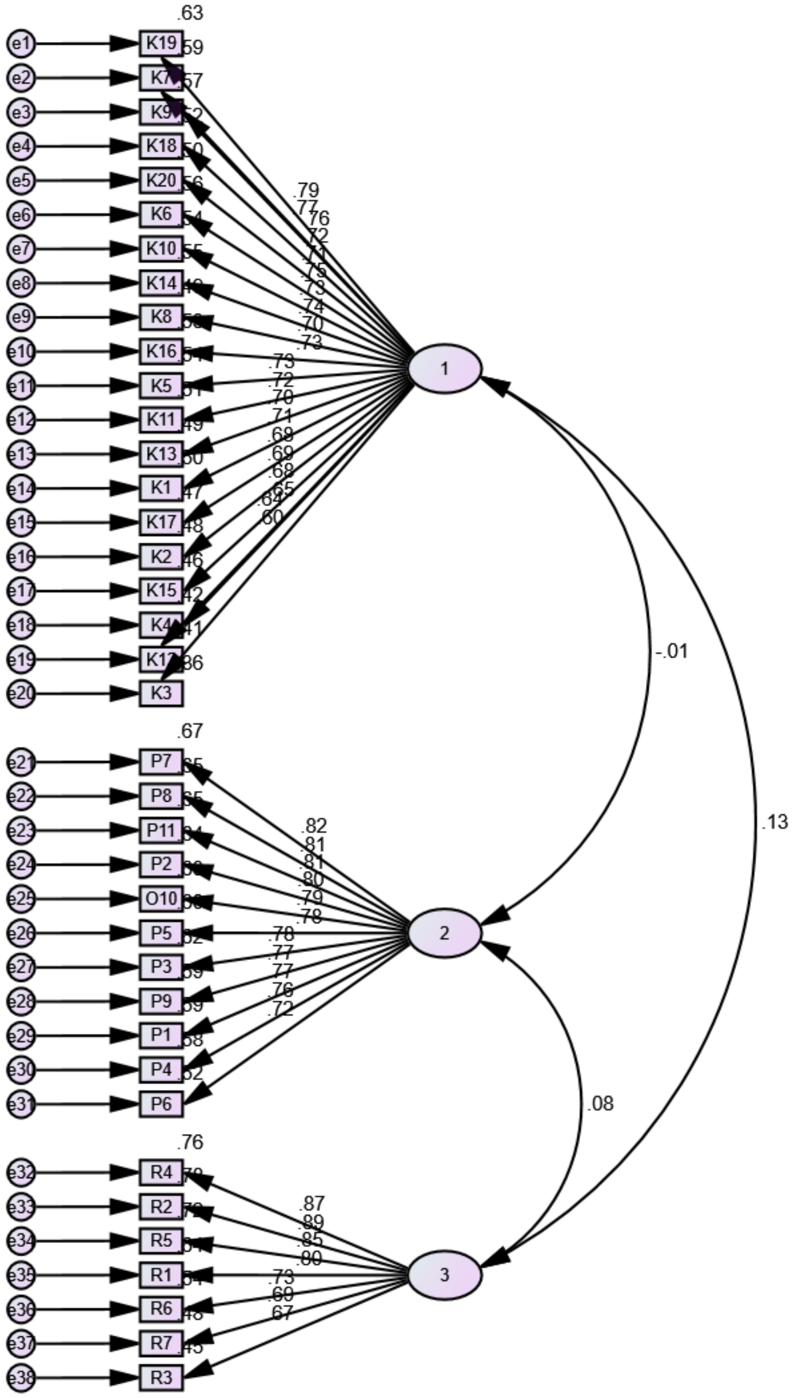

Figure 2. The Factor Structure of the Model with 38 items of the Educators KPR-XR Scale.

Table 4. The Fitness Estimates of the Model.

Measures	Estimate
P value	0.000
CMIN/DF	2.689
RMR	0.031
RMSEA	0.070
GFI	0.800
AGFI	0.776
CFI	0.879

Table 5. Reliability Quotients

Dimension	No. of Items	Cronbach's Alpha
Knowledge (K)	20	0.956
Perception (P)	11	0.945
Readiness (R)	7	0.919

Conclusion and Implications

This paper records the process of development and validation of the KPR-XR scale which is a comprehensive tool to assess educators' knowledge, perceptions, and readiness towards adopting Extended Reality (XR) technologies in their pedagogy. Starting with 41 items across the three dimensions, the scale was refined through meticulous expert review and validation processes, which resulted in a final scale with 38 items across the three dimensions. This validated scale, grounded in well-established theories (TPACK, TAM, and UTAUT), offers a reliable means to examine the critical factors that influence teachers' adoption of XR technologies. Findings from the Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) confirmed the structure and internal consistency of the scale, emphasizing its applicability for broader educational contexts (Annexure). This scale can aid educators, administrators, researchers and policymakers in comprehending and boosting XR integration in teaching, thus contributing to advanced and engaging learning environments.

The KPR-XR scale has important implications for educational practice and policy, especially as XR technologies become more prevalent in pedagogical frameworks. By detecting gaps in educators' knowledge, perceptions, and readiness, the scale can lead to targeted professional development, assisting them in developing the skills and confidence required to effectively incorporate XR. Furthermore, the insights generated from using the KPR-XR scale can be used to improve institutional support mechanisms such as resource allocation and technical support, allowing for seamless XR adoption. This tool can help policymakers to assess systemic readiness, enabling data-driven plans for incorporating innovative technology into education. Finally, the scale enables educators to offer engaging and meaningful learning experiences that meet the educational demands of the twenty-first century.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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