OPEN ACCESS

Research Paper

DINAMIKA Jurnal Ilmiah Pendidikan Dasar, 2023, 15(1)
ISSN:2655-870X (online)
10.30595/dinamika.v15i1.17238

Rasch measurement and strategies of Science Teacher's Technological, Pedagogical, and Content Knowledge in Augmented Reality

Nelson Cyril[1*], Nor Aisah Jamil[2], Zainun Mustapha[3], Khar Thoe Ng[4], Loh Su Ling[5], Subuh Anggoro[6]

[1*]Pondok Upeh Secondary School, Penang Malaysia
[2]Port Dickson Education Department, Negeri Sembilan Malaysia
[3]Universiti Pendidikan Sultan Idris, Perak, MALAYSIA,
[4]UCSI University, Cheras, Selangor, Malaysia
[5] Training and Research Division, SEAMEO RECSAM, Penang, MALAYSIA
[6] Universitas Muhammadiyah Purwokerto, Purwokerto, INDONESIA

Received 31 January 2023 ▪ Revised 20 February 2023 ▪ Accepted 29 March 2023

ABSTRACT

The use of Augmented Reality in the Teachers' Technological, Pedagogical, and Content Knowledge (TPACK) framework is one of the systematic approaches to enriching students' experience in a science classroom. A study was conducted to explore teachers' TPACK in Augmented Reality abilities. This article aims to identify science teachers' level of TPACK in Augmented Reality using a questionnaire. A group of teachers (n=100) was trained to determine science teachers' TPACK at AR levels. Selected Science teachers then responded to a survey and analyzed using the Rasch Model. Male teachers (1.77 logits) outperformed female teachers (-0.55 logit) in TPACK abilities. In addition, teachers 36-40 years of age with 6-10 years of teaching experience had higher ability in TPACK in AR. Findings also indicated the Pedagogical Knowledge (PK) scoring is at +1.23logit and TPACK +0.29 logit suggesting both PK and TPACK components were of higher difficulty level compared to other components. The findings suggest that the training on TPACK in AR especially in the areas of PK and TPACK is necessary and should be based on the teacher's demographic profile, teaching experiences, and other components of the TPACK framework.

Keywords: TPACK; Rasch model measurement; Augmented Reality; Teacher Education

INTRODUCTION

The goal of education, particularly science education, is to enhance individuals' potential by generating proficient Malaysian citizens with scientific abilities, who have high moral values and can manage nature for the benefit of humanity [1]. As a result, the secondary school science curriculum could be a feeder towards the aforementioned goal by creating a school ecosystem that piques one's interest in science and technology enabling them to solve problems and make decisions in everyday life [2]. Several studies have found that technology-enhanced lessons will result in more inventive types of teaching and learning [3], [4]. For example, Neumann et al. [5] discovered that integrating technology will provide a means to improve students' learning and participation in the classroom.

The application of Augmented Reality in innovative teaching and learning could focus on solving real-world problems, disseminating current informational resources, active simulations of concepts, and ongoing communication with professionals in the field [6], [7].

✉ cyrn1476@gmail.com **(Correspondence)**

However, the use of technology in the learning process is seen to supplement traditional types of educational methods [8]. However, according to Saidin et al. [6]. present research on AR in the field of education is minimal. He also suggests that the usage of augmented reality (AR) be included in the teaching framework.

To understand the teacher's ability on the use of AR in a pedagogical framework, this research explores the teachers' Technological Pedagogical and Content Knowledge (TPACK) on the use of Augmented Reality (AR) in science education. The objectives of this study are:

a. To identify the level of ability of science teachers to use AR technology in science classrooms.
b. To identify the training needed on TPACK in Augmented Reality (AR) among Malaysian secondary science teachers.

MATERIAL AND METHODS

Technology is gradually being integrated into many parts of human existence, including education, forming a new subject of technology education. The incorporation of technology in education, which is increasingly a fundamental tool in developing or transmitting science concepts to pupils more quickly, is referred to as technology education. According to a few studies, the integration of technology with face-to-face training may increase student involvement, resulting in a higher achievement score [9], [5].

Similarly, studying chemistry or science necessitates the integration of technology and education to create an effective learning environment for pupils. Many countries are incorporating technology into their curricula, especially science curricula, to promote best practices in education [6]. Incorporating technology into this difficult subject may pique their interest [10], [6]. Among the technology used in science, teaching includes balances, pH metres, calorimeters, and voltmeters, as well as various computer software or applications. For students to use these tools effectively, teachers must first equip themselves with the required abilities to improve student accomplishment [11]. Integrating technologies with topic content knowledge and pedagogy, or TPACK, is critical in improving students' comprehension of scientific information, as will be described further below.

The use of Technology in Malaysian Schools

The use of ICT in the education sector, particularly in public schools, is unavoidable, matched with 21st-century learning attitudes and expectations in line with the global wave of educational modernization. The use of ICT in education in Malaysia began in 1997 with the introduction of a smart school project, implemented to develop and equip students with skills to face various challenges before entering the workforce [11]. For example, the Malaysian government invested in 1BestariNet through a learning management system dubbed the Frog Virtual Learning Environment (VLE), connecting Malaysian primary and secondary schools in a cloud-based platform. Since 1997, the usage of technology has expanded fast Ebrahimi [12] and will continue to increase.

In the recent decade, the use of digital technology such as mobile phones, tablets, and personal computers has been critical in improving classroom teaching and learning, particularly in science classrooms. One such technology that is gaining traction is Augmented Reality, which has the potential to improve knowledge and the underlying scientific principles. Augmented Reality helps pupils understand abstract and difficult ideas in subjects such as physics and mathematics (Sural, 2018).

Augmented Reality

Virtual reality (VR) is being supplemented by augmented reality (AR) which combines the actual world with virtual items superimposed on real-world objects (Nechypurenko et al., 2018). They go on to argue that the ideas of AR and VR are frequently confused. Virtual applications are presented in a real setting in AR, but all actions in VR are virtual [13]. According to Saidin et al. [6], AR differs from virtual reality in that it integrates the actual world with computer graphics, whereas virtual reality immerses the user in a world of computer images.

AR applications are classified into two types: marker-based and location-based.

Cameras identify items on certain defined markers in marker-based imaging, and images are revealed in 2D or 3D on these real-time objects. Users can move the markers to network with the virtual objects that have been imposed. The smartphone employs a global positioning system (GPS) to determine the location and information stored in the applications for location-based AR. [14], [13], for example, the video game Pokemon Go. Some of the AR applications that use marker-based AR for education include ARLOOPA applications.

Many of these AR applications will necessitate the use of real-world mobile wireless devices superimposed on physical environments to enhance students' experiences and communications. A computer and a camera are required to create a local AR environment. The camera detects markers and displays both the scene it captures on the computer screen. By moving the markers, users can interact with the virtual objects [14].

As a result, AR encourages a distinct experience or perspective from previous encounters that relied on a whole physical environment. Such learning may be uninteresting nowadays, as more learning has included game-like components in science teaching and learning [15]. Non-AR experiences are unlikely to have the same favourable learning outcomes as AR experiences.

Students using AR settings may be cognitively overburdened by the large amount of information and pictures they encountered. Teachers may face difficulties while creating AR-based content because it requires them to use different technological devices and takes time [16]. In contrast, rapid advancement in the integration of AR into academic teaching has evolved considerably over the years, particularly in scientific learning. The term TPACK was coined as a result of the incorporation of technology into teaching and learning.

Technological, Pedagogical, and Content Knowledge (TPACK)

TPACK stands for Technology Pack. Pedagogical and Content Knowledge is a combination of pedagogy, content, and knowledge (PCK). Mishra and Koehler [17] define PCK as the integration of content, pedagogy, and knowledge understanding. PCK is also the method through which specific components of subject matter are organised, modified, and portrayed for instruction. The inclusion of the letter 'T', which stands for technology, combines hardware and software such as computers, educational games, and the internet. Conversely, the interactions between content, pedagogy, and technology are complicated, necessitating a pairwise examination of these components. These combinations include pedagogical and content knowledge (PCK), technical and pedagogical content knowledge (TCK), and technology and pedagogical content knowledge (TCK) (PCK). In addition, content knowledge relates to the subject matter, whereas pedagogical knowledge is concerned with the practice and methods of teaching and learning, which includes lesson plan development and assessments. The presentation of concepts using instructional methodologies to address students' various levels of understanding and alternative conceptions is then referred to as pedagogical content knowledge. Technology knowledge is derived from books, the internet, movies, and apps, whereas technological content knowledge is derived from the use of technology to deliver content or subject matter. Furthermore, technical pedagogical and content knowledge (TPACK) refers to an understanding of numerous technologies utilised in teaching and learning [9]. Mishra [18] has developed a model in this context, as shown in Figure 1.

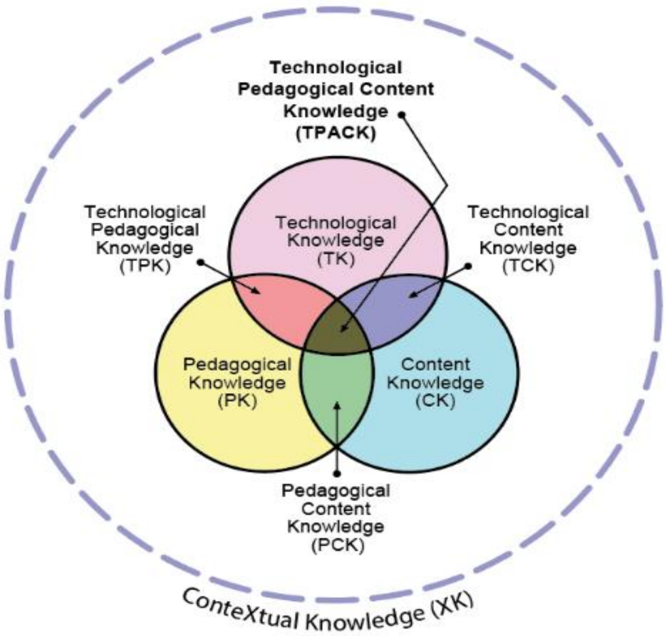

Figure 1 *Revised version of the TPACK image.*
© Punya Mishra, 2018. Reproduced with permission

In other words, TPACK is the ability to use technology incorporating pedagogy techniques to deliver concepts used in the enhancement of knowledge which is discussed next. As stated before, TPACK consists of 7 components which are described in Table 1.

Table 1. Description of the components of TPACK

Components	Description
TK	The knowledge and skills necessary for using technology such as program installations, word processors, spreadsheets, the internet etc. (Mishra and Koehler, 2006)
CK	The knowledge of a teacher about the concepts and theories related to specific subject-matter; for instance, a chemistry teacher should have adequate chemistry knowledge (Mishra and Koehler, 2006
PK	The collection of knowledge about general pedagogy such as classroom management, the way students learn and student assessment that is necessary in any class irrespective of specific subject (Mishra and Koehler, 2006; Koehler and Mishra, 2009).
TCK	The knowledge about the application of technology to teach specific content, such as simulation to teach gases in chemistry or allowing students to figure out the factors affecting chemical reactions via data logging (Mishra and Koehler, 2006).
TPK	The knowledge about how technology can be used in teaching; e.g., how smart boards or animations can be used in teaching and learning settings (Koehler and Mishra, 2009).
PCK	The blending of content and pedagogy knowledge. This is related to the application of general pedagogical knowledge within specific content; such as finding the best way to organize the radioactivity concepts in chemistry or applying instructional strategies to teach electrochemistry (Mishra and Koehler, 2006; Koehler and Mishra, 2009
TPACK	The combination of knowledge of content, technology, and pedagogy, e.g., the use of appropriate technology to assess students' understanding in electrochemistry or detecting students' prior knowledge via simulations for effectively teaching acids and bases in chemistry (Mishra and Koehler, 2006; Koehler and Mishra, 2009).

Table 1 displayed the complexities that teachers experience managing pedagogy, technology, and content knowledge. Thus, teachers require several multiple domains of knowledge in their teaching and learning [19]. This integration of domains aids teachers in their teaching content with technology. However, in creating this domain integration, it remains to be examined if these domains truly exist and if they exist how can they be determined. Niess [19] elaborated that qualitative methods may assist teachers in the case of probing teachers' understanding and use of TPACK but to measure the level of TPACK requires a quantitative approach particularly in this study is the integration of Augmented Reality in Science Teachers' TPACK.

Methodology

In this study, a survey research design was adopted. The 45 items Likert scale questionnaire was used to measure the relevant constructs. The items were developed through a review of the literature followed by items constructed by the researcher. The instrument included demographic factors such as gender, age, and teaching experience in teaching science and TPACK items on teaching science in the classroom using AR technology. The researcher then identified the purpose, research questions, and hypothesis based on the literature. Next, the researcher also determined the respondents (secondary school teachers from Penang) and the process of selecting the respondents for the development of the TAR (TPACK in AR) instrument. The questionnaire consisted of items from the literature, transformed into statements [20], [21].

Table 2 *Sources of TAR items*

Topic	Literature
Opinions about AR Technology	(Sural, 2018) [21]
Device Usage Knowledge level	(Sural, 2018) [21]
TPACK component items	(Koehler & Mishra, 2005), Archambault & Crippen, 2009), (Schmidt et al., 2009) [17], [22],
AR items	(Cai et al., 2014) [14]
AR application in science class items	(Karagozlu et al., 2019) [13]

Following that, statements were created using the Google Form features depending on the selection of acceptable scales of measurement. Using five Likert scales, scales are used to quantify a subject's response to a certain variable [20]. Measures using five-point scales have been proven to generate the variation required for investigating the links between items and scales, resulting in appropriate coefficient alpha (internal consistency) reliability estimations [23]. The validity of the draught questionnaire has been established. The ability of an instrument to measure what is supposed to be measured for a concept is referred to as its validity [24]. Expert recommendations, literature studies, and input from science teachers were used to establish construct, content, and criterion validity in this study.

The instrument of science teachers' TPACK on AR consisted of seven components with 41 items; technological knowledge (6 items), content knowledge (6 items), pedagogical knowledge (5 items), technological content knowledge (6 items), technological pedagogical knowledge (6 items), pedagogical and content knowledge (5 items), and Technological and Pedagogical and Content Knowledge (7 items). The distribution of items is shown in Table 3.

Table 3. *Distribution of items according to domain*

No	Components of instrument	Items	Total
1	Technological Knowledge	B1, B2, B3, B4, B5, B6	6
2	Content Knowledge	C7, C8, C9, C10, C11, C12	6
3	Pedagogical Knowledge	D13, D14, D15, D16, D17	5
4	Technological Content Knowledge	E18, E19, E20, E21, E22, E23	6
5	Technological Pedagogical Knowledge	F24, F25, F26, F27, F28, F29	6
6	Pedagogical and Content Knowledge	G30, G31, G32, G33, G34	5
7	Technological and Pedagogical and Content Knowledge	H35, H36, H37, H38, H39, H40, H41	7

Total items	41

The draught questionnaire is then amended based on expert recommendations for ensuring validity, or an instrument's ability to measure what is supposed to be measured for a construct [24]. The chosen sample is then given the final instrument. A random sample strategy was used in this investigation. This study's participants were Penang state secondary school science instructors. In the actual study, 100 Penang science teachers participated.

Instrument Validation

The content validity and internal consistency reliability of the instrument were established using WINSTEP for the study of the scale's psychometric qualities to validate it. Psychometric qualities for these goals were reported using item reliability, item separation, person reliability, and person separation. For each item, the suitability of the item quality was assessed using numerous criteria, including outfit mean square (MNSQ), outfit z-standardized (ZSTD), and point-measure correlation (Pt-Measure Corr) (Bond & Fox, 2007).
Content Validity and Face Validity

The items about Science Augmented Reality in this study were derived following a review of the literature. The materials were then examined by two Universiti Sains Malaysia experts (USM). On the items, the experts were asked to write comments, concerns, suggestions, and questions. This approach was designed to gather information about item concepts, language, and the appropriateness of routine and non-routine things. After the operation was completed, the elements were sorted according to the corresponding structures (efficacy, accessibility, support, active learning, and Science achievement).

The researcher analysed the remarks and suggestions made by the experts after receiving input from them. The amended instrument one was then given to two teachers for face validity testing. A copy of the questionnaire was given to each of them to solicit their feedback on the suitability of the item statements in terms of their phrasing, the instructions, and whether the scales can be interpreted to discover any problem in filling out the questionnaire. The questionnaire was utilised in a pilot study once it was completed.

Pilot Study

The pilot study emphasized an essential method for establishing a trustworthy instrument, which in turn meets the study's desired objectives [25]. Choosing a modest sample size for the pilot study follows the standards in the literature, which advised that a sample size be generally small, i.e., up to 100 respondents ([25]. The pilot test was carried out by delivering questionnaires to thirty-two secondary school Science teachers from the state of Penang using simple random selection. The participants were Augmented Reality Workshop attendees, with 32 responses. These pilot research participants were not invited to participate in the final study as the participants' subsequent behaviour may be influenced by the pilot study [26]. The next stage in the instrument's purification process, following content validity, is instrument reliability, which assures that measurements are error-free and hence produce consistent findings [27]. Cronbach's alpha coefficient average value using SPSS in the current study is 0.98. The number indicates that the instrument is trustworthy [24]. As a result, all of these items were retained for the main study and the questionnaire could be distributed to the intended samples.

Data Collection Procedures

A survey was used to measure the relevant construct. The survey method relies on a questionnaire instrument for data collection, the most common method used in social science research [28]. Thirty-three (33) schools from Penang were chosen to administer the questionnaire. Once approval is obtained from the relevant department and schools, the questionnaires are sent via google form by the researcher to each targeted school, whereby Secondary school science teachers are requested to answer. Once the teachers and the school principals gave their permission, the researcher administered the questionnaire.

Procedure for Analysing the Data

The collected data was evaluated using computer software, WINSTEPS Version 3.71.0.1, and a polytomous data Rasch model. The Rasch Measurement Model is a psychometric technique that was established to improve the precision of a constructed instrument, monitor instrument quality, and compute responder performance [29], [30]. Rasch model analysis proved to be an incredibly successful method for investigating measuring psychometric characteristics and addressing response bias [31], [32]. Meanwhile, the construct validity of an instrument can be analyzed and used by researchers to determine the instrument's reliability and validity utilising the Rasch analysis.

In this study, the Rasch model was used because it can express a person's measures on the same scale regardless of the test or survey form the participants completed [33], [31], [32]. The estimations of latent qualities were evaluated based on the characteristics of the individual and item. The Rasch model could be used to analyze the success rate of instructors in responding to test items based on the difficulty level of the items and the teachers' skill level [34], [31], [32]. Furthermore, the Rasch measurement model has specific objectivity, i.e. the difficulty of the item is dependent on the individual's capacity to take the test, and the individual's ability is dependent on the difficulty of the item [35].

Ethical Consideration

The researcher needed permission from two authorities: the Malaysian Ministry of Education's Education Planning and Research Division (EPRD) before conducting educational research in Malaysia. The State Education Department then issued an approval letter, which was followed by permission from the respective Principals. The permission of participants was also sought before data collection started.

RESULTS AND DISCUSSION

Table 4 *Demographic information of the samples.*

Variables		Frequency	Percent (%)
Gender	Male	11	11
	Female	89	89
`Age (years old)	20-25	-	-
	26-30	5	5
	31-35	22	22
	36-40	29	29
	41-45	23	23
	46-50	5	5
	More than 50	16	16
Teaching experiences (in years)	Less than a year	1	1
	1-5	7	7
	6-10	14	14
	11-15	39	39
	16-20	17	17
	21-25	10	10
	More than 25	12	12

Table 4 displayed the descriptive statistics of the respondents indicating 89 respondents were female, and most respondents were from the age group 36-40. In addition, a high number of participants had a teaching experience of 11-15 years.

Table 5. *Profile of Secondary Sciences' Teachers (levels' abilities) in TPACK on AR based on gender, age, and teaching experiences*

Variables		**Persons' ability** Average measure value (logits)
Gender	Male	1.77
	Female	-0.55
Age (years old)	20-25	-0.55
	26-30	-0.18
	31-35*	-0.32
	36-40	0.25
	41-45	-1.05
	46-50	-0.39
	More than 50	-0.26

Teaching experiences (in years)	Less than a year	-1.51
	1-5	0.06
	6-10	0.12
	11-15	-0.27
	16-20	-0.50
	21-25	-1.15
	More than 25	-0.26

Based on the result in Table 3, the male secondary Sciences Teachers in TPACK on AR with measure value is 1.77 logits, higher than females (-0.55 logits) indicating the higher ability of males in using AR. Secondary Sciences Teachers aged around 36 to 40 years old have a higher ability on TPACK in AR compared to other age categories. Secondary Sciences Teachers with teaching experiences of 6 to 10 years are of higher ability compared to other categories. Teachers with teaching experiences of around 21 to 25 years have the lowest ability on TPACK in AR skills.

Table 6 . Rating Scale of Person and Item Measurement Reliability

Person and Item Measurement Reliability	
Poor	<.67
Fair	.67-.80
Good	.81-.90
Very Good	.91-.94
Excellent	>.94

According to Mimi Mohaffyza Mohamad et al, (2015), a higher value indicates a strong relationship between the items on the test, whereas a lower value indicates a weaker relationship between test items.

Table 7. *Summary statistic of 100 persons and 41 items*

Variables	Iems	Measure	Infit MNSQ	Zstd	Outfit MNSQ	Zstd
Person	Mean	-0.30	0.95	-0.60	1.13	-0.60
	SD	2.14	0.74	2.70	1.46	2.80
	Reliability	0.97				
	Separation	5.74				
Item	Mean	0.00	0.96	-0.20	1.13	0.20
	SD	0.91	0.25	1.50	0.58	1.70
	Reliability	0.95				
	Separation	4.32				

Table 7 shows the person reliability and item reliability value indicated as excellent and satisfactory to achieve more than 0.90 (Fisher 2007). The findings also signposted the person and item separation index. Both indexes achieved more than 2.00 indicating an acceptable level. Person separation identifies how efficiently the questionnaire can separate those persons measured while an item separation is how well participants can separate those items used in the test. The higher the value of the separation index the more precise the measurement is.

The overall person separation index is 5.74, and the item separation index is 4.32. According to Fisher (2007), the separation index should be greater than 2.0 while Duncan, Bode, Lai, and Perera (2003) define appropriate item separation as a value greater than 1.50. Both the person and item separation indexes for the overall and accessibility constructs met the standards.

Table 8. *Mean for each TPACK Domain for N=100 participants*

TAR Constructs	Index Measure in agreement	Mean
TK	-0.86	3.67
CK	-0.06	3.58
PK	1.23	3.50
TCK	-0.22	3.13
TPK	-0.05	3.09
PCK	-0.22	3.50
TPCK	0.29	3.02
Mean	0.02	3.35

Table 8 shows the secondary school science teachers' level of "TPCK" has the lowest means compared to other TPACK components. Results also showed that TCK and TPK have a low mean suggesting the Penang teachers have difficulty using many AR instances in their teaching and learning. On the other hand, the index measure in agreement revealed that pedagogical knowledge (PK) and TPACK had a high number of disagreeing with the survey questions indicating these two domains are the areas where teachers needed assistance with.

Table 9. *Measures of Domains TPACK on AR*

Code	*Components TPACK on AR*	*Measure*	*Error*	*In. Msq*	*In. Zstd*	*Out. Msq*	*Out. Zstd*	*Ptme*	*P value (mean)*
TK	Technological Knowledge	-0.86	0.17	1.23	1.34	1.53	1.42	0.64	3.47
CK	Content Knowledge	-0.06	0.20	1.13	0.93	1.81*	2.28*	0.66	3.67
PK	Pedagogical Knowledge	1.23	0.21	0.92	-0.56	1.20	0.66	0.72	3.58
TCK	Technological Content Knowledge	-0.22	0.20	0.85	-0.78	0.76	-1.11	0.77	3.13

TPK	Technological Pedagogical Knowledge	-0.05	0.20	0.91	-0.56	0.96	-0.40	0.72	3.09
PCK	Pedagogical and Content Knowledge	-0.22	0.21	0.99	-0.03	1.03	0.19	0.71	3.50
TPCK	Technological and Pedagogical and Content Knowledge	0.29	0.19	0.73	-1.47	0.72	-1.28	0.75	3.02

*Outfit ZSTD score higher than 2 but not a misfit item

All items in Table 5 consisting of the 7 domains of TPACK showed fit items except for the domain of Content Knowledge indicating an unproductive item influenced by outliers (*misfit with Rasch). However, there is no conflict between items and the construct being measured suggesting the items can be retained.

This study also includes a report on the analysis of training needs for secondary Science teachers of TPACK on AR skills. According to Mazhisham et al. [36], training and development is an endeavour to improve present or future employee performance through learning, usually by changing the employee's attitude or expanding his or her skills and knowledge. A training requirements analysis is a method that identifies all of the training that is required in a specific length of time to improve teachers' performance, including progress and growth in teaching and learning. This study looked at the order of people and items on the Scalogram to see who requires training. The Scalogram ranks items from low to high difficulty levels assessed vertically, and people from high to low ability trait endowment levels measured horizontally. The red line in Figure 2 matches high trait-level respondents with the most endorsable items. Therefore, a high number of "Excellent" (blue) responses are expected, followed by a high number of "Satisfactory" (black) or "Poor" (red) responses in the bottom right corner, matching low trait level respondents with the least endorsable items.

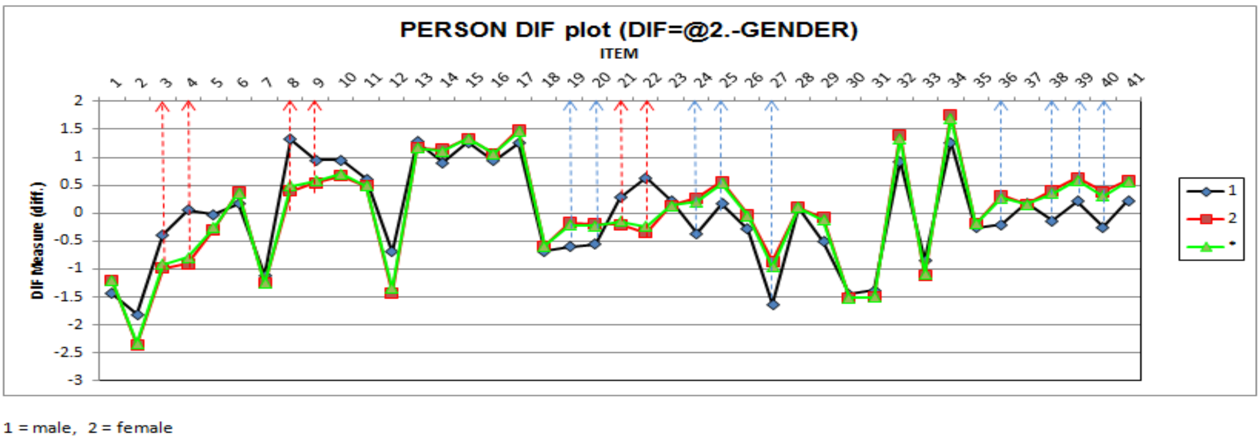

Figure 2. Person DIF plot by gender

Figure 2 depicted the Differential Item Functioning (DIF) study, which was performed to investigate gender disparities in test item answers. A gender-biased item has a t value less than -2.0 or larger than 2.0, a DIF contrast value less than -0.5 or greater than 0.5, and a p (probability) value less than 0.05 or greater than -0.05. Bond and Fox [35]; Boone et al., [37]. According to the DIF analysis's likelihood or p-value, DIF did not occur as a function of gender. In other words, there are no biassed items, and training needs can be met regardless of gender [37].

Figures 3 and 4 depict the location on the Wright map of 100 secondary Sciences teachers and 41 TPACK component items on AR based on an estimation of their ability and item difficulty on a single measurement continuum ranging from the easiest to the most difficult and the highest to the lowest ability. The Wright map analysis shows that P015 has decent internet connectivity, is female, is over 50 years old, and has employment experience ranging from 21 to 25 years, indicating a person with the highest abilities in TPACK on AR. Item G34 (I understand how to help students absorb science concepts using various teaching tactics), a pedagogical and content knowledge item (PCK). This is the hardest item for respondents to agree on. The P059, on the other hand, does not have good internet connectivity with gender, is female, aged 41 to 45 years old, and has job experience ranging from 21 to 25 years. B2 (I know how to operate a tablet), a component of technological knowledge, is the easiest item to agree on.

The respondents' maximum ability to answer is +8.17 logits, and their lowest is - 4.51 logits. The maximum item difficulty, however, is +1.70 logits, and the lowest item difficulty is - 2.33 logits. Person ability has a range of +12.68 logits, and item difficulty has a range of +4.03 logits. The mean item difficulty is 0.00, while the mean person ability is -0.30. These figures demonstrated that respondents found it slightly challenging to approve AR use in the classroom. In Wright Map, Figure 3 depicts the person's ability and item difficulty. The G34 item (I know how to help students grasp science concepts using a variety of teaching tactics), which is part of the pedagogical and content knowledge, is the most difficult for responders to agree on. B2 (I know how to operate a tablet), a component of technological knowledge, is the easiest item to agree on.

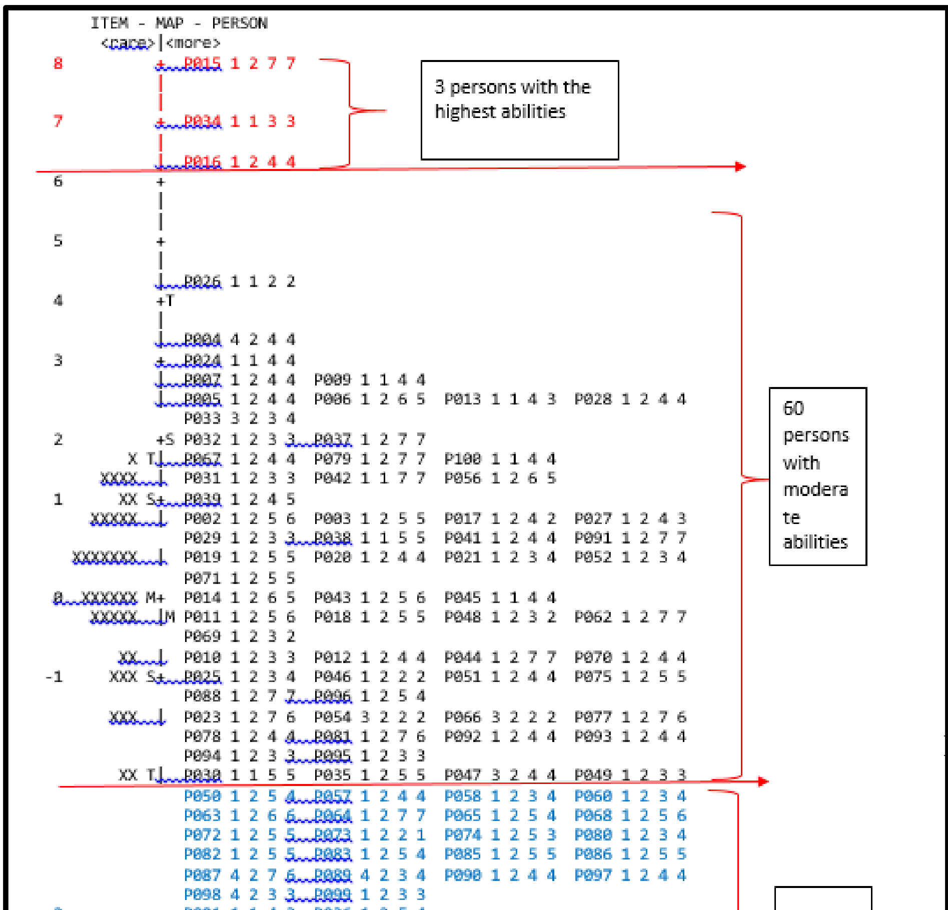

Figure 3. Wright Map of TPACK on AR person's abilities

The person Wright Map in Figure 3 illustrates that there are three respondents with high abilities, sixty moderate, and 37 teachers with low abilities. The highest ability respondent is a female aged more than 50 years with more than 25 years of teaching experience followed by a male aged 31-35 years with 6-10 years of teaching experience. The teacher with the lowest ability is a teacher that sometimes has internet, is aged 41-45 years old, and has 16-20 years of teaching experience.

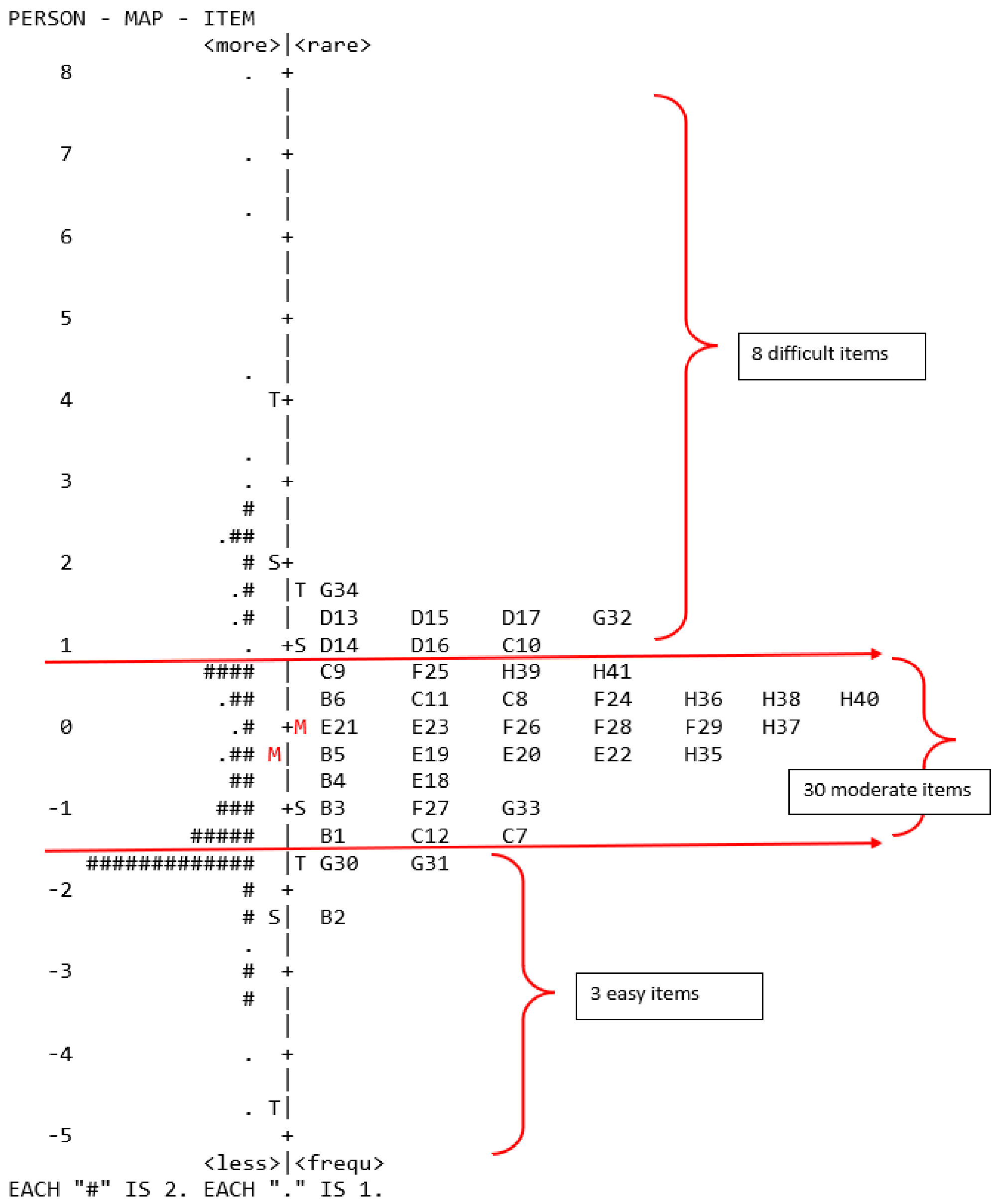

Figure 4 .*Wright Map of TPACK on AR items' difficulties*

Item Wright Map in Figure 4 showed that more difficult items can be added for high-ability respondents to answer. There are 8 difficult items, twenty moderate, and 3 easy items. The most difficult item is G34 i.e., "I know how to help students acquire science concepts using several teaching strategies". On the other hand, the easiest item is B2 "I know how to use a tablet".

This study also revealed that males who scored had higher TPACK in AR than females suggesting that more males are inclined to use AR in their teaching and learning. Thus, to increase students' usage of AR more programmes of training for female teachers shall be planned. The level of TAR practice by secondary school science teachers, results showed that there were three teachers with high ability and sixty teachers with moderate abilities in using AR. The remaining thirty-seven teachers with a low, sixty moderate, and 3 high

TPACK in AR level.

In general, the use of AR in secondary science school science teachers portrays positively indicating that the teachers' use of AR was quite favourable. The number of teachers using almost doubled and this suggested that teachers were willing to use more advanced technology in their teaching and learning of science. The findings of this study are similar to another study by Jwaifell (2019) conducted on 60 in-service science teachers in Jordan. The study revealed that teachers were ready to adopt and integrate Augmented Reality in their science classrooms. In this study, the components of Pedagogical Knowledge and TPACK are indicated by teachers' problematic areas. The Pedagogical area faced by teachers may be caused by using AR to prepare lesson plans or using AR for assessments. The result of this study however differed from another study by Medina and Ferrer (2022) that revealed Spanish pre-service language teachers had difficulties in Technological Pedagogical Knowledge (TPK).

Although many teachers in this study can use AR in their teaching the study showed that Pedagogical Knowledge and TPCK knowledge is less in agreement while using Augmented Reality. In other words, teachers find it quite difficult to adapt the use of AR in the classroom with their pedagogical skills. The highest component of TPACK is the TK or Technological Knowledge displaying teachers' knowledge in operating a mobile phone, tablet, and computer is high. Other components of TPACK, such as TCK, CK, TPK, and PCK showed a high agreement with the items. This means teachers were well-versed in their content and technological knowledge but had some difficulty with their pedagogy. Aligned with this study's finding Tzima et al. [38] concluded that AR usage among teachers was feasible under certain conditions. This 2019 study of 20 Greece teachers in a secondary school setting indicated curriculum limitations influenced available teaching time in using AR posing as the main reason teachers are shying away from AR. The study also revealed that the effective use of AR is increased by the frequent collaboration of teachers in different disciplines.

To answer research Question 2, based on the thirty-seven Penang teachers that were found to have low TPACK with AR level and will require some form of training to increase a higher value. The training needs assessment of this survey can act as the main instrument and potent process of training that assists organizations at all levels [36]. The training needs assessment feature of this study discovered content of this training include

a. Using augmented reality programmes to pique students' interest before beginning a classSelecting relevant AR technology to utilize in science classrooms
b. Using AR to enhance my pedagogical skills
c. Using different pedagogical skills using AR applications in the teaching and learning of science.
d. Integrating pedagogy, content, and AR technology in science classrooms.

These training topics will assist teachers in incorporating AR technology as well as pedagogy and content knowledge in their teaching and learning of science. These training topics could be organized in SEAMEO RECSAM under the Regular Course programme. Other education institutions such as schools and tertiary education under the Ministry of Education could also hold such Professional Development short courses in their respective schools, ensuring in-service teachers can equip themselves with current technology. The use of Augmented Reality in technology education can pave the way to more advanced technology such as Virtual Reality.

Implications and Recommendations:

This study revealed a high degree of AR use by science teachers. Thus curriculum developers can add more AR-based technology into Malaysian science and pure science textbooks. This AR questionnaire could be offered to pre-service teachers in teacher training institutes for future research. The survey can be used to determine pre-service teachers' AR levels to ensure that the training they receive is manageable. These findings would serve as estimations for future TPACK research and practice. The validity of these measurements, however, is dependent on the development and execution of an adequate instrument to measure pre-service teacher TPACK. This study was able to determine the moderate and low-ability teachers but less on the high-ability teachers. Further studies may develop more difficult items for high-ability teachers. The gap from 1.70 logits to 8.17 logits needs to be measured. Consequently, more items need to be constructed to fill in this gap.

Limitations

The sample of this research consisted of only one state in Penang. The sampling number of 100 may be a limitation in generalizing the result.

CONCLUSIONS

Augmented Reality in education represents an emerging technological tool in the teaching and learning of science. The culmination of these emerging technologies could not only improve teachers' TPACK within an education space but may also increase students' understanding and further increase their science performance in class. Challenges, especially in the TPACK component revealed in this study will need to be addressed in the future to ensure that students will have gained the best outcome between technology, pedagogy, and content knowledge in any area of study.

REFERENCES

[1] Zin, S., & Maimunah, S. (2003). Reforming the science and technology curriculum: The smart school initiative in Malaysia. *Prospects*, *33*(1), 39–50. https://doi.org/10.1023/a:1022608230500

[2] Ministry of Education (MoE). (2016). *Secondary School Curriculum Standards*. Curriculum Development Centre, Ministry of Education

[3] Shapley, K., Sheehan, D., Maloney, C., & Caranikas-Walker, F. (2011). Effects of Technology Immersion on Middle School Students' Learning Opportunities and Achievement. *The Journal of Educational Research*, *104*(5), 299–315. https://doi.org/10.1080/00220671003767615

[4] Pierson, M. E. (2001). Technology Integration Practice as a Function of Pedagogical Expertise. *Journal of Research on Computing in Education*, *33*(4), 413–430. https://doi.org/10.1080/08886504.2001.10782325

[5] Neumann, D. L., Neumann, M. M., & Hood, M. (2011). Evaluating computer-based simulations, multimedia and animations that help integrate blended learning with lectures in first year statistics. *Australasian Journal of Educational Technology*, *27*(2), Article 2. https://doi.org/10.14742/ajet.970

[6] Saidin, N. F., Dayana, N., Halim, A., & Yahaya, Y. (2015). *A Review of Research on Augmented Reality in Education: Advantages and Applications*.

[7] Uygur, M., Yelken, T. Y., & Akay, C. (2018). Analyzing the Views of Pre-Service Teachers on the Use of Augmented Reality Applications in Education. *European Journal of Educational Research*, *7*(4), 849–860.

[8] Yasak, Z., Yamhari, S., & Esa, A. (2010). Penggunaan teknologi dalam mengajar sains di sekolah rendah. *Seminar Majlis Dekan Pendidikan IPTA 2010*, 1–7. http://eprints.uthm.edu.my/id/eprint/445/

[9] Ayla, C.-D., Boz, Y., Yildiran Sonmez, D., & Demirci Celep, N. (2018). Development of pre-service chemistry teachers' technological pedagogical content knowledge. *Chemistry Education Research and Practice*, *19*(1), 167–183. https://doi.org/10.1039/C7RP00175D

[10] Jorge, R.-B., Caceres-Jensen,Lizethly, D. Celep, T., Druker, S., Bahamonde Padilla, V., Pernaa, J., & Aksela, M. (2020). Developing technological pedagogical science knowledge through educational computational chemistry: A case study of pre-service chemistry teachers' perceptions. *Chemistry Education Research and Practice*, *21*(2), 638–654. https://doi.org/10.1039/C9RP00273A

[11] Zainal, A. Z., & Zainuddin, S. Z. (2020). Technology adoption in Malaysian schools: An analysis of national ICT in education policy initiatives. *Digital Education Review*, *0*(37), 172–194. https://doi.org/10.1344/der.2020.37.172-194

[12] Ebrahimi, S., & Jiar, Y. K. (2018). The use of technology at Malaysian public high schools. *Journal of Education and Review*, *6*(3), 54–60.

[13] Karagozlu, D., Kosarenko, N., Efimova, O., & Zubov, V. (2019). Identifying Students' Attitudes Regarding Augmented Reality Applications in Science Classes. *International Journal of Emerging Technologies in Learning (IJET)*, *14*(22), 45–55.

[14] Cai, S., Wang, X., & Chiang, F. K. (2014). A case study of augmented reality simulation system application in a chemistry course. *Computers in Human Behaviour*, *37*, 31–40. https://doi.org/10.1016/j.chb.2014.04.018

[15] Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. Journal of Science Education and Technology, 18(1), 7-22.

[16] Wu, H.-K., Lee, S. W.-Y., Chang, H.-Y., & Liang, J.-C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & Education*, *62*, 41–49. https://doi.org/10.1016/j.compedu.2012.10.024

[17] Koehler, M. J., & Mishra, P. (2005). What Happens When Teachers Design Educational Technology? The Development of Technological Pedagogical Content Knowledge. *Journal of Educational Computing Research*, *32*(2), 131–152. https://doi.org/10.2190/0EW7-01WB-BKHL-QDYV

[18] Mishra, P. (2018). *Revised version of TPACK image. Retrieved from https://punyamishra.com/2018/09/10/the-tpack-diagram-gets-an-upgrade/*.

[19] Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. Teaching and teacher education, 21(5), 509-523.

[20] Radhakrishna, R. B. (2007). Tips for Developing and Testing Questionnaires Instruments. *Journal of Extension, 45(2),* 24-54. http://www.joe.org/joe/ 2007february/tt2.php.

[21] Hill, C., & Koekemoer, E. (2013).The development of the MACE work-family enrichment instrument. SA Journal of Industrial Psychology, 39(2), 116-117. doi:10.4102/sajip.v39i2.1147.

[21] Sural, I. (2018). Augmented Reality Experience: Initial Perceptions of Higher Education Students. International Journal of Instruction, 11(4), 565–576.

[22] Archambault, L., & Crippen, K. (2009). Examining TPACK among K-12 online distance educators in the United States. *Contemporary Issues in Technology and Teacher Education*, *9*(1), 71–88.

[23] Lissitz, R. W., & Green, S. B. (1975). Effect of the number of scale points on reliability: A Monte Carlo approach. *Journal of Applied Psychology, 60*(1), 10-13. https://doi.org/10.1037/h0076268

[24] Creswell, J. W., & Creswell, D. J. (2018). Research Design (5th ed.). Sage.

[25] Daniel, E. G. S. (2013). Asia pacific science education in a knowledge society. *Asia Pacific Journal of Education*, *33*(2), 170–182. https://doi.org/10.1080/02188791.2013.780705

[25] Zikmund, W. G. (2003). *Business Research Methods* (7th Ed), USA: Thompson

[26] Krieken, V. R., Smith, P., Habibis, D., Mcdonald, K., Haralambos, M., & Martin, H. (2000). Sociology: Themes and Perspectives. New South Wales: Pearson Education Australia

[27] Peterson, R. A. (1994). A Meta-Analysis of Cronbach's Coefficient Alpha. Journal of Consumer Research, 381-391.

[28] Ary, D., Jacobs, L., and Razavieh, A. (2002). *Introduction to Research. 6th Edition,* Wadsworth, Belmont

[29] Boone, W. J. (2016). *Rasch Analysis for Instrument Development: Why, When, and How?* CBE Life Sciences Education. https://doi.org/10.1187/cbe.16-04-0148

[30] Saidi & Siew. (2019). Reliability and Validity Analysis of Statistical Reasoning Test Survey Instrument using the Rasch Measurement Model. International Electronic Journal Of Mathematics Education, 14, (3), 535-546.

[31] Bradley, K., Peabody, M., Akers, K., & Knutson, N. (2015). Rating scales in survey research: Using the Rasch model to illustrate the middle category measurement flaw. Survey Practice, 8(2), 1-14.

[32] Chan, S.-W., Looi, C.-K., & Sumintono, B. (2020). Assessing computational thinking abilities among Singapore secondary. *Journal of Computers in Education. Advance online publication*. https://doi.org/10.1007/s40692-020-00177-2

[33] Khine, M. S. (2020). Objective measurement in psychometric analysis. In Khine, M. S. (Ed.). *Rasch measurement applications in quantitative educational research*, 3-7.

[34] Englehard, G. (2013). Invariant measurement, using Rasch models in the social, behavioral and health sciences. Routledge.

[35] Bond & Fox. (2015). *Applying the Rasch Model. In Applying the Rasch model: Fundamental Measurement in the Human Sciences (3rd ed.).* Routledge.

[36] Mazhisham, P. H., Khalid, M. Y., Nazli, N. N. N. N., Manap, R., Hussain, N. H. M. (2019). Identification of Training Needs Assessment in Organizational Context. *International Journal of Modern Trends in Social Science*, 1 (5), 20-30.

[37] Boone, W. J., Staver, J. R., & Yale, M. S. (2014.). *Rasch Analysis in the Human Sciences*. Springer. https://link.springer.com/book/10.1007/978-94-007-6857-4

[38] 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