Validating STEM Pedagogical Content Knowledge Scale for Secondary School Mathematics Teachers

Noor Anita Rahman[1], Roslinda Rosli[2], Azmin Sham Rambely[3]

[1]Faculty of Education, UniversitiKebangsaan Malaysia, UKM Bangi, Selangor, Malaysia.
[2]Senior Lecturer, Centre of Learning and Teaching Innovation, Faculty of Education, UniversitiKebangsaan Malaysia, UKM Bangi, Selangor, Malaysia.
[3]Associate Professor, Department of Mathematical Sciences, Faculty of Science and Technology, UniversitiKebangsaan Malaysia, UKM Bangi, Selangor, Malaysia.

Abstract: Science, technology, engineering, and mathematics (known as STEM) field and related jobs are increasingly demanding, so teachers must be equipped with STEM-based knowledge during classroom instruction in preparing students with STEM-relevant skills. However, past studies showed that many teachers were less confident in applying the knowledge that practically affected students' interest in STEM opportunities. In this study, researchers intend to measure the validity and reliability of the STEM pedagogical content knowledge instrument (STEMPCK Scale) using the Rasch model analysis. The online survey was distributed to 23 mathematics secondary school teachers' participation. The data was analyzed using Winsteps version 3.71.0.1 software. The finding showed that all the items are valid, reliable, and compatible to measure STEM-based knowledge among school teachers. The implications of the research are discussed.

Keywords: Instrument, Rasch model analysis, reliability, STEMPCK scale, validity

1.Introduction

The lack of students involved in the STEM field in schools or higher education institutions affects the demand for the STEM workforce (Zaza et al., 2020). Students are a significant asset to the country to fulfill the secure request of 21st-century skilled labor needs and achieve the Industrial Revolution 4.0 (IR4.0) (Abd Halim & Abd Halim, 2020). The increasing demand for STEM employment will become a reality if more students enter the STEM field at the school level (Evans et al., 2020). Therefore, the call for the empowerment of STEM education is an effective plan in the education system for most countries in the world (Topcu, 2020). In Malaysia, a STEM national congress held in November 2017 has announced the need for at least one million science and technology workforces in 2020. However, Malaysia only managed to produce 105 thousand up to the year 2017.

Additionally, Malaysia faces decreased participation among students entering STEM fields at the secondary and tertiary levels, contributing to STEM talent depletion (Academy of Sciences Malaysia [ASM], 2015; Kamsi et al., 2019). As a result, in 2017, only 47 percent of students in Malaysia were interested in STEM fields (Ministry of Education Malaysia [MOE], 2013). It was reported that the phenomenon happened because of STEM teaching methods, quality teachers, and ad-hoc changes in education policies (ASM, 2015; Kamsi et al., 2019; Ministry of Science, Technology and Innovation [MOSTI], 2018). Scholars also noted that STEM subjects are not fascinating to students because of the teaching approach that is theoretical, textbook-based, and examination-oriented (ASM, 2015; Choy et al., 2020; MOSTI, 2018). Teachers' skills enhancement in STEM was one initiative to strengthen STEM education through the Malaysian Education Development Plan (PPPM) 2013-2025 (MOE, 2013). Among the things that need attention is the STEM approach in schools (Changtong et al., 2020).

Teachers' role is undeniable in attracting students and subsequently venture into the field of STEM (Margot & Kettler, 2019). Teachers who teach STEM subjects at the secondary school level aim to empower the STEM approach (Nguyen et al., 2020). Exposing STEM-based knowledge among the targeted teachers embarks them to be confident in delivering teaching and facilitation sessions (Gardner et al., 2019). Mathematics is one of the attention disciplines in STEM. Mathematical literacy is the foundation of STEM education and is a crucial aspect of PISA 2021 (OECD, 2019). Focusing on mathematical literacy is the core foundation in promoting learning in other disciplines, namely science, technology, and engineering (English, 2016). Once students understand mathematics, students can generalize information, make assessments, and relate it to real-life demands (English, 2015). Literacy in mathematics requires the ability to build a predictive plan based on data-centeredness in making decisions. (Gravemeijer et al., 2017). Decisions are made based on evidence involving ethics and impact on economics and the environment. Besides that, with the quick rise in computer technology within STEM, students can build up skills in solving complex interdisciplinary problems involving the assessment of technology-enhanced STEM education (Wu & Anderson, 2015).

Recent concerns refer to how mathematics ideas and actions can give something more practical to apply to other STEM disciplines (English, 2016). Fitzallen (2015) points out that STEM provides context to cultivate mathematical skills. Chongo et al. (2020) suggested that mathematical logic improves students' computational thinking (CT). The CT skills are often associated with mathematics and computer science. Mathematics achievement has an impact on CT skills among students. Gravemeijer et al. (2017) mentioned that the role of mathematics grows together with technology, as mathematics is at the core of what computers do. Occasionally teachers must encourage students to use mathematics in their lives by solving significant problems related to the current live issues (Organization for Economic Co-operation and Development [OECD], 2019). When students think critically and apply the useful curricular to their academic and daily lives, the objective is successfully achieved (Changtong et al., 2020; Rahman et al., 2021b). Teachers who engage themselves with professional courses and STEM training opportunities can learn new knowledge and skills to implement STEM education based on the new curriculum formulated (Gardner et al., 2019; Guzey et al., 2016). Providing high-quality STEM education programs enables teachers to collaborate by integrating the four disciplines of STEM effectively into meaningful teaching and learning practices. It is believed, the process of adaptive STEM teaching is achievable when a teacher equipped themselves with STEM pedagogical content knowledge (Allen et al., 2016; Yıldırım&Sahin, 2019). Hence, an instrument to identify STEM-based knowledge among mathematics school teachers should be developed and met the standard quality through validity and reliability.

1.1 Rasch Model Analysis

Rasch model (RM) analysis is one of the successful measurements and can produce specific measurements for generalizing results and inferential studies (Mofreh et al., 2014). Traditionally, the discussion of reliability and validity of scale scores is included in RM. The RM analysis is the simplest model as an alternative way to find a valid survey result (Bock & Gibbons, 2021). It is also suited as a statistic method to examine the item difficulties, such as calculating the estimation of person separation and reliability, item polarity parameters, dimensionality, item fit, and misfit item.

2.Significance of The Study

It is undeniable that the STEM curriculum becomes the main factor of debating for the international and national education level; hence its implementation is critical (Rahman et al., 2021a). Contrary, Lowrie et al. (2017) and Rahman et al. (2021b) identified other flaws in integrating mathematics with other related STEM disciplines, such as limitation of time for teachers to skill with a different pedagogical approach, difficulties in dividing the assessment, and content knowledge, and addressing learning outcomes issues. Consequently, many teachers have insufficient expertise and experience in subjects relevant to STEM (Margot & Kettler, 2019), including the majority of mathematics teachers (Fitzallen, 2015). Scholars also argue that many mathematics teachers failed to highlight STEM connection more apparently (English & King, 2019). Furthermore, teachers' necessity to be competent in digital computers is vital to face teaching challenges of the 21st century and vast changes in information and communication technologies (ICT) (Beswick & Fraser, 2019; Maass et al., 2019; Penprase, 2020; Silva et al., 2020). Even though some professional developments of teaching skills or pedagogical approaches are not guaranteed to have a better understanding and a clear view for teachers to implement it. (Asghar et al., 2012; Baker &Galanti, 2017; Gardner et al., 2019). Without a profound understanding of the STEM content and pedagogical knowledge, it will be difficult for teachers to integrate them as interdisciplinary and transdisciplinary curriculum (Beswick & Fraser, 2019; English, 2016; Margot & Kettler, 2019). This phenomenon leads to low self-esteem and not being ready to apply the suggested approach (Gardner et al., 2019; Maass et al., 2019; Shernoff et al., 2017). This matter will affect the effectiveness of integrated teaching as teachers continue teaching STEM disciplines in silo (Dare et al., 2014; Yıldırım& Turk, 2018). Research findings indicate that student mathematics understanding can be enhanced through STEM (English & King; 2019;Siregar et al., 2019). It was proved that students' outcomes in STEM education activity, which focus on knowledge, understanding, skill development, values, and attitudes, connect with teachers' pedagogical knowledge practices (Hudson et al., 2015; Rahman et al., 2021a). Therefore, the significance of this study is to validate the instrument of pedagogical content knowledge in implementing the STEM approach. The validated instrument can be used to plan for improving teachers' readiness and confidence in teaching mathematics using STEM to expose students' ability and, hopefully, to fulfill the rising demand of STEM-related workforce.

3.Review of Related Studies

Mathematics is an essential subject in science, technology, and engineering, even though it was less highlighted (English, 2016; Fitzallen, 2015; Gravemeijer et al., 2017; Hsu et al., 2011; Stohlmann, 2019). A good foundation in mathematics is imperative to overcome future learning barriers (Grootenboer& Marshman, 2015; Maamin et al., 2020). Nevertheless, the research outcomes show that primary school students do not grasp the fundamental mathematics knowledge and skills, which impedes them from deepening advanced mathematics at the secondary level (Gravemeijer et al., 2017; Grootenboer& Marshman, 2015). It is believed, students' less credence and attentiveness in mathematics since high school affected low achievement in STEM disciplines at the tertiary level (Franzel et al., 2010; Pohjolainen, 2018; Tubb et al., 2020). Integrating STEM in mathematics classroom contexts is challenging, demanding, and complex because teachers have traditionally utilized the conventional instructional design and focus solely on the standard algorithms and procedural understanding when teaching numbers (Baker &Galanti, 2017; Fitzallen, 2015; Grootenboer& Marshman, 2015; Honey et al., 2014).A literature survey indicated that the emphasis on different subjects within the STEM field is not balanced, and the role of mathematics, in particular, is typically understated (English, 2016; Fitzallen, 2015; Maass et al., 2019).

Siregar et al. (2019) suggested more studies should be conducted to improve teachers' understanding of the teaching and learning process with the STEM approach, especially in mathematics. Some mathematics teachers are unsure of ways to implement STEM teaching and learning in the classroom and cannot be demonstrated by other peers (Song, 2019; Stohlmann, 2019). Furthermore, many teachers disregard the need to provide adequate scaffolding and assistance in developing students' 21st-century competence skills (Beswick & Fraser, 2019; Global STEM Alliance - New York Academy of Sciences [GSA-NYAS], 2016). According to Song (2019), one of the critical characteristics of integrated STEM teaching competencies is cognitive characteristics which including a) STEM sufficient knowledge, b) recognize the correct concept and value integrated STEM, c) link other STEM subjects by reorganizing curriculum, d) flexible thinking beyond the boundary of the subject, e) real-world issues and technology understanding, f) recognize problems thoroughly and creativity on inter-/multi-disciplinary knowledge. Teachers need to consider students' existing knowledge, provide them with the opportunity to become intelligible with their ideas, and build their knowledge (Koehler et al., 2015). Using learning experiences help students understand the concept clearly, and meaningful connection includes student-centered interaction between students through the activities provided (Madani et al., 2020; Priatna et al., 2020). It was mentioned in the Programme for International Student Assessment [PISA] (2018) report where teachers' zeal considered the constructive practice to embark students' ardor in learning mathematics. Teachers' knowledge in STEM can be applied to engage the students in hands-on mathematics classroom activities (Koehler et al., 2015). Therefore, teachers' preparedness in STEM pedagogical content knowledge is vital to carry out practically as they are the pillars of implementing system educational curricular to the nation. (Allen et al., 2016; Maass et al., 2019).

4.Purpose of the Study

The research aims to measure the STEM pedagogical content knowledge instrument (STEMPCK Scale) instrument using the Rasch model analysis (RMA) among mathematics secondary school teachers based on:

i) Pedagogical knowledge
ii) Science, technology, engineering, mathematics (STEM) knowledge
iii) 21st-century skills knowledge

5.Method

The STEMPCK Scale items were adapted from Yildirim and Sahin (2019) to examine teachers' STEM-based knowledge. The participants were selected through purposive sampling, which involved 23 mathematics secondary school teachers teaching STEM subjects in 2020. The questionnaire of the STEMPCK Scale was given through a Google form. The STEMPCK questionnaire (in Appendix) consisted of three main sections, which are pedagogical knowledge (12 items), STEM integration knowledge (science - 8 items; technology - 7 items; engineering - 7 items; mathematics - 8 items), and 21st-century learning (14 items). The items are given in the Likert Scale 5-point (1 through 5), as shown in Table 1.

The items were adapted from Yıldırım and Sahin (2019); thus, the appropriateness in terms of the language and the format used were evaluated. Experts in STEM education and language examined the content validity of the STEMPCK Scale instrument. Before measuring the instrument's reliability, the data were entered into the Statistical Package for the Science Social (SPSS) 20 program to perform the Exploratory Factor Analysis (EFA). The results of the output were used to evaluate the construct validity. The factor analysis value of 0.70 was computed, which is > 0.50, that met the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) requirement. According to the rotated component matrix output, the obtained distribution of items for each factor with an eigenvalue of more than 1 (one) was six factors. Factor 1 (item 1-12), factor 2 (item 13-20), factor 3 (item 21-27), factor 4 (item 28-34), factor 5 (item 35-42) and factor 6 (item 43 -56).

Table. 1. Categories of Likert scale

Item Responses	Scale
Strongly Agree (SA)	5
Agree (A)	4
Undecided (Neutral) (N)	3
Disagree (D)	2
Strongly Disagree (SD)	1

The instrument's reliability was examined using the Rasch model analysis as a tool that can measure respondents' ability to answer items and the difficulty of the question (Bond et al., 2020). The Cronbach Alpha index determines the quality of reliability ranges from 0 to 1. The higher index shows a high consistency of the items greater than 0.90 (Leppink, 2019). The reliability of the instrument is tested by applying the Rasch model analysis using software Winsteps version 3.71.0.1.

6.Results and Discussions

The Rasch model analysis can be used to measure the validity and reliability of the mathematical teachers' pedagogical knowledge of STEM-based education. The output analyzed (i) Person and item separation and reliability, (ii) Polarity item, (iii) Misfit item, (iv) Unidimensional, (v) Difficulty level, and (vi) Person map item. The researchers will discuss all the descriptions of the Rasch model analysis output.

6.1 Person and Item separation and reliability

A Rasch technique can be used to document and evaluate the measurement functioning of such an instrument. It explained whether the person answered the item or answered it correctly (Boone, 2016). To assess the reliability, the researcher used Winstep that provided indices of person separation index, item separation, person reliability, and item reliability. Person separation is used to classify people. The separation index is an estimation of the spread of items along the continuum of ability. It reflected the number of distinct strata in which the items can be divided (Bond et al., 2020). The minimum preferable values representing the right level of separation show the index of 2.0 for person separation and 0.8 for person reliability (Linacre, 2018). Meanwhile, item separation is used to verify item hierarchy. The minimum preferable value representing item separation is 3, and 0.9 represents item reliability, as presented in Table 2.

Table. 2. Person and item separation and reliability

Criteria	Person (n=23)	Item (n=56)
Separation	4.75	0.62*
Reliability	0.96	0.28*

The table showed person separation 4.75 and person reliability 0.96 fitted the requirement of the Rasch guidelines. Person separation with relevant person samples implied that the instrument was sensitive enough to distinguish between high and low performers. In that case, no need for more items. On the other hand, the item separation with the value of 0.62 and item reliability of 0.28 was below the Rasch guidelines' requirement. It implied that the person sample is not large enough to confirm the item difficulty hierarchy. Due to the small participation of respondents, resulted below requirement value of item separation and item reliability. Hence, a more significant sample is necessary to establish a reproducible item difficulty hierarchy (Linacre, 2018).

6.2 Polarity Item

The appropriateness of developing a construct with the item can be examined using the PTMEA CORR value. A positive (+) value showed that the item measures the construct. If the value is negative (-) or zeroes, the item does not measure the construct and needs to be eliminated or revised the particular items as in Table 3. The value PTMEA CORR stated in the table was positive with a range from 0.41 to 0.88. Hence, the items of the STEMPCK Scale satisfied the PTMEA CORR value.

Table. 3. Polarity Item

Item no	Measure	SE	PT-MEA CORR
13	-0.68	0.28	0.41
18	-0.98	0.27	0.44
17	-0.91	0.27	0.45

16	-0.53	0.28	0.50
19	-0.45	0.28	0.55
20	-0.76	0.27	0.55
15	-0.53	0.28	0.59
14	-0.53	0.28	0.60
30	-0.61	0.28	0.74
26	-0.45	0.28	0.75
12	-0.05	0.29	0.78
32	0.04	0.29	0.78
39	0.12	0.29	0.78
27	-0.21	0.29	0.78
24	-0.13	0.29	0.79
25	-0.29	0.28	0.79
38	0.21	0.29	0.79
10	-0.05	0.29	0.80
48	-0.05	0.29	0.80
56	0.47	0.30	0.81
22	-0.05	0.29	0.81
29	-0.21	0.29	0.81
53	0.12	0.29	0.81
42	0.12	0.29	0.82
40	0.38	0.30	0.82
44	0.12	0.29	0.82
55	0.21	0.29	0.82
28	0.29	0.30	0.82
2	0.04	0.29	0.82
6	-0.05	0.29	0.82
1	0.47	0.30	0.82
7	0.38	0.30	0.82
37	0.56	0.30	0.82
31	0.29	0.30	0.82
21	-0.45	0.28	0.82
45	0.12	0.29	0.83
50	0.29	0.30	0.83
35	0.38	0.30	0.83
36	0.29	0.30	0.83
11	-0.13	0.29	0.83
23	-0.21	0.29	0.83
4	0.12	0.29	0.84
47	0.21	0.29	0.84
34	0.04	0.29	0.84
54	0.29	0.30	0.84
9	0.21	0.29	0.84
41	-0.05	0.29	0.84
46	0.12	0.29	0.85
52	0.29	0.30	0.85
8	0.21	0.29	0.85
51	0.38	0.30	0.85
43	0.12	0.29	0.86
33	0.12	0.29	0.86
49	0.47	0.30	0.86
5	0.29	0.30	0.88
3	0.56	0.30	0.88

6.3 Instrument validity: Misfit item

Infit and Outfit statistics are used to analyze individual items and person fit. It is provided by Winsteps, where each one of these fit statistics is represented with Mean Square (MNSQ) and Z-Standardized Scores (ZSTD) (Boone, 2020). The fit analysis begins with the data of Outfit, then follows with Infit. Before analyzing ZSTD, it is advisable to start with MNSQ. Refer to Table 4 for determining the suitability and fit of the item, and three considered aspects were (i) identifying the Outfit Mean Square (MNSQ) value. The MNSQ's expected value should be approximately 1.0 (between 0.5 and 1.5) (Linacre, 2018). Exceeding value of MNSQ will lead to ZSTD checking; (ii) identifying infit ZSTD, the value ranged -2.0 < ZSTD < +2.0, indicate statistically significant model misfit (Linacre, 2018). Linacre has proposed an iterative process if there were any issues of misfitting items or individuals; (iii) identifying PTMEA CORR value, with the received value 0.4 < PTMEA CORR < 0.8 (Bond et al., 2020).

Table. 4. Misfit item (Infit MNSQ)

Item no	Measure	SE	Infit MNSQ	Infit ZSTD	Outfit MNSQ	Outfit ZSTD
13	-0.68	0.28	2.83	4.0	3.67	5.0
18	-0.98	0.27	2.55	3.6	3.55	4.8
17	-0.91	0.27	2.43	3.4	3.23	4.4
16	-0.53	0.28	2.58	3.6	2.95	4.0
19	-0.45	0.28	2.35	3.2	2.55	3.5
20	-0.76	0.27	2.35	3.2	2.55	3.6
15	-0.53	0.28	1.92	2.4	2.22	2.9
14	-0.53	0.28	1.97	2.5	2.21	2.9
30	-0.61	0.28	1.09	0.4	1.04	0.2
26	-0.45	0.28	1.05	0.3	1.11	0.4
12	-0.05	0.29	1.07	0.3	1.28	0.9
32	0.04	0.29	0.96	0.0	0.84	-0.4
39	0.12	0.29	0.95	0.0	0.98	0.0
27	-0.21	0.29	1.12	0.5	1.00	0.1
24	-0.13	0.29	0.92	-0.1	0.87	-0.3
25	-0.29	0.28	0.93	-0.1	0.93	-0.1
38	0.21	0.29	0.86	-0.3	0.96	0.0
10	-0.05	0.29	0.82	-0.5	0.86	-0.3
48	-0.05	0.29	0.98	0.0	0.83	-0.4
56	0.47	0.30	1.18	0.6	0.94	-0.1
22	-0.05	0.29	0.63	-1.2	0.71	-0.9
29	-0.21	0.29	0.79	-0.6	0.69	-1.0
53	0.12	0.29	0.86	-0.3	0.89	-0.2
42	0.12	0.29	0.96	0.0	0.89	-0.2
40	0.38	0.30	1.00	0.1	0.86	-0.4
44	0.12	0.29	0.73	-0.8	0.64	-1.2
55	0.21	0.29	0.96	0.0	0.82	-0.5
28	0.29	0.30	0.66	-1.1	0.69	-1.0
2	0.04	0.29	0.65	-1.1	0.73	-0.8
6	-0.05	0.29	0.80	-0.5	0.74	-0.8
1	0.47	0.30	0.82	-0.5	0.71	-0.9
7	0.38	0.30	1.00	0.1	0.84	-0.4
37	0.56	0.30	1.05	0.3	0.85	-0.4
31	0.29	0.30	0.60	-1.3	0.79	-0.6
21	-0.45	0.28	0.64	-1.2	0.66	-1.1
45	0.12	0.29	0.83	-0.4	0.76	-0.7
50	0.29	0.30	0.72	-0.8	0.69	-1.0
35	0.38	0.30	0.75	-0.7	0.71	-0.9
36	0.29	0.30	0.82	-0.5	0.74	-0.8
11	-0.13	0.29	0.56	-1.5	0.54	-1.6
23	-0.21	0.29	0.61	-1.3	0.57	-1.5
4	0.12	0.29	0.55	-1.5	0.70	-0.9
47	0.21	0.29	0.70	-0.9	0.70	-1.0
34	0.04	0.29	0.69	-0.9	0.58	-1.4
54	0.29	0.30	0.59	-1.4	0.58	-1.4
9	0.21	0.29	0.68	-1.0	0.64	-1.2
41	-0.05	0.29	0.57	-1.4	0.62	-1.3
46	0.12	0.29	0.57	-1.4	0.60	-1.3
52	0.29	0.30	0.55	-1.5	0.55	-1.6
8	0.21	0.29	0.40	-2.3	0.60	-1.4
51	0.38	0.30	0.58	-1.4	0.56	-1.6
43	0.12	0.29	0.47	-1.9	0.44	-2.1
33	0.12	0.29	0.44	-2.1	0.57	-1.5
49	0.47	0.30	0.60	-1.3	0.55	-1.6
5	0.29	0.30	0.35	-2.6	0.42	-2.31

3	0.56	0.30	0.54	-1.6	0.53	-1.7

It shows that items 13, 18, 17, 16, 19, 20, 15, and 14 were not listed in the range of MNSQ values. The items not listed in ZSTD were 13, 18, 17, 16, 19, and 20. However, all items are within the specified PTMEA CORR range value. Fifty items met the MNSQ and ZSTD values, while the other six items were further revised and refined.

6.4 Unidimensional

Unidimensionality within RMA is analyzed by Principal Component Analysis (PCA) of residuals. PCA is an approach to identify the condition of useful items (Boone & Staver, 2020). According to Linacre (2018), the minimum unidimensional percentage of the instrument is 20%. It is suggested by Fisher (2007), unexplained variance by first contrast, the Eigenvalue with less than three percent considered excellent. A very good Eigenvalue ranged from 3% to 5%, a good value within 5% to 10%, and a Fair value fall between 10% to 15%. In contrast, the Eigenvalue higher than 15% is considered weak. Besides that, raw variance explained by RMA measures needs at least a minimum of 40% (Fisher, 2007). On the other hand, Linacre (2018) suggested more than 60% for better measurement. Table 5 shows the standard residual variance of PCA.

Table. 5. Standardized residual variance

	Empirical (%)
Total variance in observations	100
Raw variance explained by measures	63.2
Raw variance explained by persons	43.4
Raw variance explained by items	19.8
Raw unexplained variance (total)	68.3
Unexplained variance in 1st contrast	13.7

As stated in table 5, the percentage of raw variance explained by measures is 63.2, while the unexplained variance in the first contrast is 13.7. These values represent acceptable evidence as the STEMPCK Scale instrument is fit for unidimensionality.

The identification of dependency item or multicollinearity relies on the most significant standardized residual correlation. The locally dependent item pairs are highlighted in Table 6. Based on Linacre (2018), highly correlated dependent item pairs value more than 0.7 are considered unnecessary to be included in the instrument. Hence, it is advisable to remove or rephrase the particular item pairs.

Table. 6. Standardized residual correlation

Correlation	**Item (Q)**	**Item (Q)**
0.93	13	16
0.93	9	55
0.92	13	17
0.92	14	15
0.92	16	18
0.92	16	19
0.91	17	18
0.90	16	17
0.90	18	19
0.89	35	40

The table shows 20 items (10 pairs) out of 56 items exceeding 0.7 limits, leading to possible multicollinearity problems. Therefore, a suggestion for removing or rephrasing the ten-pair items is recommended. Even though the ten pair items have a multicollinearity problem, none of the items breaks the goodness of MNSQ and ZSTD fit criteria. It is proven that the STEMPCK Scale consisting of 56 items is suitable for measure teacher STEM pedagogical content knowledge.

6.5 Item difficulty level

The item difficulty level of the questionnaire can be determined using the logit scale value. Five categories of item difficulties logits (Stachl&Baranger, 2020) are (i) very easy (less than -2.0); (ii) easy (-1.9 - +0.5); (iii) medium (-0.4 - +0.4); (iv) hard (0.5 - 1.9) and very hard (more than 2) as shown in Table 7. It clearly stated that 51 items were categorized as a medium while five items were considered hard.

Table. 7. Item difficulty level

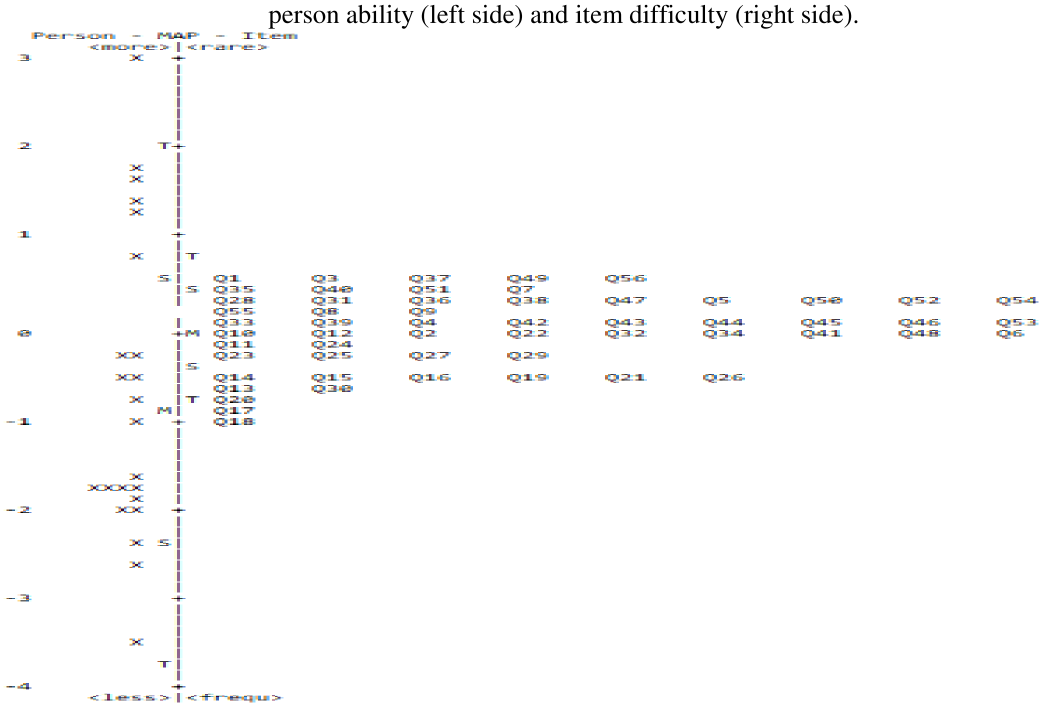
Q (number)	Logit value	Level
Q2, Q4, Q5-Q36, Q38-Q48, Q49-Q55	-0.98 - +0.29	Medium
Q1, Q3, Q37, Q49, Q56	0.56	Hard

6.6 Person item map

In RMA, Person-Item-Map or Wright Map is a tool for analyzing the outlook of the data comprehensively. This construct map provides information regarding the same logit ruler of the person's abilities and item difficulties (Wilson, 2004). Using the logit scale, it can measure the maximum and minimum value of person and item. The Wright map shows (Figure 1) that the range of logit measures is from a low of -1 to a high of +1.

The data shows it is skewed concerning item difficulty. Item difficulties range from about -0.98 logits for the available item to about +0.56 logits for the medium item. There are some items with similar difficulty levels, such as items Q35, Q40, Q51, Q7, Q28, Q31, Q36, Q38, Q47, Q5, Q50, Q52, Q54, Q55, Q8, Q9, Q33, Q39, Q4, Q42, Q43, Q44, Q45, Q46, Q53, Q10, Q12, Q2, Q22, Q32, Q34, Q41, Q48, Q6, Q11, Q24, Q23, Q25, Q27, Q29, Q14, Q15, Q16, Q19, Q21 Q26, Q13, Q30, Q20, Q17, and Q18. Meanwhile, mathematics teachers readily agree on Q1, Q3, Q37, Q49, and Q56.

Figure.1. Person-item map of STEMPCK Scale data. Note: Dashed vertical line separates logit values for person ability (left side) and item difficulty (right side).



7.Recommendations

Upcoming research considering the aspect of mathematics teachers' pedagogical content knowledge in STEM approach by:

- Investigating its effect in preparing activities for teaching and learning within the classroom or as co-curricular activities.
- Providing professional development among in-service teachers in strengthen up STEM-based knowledge for a successful teaching application.
- Compulsory STEM approach training courses to preservice teachers in college or tertiary education programs from theoretically to practically as preparation in teaching mathematics.

- Enhancing digital knowledge of mobile data, big data, and the internet of things (IoT) with mathematics when facing unexpected pandemic worldwide such as contagion of covid-19 where teachers are expected to carry out the teaching session from home.

8.Conclusion

The Rasch model analysis is a reliable application to measure the instrument's validity and reliability, including the STEMPCK Scale. Through this study, the instrument of 56 items is proven as valid and trustworthy to find out the response of teachers' knowledge towards STEMPCK. The items were operating well within the Rasch model. The unidimensionality of the instrument was authenticated too. Once the validity and reliability of the instrument are tested, a researcher can distribute it to the other relevant respondents after carried out the pilot study. This instrument is beneficial to STEM education program leaders, teacher educators, and preservice or in-service school teachers to identify what they know or do not know concerning STEM teaching.

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APPENDIX

	Strongly Agree (5)	Agree (4)	Undecided (Neutral) (3)	Disagree (2)	Strongly Disagree (1)
PEDAGOGICAL KNOWLEDGE					
1. I can use more than one teaching strategy, method, and technique in teaching a lesson.					
2. I can guide students in every aspect.					
3. I can help students in their research studies.					

4. I can use alternative measurement and evaluation approaches.					
5. I can create an effective learning environment in the classroom.					
6. I can communicate effectively with students.					
7. I can motivate students to learn courses.					
8. I can determine whether the students have achieved their goals.					
9. I can give students feedback and correction about the course.					
10. I am qualified enough about how to evaluate students.					
11. I can teach quality and efficient lessons.					
12. I can teach lessons according to class level.					

SCIENCE					
1. I have enough knowledge to teach science.					
2. I follow current developments and trends in the science field.					
3. I can call students' attention to the course subject by asking science questions.					
4. I can teach concepts, knowledge, theories, and laws of science.					
5. I think that I will be effective in science education.					
6. I can do advanced studies in science.					
7. I encourage students to use science concepts.					
8. I think that I am interested in a science course.					

TECHNOLOGY					
1. I have enough knowledge to teach technology.					
2. I can use technological tools in class.					
3. I have enough knowledge to integrate technology into different courses.					
4. I follow current developments in technology.					
5. I can find new and different solutions to technological problems.					
6. I know about different technologies.					
7. I can link different disciplines with technology.					

ENGINEERING					
1. I think that engineering is based on science and mathematics.					
2. I think that I can help students in engineering education.					
3. I follow current developments in engineering.					
4. I think that technology is the application area of engineering.					
5. Work activities related to engineering makes me feel good.					
6. I think that engineering is fun.					
7. I can combine my courses in engineering education.					

MATHEMATICS					
1. I have enough content knowledge in mathematics.					
2. I believe that I can teach concepts, theorems, and theories in mathematics lessons, effectively.					
3. I encourage students to use mathematics concepts.					
4. I can do advanced studies in mathematics.					
5. I think that mathematics is a discipline with terms and theories.					
6. I have the skills and qualifications necessary for teaching mathematics.					
7. I know to use mathematics and science together.					
8. I follow developments in mathematics.					

21st CENTURY SKILLS KNOWLEDGE					
1. I can improve students' critical thinking skills.					
2. I will help students to develop problem-solving skills necessary in their everyday life.					
3. I can communicate effectively with my friends.					
4. I can put myself in someone's place and empathize.					

5. I can do group work with my friends.					
6. I can make new and different designs.					
7. I respect my friends' thoughts.					
8. I can lead my friends.					
9. I am tolerant of criticism.					
10. I am sure that I will consider the views of others while making decisions.					
11. I can help my friends improve their imagination.					
12. I believe that I can set my own learning goals.					
13. I am confident that I can manage my time wisely while working alone.					
14. I think that the problems are more than one solution.					