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Rasch Analysis and Differential Item Functioning of STEM Teachers' Instructional Preparedness Instrument for Urban and Rural Teachers

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Abstract
STEM Teachers' Instructional Preparedness instrument (STEMTIP) was developed in this study with of 40 items and consists of 5 main constructs. Using multistage cluster sampling, 252 teachers in Malaysia was selected as sample of the study. Rasch Model analyses the psychometric properties of the STEMTIP instrument. The results indicate that 40 items of the STEMTIP are well fitted to a latent unidimensional structure, as required by the Rasch Model. There are two items (ELA1 and EVA8) that show a psychometric properties of Differential Item Functioning in STEMTIP concerning school location. Finally, psychometric implications derived from the results of the present study are discussed and suggestions are provided for future investigations.
Keywords: Rasch Model, Differential Item Functioning, STEM, Preparedness, Malaysia

Introduction
STEM is an acronym of Science, Technology, Engineering and Mathematics. The merger of these discipline makes it a high demand in the job market. In 2017, the US Bureau of Labor Statistics reported that STEM related workforce grew by 10.5% between May 2009 and May 2015 compared to a 5.2% net growth in non-STEM related workforce showing a high demand

in STEM related occupations (Fayer, Lacey, & Watson, 2017). Malaysia is also not lagging behind with a target of 1 million workers by 2020. However, what is worrying is the latest figure of STEM workforce in 2012 that was only 120K (Academy of Sciences Malaysia, 2015). Therefore, to ensure that goal is met, the related stakeholders have made an initiative towards preparing a quality STEM workforce. Among them is the efforts of Malaysia's Ministry of Education to include STEM as one of the approaches in the standard curriculum of schools beginning 2017 (Curriculum Development Division, 2016).

Previous study have reported that the effort to attract students to the science stream in Malaysia has begun since 1967 with the policy of 60:40 Science/Technical: Arts (60:40) (Ministry of Education Malaysia, 2013). The policy refers to the Ministry's target to get more students on science stream compared to the arts stream. However, this policy's target has never been met due to various factors. The highest ratio was 44: 56 in 2011 and then it dropped to 21:79 in 2014 (Academy of Sciences Malaysia, 2015).

Among the factors that influence the lack of student enrolment in STEM are teachers. Teachers have great inspiration in building student interest and motivation in STEM (Price, 2010; van Tuijl & van der Molen, 2016). However, teachers stated that some obstacles in the implementation of STEM in teaching and learning include motivation, syllabus, time constraints, lack of training, inadequate facilities, students' involvement as well as school and community response (Nur Farhana Ramli & Othman Talib, 2017). In addition, the achievement gap for science and mathematics subjects between urban and rural areas is also due to the fact of teachers who have not fully grasped and internalized the standard curriculum (Ministry of Education, 2017).

The Malaysia Education Blueprint 2013-2025 reported that besides the factor of limited awareness, perceived difficulties in STEM subjects, limited and outdated infrastructure, teachers' instructional quality are also one of the factors of the declining of STEM enrolment. Teachers reportedly failed to create a student-centered learning environment and still maintain inactive instructional innovations (Academy of Sciences Malaysia, 2015; Nordin & Ling, 2011). Since student interest is based on a teacher's instructional method (Henry et al., 2011; Slavit, Nelson, & Lesseig, 2016), the role of the teacher in shaping a pupil's future is important.

Teacher Preparedness in STEM Implementation

One of the STEM approaches in teaching is through inquiry-based learning. In inquiry-based learning, the teacher will act as a facilitator. In the process, teachers need to master how to offer the right amount of support to scaffolod student learning. Belland (2017) defines instructional scaffolding as support given to allow students to participate and gain skills at a task that they cannot solve without help. The instructional scaffolding may come from the help of teachers, parents, peers or computer aided scaffolding (Belland, 2014). In STEM teaching and learning, instructional scaffolding has been used and is proven to be effective in assisting students in their learning process (Crippen & Archambault, 2012; Dani, Hartman, & Helfrich, 2017; Rehmat & Bailey, 2014).

Teachers' preparedness in instructional is crucial to ensure the success of the curriculum. Teachers' preparation symbolizes their quality (Darling-Hammond, Chung, & Frelow, 2002). The STEM instructional process requires teachers to play a role and plan to inspire and give opportunities to students to appreciate STEM. Among the tasks of teachers in giving instructional support to pupils are like brainstorming, guiding and developing students' thinking skills, and giving comments and suggestions to given tasks (Curriculum Development

Division, 2016b). For that reason, the teacher's instructional preparedness is very vital and needs to be measured as the information obtained can benefit stakeholders and teachers themselves.

Previous studies reported that there is an achievement gap reported due to the geographical location of schools, i.e., urban and rural schools (Ministry of Education Malaysia, 2013). Teachers and students in rural areas are also lagging in terms of ICT exposure compared to pupils and teachers in urban areas (Hazura, Hairulliza, Noor, & Yusiof, 2012). They are also more focused on rote learning and teachers do not expose students to thinking skills. This inevitably negatively impacts students' academic achievement (Ministry of Education, 2017).

Various efforts have been undertaken to reduce urban and rural differences. One of it is The District Transformation Program (DTP) that aimed at narrowing the gap using the School Improvement Specialist Coach (SISC +). These experts help rural teachers especially in instructions to improve teaching and learning process.

Thus, with the determinations undertaken, it is necessary to measure teachers' instructional preparedness in implementing STEM. The objectives of this study are to analyse the psychometric properties and to identify the biased items in the new development instrument, STEMTIP. Besides producing fair instruments, this study is also expected to provide gap information between the urban and rural teachers.

Methodology

Sample

The sample consisted of 252 science teachers aged from 28 to 59 years old (M age = 43.58 years, SD = 7.752) from secondary schools all over Malaysia. Roughly, 12.7% of the sample was from the north zone, 22.6% from the central zone, 31.3% from the south zone and 33.3% from east coast zone. A total of 252 science teachers were involved in the study consisting of 145 (57.5%) teachers from the city and 107 (42.5%) from rural areas. 35 (13.9%) teachers were male teachers and the rest were females at 217 (86.1%) teachers.

All teachers have a teaching experience ranging from 2 to 36 years (M experience = 17.66 years, SD = 6.89 years). All teachers teach either science, chemistry, biology or physics. The breakdown of the teacher based on the taught subjects is displayed in Table 1.

Table 1

Teacher information based on taught subject

Subject	N	%
Biology	46	18.3
Physic	38	15.1
Chemistry	37	14.7
Science	131	52
Total	252	100

Instrument

STEM Teacher Instructional Preparedness (STEMTIP) instrument consists of 40 items developed for this study. There are 5 main constructs in STEMTIP instrument, which are engagement, exploration, explanation, elaboration and evaluation. These items were constructed based on the social constructivist theory, 5E Instructional Model and STEM Teaching and Learning Approach Model. STEMTIPI is measured based on response rate of four-point scales of never, seldom, some of the time and always.

Data Analysis

Data was analysed using the Rasch measurement model. The Rasch measurement model can provide significant advantages in getting the most accurate analytical result and provide more specific information for unobservable latent constructs such as teacher instructional preparedness. This model has the advantage of converting raw data scores into equal interval unit of measurement called log odd unit (logit) (Bond & Fox, 2015; Kaseh Abu Bakar & Siti Aishah Hassan, 2009). This value can provide a standard measurement value like a ruler. The logit value can then arrange items and also samples in a standard ruler scale and can also show the difference. The model independently scales the endorsebility of both items and persons along a theorized underlying latent continuum (Hassan, Ayub, & Bakar, (2017)
In the Rasch measurement model, the concept of fit is a quality control to indicate whether the measurement value for the person and the item can be represented by interval-level measures (Bond & Fox, 2015). There are five categories for fit item range, which are poor, fair, good, very good and excellent. The items in the instrument are on an excellent range if they are within the infinity range and Outfit MNSQ 0.77-1.3 (Fisher, 2007). The infit MNSQ value refers to the sensitivity to the response pattern of the item and respondent while the MNSQ Outfit refers to the outlier match. In addition, the main condition of identifying unidimensionality is that the instrument should have at least 40% raw explained by measure (Azrilah Abdul Aziz, Mohd Saidfudin Masodi, & Azami Zaharim, 2013).
Apart from the assumption of the data fit model and unidimensionality, this study also carried out the Differential Item Functioning (DIF) test. This test is conducted on each item in this instrument to identify items that indicate the difference in the STEM instructional preparedness of urban and rural teachers. This test has a straightforward procedure in identifying DIF items. DIF contrasts with the value of > 0.64 logits, p <0.05 will indicate that the particular item functions differently between the groups, in this study, urban and rural science teachers (Linacre, 2012).

Result and Discussion

The Rasch Model Analysis from Winstep 3.71 identified 11 items (item 1 (ENG1), 24 (EPL1), 25 (EPL2), 26 (EPL3), 31 (EPL8), 37 (ELA4), 39 (ELA 6), 41 (ELA8), 42 (ELA9), 45 (EVA3) and 51 (EVA9) which did not fit the model expectation. These items diverge unacceptably from the expected ability and difficulty pattern and thus removed from further analysis. Table 2 shows the final statistics of 40 items from the Rasch Model Analysis. All the items show excellent infit and outfit MNSQ values between 0.77 to 1.3 logits.

Table 2
Item statistic

ENTRY NUMBER	RAW SCORE	COUNT	MEASURE	MODEL S.E	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEA CORR	ITEM
1		DELETED								ENG1
2	836	252	-0.88	0.12	1.21	2.3	1.16	1.5	0.5	ENG2
3	805	252	-0.43	0.12	1.06	0.7	1.02	0.2	0.64	ENG3
4	743	252	0.42	0.12	0.82	-2.2	0.83	-2	0.61	ENG4
5	734	252	0.54	0.11	0.92	-0.9	0.92	-0.9	0.6	ENG5
6	789	252	-0.2	0.12	0.95	-0.6	0.93	-0.8	0.66	ENG6
7	818	252	-0.61	0.12	0.85	-1.9	0.87	-1.4	0.6	ENG7
8	713	252	0.82	0.11	1.11	1.3	1.12	1.3	0.55	ENG8
9	759	252	0.21	0.12	1.09	1	1.27	2.8	0.56	ENG9
10	733	252	0.55	0.11	1	0	0.99	-0.1	0.58	EPO1
11	681	252	1.23	0.11	0.78	-2.6	0.78	-2.7	0.65	EPO2
12	685	252	1.18	0.11	1.06	0.8	1.11	1.2	0.55	EPO3
13	628	252	1.91	0.11	0.83	-2.1	0.81	-2.2	0.65	EPO4
14	691	252	1.1	0.11	0.88	-1.4	0.88	-1.4	0.62	EPO5
15	754	252	0.28	0.12	1.01	0.2	1.01	0.1	0.62	EPO6
16	697	252	1.02	0.11	1.14	1.6	1.15	1.6	0.64	EPO7
17	819	252	-0.63	0.12	1.17	1.9	1.14	1.4	0.64	EPO8
18	831	252	-0.8	0.12	0.82	-2.3	0.82	-1.9	0.66	EPO9
19	825	252	-0.72	0.12	0.95	-0.6	0.89	-1.1	0.67	EPO10
20	817	252	-0.6	0.12	1.07	0.8	1.06	0.6	0.6	EPO11
21	801	252	-0.37	0.12	0.91	-1	0.93	-0.7	0.62	EPO12
22	849	252	-1.08	0.12	0.92	-1	0.89	-1.1	0.65	EPO13
23	852	252	-1.12	0.12	0.82	-2.2	0.79	-2.1	0.66	EPO14
24		DELETED								EPL1
25		DELETED								EPL2
26		DELETED								EPL3
27	807	252	-0.46	0.12	0.87	-1.6	0.86	-1.6	0.67	EPL4
28	748	252	0.36	0.12	1.26	2.8	1.28	2.9	0.57	EPL5
29	791	252	-0.23	0.12	1.01	0.1	1	0	0.64	EPL6
30	770	252	0.06	0.12	0.79	-2.6	0.78	-2.6	0.7	EPL7
31		DELETED								EPL8
32	851	252	-1.11	0.12	0.81	-2.3	0.78	-2.1	0.68	EPL9
33	869	252	-1.4	0.13	0.87	-1.6	0.85	-1.3	0.64	EPL10
34	820	252	-0.64	0.12	0.97	-0.3	0.96	-0.4	0.61	ELA1
35	843	252	-0.99	0.12	0.96	-0.5	0.92	-0.7	0.65	ELA2
36	815	252	-0.57	0.12	0.85	-1.8	0.85	-1.6	0.64	ELA3

37		DELETED								ELA4
38	813	252	-0.54	0.12	0.82	-2.3	0.82	-2	0.63	ELA5
39		DELETED								ELA6
40	857	252	-1.2	0.13	0.82	-2.2	0.8	-1.9	0.66	ELA7
41		DELETED								ELA8
42		DELETED								ELA9
43	714	252	0.8	0.11	1.11	1.3	1.11	1.3	0.6	EVA1
44	694	252	1.06	0.11	1	0	1.01	0.1	0.58	EVA2
45		DELETED								EVA3
46	725	252	0.66	0.11	0.86	-1.7	0.85	-1.7	0.67	EVA4
47	854	252	-1.16	0.13	1.02	0.2	0.99	0	0.64	EVA5
48	758	252	0.22	0.12	1.08	1	1.07	0.8	0.61	EVA6
49	779	252	-0.06	0.12	0.9	-1.2	0.89	-1.2	0.66	EVA7
50	748	252	0.36	0.12	0.86	-1.7	0.85	-1.7	0.66	EVA8
51		DELETED								EVA9

Meanwhile, based on figure 1, the raw material explained by measures was 46.9%, 4.7% unexplained variance in the first contrast and 3.5 Eigen values indicate that there is no clear second dimension (Fisher, 2007). Because the data meets the assumptions of the fit data model and unidimensionality, the items' measure form the analysis demonstrates the property of equal interval.

		-- Empirical --			Modeled
Total raw variance in observations	=	75.3	100.0%		100.0%
Raw variance explained by measures	=	35.3	46.9%		46.9%
Raw unexplained variance (total)	=	40.0	53.1%	100.0%	53.1%
Unexplained variance in 1st contrast	=	3.5	4.7%	8.8%	

Table 3 demonstrates DIF analysis of all 40 items based on urban (class 1) and rural (class 2) teachers. 38 items did not show any significant difference which is less than .64 logits and p <0.05 (Linacre, 2012). It can therefore be concluded 38 items are fair to both rural and urban teachers in terms of instructional preparedness to implement STEM. Overall, this study shows satisfactory results where 38 out of 40 items (95%) worked to measure the preparations of urban and rural teachers without bias. Only two items, i.e. item 29 (ELA 1) and item 40 (EVA8) show the opposite function.

Table 3
DIF Analysis

CLASS	DIF MEASURE	DIF S.E.	CLASS	DIF MEASURE	DIF S.E.	DIF CONTRAST	JOINT S.E.	Prob	Item No	Name
1	-1.01	0.17	2	-0.63	0.19	-0.38	0.25	0.1319	1	ENG2
1	-0.42	0.16	2	-0.31	0.19	-0.11	0.25	0.6501	2	ENG3
1	0.36	0.16	2	0.73	0.18	-0.37	0.24	0.1206	3	ENG4
1	0.7	0.16	2	0.56	0.18	0.13	0.24	0.5784	4	ENG5
1	-0.17	0.16	2	-0.1	0.18	-0.06	0.24	0.7956	5	ENG6
1	-0.57	0.16	2	-0.57	0.19	0	0.25	1	6	ENG7
1	0.77	0.16	2	1.15	0.18	-0.38	0.24	0.1108	7	ENG8
1	0.18	0.16	2	0.43	0.18	-0.25	0.24	0.2998	8	ENG9
1	0.53	0.16	2	0.83	0.18	-0.3	0.24	0.2114	9	EPO1
1	1.33	0.16	2	1.45	0.18	-0.12	0.24	0.621	10	EPO2
1	1.32	0.16	2	1.32	0.18	0	0.24	1	11	EPO3
1	2.16	0.16	2	2.08	0.18	0.08	0.24	0.7351	12	EPO4
1	1.24	0.16	2	1.24	0.18	0	0.24	1	13	EPO5
1	0.26	0.16	2	0.5	0.18	-0.24	0.24	0.3151	14	EPO6
1	1.09	0.16	2	1.25	0.18	-0.16	0.24	0.4914	15	EPO7
1	-0.45	0.16	2	-0.78	0.19	0.33	0.25	0.1931	16	EPO8
1	-0.79	0.16	2	-0.74	0.19	-0.05	0.25	0.8314	17	EPO9
1	-0.85	0.16	2	-0.45	0.19	-0.4	0.25	0.1151	18	EPO10
1	-0.34	0.16	2	-0.85	0.19	0.5	0.25	0.0454	19	EPO11
1	-0.22	0.16	2	-0.45	0.19	0.23	0.25	0.3445	20	EPO12
1	-0.9	0.17	2	-1.27	0.2	0.37	0.26	0.1556	21	EPO13
1	-0.98	0.17	2	-1.27	0.2	0.29	0.26	0.2719	22	EPO14
1	-0.34	0.16	2	-0.49	0.19	0.14	0.25	0.5686	23	EPL4
1	0.4	0.16	2	0.5	0.18	-0.09	0.24	0.6949	24	EPL5
1	-0.14	0.16	2	-0.21	0.19	0.07	0.24	0.7904	25	EPL6
1	0.01	0.16	2	0.3	0.18	-0.29	0.24	0.2285	26	EPL7
1	-1.08	0.17	2	-1.11	0.2	0.03	0.26	0.9079	27	EPL9
1	-1.36	0.17	2	-1.43	0.2	0.07	0.26	0.7836	28	EPL10
1	-0.9	0.17	2	-0.21	0.19	-0.69	0.25	0.0057	29	ELA1
1	-1.07	0.17	2	-0.81	0.19	-0.26	0.26	0.3168	30	ELA2
1	-0.58	0.16	2	-0.45	0.19	-0.13	0.25	0.6065	31	ELA3
1	-0.55	0.16	2	-0.42	0.19	-0.14	0.25	0.5808	32	ELA5
1	-1.27	0.17	2	-1.08	0.2	-0.19	0.26	0.4575	33	ELA7
1	1.04	0.16	2	0.76	0.18	0.28	0.24	0.2477	34	EVA1
1	1.45	0.16	2	0.86	0.18	0.59	0.24	0.0139	35	EVA2
1	0.77	0.16	2	0.77	0.18	0	0.24	1	36	EVA4
1	-1.01	0.17	2	-1.31	0.2	0.3	0.26	0.2541	37	EVA5
1	0.53	0.16	2	0	0.18	0.53	0.24	0.0296	38	EVA6
1	0.01	0.16	2	0.01	0.18	0	0.24	1	39	EVA7
1	0.75	0.16	2	0.03	0.18	0.71	0.24	0.0034	40	EVA8

Item 29 (ELA 1) (*I provide questions based on the level of thinking skills*), urban teachers are shown as significantly more prepared (measure = -0.9 logits) compared to rural teachers (measure = -0.21 logits). This difference suggests that rural teachers feel unwilling to carry out STEM teaching and learning with the incorporation of thinking skills. Although the DTP

program has been specifically tailored to rural teachers to reduce the gap between urban and rural areas, teachers still practice rote learning as reported in the previous study (Ministry of Education, 2017). This should be taken seriously on behalf of the stakeholder because in the STEM approach proposed by the ministry, thinking skills are a crucial skill that students need to master. Thinking skills are the key to learn inquiry where the students are required to think and solve problems creatively and critically.
However, for **item 40 (EVA8)** (*I talked to the students about the achievement of STEM activities after the evaluation was conducted)*, it showed otherwise. For this item, rural teachers show significantly more prepared (measure = 0.03 logits) compared to urban teachers (measure = 0.75 logits). This is surprising since the discussions on the achievement of STEM activities are important regardless where the school location are (Curriculum Development Division, 2016b). There is a possibility that time constraint is a factor in the lack of teacher-student communication in STEM implementation as reported in the previous study (Nur Farhana Ramli & Othman Talib, 2017). Stakeholders need to take action to find ways to improve effective communication between students and teachers as it important to identify the strengths and weaknesses of their STEM tasks. It is suggested to use mediums such as Virtual Learning Environment (VLE) as a medium for student and teacher discussions since it is proven effective to strengthen communication and discussion between teachers and students (Ministry of Education, 2017).

Conclusion

Teacher preparedness are an important factor in determining the success of STEM implementation in the curriculum. Therefore, it is important to have a valid and reliable instrument to measure STEM teachers' preparedness. This study reports the unidimensionality, item fit and differential item function of the new developed instrument, STEMTIP. The data shows the proof of fit data model and unidimensionality. However, there are two items that show the differences of teacher preparedness in urban and rural area. Teachers in rural areas are reportedly unprepared in providing questions based on different levels of thinking than urban teachers. Conversely, they are reported to be more willing to talk to students about STEM achievements than urban teachers. These findings are especially important for stakeholders who intend to bridge the educational gap between urban and rural education.

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