Assessing Pre-Service Physics Teachers' Energy Literacy: An Application of Rasch Measurement

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Assessing Pre-Service Physics Teachers' Energy Literacy: An Application of Rasch Measurement

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Abstract. This paper aims to present a summary of pre-service physics teachers' responses on energy literacy assessment. A total of 123 pre-service physics teacher in first through third year of education participated. Data were analyzed using Rasch modeling. Research findings indicate that pre-service physics teachers show their low self-system toward energy conservation. They were also still lack of metacognitive and cognitive competencies. These finding provide information for the future development of curriculum, teaching and learning that can improve pre-service physics teachers' energy literacy.

1. Introduction

Energy is a concept in physics that plays important role in human daily life. Energy is needed by human and animal to do work. Energy is also needed to run vehicle, power industry and manufacturing, and provide us with electricity. Energy, in one hand, can help economics growth, but in the other hand, energy also can cause environmental and societal impact. Overcoming these issues, energy literacy becomes a key of solution.

Previous research on energy literacy measurement [1]–[11] mostly studied of secondary school students. This indicates that there is still a lack of energy literacy studies of higher education students. However, higher education plays an important role in society. With respect to environmental conditions, universities are challenged to facilitate society-wide changes, such as by strengthening climate change mitigation efforts by reducing carbon emissions through promoting climate policy development, fostering behaviour change, and advancing low-carbon emitting technological change [12]. Furthermore, higher education has a particular and specific function, to graduate influential citizens who value their environment and appreciate that they have a responsibility to help to sustain it [13]. Seen from this perspective, higher education students particularly pre-service physics teachers, have to be prepared to deal with these challenges. If we expected that teachers are to effectively cope with the challenge of helping students develop energy literacy, it follows that they need to possess adequate energy literacy themselves.

The aim of the study was to measure pre-service physics teachers' energy literacy. This paper focuses on the results of a field test of energy literacy assessment. The items were developed using Rasch model to meet construct validity. During item development, experts judgement were used to ensure content validity. Then, pilot testing was conducted to obtain empirical evidences to revise items. After being analysed and revised, the items were then field tested on a large scale to determine their psychometric properties.

2. Methods

The data reported on here resulted from a field test of 33 items that purported to measure pre-service physics teachers' energy literacy. The instrument was developed based on previous work [3]. The instrument consists of two forms: constructed response and multi-select question across three domains (self-system, metacognitive, and cognitive). Pre-service physics teachers from three state universities, from two provinces in Indonesia involved as test taker in this study. Data from 123 students who responded to at least 50% of the items are analized. The data were analyzed using Rasch partial credit model [15], and using Winstep [16].

Table 1. Competencies of energy literacy measured relate to six levels of thinking

System of thinking	Competencies	Items
Retrieval	Recognizing nonrenewable and renewable energy resources.	SE1
Comprehension	Interpreting and to conclude energy-related information from table or graph.	BL2, BL4
	Counting energy consumption of electrical equipment.	BL5
	Counting energy generation from an energy resource.	PV1
Analysis	Analyzing errors of an information provided about energy.	BL1, PV1, KE3, PE3
	Analyzing the environmental impact of fossil fuel usage.	SE2, SE3, SE4, SE5, SE6
Knowledge utilization	Using information to make a decision about energy use and purchase.	BL3, AC1, SE7, SE8
	Using information to solve problem about energy.	AC2, KE6, PE2, PV3
	Proposing action to conserve energy.	AC3, AC4, KE1
Metacognition	Specifying goals of conserving energy.	KE5
	Specifying learning objective of energy concept.	PE5 PE1
	Having clarity and/or accuracy about energy concept	
Self-system	Examining importance of energy conservation.	BL6, PE4 KE2, PE7
	Identifying beliefs about one efficacy to conserve energy.	PV2, KE4
	Identifying one emotional response related energy use	PE6
	Identifying overall level of motivation to take action in energy conservation.	

3. Results and Discussion

3.1. Rasch fit statistics and wright map

The field test data showed a good fit to the Rasch model. There were no negative values for the point-measure correlation, and ranged from 0.10 to 0.60. The infit mean-square values ranged from 0.80 to

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1.18, and the Z standardized values ranged from -1.3 to 1.7. Outfit mean-square values ranged from 0.70 to 1.15, and Z standardized values ranged from -1.3 to 1.3. These values of both infit mean-square and outfit mean-square for all of the items were within the acceptable range of 0.70 to 1.30, also for Z standardized values [17]. The item separation index was 6.38, which is equivalent to an item reliability coefficient of 0.98. The person separation index was 2.10, which is equivalent to a person reliability coefficient of 0.82. The standard errors for the field test items ranged from 0.11 to 0.23. Table 2 summarizes the Rasch statistics of the instrument.

Table 2. Summary of Rasch statistics

Parameters	Minimum	Maximum
Point-measure correlation	0.10	0.60
Outfit mean square (Zstd)	0.70 (-1.3)	1.15 (1.3)
Infit mean square (Zstd)	0.80 (-1.3)	1.18 (1.7)
Standard error	0.11	0.23
Person separation index (reliability)	6.38 (0.98)	
Item separation index (reliability)	2.10 (0.82)	

```
MEASURE     PERSON - MAP - ITEM
                  <more>|<rare>
   3                    +
                        |
                        |
                        |
                        |  PV2
   2                    +T
                 .##  T|  SE7
                    .  |  PE1
                  .##  |
                 ####  |  BL6     KE3    PE2
   1             .###  S+S SE5
                #####  |  AC1     AC2    SE1
           .#########  |  BL5
            .########  M|  PV1
              .######  |  BL1     SE6
   0            #####  +M AC3     KE5    PE3
              .#####  S|  PE5     SE2
                   ##  |  BL3
                   ##  |  BL2     PV3    SE3
                  ###  |  AC4     KE4    PE4    SE4
  -1                #  T+S BL4
                       |  KE1
                    .  |  PE6     PE7
                       |  KE6
                       |  KE2
  -2                   +T
                  <less>|<freq>
```

Figure 1. Wright map showing the distribution of pre-service physics teachers abilities on the left and item difficulties on the right. Each "#" is 2 and "." is 1.

Figure 1 shows a Wright map comparing pre-service physics teachers ability measures and item difficulty measures. Pre-service physics teachers ability is shown on the left side of the vertical line from low ability at the bottom to high ability at the top. The spread of item difficulties are shown on the right side of the vertical line ranging from easiest at the bottom of the map to most difficult at the top. Person who is located at the same level on the map as an item's difficulty measure has a 50% chance of solving that particular item and who is located below that item has a lower chance of solving it succesfully. For these pre-service physics teachers' ability measure were 0.33 logits, slightly higher

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than item difficulty (was set by default at 0.0). It indicates that the items within the instrument were, on average, relatively easy for these pre-service physics teachers.

3.2. Pre-service physics teachers performance on energy literacy assessment

3.2.1 Self-system. Wright map in Figure 1 shows that the easiest items are dominated by items on self-system domain, namely Item KE2, PE6 and PE7. Item KE2 asked pre-service teachers' whether they believed that they can use energy efficiently. Item PE6 asked if they are a teacher whether they motivated to teach energy conservation to their students. Item PE7 asked if they are a teacher whether they believed that they can influence their students behavior toward energy conservation through energy concept teaching at school. To scored the responses, we used scoring rubrics. If the response indicates that one believes (or motivated, for Item PE6) with logical reason, then he/she got score 2. If one answers that he/she does not believe (or motivated, for Item PE6), then the score is 1. Score 0 is for one who gives irrelevant response to the question. If one gives no response then it is denoted as missing data. Table 3 summarizes the category structure of Item KE2, PE6, and PE7.

Table 3. Category structure of three items on self system domain.

Item	Category label	Score	Observed count	%	Observed average
KE2	0	0	1	1	-0.30
	1	1	54	45	0.22
	2	2	64	55	0.58
	Missing		4	3	-0.17
PE6	0	0	3	3	-0.30
	1	1	52	45	0.05
	2	2	61	53	0.70
	Missing		7	6	0.56
PE7	0	0	1	1	-0.78
	1	1	78	70	0.23
	2	2	33	29	0.76
	Missing		11	9	0.55

Table 3 shows that albeit the items were easy for the pre-service physics teachers, there were great amount of them who got score 1 across the three items. Most of the pre-service physics teachers (70%) even got score 1 on Item PE7, and 9% did not give response. The data indicate that the pre-service physics teachers have low self-efficacy regarding energy conservation.

Other items in the same level of thinking, self-system, are located at the top end of Wright map. Item PV2 even was the most difficult item. Item PV2, together with Item KE4 are intended to measure competency of identifying own emotional response related energy use (see Table 1). Different from Item PV2, Item KE4 also PE4 are located lower on the Wright map. This is not surprising that Item PV2 is more difficult than Item KE4 and PE4 because of familiarity of Item PV2 than the others. The more familiar one with a process, the easier it becomes [18]. Item PV2 was about photovoltaic, an unfamiliar things for Indonesian people.

3.2.2. Metacognitive. As shown in Table 1, items on metacognitive domain are KE5, PE1, and PE5. Item KE5 asked pre-service teachers' when they have just finished watching the television what then they did, let the television was on, switched the television off but remain the cable power plugged, or switched the television off and unplugged the cable power, and what was their action purpose. Item PE1 asked pre-service teachers' whether they were still confused about definition of energy. Item PE5 asked pre-service teachers' to write down what they thought as the important learning outcome for students to reach related to energy concept. Table 4 summarizes the category structure of the three items.

Table 4. Category structure of three items on metacognitive domain.

Item	Category label	Score	Observed count	%	Observed average
KE5	1	1	30	25	0.13
	2	2	41	35	0.25
	3	3	51	42	0.67
	Missing		1	1	-0.17
PE1	0	0	67	64	0.22
	1	1	28	27	0.77
	2	2	9	9	0.68
	Missing		19	15	0.31
PE5	0	0	6	5	0.12
	1	1	62	55	0.24
	2	2	14	13	0.67
	3	3	30	27	0.76
	Missing		11	9	0.55

Although mostly pre-service physics teachers stated that they intended to save energy, but 60% of them chose inappropriate actions (scored 1 and 2 in the items). Only 27% of pre-service physics teachers included affective and behavior as well as knowledge aspects as important learning outcome should be reached by students. Similarly, only 9% of pre-service physics teachers stated that they were not confused about definition of energy.

Figure 1 shows that Item KE5 and PE5 are located close each other on the Wright map. Item PE1 is upper location on the map. This indicates that the pre-service physics teachers lack of clarity of energy definition. There were 64% of them still confused about energy definition and 15% did not answered the item. Most of pre-service physics teachers defined energy related to the energy conservation law. Indeed, energy is a quantity that cannot be defined by a unique sentence, it needs a progressive construction of meaning and it can be really understood only after using it in different contexts and problems [19].

3.2.3. Cognitive. Wright map in Figure 2 shows that most pre-service physics teachers are located at the same level with Items BL5 and PV1. These two items are require competency in solving mathematical problems. Item PV1 Item SE1 was an item with retrieval process of thinking that asked pre-service physics teachers to recognize nonrenewable and renewable energy resources. Pre-service physics teacher who responded incorrectly were much greater than who was correctly. Most of the incorrect answer was to suppose that nuclear is a renewable energy source. Other misconception also held by the most pre-service physics teacher was regarding energy conservation law (Item PE3). Mostly they confused between the concept of energy conservation and energy degradation (Item KE3). They also held misconception that energy is a concrete quantity (Item PE2). These misconceptions are consistent with previous research [20]–[25]. A great amount of incorrect answer for Item SE6 provide information of the lack of knowledge about the impact of energy consumption on climate change. The lack of knowledge utilization also shown by the pre-service physics teacher. When making energy-related decision, they tended to ignore economical factors and/or environmental impact. The major weakness of teaching energy that leads students to the less appreciation of the importance of conserved quantities and the value of energy is giving a great emphasis on the quantitative aspects of energy with solving more numerical problems [26].

4. Conclusion

In general, pre-service physics teachers had positive self-system, albeit still having low self-efficacy regarding energy conservation. They showed low motivation and self efficacy to conserved energy in term of action-related knowledge as well as pedagocical content knowledge. Pre-servise physics teachers also showed that the have low metacoginition. They still lacking in specifying goals of conserving energy, specifying learning objective of energy concept, as well as in having clarity and/or accuracy about energy concept. Mostly of pre-service physics teachers still held some misconceptions about energy. They were lack of ability to differentiate between energy conservation and energy degradation. Pre-service physics teachers performance on decision-making about energy-related issues are still lacking too.

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