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Implementation of Rasch Model for Mapping Students' Metacognitive Awareness

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Abstract

This study aim is to map students' metacognitive awareness in physics subjects. This research was conducted at SMAN 1 Bantarsari in 2020. A total of 112 respondents (male = 17% and female = 83%) from class XI and XII were selected using a combination of snowball techniques and convenience sampling. Students' metacognitive physics awareness was administrated using the Physics Metacognition Inventory (PMI) and analyzed using the Rasch model. The PMI inventory consists of 26 items and uses a Likert scale of 5 ratings ranging from 1 (never) to 5 (always). Mapping students' physics metacognitive awareness based on the Logit Value of Person. Metacognitive awareness is classified into four levels, namely: low, medium, high, and very high levels. The results showed that more than 80% of students had metacognitive awareness at moderate and high levels. Dominant female students have metacognitive awareness at a high level and male students at a moderate level. The students' metacognitive awareness in class XI and XII were at very high and moderate levels, respectively. The 15-16 year age group was dominant at a moderate level and the 17-18 year age group at a high level.

Keywords: mapping metacognition; metacognitive awareness; rasch model

INTRODUCTION

21st-century education equips students with a large amount of knowledge and information and prepares students to be effective and independent learners who have self-regulating skills (Abdelrahman, 2020). Training the metacognitive activity of learners is one of the efforts that can be achieved.

Metacognitive terminology, first used by Flavell in 1979, is defined as thinking about thinking (Craig et al., 2020; Desoete & De Craene, 2019). Over four decades, many researchers have proposed various definitions (Abdellah, 2015). A recent study classified metacognition into two main components: Knowledge of cognition and regulation of cognition. Knowledge of cognition is what we know about our cognitive processes. Meanwhile, regulation of cognition is an activity that controls a person's thinking and learning. Knowledge of cognition includes three sub-components: declarative, procedural, and conditional knowledge. Meanwhile, regulation of cognition includes three sub-components: planning, monitoring, and evaluation (Schraw & Moshman, 1995). In its development, there are two additional sub-components of cognitive regulation:

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debugging and information management (Free-Body Diagrams) (Taasoobshirazi et al., 2015; Taasoobshirazi & Farley, 2013).

Metacognitive is one of the abilities students need to understand, monitor, and direct their learning (Wolters, 2003). Various studies reported the critical role of metacognitive for students' academic success. Therefore, it is very logical if the metacognitive concept becomes the main focus of teaching and its impact on learning outcomes (Zohar & Barzilai, 2013). Metacognitive awareness has had various positive impacts on students. Students who have metacognitive awareness tend to be independent learners, manage information, and choose various learning strategies to deal with problems (Thamraksa, 2005). Metacognition also plays a role in academic learning procedures, especially in understanding concepts (Abdelrahman, 2020).

Several internal factors affect metacognitive awareness, such as learning strategies and memory factors in subjects (Alkadrie et al., 2015). Besides, external factors also contribute to students' metacognitive awareness, namely: gender, class, type of school, geographic location of the school, learning facilities, opportunities to speak thoughts, and student participation in school (Abdelrahman, 2020; Alghamdi et al., 2020; Sarwer & Govil, 2017; Sriyanto & Sukarelawan, 2019).

Based on school observations, there is no information or metacognitive data available on students, especially on physics subjects. For teachers and schools, this information is essential for making policies and designing learning strategies used, such as problem solving based learning (Mariati et al., 2017; Tan, 2004). As stated earlier, metacognitive plays an essential role in students' academic success. Therefore, teachers and schools need to map students' metacognitive awareness. The data collected can be used as content for evaluating so far-designed learning activities. Students who are still low in metacognitive awareness need to be given special efforts so that they are accustomed to using metacognitive in learning. Meanwhile, students accustomed to using metacognitive learning need to be motivated to maintain their learning patterns.

Classical Test Theory (CTT) and item response theory (IRT) are two approaches that can be used to conduct individual assessments (Jabrayilov et al., 2016). Some of the advantages of IRT over CTT are: The difficulty level of the item does not depend on the sample, the difficulty index is more stable in all test forms, has a more stable internal consistency than CTT, and The IRT has significantly less measurement error than the CTT approach (Magno, 2009). The Rasch approach is an approach based on item response theory (IRT). The Rasch approach can predict missing data and analyze it down to the individual level (Sumintono & Widhiarso, 2014). Therefore, this study aims to map the metacognitive awareness of students of SMAN 1 Bantarsari in physics using Rasch analysis. Mapping was done using the Physics Metacognition Inventory (PMI).

METHOD

This study used a survey research design and was carried out at SMAN 1 Bantarsari. A total of 112 respondents (male = 17% and female = 83%) were selected using snowball techniques and convenience sampling. Respondents' ages ranged from 15-18 years (mean = 16.11 years and SD = 0.63 years). Respondents came from class XI and XII MIPA.

Physics Metacognition Inventory (PMI) was used to map students' metacognitive awareness of physics (Taasoobshirazi et al., 2015). The PMI instrument used has received permission to use it from the developer. The PMI consists of 26 items which include, the Knowledge of Cognition component (6 items), Planning (5 items), Free-Body Diagrams (4 items), Monitoring (4 items), Debugging (3 items), and Evaluation (4 items). The description of each component has been described in Table 1. The PMI uses a 5-ranking Likert scale starting from 1 (never) to 5 (always). Before use, the inventory has been translated by the author and then consulted with an English lecturer.

Table 1. Description of item in PMI

Item Knowledge of Cognition	Description
KC1	Statement about student self-assessment in solving physics problems.
KC2	Statement about student understanding chooses the best way when solving physics problems.
KC3	Statement about students' understanding of applying physics problem-solving strategies
KC4	Statement about the specific goals of students choosing certain strategies in solving physics problems
KC5	Statement about when students use specific strategies in solving physics problems
KC6	Statement about students' understanding of choosing a particular strategy
Planning	
PL1	Statement about students identifying the problem to be asked before solving physics problems
PL2	Statement about students identifies essential information before solving a physics problem.
PL3	Statement about students ignores information that is not needed before solving a physics problem.
PL4	Statement about students predicting logical answers before solving physics problems
PL5	Statement about students making plans in solving physics problems
Free-Body Diagrams	
FB1	Statement about students drawing free-body diagrams to solve physics problems
FB2	Statement about students using free-body diagrams to solve physics problems
FB3	Statement about using free-body diagrams can help solve physics problems.
FB4	Statement about the urgency of using free-body diagrams to solve physics problems
Monitoring	
MO1	Statement about solving physics problems, students ask themselves how well the job they have done.
MO2	Statement about students periodically evaluating the work they are doing.
MO3	Statement about solving physics problems, students check whether their goals have been met.
MO4	Statement about solving physics problems, students check periodically whether their goals have been met.
Debugging	
DE1	Statement about requests for help when students do not understand physics problems
DE2	Statement about a request for help when a student does not understand a physics problem that is being solved
DE3	Statement about the change in solving strategy if the student fails to solve a physics problem
Evaluation	
EV1	Statement about students rechecking answers after solving a physics problem
EV2	Statement about students re-examining work after solving a physics problem
EV3	Statement about students re-checking the correctness of procedures in solving physics problems
EV4	Statement about students checking the logic of the answers they have received

The Indonesian version of the Physics Metacognition Inventory is formatted into Google Form and distributed via the WhatsApp platform. Students who have filled in are advised to distribute the google form link to other students. Data were collected in July 2020 and analyzed using the Winsteps analysis program version 4.6.1.

Data analysis begins with the screening of misfit persons and determines the reliability of items and persons. The statistical value of Infit and outfit MNSQ is used to assess the suitability of the items and persons. Items and persons are declared fit if the MNSQ Infit and Outfit values are in the 0.5-1.5 range (Abdullah & Lim, 2013; Bond & Fox, 2015; Sumintono & Widhiarso, 2014). Furthermore, item and person categorization was carried out on four levels. The item difficulty grouping refers to the Logit Value of Item (LVI) value, and the group of students' physics metacognitive awareness level refers to the Logit Value of Person (LVP) (Setiawan et al., 2018). Grouping items and metacognitive awareness of physics were guided by Table 2 and Table 3.

Table 2. Item difficulty criteria

Logit range of values	Criteria
LVI ≥ M + SD	Very difficult
M ≤ LVI < M + SD	Difficult
M – SD ≤ LVI < M	Easy
LVI < M – SD	Very easy

*M = 0.00; SD = 0.62

Table 3. Physics metacognitive awareness criteria

Logit range of values	Criteria
LVP ≥ M + SD	Very high
M ≤ LVP < M + SD	High
M – SD ≤ LVP < M	Moderate
LVP < M – SD	Low

*M = 0.66; SD = 0.65

RESULTS AND DISCUSSION

Instrument reliability

Initial screening is performed on misfit persons. Thirteen of the 112 respondents were excluded from the analysis because of a misfit. The instrument statistics were estimated by person and item, then summarized in Table 4. Person and item reliability were 0.82 and 0.96, respectively. The Cronbach alpha coefficient is 0.85. These three reliability values are included in the excellent category (Canbulat et al., 2020) and show the consistency of person-items in PMI (Cronbach, 1951; Didino et al., 2019). The person means (0.66 logit) is higher than the item mean (0.00 logit). This shows that persons tend to have more heightened metacognitive awareness than the item difficulty level. The person and item strata index was 3.18 and 6.72, respectively. These two values indicate that PMI can distinguish person and item well (Van Lieshout et al., 2020).

Table 4. Summary of Physics Metacognition Inventory Statistics

	Item	Person
Measure		
Mean	0.00	0.66
SD	0.62	0.65
Strata	6.72	3.18
Reliability	0.96	0.82
Cronbach's α	0.85	

Item Fit

Table 5 shows that item-to-model fit statistics. The Free-Body Diagrams (FB), Monitoring (MO), Debugging (DE), and Evaluation (EV) components have the infit and outfit MNSQ is within the acceptance range. Whereas in the Knowledge of Cognition and Planning component, it was found that each item (KC1 and PL3) misfit the Rasch model. Therefore, these two items were omitted and re-analyzed.

Item difficulty

The difficulty of items in the PMI has been grouped based on the Logit Value of Item (LVI). The items are distributed based on the criteria specified in Table 2. Table 6 classifies 24 items of PMI into 4 levels, namely: very easy (LVI < -0.62), easy (-0.62 ≤ LVI < 0.00), difficult (0.00 ≤ LVI < +0.62), and very difficult (LVI ≥ 0.62). There were 8.3% of items very easy to approve, 50% of items in the easy level of approval, 16.7% of items in the difficult level to approve, and 25% of the items in the very difficult level of approval.

Table 5. Summary of item statistics

Item	Infit MNSQ	Outfit MNSQ	Measure (Logit)	Criteria
KC1	**0.47**	**0.47**	**0.48**	**MISFIT**
KC2	0.79	0.79	0.68	FIT
KC3	0.76	0.76	0.79	FIT
KC4	0.99	0.99	0.60	FIT
KC5	0.93	0.94	0.65	FIT
KC6	0.77	0.78	0.56	FIT
PL1	1.11	1.11	0.00	FIT

Item	Infit MNSQ	Outfit MNSQ	Measure (Logit)	Criteria
PL2	0.99	1.02	-0.30	FIT
PL3	**1.92**	**1.93**	**0.68**	**MISFIT**
PL4	1.01	1.02	-0.25	FIT
PL5	0.8	0.82	-0.05	FIT
FB1	1.09	1.09	0.81	FIT
FB2	1.05	1.05	0.84	FIT
FB3	1.12	1.12	0.62	FIT
FB4	1.09	1.09	0.53	FIT
MO1	1.32	1.30	-0.37	FIT
MO2	0.96	0.98	-0.02	FIT
MO3	0.99	1.01	-0.37	FIT
MO4	1.09	1.09	-0.17	FIT
DE1	1.24	1.25	-1.37	FIT
DE2	1.37	1.34	-1.39	FIT
DE3	0.80	0.8	-0.37	FIT
EV1	1.03	1.03	-0.42	FIT
EV2	0.98	0.97	-0.37	FIT
EV3	0.91	0.90	-0.30	FIT
EV4	0.91	0.88	-0.33	FIT

KC = Knowledge of Cognition; PL = Planning; FB = Free-Body Diagrams; MO = Monitoring; DE = Debugging; EV = Evaluation.

Table 6. The difficulty level of metacognitive awareness items

Component	Difficulty Level			
	Very Easy	Easy	Difficult	Very Difficult
Knowledge of Cognition			KC4, KC6	KC2, KC3, KC5
Planning		PL2, PL4, PL5	PL1	
Free-body diagrams			FB4	FB1, FB2, FB3
Monitoring		MO1, MO2, MO3, MO4		
Debugging	DE1, DE2	DE3		
Evaluation		EV1, EV2, EV3, EV4		

Table 6 shows the item difficulty grouping based on LVI. As shown in Table 6, 60%of the Knowledge of Cognition component are at a very difficult level (3 of 6 items of Knowledge of Cognition component), and 75% of the constructs of Free-Body Diagrams are at a difficult level (3 of 4 items of Free-Body Diagrams component). In contrast, 75% of the Planning component (3 of 4 items of Planning component)., 100% of the Monitoring component (all monitoring component items), and 100% of the Evaluation component (all monitoring Evaluation items) are easy. Finally, 67% of the Debugging components are at the very easy level (2 of 3 items of Debugging component). Overall, most item difficulty levels are spread over the easy level (50%, 12 of 24 items), 25% (6 items) are at a very difficult level, 16.7% (4 items) are at a difficult level, and 8.3% (2 items) are at a very easy level.

Wright map

Figure 1 is an item-person map generated using WINSTEPS 4.6.1 software. The right side of the map depicts the difficulty level of the item. The left side of the map represents students' metacognitive physics awareness (in logit units). The items' difficulty level ranged from -1.39 logit (Item DE2, most easily approved by students) to +0.84 logit (Item FB2, the most difficult for students to agree with). Students with high metacognitive awareness (logit score = +2.01) were at the top. Students with low metacognitive awareness (logit score = -0.57) were at the bottom.

Person level of metacognitive awareness

Classification of students 'metacognitive awareness refers to Table 3. Table 7 shows students' metacognitive awareness based on demographics in 4 levels, starting from Low (LVP < 0.01), Moderate (0.01 ≤ LVP < 0.66), High (0.66 ≤ LVP < 1.21), and Very High (LVP ≥ 1.21).

Based on Table 7, the level of metacognitive awareness of 99 students was spread over high (30.3%) and moderate (29.3%) levels. Based on gender, male students had the most metacognitive awareness at a moderate level (41.2%), and dominant female students had high metacognitive awareness (35.4%). These findings are consistent with previous reports that found that metacognitive awareness of female students was higher than that of male students (e.g. Abdelrahman, 2020; Alghamdi, Karpinski, Lepp, & Barkley, 2020; Liliana & Lavinia, 2011; Nunaki, Damopolii, Kandowangko, & Nusantari, 2019; Sriyanto & Sukarelawan, 2019). However, several other studies found no significant differences between male and female students (e.g. Ahmed, Senam, & Wiyarsi, 2019; Herlanti, 2015). Based on class demographics in Table 7, the dominant class XI students have metacognitive awareness in the Very High category, namely 35.5% (22 students from the total class XI). While the dominant class XII has metacognitive awareness in the Moderate category, namely 54.0% (20 students from the entire class XII). The dominant 15-16 year age group had Moderate metacognitive awareness, namely 32.9% (25 students of the total age 15-16 years). Meanwhile, the 17-18 year age group had high metacognitive awareness, namely 39.1% (9 students from a total age of 17-18 years). The level of students' metacognitive awareness for each component is shown in Figure 2.

Based on Figure 2, the level of students' metacognitive awareness on the components of Knowledge Cognition, Free-Body Diagram, Debugging, and Evaluation is dominant at the "High" level. This shows that students have been able to understand cognitive. Students have been able to manage information effectively in solving physics problems through the use of Free-Body Diagrams. The use of free diagrams allows students to reduce the amount of information involved and determine the right approach in solving problems. After solving the physics problem, students re-evaluate the procedure, and the final answer obtained. If students find it difficult to solve physics problems, students will seek help from teachers and peers who they think are capable of helping (Taasoobshirazi et al., 2015).

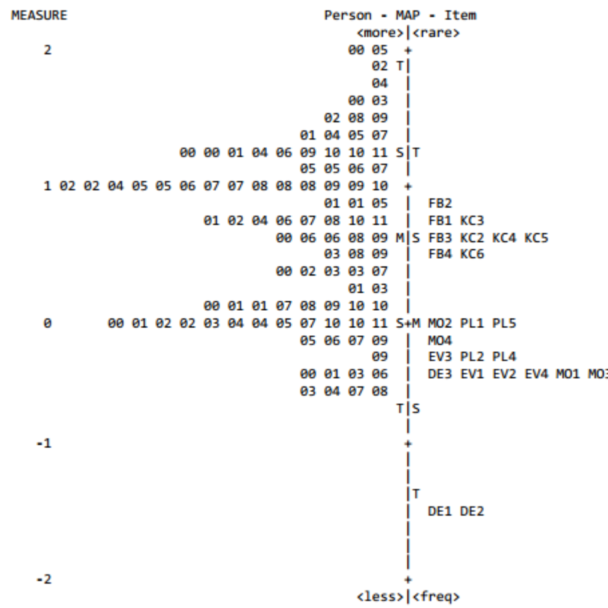
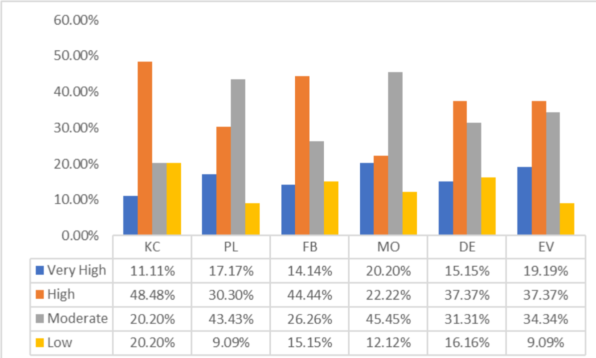


Figure 1. Wright's map of metacognitive awareness

Table 7. The level of students' metacognitive awareness of physics

Demographics(total)	Student's level of awareness			
	Low	Moderate	High	Very High
Gender				
Male (17)	5	**7**	1	4
Female (82)	11	22	**29**	20
Class				
XI (62)	13	9	18	**22**
XII (37)	3	**20**	12	2
Age (years)				
15 – 16 (76)	11	**25**	21	19
17 – 18 (23)	5	4	**9**	5
Total	(16.2 %)	**(29.3%)**	**(30.3 %)**	(24.2 %)



	KC	PL	FB	MO	DE	EV
Very High	11.11%	17.17%	14.14%	20.20%	15.15%	19.19%
High	48.48%	30.30%	44.44%	22.22%	37.37%	37.37%
Moderate	20.20%	43.43%	26.26%	45.45%	31.31%	34.34%
Low	20.20%	9.09%	15.15%	12.12%	16.16%	9.09%

Figure 2. The level of students' metacognitive awareness for each component

Meanwhile, the Planning and Monitoring component is dominated at the "Medium" level. However, at least 9% to 20% of students have a "Low" level of metacognitive awareness. More than 15% of students have Knowledge of Cognition, Free Body Diagrams, and Debugging at a "Low" level. Meanwhile, students who had metacognitive awareness in the Planning, Monitoring and Evaluation components were not more than 13%.

Not many students have Planning, Monitoring, and Evaluation skills at the "Low" level. These three competencies cannot be ignored, however, because they affect problem-solving competencies. In the end, they impact students' academic success. Every individual student has the same right to achieve academic success. Planning is a series of actions known to solve specific problems (Taasoobshirazi et al., 2015). If students do not learn a proper sequence of steps, solving problems becomes difficult (Inder, 1996). Good planning skills will have a good impact on solving complex problems (Eichmann et al., 2019). Monitoring is carried out to monitor the extent to which planning has been implemented and ensure that the solutions implemented are expected (Taasoobshirazi et al., 2015). Evaluation is an ongoing assessment of the goals, work, and performance that have been carried out during problem-solving (Taasoobshirazi et al., 2015).

Metacognitive awareness is an essential factor in determining student learning success. Gender differences and cognitive development levels need to be an initial reference for educators to choose appropriate learning methods, giving special attention to students who are in the low category. Even schools can design an activity that can train students' metacognitive awareness.

CONCLUSION

To date, only the Rasch model has met the five objective measurement criteria. Based on the Rasch model, more than 80% of students have good metacognitive awareness of physics. Overall, students' metacognitive awareness was at a high (30.3%) and moderate (29.3%) level. Based on gender, the metacognitive awareness of female students was at a high level (35.4%) and male students at a moderate level (41.2%). Based on the grade level, students in class XI and XII are at very high (35.5%) and moderate (54.0%) levels. Based on age, the 15-16 year age group is at a moderate level (32.9%), and the 17-18 year age group is at a high level (39.1%). Students already have awareness in understanding their cognitive. Information is managed effectively through the use of free diagrams to solve problems. When students have difficulty solving physics problems, they will seek help from people they think can provide solutions, such as teachers or peers.

From a practical aspect, these findings can be sources of information for teachers and schools as evaluation materials in designing learning activities and making policies. Boys and girls have the same potential for success academically. Teachers need to train class XII students' metacognitive awareness through various learning activities, especially in the aspects/components of planning, monitoring and evaluation. Therefore, it needs the right policy from the school. Schools need to equip teachers with skills to facilitate metacognitive awareness in students.

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