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Psychometric Analysis of Physics Motivation Questionnaire Using the Rasch Model in Muhammadiyah Upper Secondary Schools

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Abstract

Motivation to learn is a key factor in the success of physics learning, which requires conceptual understanding and higher-order thinking skills. This study aims to examine the psychometric characteristics of the Physics Motivation Questionnaire (PMQ) among students at Muhammadiyah high schools using the Rasch model. The study participants consisted of 256 students from Muhammadiyah high schools and Muhammadiyah vocational high schools in Yogyakarta. The instrument used was the Physics Motivation Questionnaire (PMQ). Data were analyzed using the Rating Scale Model (RSM) via Winsteps software version 4.6.1. The results showed a person reliability coefficient of 0.90 and an item reliability coefficient of 0.93. A person separation coefficient of 2.98 indicates that the instrument is capable of distinguishing between students' motivation levels. All items met the criteria for fit with the Rasch model. The PMQ also satisfied the assumption of unidimensionality, with 49.1% of the raw variance explained by the Rasch measures. Furthermore, the Wright Map indicated that students' ability levels tended to be higher than the difficulty levels of the items. Overall, the PMQ demonstrated high reliability and good fit with the Rasch model in the context of Muhammadiyah high school students. The findings suggest that the PMQ may serve as a useful tool for assessing physics learning motivation among students in Muhammadiyah upper secondary schools. However, further studies examining measurement invariance across Muhammadiyah senior high schools and vocational high schools are needed before broader application across different school types.

INTRODUCTION

Learning motivation is one of the key factors influencing student success in the learning process, particularly in physics, which requires conceptual understanding and higher-order thinking skills [1-3]. Motivation not only influences students' interest in learning but also determines their level of engagement, perseverance, and learning outcomes [4]. Therefore, measuring motivation to learn

physics is a crucial aspect of science education research because it provides information regarding students' engagement, self-efficacy, and sense of responsibility in the learning process [5-7].

In Indonesia, upper secondary education consists of three types of educational institutions with distinct characteristics: public schools that follow the national curriculum without a specific religious orientation; religion-based schools (such as Muhammadiyah, Nahdlatul Ulama, or Christian schools) that integrate religious values into the learning process; and vocational high schools (SMK) focused on developing job skills. Although Muhammadiyah senior high schools and Muhammadiyah vocational high schools differ in their academic orientation, both operate within the same Muhammadiyah educational system, integrate Islamic values into teaching and learning, and share similar institutional missions. Therefore, they were considered to represent the broader context of Muhammadiyah upper secondary education in this study. Previous research by Sukarelawan et al. [8] tested the Physics Motivation Questionnaire (PMQ) in the context of public schools with 107 students and reported that the instrument had good validity and reliability, although the five-point Likert scale did not function optimally. However, to date, the PMQ has never been tested in the context of religion-based schools. Therefore, this study involved students from Muhammadiyah high schools (general academic schools that integrate religious values) and Muhammadiyah vocational high schools (vocational schools that also integrate religious values). Although these two types of schools have different educational orientations, data from both were combined to represent Muhammadiyah high school students in general. This approach aims to provide an initial overview of the psychometric characteristics of the PMQ in a religion-based educational context before conducting separate analyses of Muhammadiyah high schools and Muhammadiyah vocational high schools in future research.

Comprehensively measuring motivation to learn physics requires an instrument with adequate validity and reliability. One such instrument developed for this purpose is the Physics Motivation Questionnaire (PMQ) by Sukarelawan et al. [8], which covers several important dimensions: motivation, self-efficacy, and responsibility for learning. The PMQ was adapted from the Biology Motivation Questionnaire (BMQ) developed by Janštová and Šorgo [18] through a systematic adaptation process involving the modification of biology-specific content into a physics context, followed by forward–backward translation, expert judgment, and psychometric evaluation. Such cross-disciplinary adaptation requires not only linguistic equivalence but also conceptual equivalence to ensure that the construct being measured retains the same meaning across subject domains. However, this instrument has not been extensively tested in the context of religious schools. Although Sukarelawan et al. [8] provided initial evidence supporting the psychometric quality of the adapted PMQ, contemporary validity theory recognizes that validity is not an inherent property of an instrument but is based on the interpretation of scores within a particular context and population. Therefore, validity evidence is cumulative and should continue to be evaluated when an instrument is applied in a new educational setting. In measuring latent constructs such as motivation, classical approaches have limitations, primarily because item characteristics and respondent abilities are interdependent. Therefore, this study employs the Rasch model because it can estimate respondents' abilities and item characteristics separately through the principle of specific objectivity, thereby yielding more objective parameter estimates that are independent of both the sample and the set of items used [9,10]. Furthermore, the Rasch model allows for a more comprehensive evaluation of instrument quality, including item fit, reliability, and construct validity.

The study by Sukarelawan et al. [8] provides preliminary evidence regarding the validity of the PMQ in the context of public schools, involving 107 students. It is important to note that the present study does not re-evaluate the adaptation process from the BMQ to the PMQ, as this process has already been completed and psychometrically supported in the previous study. Instead, the present study seeks to extend the validity evidence of the PMQ by examining whether the instrument maintains satisfactory psychometric properties when administered in a different educational context. However, the accuracy and precision of a measurement instrument depend on the context of the respondents being measured. The characteristics of students in religious-based schools, such as Muhammadiyah schools, have the potential to result in a different motivational structure due to the integration of religious values into the daily learning process. In addition, differences in educational context may influence how respondents interpret questionnaire items and use the response categories,

potentially affecting the instrument's psychometric performance. These contextual differences may affect the instrument's accuracy in measuring the intended construct as well as its precision in producing consistent measurements. Therefore, retesting the PMQ on a different population is necessary to ensure that the instrument remains accurate and precise when applied to Muhammadiyah students.

In the context of education, Muhammadiyah schools have distinct characteristics compared to public and vocational schools, particularly in integrating religious values and character education into the learning process [11-13]. These characteristics have the potential to influence students' motivational structure, making it important to retest the PMQ in this context. Previous research by Sukarelawan et al. [8] showed that the PMQ has good validity and reliability. However, that study was limited to the context of public schools and did not comprehensively test the psychometric characteristics of the instrument using the Rasch model in religion-based schools. Therefore, this study aims to examine the psychometric characteristics of the PMQ among students at Muhammadiyah high schools. The novelty of this study lies in the validation of the PMQ using the Rasch model in the context of a religious-based school (Muhammadiyah), which has not been reported in previous research to date.

RESEARCH METHODOLOGY

This study employed a quantitative approach with a survey design to measure students' motivation to learn physics using the Physics Motivation Questionnaire (PMQ). The study respondents consisted of 256 students, including 142 students from Muhammadiyah Senior High School and 114 students from Muhammadiyah Vocational High School in Yogyakarta. The sampling technique used was cluster sampling.

The instrument used was the Physics Motivation Questionnaire (PMQ) developed by Sukarelawan et al. [8]. This instrument consists of 14 items divided into three dimensions: motivation, self-efficacy, and learning responsibility. Each item uses a five-point Likert scale, ranging from "strongly disagree" to "strongly agree." The PMQ used in this study is the result of language adaptation and validation conducted by Sukarelawan et al. [8] through a forward-backward translation process involving applied linguists and expert judgment. Since the instrument was adopted without modification, language validation was not repeated in this study. The five-point Likert scale was retained to test whether the findings of Sukarelawan et al. [8] regarding the non-functionality of the "Disagree" category were specific to a particular context or could be generalized to different contexts.

Data were collected online using Google Forms before regular classes began. Student participation was voluntary, and each respondent was given the freedom to withdraw their responses if they felt uncomfortable [14]. This procedure was implemented as part of applying research ethics principles in the data collection process.

Data analysis was conducted using the Rasch model with the Rating Scale Model (RSM) approach via Winsteps software version 4.6.1 [15]. The analysis focused on several key parameters, including reliability, separation, item fit to the Rasch model, construct unidimensionality, and rating scale functioning.

RESULTS AND DISCUSSION

Content Validity

Content validity is a crucial aspect for ensuring that each item in the Physics Motivation Questionnaire (PMQ) truly represents the construct of motivation to learn physics that is intended to be measured. As explained by [16] and [17], content validity ensures that the instrument is capable of measuring the construct it is intended to assess. The PMQ used in this study is an adaptation of the Biology Motivation Questionnaire (BMQ) developed by Janštová and Šorgo [18]. The adaptation process involved converting biological terminology into a physics context and applying a forward-backward translation procedure involving applied linguists. Of the 30 original items in the BMQ, 14 were found to meet the criteria based on factor analysis results and were subsequently retained in the PMQ [18]. Subsequently, Sukarelawan et al. [8] adapted the PMQ to the Indonesian context and confirmed its content validity through expert judgment. In this study, the PMQ was applied in the

context of Muhammadiyah schools, and its content validity was supported by the results of a pilot study, which showed that all items were well understood by the respondents. Thus, the PMQ is considered to have good content validity for measuring physics learning motivation among Muhammadiyah students.

Representativeness

The representativeness of the PMQ instrument was evaluated using the person separation index (G) and the item separation index (H). Based on the statistical summary in Table 1, the person separation value was 2.98, and the item separation value was 3.74. Both values are above the recommended minimum thresholds, indicating that the instrument is capable of distinguishing between respondents' motivation levels as well as between the difficulty levels of individual items.

The strata (H) values were calculated using the formula $H = \frac{(4G+1)}{3}$. Based on the calculations, the person strata value is 4.31, and the item strata value is 5.32. Both values indicate that the PMQ has excellent classification ability. Thus, this instrument is capable of grouping respondents into more than four distinct levels of motivation and distinguishing items based on several levels of difficulty.

In terms of reliability, the person reliability coefficient is 0.90, and the item reliability coefficient is 0.93, both of which fall into the high category (≥ 0.80). The high person reliability indicates consistency in students' responses to the PMQ items, while the high item reliability indicates that the items are highly effective in measuring the construct of motivation. The instrument's internal consistency is further supported by a Cronbach's alpha value of 0.93, which falls into the very high category (α > 0.90).

Table 1. Summary Statistic of PMQ

	Measure		Separation	Reliability	Cronbach's α
	Mean	SD			
Item	0.00	0.38	3.74	0.93	0.93
Person	1.25	1.90	2.98	0.90	

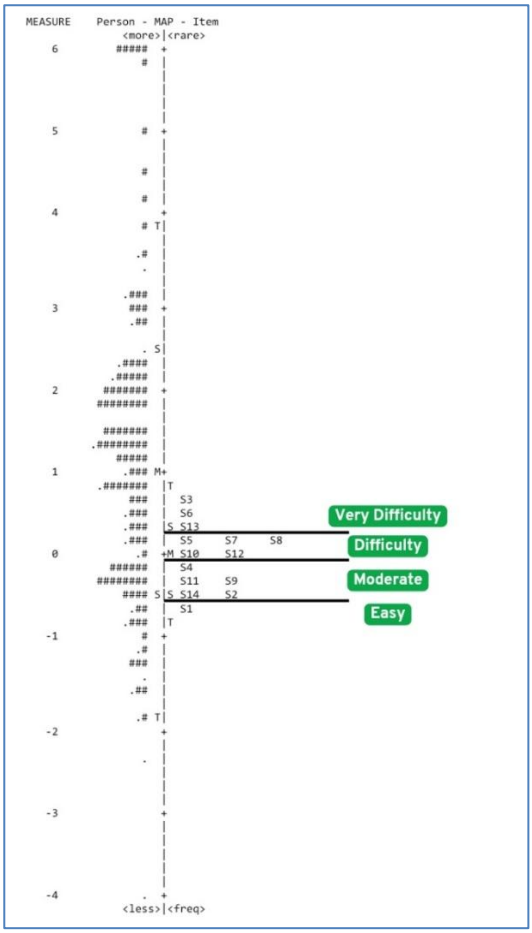

Figure 1. Wright's Map of Student Physics Motivation

Wright's map in Figure 1 shows the distribution of student ability (left side) and item difficulty (right side) on the same logit scale. The items range from negative to positive logits, indicating that the instrument has varying levels of difficulty, ranging from easy to difficult. The uneven distribution of items, with some clustered together and others scattered, is a common occurrence in educational assessment and does not indicate a weakness in the instrument. More importantly, all items lie on the same logit continuum, meaning the instrument is capable of measuring the same construct (unidimensional). The average student ability (M = 1.25 logits) is higher than the average item difficulty level (M = 0.00 logits), indicating that most students have relatively high motivation compared to the difficulty level of the items. Furthermore, no items fell far outside the range of student ability, so all items were deemed relevant for this group of respondents. However, the potential for a ceiling effect suggests the need to include items with higher difficulty levels in future studies.

Technical Quality

The technical quality of the PMQ was evaluated through an analysis of item fit to the Rasch model using the infit and outfit mean-square (MnSq) values. Based on the criteria recommended by [19], MnSq values in the range of 0.50–1.50 are categorized as fitting the model, while values outside this range indicate a misfit.

As shown in Table 2, all 14 PMQ items had MnSq infit and outfit values within the range of 0.50–1.50. The lowest MnSq infit value of 0.82 was found for item S6, while the highest value of 1.28 was found for item S3. Similarly, the lowest MnSq outfit value of 0.81 was obtained for item S6, while the highest value of 1.28 was found for item S3. All Zstd values for infit and outfit fell within the range of −2.0 to +2.0, except for item S3, which had a Zstd value above 2.0. Nevertheless, since the MnSq value for that item remains within acceptable limits-that is, less than 1.50-item S3 was retained.

These findings indicate that no items need to be deleted or revised based on the Rasch model fit criteria. These results differ from the study by Sukarelawan et al. [8], which reported one misfit item (Mo3) with an Outfit MnSq value of 1.62. In the context of Muhammadiyah students, all PMQ items demonstrated a higher level of consistency. This outcome is likely influenced by the more homogeneous characteristics of respondents at religious-based schools as well as the larger sample size (n = 256). Thus, the PMQ demonstrates excellent technical quality when applied to Muhammadiyah students.

Table 2. PMQ 14-item model fit

Item	Measure (Logit)	Model S.E (Logit)	Infit		Outfit	
			MnSq	Zstd	MnSq	Zstd
S1	-0.55	0.10	1.03	0.32	1.10	1.04
S2	-0.50	0.10	1.02	0.26	1.04	0.46
S3	0.67	0.09	1.28	2.91	1.28	2.86
S4	-0.14	0.10	1.10	1.08	1.14	1.42
S5	0.27	0.09	0.96	-0.45	0.97	-0.35
S6	0.55	0.09	0.82	-2.06	0.81	-2.20
S7	0.27	0.09	0.88	-1.32	0.84	-1.76
S8	0.15	0.10	1.08	0.84	1.06	0.66
S9	-0.30	0.10	0.84	-1.80	0.84	-1.79
S10	0.01	0.10	0.85	-1.66	0.83	-1.94
S11	-0.27	0.10	0.95	-0.49	1.10	1.04
S12	-0.04	0.10	0.84	-1.79	0.83	-1.87
S13	0.40	0.09	1.02	0.26	1.03	0.34
S14	-0.50	0.10	1.26	2.61	1.20	2.00

Structural Aspects of Construct Validity

The assumption of unidimensionality is one of the key requirements for construct validity, which requires that all items in an instrument measure the same latent construct. To test the

unidimensionality of the PMQ, Principal Component Analysis of Residuals (PCAR) was used, as recommended by Shoahosseini & Baghaei [20].

The analysis results in Table 3 show that the raw variance explained by the measures is 49.1%, exceeding the recommended minimum threshold of 40%. This value indicates that nearly half of the total data variation can be explained by the main construct being measured, namely motivation to learn physics. Furthermore, the unexplained variance in the first contrast was recorded at 8.7%, well below the maximum threshold of 15% recommended by [19]. The low value of unexplained variance in the first contrast indicates that there are no other dimensions that significantly influence student responses. Thus, the PMQ meets the assumption of unidimensionality, indicating that this instrument validly measures a single latent construct, motivation to learn physics, without being significantly influenced by other dimensions.

Table 3. Principal Component Analysis of Residuals (PCAR)

Parameter	value (%)
Total raw variance in observations	100,0%
Raw variance explained by measures	49,1%
Raw variance explained by persons	30,4%
Raw variance explained by items	18,7%
Unexplained variance in 1st contrast	8,7%
Unexplained variance in 2nd contrast	6,5%
Unexplained variance in 3rd contrast	5,1%

Likert Rating Scale Functionality

The functionality of the five-point Likert scale was analyzed to ensure that the five available response categories (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree) could be clearly understood and distinguished by respondents. This analysis was conducted by examining the response probability curves (Figure 2) and the Andrich Threshold values.

The results of the analysis indicate that all five response categories functioned well in the context of Muhammadiyah students. The probability curve in Figure 2 shows distinct and sequential peaks for each category, from Category 1 to Category 5. This indicates that respondents were able to consistently distinguish between each level of agreement. Quantitatively, the Andrich Threshold values for each category are as follows: the threshold between categories 1 and 2 is −2.27 logits, between categories 2 and 3 is −1.49 logits, between categories 3 and 4 is 0.62 logits, and between categories 4 and 5 is 3.15 logits. All threshold values show a monotonically increasing sequence (−2.27 → −1.49 → 0.62 → 3.15), so no category disordering was found. Although the distance between the thresholds for categories 2 and 3 is only 0.78 logit, slightly lower than the ideal distance of 1.4 logit recommended by [19]. Overall, the five-point Likert scale structure can still be considered to function well because all thresholds are arranged in the correct order.

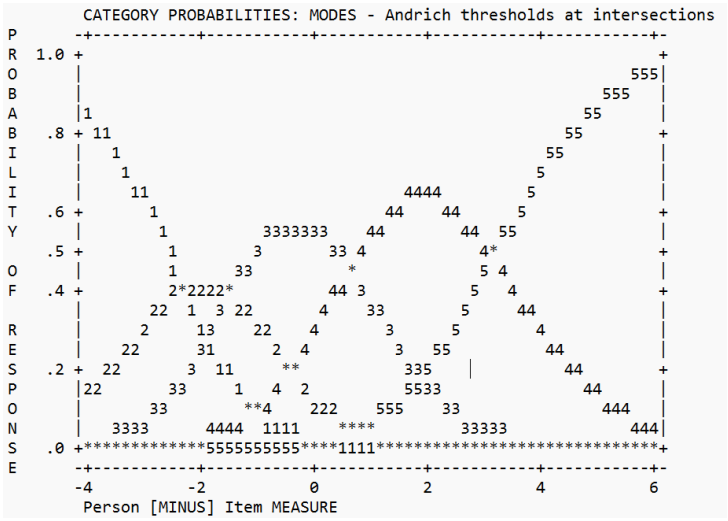

Figure 2. Likert rating scale functionality probability curve in PMQ

These findings differ from those of Sukarelawan et al. [8], who conducted a study in public schools and reported that the "Disagree" category did not function optimally, recommending the use of a four-point scale. In the context of Muhammadiyah high school students, the five-point Likert scale continued to demonstrate optimal performance. This difference is likely influenced by two factors. First, the sample size in this study (256 students) was larger than that in the study by [8], which involved only 107 students. Smith et al. [21] state that a larger sample size yields more stable and accurate estimates of Rasch parameters. Second, the characteristics of respondents in each population can influence patterns of Likert scale usage, so that the function of response categories may differ in each research context.

CONCLUSION

Based on the results of the analysis using the Rasch model, the adapted Physics Motivation Questionnaire (PMQ) demonstrated good psychometric characteristics among Muhammadiyah high school students. This is indicated by a person reliability coefficient of 0.90, an item reliability coefficient of 0.93, all 14 items conforming to the model (MnSq = 0.81–1.28), the fulfillment of the unidimensionality assumption (raw variance explained = 49.1%; 1st contrast = 8.7%), and the optimal functioning of the five-point Likert scale. These findings differ from the results of a study by Sukarelawan et al. [8] conducted in public schools. Thus, the findings provide evidence that the PMQ demonstrated satisfactory validity and reliability for measuring physics learning motivation in the sample of Muhammadiyah upper secondary students included in this study.

For future research, it is recommended to conduct separate psychometric evaluations among Muhammadiyah senior high schools and Muhammadiyah vocational high schools to examine the consistency of the instrument across different educational settings; add items with higher difficulty levels to reduce the potential for a ceiling effect; test the instrument's invariance based on gender and educational level; conduct longitudinal studies; examine the relationship between PMQ scores and academic achievement; and expand the scope of the research to include Muhammadiyah junior high and elementary schools. Furthermore, given that this study involved only two schools in Yogyakarta, the generalization of the research results should be done with caution.

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