Utilizing Rasch Model to Analyze A Gender Gap in Students’ Cognitive Ability on Simple Harmonic Motion

Sariaman Siringo Ringo¹*, Achmad Samsudin¹, Taufik Ramlan Ramalis¹

¹Universitas Pendidikan Indonesia, Indonesia

*sariamanring@upi.edu

Abstract. Previous research provided evidence that cognitive ability is one of the learning outcomes that students need to achieve. The purpose of this study was to analyze gender gap in cognitive abilities between male students and female students in learning of simple harmonic motion. The number of students involved in this research consisted of 14 male students and 22 female students with an age range of 15-17. The instrument employed in this study was a cognitive ability test with ten questions compiled based on Bloom's taxonomy and was analyzed with the Rasch model. Cognitive ability which was measured included the ability to remember, understand, apply, and analyze. The data obtained were analyzed using person reliability, item reliability, Wright map, person measure, DIF and t-test. The results showed that there was no significant difference between male and female students’ cognitive ability. Therefore, the study indicated that there was no gender gap in students’ cognitive ability after attending physics class. However, students had poor cognitive ability, so educators need to design a simple harmonic motion learning process that is able to improve students’ cognitive ability.

1. Introduction

In the field of education, the implementation of the test is carried out to obtain information related to students' abilities after participating in the learning process. To obtain accurate information, an analysis of student answers is needed. One approach that can be used to analyze student answers is the Rasch model. Rasch model or Rasch analysis is a psychometric approach that is used to provide information related to the difficulty of the problem and also the ability of people who answer the question [1]. Since it was first introduced by Rasch (1960), research related to the Rasch model has been done quite a lot by researchers in various fields of science, such as in mathematics e.g., [2-3], biology e.g., [4], English e.g. [5], dan nursing education e.g. [6-7]. In physics education research, the Rasch model is also often used, such as to develop and assess students’ alternative conceptions [8], to assess pre-service physics teachers’ energy literacy [9], to develop instruments to measuring students’ conceptual understanding of wave optics [10], to analyze the impact of physics teachers’ pedagogical content knowledge and motivation on students’ achievement and interest [11], to analyze students’ understanding of graphs in different contexts [12], to analyze the force concept inventory [13], to assess students’ level of knowledge and analyzing the reasons for learning difficulties in physics [14]. However, in physics education, research data on gender disparities in learning physics are rarely analyzed using the Rasch model.

Gender disparity is a topic that is often discussed in the world of science [15] and its influence on student learning outcomes in science has been widely studied since the 1980s [16]. Gender gap is a
condition where there are relatively large differences in achievement between male and female students. There are many researchers who have conducted gender-related research in learning physics, as conducted by [17], [28]. The results showed that male students almost always outperformed female students in learning physics [21]. However, the research results obtained by Kost, Pollock, and Finkelstein [29] explain that although the physics test results of male students are always higher than the scores of female student exams, the homework done by female students is better than the tasks completed by male students. Some researchers also found that there was no significant difference between the achievement of male students and female students. This indicates the need for more research related to gender disparities in learning physics. Furthermore, studies of gender disparities in cognitive abilities (Bloom's taxonomy) are still not widely found.

Cognitive ability is one of the learning outcomes obtained by students after participating in the learning process. According to Bloom et al. [30], cognitive abilities are divided into six levels, namely knowledge, comprehension, application, analysis, synthesis, and evaluation. This ability level is then revised to remember, understand, apply, analyze, evaluate, and create [31]. There are many frameworks proposed by researchers to be used to measure cognitive abilities, but the most well-known and widely used framework is Bloom's taxonomy [32]. Since its emergence, Bloom's taxonomy has had a great influence on teaching theory and curriculum development [33]. In learning physics, teachers need to know how far students' achievements after learning and Bloom's taxonomy is often used as a basis for compiling items to measure students' cognitive abilities, especially in Indonesia. One of the physics materials that students often have difficulty understanding is simple harmonic motion. In their research, Somroob and Wattanakasiwich [34] found that most students had misconceptions about restoring force and had difficulty connecting mathematical solutions to real motions. The equation of restoring force in the pendulum is shown in the equation below.

\[ F = -mg \sin \theta \]  

In this article, the author tries to dig up information on whether there are gender gaps in students' cognitive abilities after participating in simple harmonic motion. This gender gap analysis can provide a picture related to whether the physics learning that has been carried out is able to facilitate students to develop cognitive abilities without benefiting certain gender. Finally, the aim of this article is to analyze gender gap in cognitive abilities between male students and female students in learning of simple harmonic motion.

2. Method

In order to investigate the result of teacher’s instruction, the study was designed as one-shot case study. The teacher taught simple harmonic motion content using lecture method which is commonly used by the teacher and the instruction lasted for 3 hours.

2.1 Participant

Participants in this study were 10th grade students (n = 36) in one high school in the city of Bandung in the 2018/2019 school year. The students involved consisted of 14 male and 22 female students who had ages ranging from 15-17 years. All participants had followed the learning process of simple harmonic motion before taking a cognitive ability test. The results of this test were then used as data analyzed in this study.

2.2 Research instrument

The instrument used in this study was a test instrument on simple harmonic motion consisting of 10 multiple choice items. This cognitive ability instrument was compiled based on Bloom's revised taxonomy to measure the ability to remember, understand, apply, and analyze. Bloom's taxonomy is a tool for designing, assessing, and evaluating the learning process [35]. By using Bloom's taxonomy, the teacher can arrange questions with certain levels [32], [35]. In the development process, every single question also refers to some specific indicators of competency achievement developed based on
a syllabus issued by the government. Then, the instrument was examined by experts in the field of assessment and expert advice was used to improve the instrument so that it can be used properly. The results of the analysis using WINSTEPS software showed that the instrument used has Cronbach alpha worth 0.61 and item reliability 0.91 (very good).

![Example of multiple-choice question.](image)

**Figure 1.** Example of multiple-choice question.

2.3 **Data analysis**

In this study, data obtained from the cognitive abilities instrument were analyzed with the Rasch model. To analyze gender gaps in students' cognitive abilities, researchers used person reliability, item reliability, Wright map, person measure, and differential item functioning (DIF) from the results of data analysis using WINSTEPS 4.4.5. Furthermore, the Wright map was developed by grouping students according to gender and grouping test questions based on the level of cognitive ability. Wright map analysis accompanied by person measure information provided information about students’ cognitive abilities and the difficulty level of questions. In data analysis, each student was given a special code, such as 01F and 22M. Codes 01 and 22 describe the student number, F means female, and M means male. In addition, each item was also given a special code, such as Q3. The letter Q indicates that the item is an item and the number 3 indicates the serial number of the problem. We also utilized the t test to determine whether the gender gap on students' cognitive abilities was significant or not.

3. **Result and discussion**

3.1 **Item and person labiality**

In analyzing data using the Rasch model, we can find out item reliability and person reliability. The reliability items indicate the quality of the reliability of the items used, while the reliability of the person explains the consistency of student answers. The results of summary statistics indicated that the value of item reliability for items about students' cognitive abilities was 0.93 and the value of person reliability was 0.56. This score showed that the test questions used had a very good aspect of reliability, but the consistency of student answers was relatively weak.

3.2 **Wright map**

Wright map illustrates the distribution of respondents' abilities and the distribution of difficulty levels with the same logit scale [36-37]. High logit scores indicate the ability of respondents is high and increasingly difficult questions to be answered correctly by students. These two distributions are placed in opposite positions, namely the ability of the response is on the left side and the distribution of the difficulty level of the questions is on the right side. Wright map allows users to group respondents' distribution of abilities and difficulty of questions based on specified criteria. In this study, the distribution of students' cognitive abilities in learning simple harmonic motion was grouped according to the gender of students, while cognitive abilities that were measured using items were grouped based on Bloom’s taxonomy.
On the right side of Wright map, Q5 was at the highest logit and followed by Q7 in the second position (figure 2). More specifically, the summary of item measures reported that Q5 and Q7 were in logits 3.27 and 2.77, respectively. Both of these questions were arranged together to measure students’ ability of analyzing. On the left side, the respondents who received the highest scores were 14M and 22M who had a logit value of 3.56. This value was higher than the logit value owned by Q5 and Q7. These results pointed out that these two male students mastered analytical skills and might have higher cognitive abilities. In addition, there were no other students who had logit that exceeded or was equivalent to the item logit in Q5 and Q7. This condition indicated that all respondents, except 14M and 22M, have not mastered the ability to analyze.

![Wright map showing students' cognitive abilities grouped by gender and difficulty level of questions grouped according to Bloom's Taxonomy.](image)

**Figure 2.** Distribution of Students’ Cognitive Abilities Grouped by Gender and Difficulty Level of Questions Grouped According to Bloom's Taxonomy.

Some students, 01F, 02F, 03F, 17F, 19F, 25F, and 24M, occupied the same logit which was 2.41. This logit value was greater than the logit value occupied by Q3 and Q9. Furthermore, these results showed that 6 female students and 1 male student have mastered cognitive abilities at the level of
applying, but have not yet reached the ability to analyze. 1 logit under 7 students, there were 4 male students and 4 female students who were between logits Q3 and Q9. These 8 students could be said to have not fully mastered the ability to apply because they have not consistently answered the questions of applying correctly. On the other hand, 33F, 31F, 26F, 28M, and 30M were completely deemed not to have the ability to apply. Some students pointed out that their cognitive abilities were below the average standard level of difficulty of the questions. 5 female students and 5 male students ranged from 0.0 to -1 logit. Lower results were obtained by 3 female students (07F, 18F, and 29F). Even though they were far below the average logit of the difficulty of the questions, these students were still able to answer several questions at the level of remembering and understanding. In contrast, 15F, which was at -3.37 logit, was the only female student who was unable to answer all questions correctly.

Wright map has the average logit item and the average logit person. The average value of logit items shows the reference point of the scale and is always set in 0.0 logit, while the average value of logit person describes the average ability of students. More specifically, the summary of the person measure reveals that the average ability of students was at 0.77 logit. When compared with the question logit value, the average logit score of this student's ability was only higher than the question logit which measures cognitive abilities at the level of remembering and understanding. It meant that the average student's ability did not reach the level of applying and analyzing or the cognitive ability of students was still at the level of low order thinking (LOT).

3.3 Gender comparison
On average, male students obtained higher scores than female students (Table 1). However, the results of the t test revealed there was no significant difference between male and female students in cognitive ability ($t = 1.016, p > 0.05$). This result was contrary to the results of research which state that male students almost always outperform female students in learning physics. Nevertheless, the result was in line with the result obtained by Olasehinde and Olatoye [38] who found that there was no gender gap in the achievement of science learning outcomes. However, in this study, the average score of male students was higher than the average score of female students, while Olasehinde and Olatoye [38] obtained the opposite results.

| Gender | N  | Mean  | Std. Dev | df  | t    | p value | Remark |
|--------|----|-------|----------|-----|------|---------|--------|
| Male   | 14 | 64.29 | 15.549   | 34  | 1.016| 0.317   | NS     |
| Female | 22 | 57.73 | 20.686   |     |      |         |        |

NS = Not significant

The result showed by tabel 1 could be supported by the analysis of differential item functioning (DIF). DIF is usually used to indicate the presence of bias, but it also could give information about item difficulty level for every single item. If an item has value of DIF probability less than 0.05, it completely has bias [39]. Figure 3 shows the probability value of each item was greater than 0.05 (5%), so there was no bias in gender differences in the cognitive abilities.
Graphically, these results are illustrated in figure 4. Commonly, articles about gender gap utilize the Microsoft Excel to show graphs but in this research we used WINSTEPS 4.4.5 which is easier to use and to process data. In the figure 4, blue line represents female students, red line represents male students, and green lines indicate mean values. This figure reveals that all questions did not give some advantage to certain gender. Furthermore, it also can be assumed that both female and male students do not outperform each other.

This study found that there was no gender gap in students' cognitive abilities after learning simple harmonic motion. However, this result cannot be said to be a good result of the learning process because overall the cognitive abilities of students were still low or had not yet reached the level of analyzing. With this finding, we could not conclude that lecture method is able to reduce the gender gap in students’ cognitive ability. Furthermore, teaching methods that can reduce a gender gap should make students have good cooperation and communication in the classroom with the teachers and other students [40]. On the other hand, the lecture method creates a passive learning experience for students where students just obtain all information passively [41].

4. Conclusion
The result of this study indicates that there is no gender gap in the cognitive abilities of students after participating on simple harmonic motion learning. This finding is contrary to the results of previous
studies which reported that male students always outperform female students in achieving physics learning outcomes. However, this study also informs that the cognitive abilities of high school students on simple harmonic motion are still at the level of low order thinking (LOT). Therefore, physics teachers need to design learning processes that are not only able to reduce gender disparities, but also are able to improve students’ cognitive abilities.

References
[1] C. Geller, K. Neumann, W. J. Boone, and H. E. Fischer, 2014 What Makes the Finnish Different in Science? Assessing and Comparing Students’ Science Learning in Three Countries Int. J. Sci. Educ. 36 18 3042–3066.
[2] G. Prieto and A. R. Delgado 2007 Measuring math anxiety (in Spanish) with the rasch rating scale model J. Appl. Meas. 8 2 149–160.
[3] B. Rittle-Johnson, P. G. Matthews, R. S. Taylor, and K. L. McElloon 2011 Assessing Knowledge of Mathematical Equivalence: A Construct-Modeling Approach J. Educ. Psychol. 103 1 85–104.
[4] M. Jüttner, W. Boone, S. Park, and B. J. Neuhaus 2013 Development and use of a test instrument to measure biology teachers’ content knowledge (CK) and pedagogical content knowledge (PCK) Educ. Assessment, Eval. Account. 25 1 45–67.
[5] C. Wang, D. H. Kim, M. Bong, and H. S. Ahn 2013 Examining measurement properties of an English Self-Efficacy scale for English language learners in Korea Int. J. Educ. Res. 59 24–34.
[6] I. Blackman, C. De Crespigny, and S. Parker 2006 Mapping self-confidence levels of nurses in their provision of nursing care to others with alcohol and tobacco dependence, using Rasch scaling Int. Educ. J. 7 3 245–258.
[7] O. Guttersrud, J. O. Dalane, and S. Pettersen 2014 Improving measurement in nutrition literacy research using Rasch modelling: Examining construct validity of stage-specific ‘critical nutrition literacy’ scales Public Health Nutr. 17 4 877–883.
[8] A. H. Aminudin, I. Kaniawati, E. Suhendi, A. Setiawan, N. Y. Rustaman, and I. Kaniawati 2017 Assessing Pre-Service Physics Teachers’ Energy Literacy: An Application of Rasch measurement J. Phys. Conf. Ser. 895 1.
[9] V. Mešić, K. Neumann, I. Aviani, E. Hasović, W. J. Boone, N. Erceg, V. Grubelnik, A. Sušac, D. S. Glamočić, M. Karuza, A. Vidak, A. Alihodžić, and R. Repnik 2019 Measuring students’ conceptual understanding of wave optics: A Rasch modeling approach Phys. Rev. Educ. Res. 15 1 1–20.
[10] M. Planinic, L. Ivanjek, and Z. Milin-Sipus 2013 Comparison of university students’ understanding of graphs in different contexts Phys. Rev. Spec. Top. - Phys. Educ. Res. 9 2 1–9.
[11] M. Planinic, L. Ivanjek, and Z. Milin-Sipus 2013 Comparison of university students’ understanding of graphs in different contexts Phys. Rev. Spec. Top. - Phys. Educ. Res. 9 2 1–9.
[17] R. Henderson, J. Stewart, and A. Traxler 2019 Partitioning the gender gap in physics conceptual inventories: Force Concept Inventory, Force and Motion Conceptual Evaluation, and Conceptual Survey of Electricity and Magnetism Phys. Rev. Phys. Educ. Res. 15 1 10131.

[18] P. Wulff, Z. Hazari, S. Petersen, and K. Neumann 2018 Engaging young women in physics: An intervention to support young women’s physics identity development Phys. Rev. Phys. Educ. Res. 14 2 2013.

[19] J. Day, J. B. Stang, N. G. Holmes, D. Kumar, and D. A. Bonn 2016 Gender gaps and gendered action in a first-year physics laboratory Phys. Rev. Phys. Educ. Res. 12 2 1–14.

[20] V. Jurik, A. Gröschner, and T. Seidel 2014 Predicting students’ cognitive learning activity and intrinsic learning motivation: How powerful are teacher statements, student profiles, and gender? Learn. Individ. Differ. 32 132–139.

[21] A. Madsen, S. B. McKagan, and E. C. Sayre 2013 Gender gap on concept inventories in physics: What is consistent, what is inconsistent, and what factors influence the gap? Phys. Rev. Spec. Top. - Phys. Educ. Res. 9 2 1–15.

[22] A. T. Danielsson 2012 Exploring woman university physics students ‘doing gender’ and ‘doing physics’ Gend. Educ. 24 1 25–39.

[23] Z. Hazari, G. Sonnert, P. M. Sadler, and M.-C. Shanahan 2010 Connecting high school physics experiences, outcome perceptions, physics identity, and physics career choice: A gender study J. Res. Sci. Teach. 47 8 978–1003.

[24] Z. Hazari, P. M. Sadler, and R. H. Tai 2008 Gender Differences in the High School and Affective Experiences of Introductory College Physics Students Phys. Teach. 46 7 423–427.

[25] L. McCullough 2004 Gender, context, and physics assessment J. Int. Womens. Stud. 5 4 20–30.

[26] E. Hazel, P. Logan, and P. Gallagher 1997 Equitable assessment of students in physics: Importance of gender and language background Int. J. Sci. Educ. 19 8 978–1003.

[27] D. J. Young and B. J. Fraser 1992 Sex Differences in Science Achievement: A Multilevel Analysis p. Report: ED356947 12.

[28] A. T. Jones and C. M. Kirk 1990 Gender differences in students’ interests in applications of school physics Phys. Educ. 25 6 308–313.

[29] L. E. Kost, S. J. Pollock, and N. D. Finkelstein 2009 Characterizing the gender gap in introductory physics Phys. Rev. Spec. Top. - Phys. Educ. Res. 5 1 1–14.

[30] Bloom, Engelhart, Furst, Hill, and Krathwohl 1956 Taxonomy of educational objectives: The classification of educational goals. Handbook 1: Cognitive domain. New York: David McKay.

[31] D. R. Krathwohl 2002 A Revision of Bloom’s Taxonomy,” Theory Pract. 41 4 212–219.

[32] B. J. Jansen, D. Booth, and B. Smith 2009 Using the taxonomy of cognitive learning to model online searching Inf. Process. Manag. 45 6 643–663.

[33] M. G. Simkin and W. L. Kuechler 2005 Multiple-Choice Tests and Student Understanding: What Is the Connection? Decis. Sci. J. Innov. Educ. 3 1 73–98.

[34] S. Somroob and P. Wattanakaswich 2017 Investigating student understanding of simple harmonic motion J. Phys. Conf. Ser. 901 1.

[35] T. Lord and S. Baviskar 2007 Moving students from information recitation to information understanding: Exploiting Bloom’s Taxonomy in creating science questions J. Coll. Sci. Teach. 5 40–44.

[36] M. Planinic, W. J. Boone, A. Susac, and L. Ivanjek 2019 Rasch analysis in physics education research: Why measurement matters Phys. Rev. Phys. Educ. Res. 15 2 20111.

[37] S. W. Chan, Z. Ismail, and B. Sumintono 2014 A Rasch Model Analysis on Secondary Students’ Statistical Reasoning Ability in Descriptive Statistics Procedia - Soc. Behav. Sci. 129 133–139.

[38] K. J. Olasehinde and R. A. Olatoye 2014 Comparison of male and female senior secondary school students’ learning outcomes in science in Katsina State, Nigeria Mediterr. J. Soc. Sci., 5 2 517–523.
[39] B. Sumintono 2000 Rasch Model Measurements as Tools in Assessment for Learning 173 2017 38–42.

[40] P. Labudde, W. Herzog, and M. P. Neuenschwander 2000 Girls and physics: Teaching and learning strategies tested by classroom interventions in grade 11 Int. J. Sci. Educ. 22 2 143–157.

[41] D. C. Shakarian 1995 Beyond Lecture: Active Learning Strategies that Work,” J. Phys. Educ. Recreat. Dance. 66 5 21–24.