Using Rasch model analysis to analyse students’ mastery of concept on newton law

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Abstract. The objective of this research was to describe the concept mastery of the tenth year students in the learning topic of Newton Law by using Rasch model analysis. This was a case study research by applying group post-test only research design. There were 30 students taken as a sample consisting of 6 male students and 24 female students with an average age of 15 to 16 years. There were 20 items of multiple-choice tests used in this research (r = 0.88). The result of analysis by using Rasch model such as person fit order where there were 8 students with the outfit mean-square score out of the limit. The students “18P” code is categorized as not smart students because they were not able to solve the easiest problems of the test but they could solve more difficult problems. Generally, the percentage of the students’ mastery of concept mastery was categorized as low.

1. Introduction

Physics is an important subject to support students’ knowledge of the development of science and technology. Physics is one of the subjects focused to study and investigate the phenomenon of nature systematically, and to study the laws and principles on it. One of the physics learning topics following both of them is Newton Law. Generally, there are three laws of Newton, they are the first law of Newton, the second law of Newton, and the third law of Newton. These three laws of Newton are the law of movement considered important in the teaching of Physics [1]. One of Newton’s laws is the second law stating that the object velocity resulted from the total energy is equivalent to the total force [2] known in modern form as \( \sum F = ma \) where \( F \) is the external energy, \( m \) is the mass inertia, \( a \) is velocity [3]. Besides, Newton’s third law states that every action has a reaction that is equivalent and adverse, where \( \sum F_{\text{action}} = -\sum F_{\text{reaction}} \) [2]. Understanding the language of Physics, Mathematics, Visual, and Intuition is the key to understand the concept of Physics [4]. Conception becomes one of the important aspects for students [5,6]. Students build concepts in their minds from their experience while studying at school or the experience of their daily lives [6,7]. Conceptual knowledge can be described as abstract and general knowledge about the main domain concept [4,8,9]. Information about the concept of knowledge is important for the students to know whether they truly have and understand materials taught [9].

The assessment of the students’ concept gained from the students’ answers analysed through the Rasch model. The researchers have not found any research on the analysis of conceptual understanding through the Rasch model in the learning topic of Newton Law. Most of the research is about the students’
misconception on the learning topic e.g. [5,10-14] and through the Rash model to develop and evaluate an efficient multiple choice on mechanical Newton Law e.g. [9].

Therefore, the objective of this research was to describe the competence mastery of the eleventh year students on Newton Law by using Rash model analysis. The Rash model has a probability principle for each option in the form of classical theory [15]. Rash analysis model needs the use of the application as processing software which is the 3.7 version Winstep. It is software mostly used to help people processing Rash model analysis.

![Figure 1. Menu bar visual in winstep.](image)

In figure 1 there is an "Output of table" which is the menu bar that will be used in the analysis in this study. Analyses that can be used by output analysis are test items, research samples, and graph relationships. If one index chooses the output table, Winstep will display the results of the analysis as expected automatically and simply.

2. Methods
In this research, the sample of the research was 30 students who are in the tenth year in one of the high schools in the City of Medan. The sampling technique used was a purposive sampling technique. The sample of the research consisted of 6 male students and 24 female students who have learned the Law of Newton. The average age they have is 15 to 16 years old.

![Figure 2. Process of students’ mastery of concept competence analysis.](image)

This is a case study research design. The test is given for two hours of study, where each study hour is 45 minutes. Researchers provide test instrument items on the topic of Newton's law with questions in the form of multiple choices. Test results were analysed using the Rasch Model to illustrate mastery of
student concepts. The design for the process of analysing students' concept mastery competence can be seen in Figure 2.

**Table 1.** Competence domain of concept mastery in instrument.

| Cognitive Domain | Test Item Number |
|------------------|------------------|
| Remember         | 6, 15            |
| Understand       | 14, 17, 20       |
| Apply            | 2, 9, 11, 13, 16 |
| Analyse          | 3, 5, 7, 10, 18  |
| Evaluate         | 4, 12, 17        |
| Create           | 1                |

Multiple choice test consisted of 20 items and validated by using rash model. The instrument is considered valid if the use of MNSQ between $0.5 < \text{MNSQ} < 1.5$. The reliability result of the students was 0.7 and the test item reliability was 0.88. It means that the students’ answer consistency was low but the quality of the test can be categorized as good. The test item distribution for each competency domain of concept mastery can be seen in table 1.

3. Results and discussion

One of Rash model features with Winstep program is that it is able to detect if there is an individual’s pattern of response mismatched. Different response patterns can be defined as mismatched answers of an individual’s different patterns of the response given based on his/her ability compared to the ideal model. These can be used by the teacher to know the students’ consistency in thinking. The teacher can also use it to know if there is cheating done by the students. The criteria used to examine the test item congruence (outliers and misfits) as following.

**Table 2.** Person fit criteria level.

| Person Fit Criteria                        | Value |
|--------------------------------------------|-------|
| Nilai Outfit mean square (MNSQ)            | $0.5 < \text{MNSQ} < 1.5$ |
| Outfit Z-standart (ZSTD)                   | $-2.00 < \text{ZSTD} < +2.0$ |
| Point Measure Correlation (Pt Mean Corr)   | $0.4 < \text{Pt Measure Corr} < 0.85$ |

As noted, the value of ZSTD is affected by the number of samples. When the sample is in a large number, it can be curtailed that the value of ZSTD will be always higher than 3. Therefore, some experts recommend not to use ZSTD when the sample size used in calibration is big ($N>500$) [16].

![Figure 3. Person fit order.](image-url)
From the figure above, there were 8 students sequencing the misfit response pattern with the model; model 06P, 04P, 29P, 15L, 28P, 30L, 18P, and 26P. The score of outfit means-square of the 8 students was out of the limit. While the outfit z-std aspect, there were only 4 students fulfilling the requirements namely with the model 30L, 18P, and 24P. The score of point-measure correlation 06P and 04P was negative; -0.27, -0.9 indicating there was a response pattern which is the outfit. The information on unusual response patterns is presented further in the scalogram. Through this matrix of Guttman, we will know directly what causes the response pattern outfit of the mode.

Students of 18P are categorized as students who are careless, where the third easiest test item (Number 9) and the fourth easiest test items (number 7) could not be answered correctly, whereas, they could answer more difficult test items correctly (e.g test item number 2 and 8). Students 09P and 11L had the same response, indicating that they did cheating.

Students 06P, besides they are not smart (cannot answer the easiest test items correctly, item number 2), they also could not answer the most difficult answer correctly (item number 6) where the difficulty level
is higher than ability logic. This indicated that they did guessing (lucky guess). If the students can answer the difficult test items, they must be able to answer easier test items. If the students cannot answer easy test items, they should have not been able to answer test items which are more difficult; they are only able to answer easy test items [16]. Generally, the percentage of the students’ competence in concept mastery can be seen in figure 6.

![Figure 6. Students answering correctly the concept mastery.](image)

Based on the data gained in figure 6, the percentage of students who answered the test items correctly in every concept mastery namely; aspect of remember (52%), aspect of evaluation (50.6, 8%), aspect of analysing (48%), understanding (47.3 %), aspect of applying (45.6%), and creating (36%).

The highest aspect was remember (C1) with a gained percentage of 52%. In this aspect, students were given two problems were one of the questions of the aspect of memorizing with the purpose to enable the students to define the mass of the things. However, there are only half of the students could answer the items correctly. Some students let the answer sheet blank and some chose the wrong answers.

The second highest aspect was evaluation (C5) with the percentage of 50.6%, in this aspect, students were given three questions where one of the questions enabled the students to conclude Newton’s third law in their daily lives. This is quite surprising because it is one of the highest aspects (C5) but half of the students are able to answer it correctly. Maybe there are those who already understand or just coincidence because at the second-lowest aspect, namely understanding (C2) students only about 47.3% answered correctly. The second-lowest aspect has a purpose in which one of the three questions is for students to understand the concept of Newton's second law. But some students answer incorrectly and some even leave their answer sheets. This research is the same as what was done by Nursaila [2] where students failed to interpret meaning through words because they were too dependent on textbooks or reference books without understanding what those meanings are, from this wrong principle that causes misinterpretation.

The third highest was analysing (C4) gaining a score percentage of 48.5%. In this aspect, students were given six-question in which one of the purposes was to enable the students to analyse the working style of a jumper. In this question, many students provided wrong answers. Research conducted by Terry [15] when providing the first question related to the static situation when someone stands on the ground and the students are asked to identify Newton’s Third Law paired with the mass-energy. There were only two students from 39 able to identify correctly.

Aspect with the lowest score was creating (C6) with the gain percentage was 36%. In this aspect, students were given a question so that they are able to determine force using the first law of Newton. In this question, many students did not provide an answer. Lack of time may be one of the factors because this question was the last from 20 questions.

4. Conclusion
Based on the result of the research, the competence of the students on concept mastery can be categorized as low. This implies that the learning process could not effectively develop the students’ mastery of the concept. There must be more efforts to improve the learning process so that the students
can be trained on how to understand the concept, for instance by implementing various learning models, methods, and media that can be accepted by the students.

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