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# Understanding Newton's Third Law: A Study of Prospective Physics Teachers' Knowledge Structure

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**Abstract**

This research aims to explore the ability to understand concepts and the characteristics of the knowledge structure of prospective physics teachers regarding Newton's Third Law. This research was conducted on 26 Physics Education students in their first year who had received material on Newton's Laws. The instrument used is the Force Concept Inventory (FCI) test instrument. Using four multiple-choice questions accompanied by reasons, the quantitative data source comes from students' choice of answers. In contrast, the qualitative data source comes from students' reasons for choosing answers, which are used to see the characteristics of knowledge structures. The data analysis technique used is descriptive statistics to present a picture of the ability to understand concepts and the level of character of the knowledge structure of prospective teachers. The results show that the concept understanding ability of prospective physics teachers has an average of 67.31 and is classified as sufficient. The knowledge structure characteristics of prospective physics teachers at the expert level is 62.50%, the beginner level is 14.42%, and the intermediate level is 24.04%. These results show that the ability to understand the concept of Newton's Third Law and the characteristics of knowledge structures have a coherent influence. Prospective teachers with the characteristics of an expert knowledge structure can solve physics problems using correct physics principles. These findings require further research to explore the factors influencing understanding concepts and characteristics of prospective teachers' knowledge structures and more effective teaching strategies.

**Keywords**: understanding concepts, Newton's three laws, characteristics of knowledge structure

## INTRODUCTION

Newton's Third Law is one of the essential concepts that prospective physics teachers must master. Newton's third law explains physical phenomena in real life (Sornkhatha & Srisawasdi, 2013; Mutoharoh & Diah, 2021). This concept is the main topic in introductory physics at school and university levels (Hairan et al., 2019). It is shown by applying Newton's third law in all branches of physics, special relativity, electromagnetism, quantum mechanics, and others (Cornille, 1999; Sharma, 2024). In addition, Newton's third law is essential for developing the qualitative force concept of prospective physics teachers. This material clarifies the quality of force relationships, which may need to be emphasized in physics teaching (Brown, 1989; Fratiwi, 2020). Therefore, it is essential to understand the concepts related to Newton's Laws before proceeding to other fields in physics (Low et al., 2023).

Even though the physics concept of Newton's Laws is essential for prospective physics teachers, it turns out that there are still several difficulties (Kapanadze et al., 2023). Some difficulties are in the context of understanding concepts. Several studies state that prospective physics teachers have difficulties because they still forget that action-reaction forces have the same magnitude and opposite directions (Brown, 1958; Irez et al., 2018; Suwasono et al., 2023). Additionally, prospective teachers must understand that Newton's Third Law involves interactions between 2 different objects (Bao et al., 2002; Chen et al., 2021). Most prospective teachers need help understanding the context of interaction style pairs or what is usually called action-reaction style. Even though forces are always paired, for example, when someone's body pushes another person, the other person's body pushes back with the same amount of force.

The difficulties of prospective physics teachers with the concept of Newton's Third Law are caused, among other things, by the knowledge structure not being fully formed, and the knowledge they possess is still fragmented (Docktor & Mestre, 2014; Bao & Fritchman, 2021). So, they cannot integrate correct knowledge and can only connect familiar or memorized contexts (Nie et al., 2019; Snyder, 2000). Apart from that, the difficulties of prospective physics teachers are also caused by the use of action-reaction language, which is not interpreted as cause-and-effect (Smith & Wittmann, 2007; Chen et al., 2021). Therefore, to understand the concept of Newton's Third Law, a coherent knowledge structure is needed based on correct knowledge, in this case, physics. The gap in understanding Newton's Third Law causes several difficulties. Such as difficulty solving physics problems in real and everyday life (Shishigu et al., 2017; Taqwa et al., 2020).

A well-integrated knowledge structure leads prospective physics teachers to improve their understanding of concepts. As is known, experts tend to have a good knowledge structure. Experts can integrate their knowledge correctly and keep the same despite being given different problems (Chen et al., 2020). The characteristic of an expert knowledge structure is pushing a series of central ideas through various contexts when solving problems (Lee et al., 2011; Keane et al., 2016). The knowledge structure of prospective physics teachers who are experts have correct knowledge of Newton's Third Law and can solve problems based on central ideas and physics principles (Larkin et al., 1980; Smith & Wittmann, 2007; Bao & Fritchman, 2021). This proves that knowledge structures are important for prospective teachers (Malone, 2008; Kaufman & Ireland, 2016).

The knowledge structure still often found in prospective teachers is a beginner's knowledge structure (Urey, 2018). The knowledge structure of beginners certainly needs to be revised to understand concepts. The knowledge structure of beginners has the characteristics of knowledge that is yet to be complex and still needs to be fragmented. Beginners in solving problems are only able to solve problems based on the problems usually given by the instructor. This is because beginners can only rely on knowledge in their memory and weak conceptual knowledge to solve problems (Bagno et al., 2000; Gerace, 2001; Malone, 2008; Wöhlke & Höttecke, 2022). An expert-like knowledge structure in prospective teachers can increase understanding of physics concepts, especially the concept of Newton's Third Law. Therefore, exploring prospective teachers' knowledge structure categories is expected to help educators and prospective teachers develop an understanding of physics concepts through good knowledge integration. Educators can determine strategies and media in learning based on the knowledge structure categories found.

## METHODS

The research method used in this research is a descriptive research method with a quantitative-qualitative approach. The participants in this research were 26 prospective first year physics teachers who met the criteria of having received Newton's Laws material. The data taken was the ability to understand concepts using the FCI (Force Inventory Concept) test. The FCI test was chosen because it has been validated and widely recognized as a valid and reliable instrument for measuring the understanding of fundamental physics concepts, especially Newtonian mechanics. The FCI test gives additional reasons in the form of reasons where a reason must accompany each answer chosen by the prospective teacher. The reasons given help look at the characteristics of the knowledge structure of prospective physics teachers. The number of questions used was four questions consisting of questions number 4, 15, 16, and 28. Prospective physics teachers chose four questions because the physics problems focused on Newton's Third Law material. Quantitative data analysis uses the FCI test results, which consist of 4 multiple-choice questions. The test results are analyzed using descriptive statistics to see prospective physics teachers' average physics concept ability scores. Next, quantitative data determines the distribution of levels of understanding of physics concepts: expert, intermediate, and beginner. Qualitative data analysis was obtained from the reasons for the answer choices on the FCI test presented by prospective teachers. These reasons are categorized based on the characteristics of the knowledge structure of prospective teachers at expert, intermediate, and beginner levels developed by Bao (2021), presented in TABLE 1.

**TABLE 1.** Level of Knowledge Integration in Knowledge Structure

| Level | Characteristics of Knowledge Structures | Form of Answer to Solve Problems |
|---|---|---|
| **Novice** | The knowledge structure held usually needs to be more cohesive. | Answer with intuitive understanding (without thinking). Answer by memorizing the examples you have studied |
| **Intermediate** | Have a more profound and broader level of reasoning to develop a deeper understanding of contextual variables. | The answers still tend to rely on examples and memorized procedures to solve problems but at a higher level than novice students. |
| **Expert** | Central ideas are able to be used when answering typical and atypical questions because their knowledge structure is strong and well connected. | Answers are by the principles of the field (principles of physics), which are presented on a scientific basis, not through rote memorization or intuitive understanding |

Quantitative data is obtained by adding up the scores of those who answered correctly. Next, the data was analyzed using descriptive statistics, namely the centrality measure consisting of the average, median, and mode, and the measure of data distribution, namely the standard deviation. Qualitative data is obtained from the reasons given in answering each answer choice. This reason is used to see the level of knowledge integration in students' knowledge structures.

## RESULTS AND DISCUSSION

Descriptive statistical data are presented in TABLE 2 to describe students' conceptual understanding of Newton's third law.

**TABLE 2.** Descriptive Statistical Data for Understanding Kinematic Concepts

| Descriptive statistics | Score |
|---|---|
| **Mean** | 67.31 |
| **Median** | 75 |
| **Modus** | 50 |
| **Standard Deviation** | 25.27 |

The descriptive statistical data in TABLE 2 show that students' ability to understand Newton's Third Law is quite good. The average score achieved by students was 67.31. The percentage of students who answered correctly on each question item is presented in FIGURE 1.

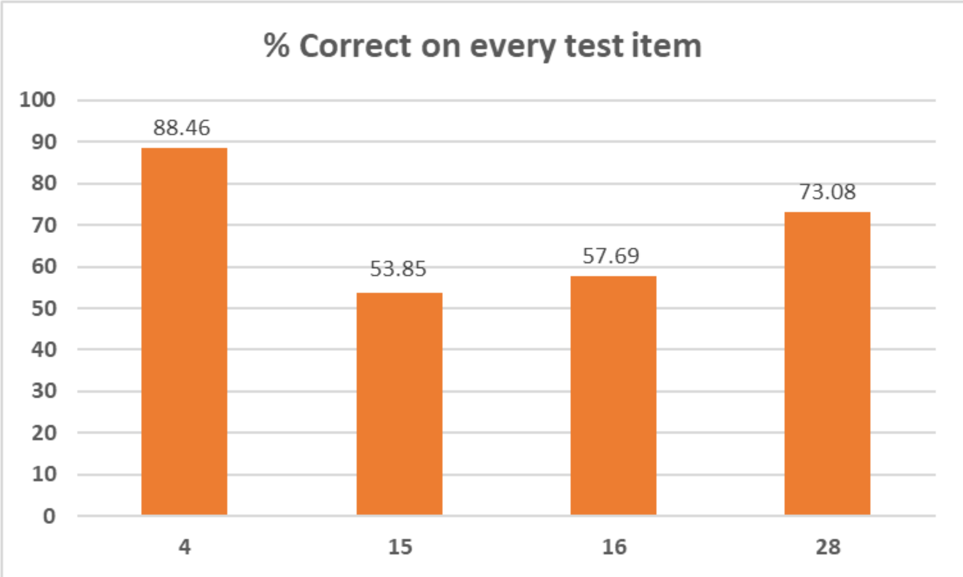


**FIGURE 1.** Percentage of students answering correctly on each question item

In FIGURE 1, it can be seen that students' ability to understand Newton's Third Law in question 4 is relatively high, where the question given determines the magnitude of the force that acts on two objects with different masses when they collide. 88.46% of students could answer question 4 correctly. On the other hand, question 15 had a lower percentage of students who answered correctly than question 4, namely 53.86%, meaning that of the total number of students, only a few could answer the question. Question 15 tests how students can determine the amount of pushing force when an object with a smaller mass can force an object with a larger mass to move until it reaches the desired speed. These two questions are presented in FIGURE 2.

4. A large truck collides head-on with a small compact car. During the collision:
   (A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
   (B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
   (C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
   (D) the truck exerts a force on the car but the car does not exert a force on the truck.
   (E) the truck exerts the same amount of force on the car as the car exerts on the truck.

**USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).**

A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.


15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
    (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
    (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
    (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
    (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
    (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

**FIGURE 2.** FCI questions number 4 and number 15

The reasons students give when choosing answers that are considered correct still indicate answering intuitively. Even with answers with correct choices, students are still considered to give reasons without using physics principles. This article discusses how to describe the characteristics of students' knowledge structures in providing reasons for choosing answers based on the level of Knowledge Integration in Knowledge Structures developed by Bao (2021).

## Knowledge Integration Levels in Knowledge Structures

The level of knowledge integration in knowledge structure describes the characteristics of students' knowledge structures, whether they are classified as expert, intermediate, or beginner. The data collected is in the form of students' reasons for answering choices that are considered correct. The percentage is obtained from the number of prospective physics teachers who have characteristic knowledge structures at each level. The data is presented in TABLE 3.

**TABLE 3.** Results of Student Knowledge Structure Characteristic Levels

| **Level** | **Characteristics of Knowledge Structures** | **% Question Number** | | | | **% Average** |
|---|---|---|---|---|---|---|
| | | **4** | **15** | **16** | **28** | |
| **Novice** | The knowledge structure held needs to be more cohesive. | 11.54 | 11.54 | 23.08 | 11.54 | 14.42 |
| **Intermediate** | Have a more profound and broader level of reasoning to develop a deeper understanding of contextual variables.. | 0.00 | 38.46 | 38.46 | 19.23 | 24.04 |
| **Expert** | Central ideas are able to be used when answering typical and atypical questions because their knowledge structure is strong and well connected. | 88.46 | 50.00 | 42.31 | 69.23 | 62.50 |

In TABLE 3, the characteristics of students' knowledge structure for each question item previously presented were the percentage of students who answered correctly for each question item. Question 4 had the highest percentage of correct answers. Judging from the level of knowledge structure characteristics of students in question 4, they are classified as expert level at 88.46%. The percentage gain is obtained from the number of prospective physics teachers with knowledge structure characteristics at the expert level, namely 23 out of 26 prospective physics teachers. The form of reasoning presented at the expert level uses correct physics principles, namely, using the concept of Newton's third law. Prospective teachers present reasons that trucks and sedans experience an action-reaction when they collide where the truck exerts a force on the sedan equal to the force exerted by the sedan on the truck. Prospective teachers with expert-level characteristics can use central ideas when answering questions; the central idea in question is being able to answer with correct physical principles presented scientifically, not through rote memorization or intuitive understanding. This means that there is a coherent relationship between conceptual understanding and knowledge structure, as found in research results (Malone, 2008; Bao & Fritchman, 2021), which reveal that students who have solid conceptual abilities have a strong knowledge structure and are always well connected in solving problems.

In question 15, 13 of the 26 prospective teachers had knowledge structure characteristics at the expert level, with a percentage gain of 50%. The form of reasoning uses Newton's third law, but only half of the prospective teachers use the principles of Newton's third law on this problem. Ten prospective teachers gave reasons with the characteristics of knowledge structures at the secondary level, with a percentage of 38.46% in terms of the reasons given. Their reasoning was deep and broad, but they could not call out the concept used in this question, the concept of Newton's third law. The beginner level was 11.54%, obtained by three prospective teachers who gave reasons that needed to be completely correct using physics principles. The prospective teachers still thought that the mass of a truck was greater, so the force required by a sedan car had to be more significant to push the truck. The knowledge structure they possess still needs to be completed. Prospective teachers provide reasons based on their experiences and use intuition rather than physics principles.

Question 16, the percentage of knowledge structure level at expert level was 42.31% obtained from 11 prospective teachers giving reasons with central ideas by physics principles. Prospective teachers provide reasons by claiming that the problem in question 16 is the concept of Newton's third law, where the magnitude of the pushing force of the sedan on the truck is the same as the pushing force of the truck back on the sedan. Meanwhile, 10 of the 26 prospective teachers had knowledge structure characteristics at the intermediate level, with a percentage of 38.46% of the reasons given that the phenomenon in question 16 was the same as in question 15. Still, the reasons given did not invoke the principle of Newton's third law. Prospective teachers indicated that they gave reasons. That in case 16 is the same as 15 then the force exerted by the sedan on the truck is the same as the force exerted by the truck on the prospective teacher's sedan does not provide a reason that this event has occurred in interaction.

Meanwhile, six prospective teachers were classified as having knowledge structure characteristics at the beginner level. Judging from the answers, three answered correctly because mass influences the amount of force exerted by the sedan. The reasons given by prospective teachers still do not invoke the principles of Newton's third law and provide reasons with the reasoning that mass influences the amount of force exerted. Apart from that, 3 of the prospective teachers who were classified as beginners, judging from the answers chosen, were wrong; the prospective teachers answered option B, "The magnitude of the pushing force of the sedan on the truck is smaller than the pushing force of the truck returning to the sedan." The three prospective teachers who answered gave no reason, only repeating the sentence in option B.

In question 28, 18 prospective teachers had a knowledge structure at the beginner level with a percentage of 69.23% of the reasons given by the prospective teachers for using the concept of Newton's third law. The prospective teachers claimed that student A and student A exerted the same force because as long as they were pushed and The students were still touching, there was interaction according to the principle of Newton's third law so that both students exerted the same force on each other. Furthermore, 5 out of 26 prospective teachers are classified as having a beginner-level knowledge structure; the reasons presented do not fully use Newton's law. Prospective teachers have provided reasons with the data in the questions, such as "because the two students are touching, the force exerted is the same." The reasons presented do not mention that the principle of Newton's third law is used. Apart from that, three prospective teachers are classified as beginners because they have an incomplete knowledge structure. This reason has led to the principle of Newton's third law. The prospective teacher claims that interaction has occurred, but the answer is incorrect, namely choice C: "Each student acts on each other's force, but student B acts on a larger force." The knowledge structure of novice-level teacher candidates still needs to be completed. This could be because the knowledge possessed by prospective teachers still needs to be coherent and is fragmented.

## CONCLUSION

The concept of Newton's Third Law has an important role for prospective physics teachers in developing a complete concept of mechanics. The ability to understand the concept of Newton's Third Law of prospective teachers has an average of 67.31, and the level of knowledge structure characteristics is at the expert level at 62.50%, at the intermediate level 24.04%, and at the beginner level 14.42%. For prospective teachers to have strong and correct conceptual abilities, a solid integration of knowledge is needed in the knowledge structure so that prospective teachers can solve physics problems, especially Newton's Third Law, using physics principles, not intuition or memorizing the examples that are often given. Relying on frequently provided examples can limit in-depth understanding of concepts. Therefore, it is essential to strengthen knowledge integration in the knowledge structure of prospective teachers. These findings emphasize the need to improve teacher training programs in physics that emphasize understanding concepts and their application in actual content. Therefore, updated and improved strategies are needed that emphasize an in-depth understanding of concepts and integration of knowledge to improve prospective physics teachers' quality as provisions for teaching physics.

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