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Assessing Junior High School Science Teachers' Conceptual Understanding of Force and Motion: Implications for Science Education

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Abstract. This research investigates the prevalence of alternative conceptions regarding Force and Motion among junior high school Physics teachers from public and private schools in Tacloban City, Philippines. The study involved 30 respondents who were selected using the stratified random sampling technique. The Science Teachers Conceptions of Physics Concepts (STCPC) was used as the research instrument, consisting of 30 questions related to Force and Motion with five alternative answers. Descriptive statistics and statistical inference techniques were used to analyze the data collected. Results revealed a high level of misconceptions, particularly in Newton's First Law. Furthermore, there was no significant difference in the level of alternative conceptions across gender. The research recommends using metacognitive strategies to improve teaching skills and promote student-centered learning among junior high school Physics teachers in Tacloban City, Philippines.

Keywords: Alternative conception, Conceptual Understanding, Force, Motion

INTRODUCTION

Correctly understanding scientific and technical subjects requires a sound knowledge of physics, as Bayraktar (2008) stated. Physics is crucial in the junior high school curriculum because it contributes significantly to any society's technological and scientific development. In addition, physics is a prerequisite for studying medicine, engineering, physical sciences, and other related courses in higher education institutions.

Without adequate knowledge and foundation of physics in our society, scientific and technological advancement in the Philippines will be hindered. Therefore, students must develop a solid understanding of physics to promote the development and improvement of science and technology in our society. Omosewo (2008) suggests that to achieve this, physics students must have the correct conceptions of the various scientific concepts they are exposed to in schools and apply this understanding to their daily activities.

By providing a solid foundation in physics, students will be equipped to tackle real-world problems and significantly contribute to our society's scientific and technological advancements. Therefore, it is vital to prioritize the teaching of physics in the junior high school curriculum and ensure that students have a solid grasp of the fundamental concepts of physics. This will contribute to advancing science and technology in our society and provide students with a strong foundation for future academic and professional pursuits.

Over the past decade, students' performance in physics courses has been disappointing, with a clear downward trend (Larkin, 2012). The root cause of this trend has been attributed to students' lack of knowledge of the basic principles, concepts, and laws of physics and their inability to apply this knowledge to solving physics problems, as highlighted by Bani-Salameh's study in 2016. This situation can be attributed to various factors, one of which is students' possession of alternative conceptions, which are inconsistent with scientific views and explanations of physics concepts.

Misconceptions are a significant obstacle to good performance and a thorough understanding of physics. Research on students' understanding of physics concepts has revealed that many students hold misconceptions that impede their understanding of the subject (Hestenes & Halloun, 1995). A significant number of students have been found to have misconceptions about key concepts such as motion and force (Coletta et al., 2007), light (Oktarisa et al., 2017), signals and systems (Larkin, 2012), conservation of principles and fields (Gibb, 2010), and electricity and magnetism (Luangrath et al., 2011), among others.

To improve students' performance in physics, it is essential to identify and address these misconceptions. Teachers should have the knowledge and skills to identify misconceptions and provide appropriate instruction. Furthermore, students should be encouraged to engage in interactive learning activities, such as laboratory experiments, simulations, and discussions, which can help to clarify and reinforce their understanding of physics concepts. Addressing students' misconceptions and promoting active learning can foster a deeper understanding of physics and improve students' performance.

The issue of students' misconceptions in physics is complex. It can be caused by various factors, including interactions with the socio-physical world, textbooks, reference books, language, cultural beliefs, practices, and teachers themselves (Sobel, 2009). However, teachers play a crucial role in addressing students' alternative conceptions because they are students' primary source of knowledge and authority. Formal science instruction is expected to lead to a reduction, modification, or even a change in students' alternative conceptions. Effective teaching should convey accurate scientific knowledge and challenge and correct students' misconceptions (Dergisi, 2010).

According to Haney and McArthur (2002), a child is ready to learn when the teacher is prepared to teach. This means that effective teaching is essential for students to understand physics properly. Therefore, teachers significantly promote students' understanding of scientific concepts by challenging and changing their misconceptions. It is essential that teachers are equipped with the necessary skills and knowledge to teach physics effectively and that they continually evaluate and modify their teaching approaches to address students' misconceptions. By doing so, students can develop a strong foundation in physics and be better prepared for higher education and future careers in science and technology.

In light of the findings of Bektas's (2015) study, it is crucial for physics teachers to be aware of their students' misconceptions and to have a strong conceptual understanding of the subject matter they are teaching. Without this, teachers may unintentionally reinforce misconceptions or fail to challenge and correct them effectively.

Content knowledge is a crucial component of a teacher's professional expertise. It allows them to make informed decisions about what and how to teach and anticipate and address student misconceptions. However, content knowledge alone is not sufficient for effective teaching. Teachers must also possess pedagogical knowledge, which refers to understanding how to teach the content effectively to students, and knowledge of their student's cognitive and emotional development (Burgoon et al., 2009). Teachers can create meaningful and engaging learning experiences that foster conceptual change and promote a deep understanding of physics concepts by combining content and pedagogical knowledge.

Teachers play a critical role in helping students overcome misconceptions and learning difficulties in physics. However, this is only possible if teachers have a proper conceptual understanding of the content they teach. Without a solid grasp of the physics concepts, teachers may not be aware of students’ misconceptions and may be unable to facilitate meaningful conceptual change in students.

Studies have shown that some physics teachers lack a sufficient understanding of the concepts they teach, which can lead to a lack of awareness of students’ misconceptions (Omosewo, 2008). This can result in ineffective teaching, affecting students' learning outcomes. Therefore, it is essential to investigate teachers' conceptual understanding of physics concepts to identify areas of weakness and to improve teacher efficacy in the classroom.

One way to improve teacher efficacy is by focusing on improving their conceptual understanding of specific physics concepts, such as motion and force. These concepts are widely taught in schools and are prone to alternative conceptions among students (Fatokun, 2016). By understanding these concepts thoroughly, teachers can identify students' alternative conceptions and facilitate meaningful conceptual change.

It is essential to note that teachers serve as a source of influence for knowledge students. Therefore, any effort to correct misconceptions in students should start with improving the teacher's conceptual understanding of the subject matter. This is because the conceptual understanding of the teacher must improve before any meaningful improvement can be expected in students' learning and understanding of physics concepts.

This study investigates junior high school science teachers' conceptual understanding of motion and force. The findings of this study could help identify areas of weakness and provide insights into improving teacher efficacy in the classroom. Doing so will contribute to improving students' learning outcomes in physics.

Kruger, Palacio & Summers (1992) conducted a study investigating British primary school teachers' understanding of the force. The study found that many teachers were uncertain about what could be considered a force, particularly regarding reaction force, friction, and weight. About 40% of the teachers were unsure whether weight could be considered a force, and more than half were unaware that weight is a gravitational force. Additionally, many teachers had difficulty finding resultant force via vector addition. Responses to questions related to dynamic situations revealed that primary school teachers' conceptions of force and motion were not Newtonian. Furthermore, as many as 91% of the teachers believed in naïve impetus theory, and many could not differentiate between momentum and force.

In the Philippines, research on the understanding of science concepts has mainly focused on student misconceptions in high school and college, with little empirical work done on teachers' understanding. One such limited study was conducted by Demirci (2008), which only considered teachers from public secondary schools and the effect of qualification on their understanding. This study aims to include teachers from private and public junior high schools to ensure the external validity of the results, as student performance in physics is reported for both types of schools. Additionally, this study will examine the influence of teaching experience, specialization, and qualification on the conceptual knowledge of physics teachers in the selected concepts. By providing current data on the understanding of motion and force concepts among teaching staff, this research will contribute to understanding high school physics education in the Philippines. Furthermore, this study will compare results with studies on the same topic in other countries to determine whether cultural differences affect high school teachers' alternative conceptions.

Over the years, student performances in external physics examinations have been consistently poor, possibly due to their misconceptions of essential physics concepts. Studies have shown that these misconceptions hinder students' understanding of the subject and negatively affect their performance. It is widely believed that teachers' conceptual knowledge of their teaching topics can lead to better student outcomes. However, several studies have shown that students still possess alternative conceptions of science concepts, even after being taught in secondary schools. This highlights the need to investigate teachers' conceptual understanding of physics concepts.

In the Philippines, most studies on science concepts have focused on student misconceptions at the high school and college levels, with little empirical research on teachers' understanding. This research addresses this gap by investigating misconceptions and alternative conceptions of Force and Motion among junior high school teachers, considering both gender and school type (public and private).

The research questions are: (a) What is the level of alternative conceptions of Force and Motion among junior high school teachers? (b) Is there a significant difference in the level of alternative conceptions of Force and Motion among junior high school teachers across gender?

This study is essential as it significantly impacts curriculum development and student achievement. Furthermore, this study aims to pave the way for further research on teachers' conceptions of science, which is crucial in ensuring better student outcomes. By identifying and addressing teachers' alternative conceptions, it may be possible to improve student performance in physics.

METHODOLOGY

The research design used in this study was a Survey research design, which involved providing a two-tier diagnostic test instrument to junior high school science teachers to gather information about their conceptual understanding of the concepts under study. The focus population of the study was all science teachers teaching physics in public and private junior high schools in Tacloban City Division. The researchers used a stratified random sampling technique to select 30 teachers from the target population, ensuring that each subgroup was adequately sampled and represented.

A two-tier diagnostic instrument for assessing Science Teachers' Conceptions of Physics Concepts (STCPC) was used to achieve the study's objective. The STCPC consisted of two parts, with 20 multiple-choice questions and a reliability score of 0.77. The questions were divided into five Newtonian concepts. The instrument was validated by two Physics teachers in junior high schools and college, a professor in the science department of teacher education at the University of Tacloban City, and an expert in measurement and evaluation.

The researchers modified the two-tier diagnostic instrument Fatokun (2016) to obtain relevant information from the teachers to suit this study, including demographic profiles and an opportunity for teachers to explain their options. The instrument was designed to elicit the correct conception or alternative conceptions held by the participants.

The data collected were analyzed using SPSS software, with descriptive statistics presented in mean, standard deviation, and percentage. The researchers also used a t-test to determine whether there were any differences among Physics junior high school teachers on the subtopic of Force across gender. Finally, the percentage of misconception for every subtopic of the Newtonian concept was obtained by dividing the marks of the incorrect answers with the total scores of each subtopic and compared to the Alternative Conception Division Level Table.

Overall, the study's research design, instrument, and sampling technique were well-planned and implemented, allowing the researchers to gather relevant information about junior high school science teachers' conceptual understanding of the concepts under study. The study's findings may have implications for science teacher training and professional development, and further research in this area is warranted.

Table 1. Alternative Conceptions Division Level Table

Percentage	Level of Alternative Conception
85 - 100	Very High
70 - 84	High
55 - 69	Moderate
40 - 54	Low
0 -39	Very Low

To administer the STCPC instrument, the researchers followed a series of steps. The initial step involved seeking permission to conduct the research and scheduling a meeting with 30 teacher respondents. During this meeting, the researchers gave instructions on completing the inventory, stressing the need to keep the questions confidential. Once the respondents received the inventory, it was later collected, and each respondent was presented with a token of appreciation as a souvenir.

The process of marking the inventory was conducted over three weeks, from week three to week five. The data collected were entered into the Statistical Package for Social Science (SPSS) software the following week. The data were analyzed and presented descriptively, using percentages, mean, and standard deviations to provide a comprehensive overview of the findings. Finally, in week eight, the inventory results were fully reported, highlighting the study's alternative conceptions held by junior high school teachers.

RESULTS AND DISCUSSION

This study’s results highlight several misconceptions junior high school teachers held about the subtopic of Force and Motion. Table 2 shows that the overall level of alternative conception among the respondents was high (74.39%). The subtopics with the highest levels of alternative conception were First Law (86.19%), Superposition (83.33%), and Kinematics (80.56%). The subtopics with moderate levels of alternative conception were the Second Law (65.00%), Forces of Fluid Contact (65.00%), and Third Law (69.17%). Of these subtopics, the highest percentage of alternative conceptions were found about Newton’s First Law. Many respondents were uncertain about the definition and held a common misconception that “if no net force acts on an object, the object must be at rest.” This misconception is related to the impetus theory, which describes a force that acts on an object, giving it a momentum that keeps it moving even when no force is in contact with it. Fifth-century philosopher Philoponus introduced this idea to explain projectile motion, which is incompatible with Newton’s First Law.

Table 2. The Level of Alternative Conception among junior High School Teachers on The Subtopic of Force and Motion.

Concept	Mean	Standard Deviation	Percentage (%)	Level of Alternative Conception
1. Kinematics: Discrimination of position, velocity, and acceleration; Constant acceleration; Vector addition of velocities	4.83	0.95	80.56	High
2. Newton's First Law: With no force; With canceling forces	6.03	1.3	86.19	Very High
3. Newton's Second Law: Impulse force; Constant force implies constant acceleration	2.6	1.22	65	Moderate
4. Newton's Third Law: For impulse force; For continuous force	2.77	0.68	69.17	Moderate
5. Superposition: For impulse force; For continuous force	2.5	0.86	83.33	High
6. Kinds of Force:				
Solid contact: passive, impulse, friction opposing motion	3.03	0.89	75.83	High
Fluid contact: air resistance, buoyant	1.3	0.65	65	Moderate
Gravitation: acceleration independent of weight; Parabolic trajectory	7	1.29	70	High
Total	**30.06**	**7.84**	**74.39**	**High**

Another subtopic with high levels of misconception was Superposition. Respondents were confused about the action/reaction pair with the Superposition of oppositely directed forces on a single object. This highlights the need for teachers to help their students understand the difference between these concepts. In the subtopic of Kinematics, respondents had high levels of misconception regarding the three vital concepts of position, velocity, and acceleration. The Science Teachers' Conceptions of Physics Concepts successfully reflected the ability of junior high school teachers to recognize the vectorial nature of velocity and acceleration. However, the high level of misconceptions in this subtopic suggests that there is still room for improvement.

Other studies using the STCPC have shown similar findings, with high levels of misconception among pre-service teachers in Turkey (Bayraktar, 2008) and British primary school teachers (Kruger, Palacio, & Summers, 1992). T-test analysis (Table 3) showed no significant mean difference between male and female respondents in the level of misconceptions, suggesting that both genders have similarly high levels of misconceptions.

This study highlights the importance of addressing misconceptions about Force and Motion among junior high school teachers. These misconceptions can significantly impact students' understanding of physics concepts, so teachers must be aware of them and address them in the classroom.

Table 3. The Alternative Conception among Junior High School Teachers on The Subtopic of Force and Motion.

Alternative Conception	N	Mean	Standard Deviation	df	t	Sig.
Male	9		4.77			
Female	21	21.667	3.192	28	-0.29	0.468

Based on the research findings, there was no significant difference between male and female respondents regarding the level of misconception at the significant level of 0.05. Although there is a slightly different mean between male and female respondents, with males having a mean of 21.667 and females having a mean of 22.095, the level of alternative conceptions between both genders is still high.

A previous research study conducted by Temizkan (2003), titled 'Effect of Gender on Different Categories of Students' Misconceptions about Force and Motion,' also found no significant difference in the level of misconception between male and female respondents. The study involved 651 high school students from 20 different high schools in the Middle East. However, the mean value for male respondents was much higher than that of female respondents, with 9.73 and 37.85, respectively.

Both research studies show slight differences in mean values between male and female respondents, with one gender having a higher mean than the other. The findings of Derya Temizkan's study suggest that male students had more experience with force and motion than female students, possibly due to gender bias in the Middle Eastern education system. This gender bias has been highlighted in previous reports, such as the AAUW Report: How Schools Shortchange Girls (Wellesley College Center for Research on Women, 1992), which showed that girls were not receiving the same quality or quantity of education as boys.

It is important to note that the culture and education system in Asian countries may differ from those in the Middle East and the Western world. Therefore, female respondents with a higher mean than male respondents in this study may be acceptable.

CONCLUSION

In this study, the researcher examined the level of understanding of junior high school teachers on the physics concepts of Force and Motion, focusing on gender differences. The study concluded that junior high school teachers understand the concept of Force and Motion, and there was no significant difference between male and female teachers.

To further improve the understanding of physics concepts among junior high school teachers, it is recommended to apply a teaching approach that emphasizes conceptual understanding. This approach can help to address the issue of alternative conceptions, which can lead to misconceptions among students.

Özdemir, E. (2010) suggests that teachers should use various teaching styles and situations to help students apply the concepts they have learned and provide explanations for their answers. Teachers can help students develop an honest and accurate understanding of physics concepts using a more comprehensive teaching approach.

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