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Jordanian Pre-Service Physics Teacher's Misconceptions about Force and Motion

Mohammad S. AL-RSA'I[1], Jebreel M. KHOSHMAN[2], Khalid ABU TAYEH[3]

[1]Department of Curriculum and Teaching, Al-Hussein Bin Talal University, Ma'an, Jordan, ORCID ID: 0000-0002-8043-5500
[2]Department of Physics, Al-Hussein Bin Talal University, Ma'an, Jordan, ORCID ID: 0000-0003-3784-2562
[3]Department of Curriculum and Teaching, Al-Hussein Bin Talal University, Ma'an, Jordan, ORCID ID: 0000-0002- 9730-7660

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ABSTRACT

The objective of this study was to investigate the physics student-teachers misconceptions in force and motion concepts in Jordanian universities by using the Force Concept Inventory (FCI) test and to identify the cause of misconceptions related to these concepts. Also, the FCI has been used to detect whether misconceptions vary according to gender, the geographical place of the university in Jordan, and students' attitudes towards physics as a major. The study was conducted on (97) student-teachers attending to the different universities in Jordan. Data were analyzed by using t-test and ANOVA test. The results of the study indicated that physics student-teachers grasp high misconceptions about the impetus and active force. 20% of the students correctly answered the questions related to Newton's third law. In addition, the differences among the studied universities were not statistically significant in the FCI test ($F = 1.311$ and $p = 0.247$). Based on the Pearson Correlation Coefficient (PCC), there was no correlation between the GPA of the students at high school and their performance in the FCI test, whereas a significant correlation was found between the GPA of the students at university and their performance on the test. The results also demonstrated that the performance of the students on the test did not reflect significant differences in their major attitude as well as their gender at any University in Jordan. Thus, this study could be initiated with the aim of probing the Jordanian Universities attitudes towards learning Physics and their conceptual understanding of the Newtonian force concept in Physics.

Keywords: Force and motion, misconceptions, Newton's laws, physics teachers, FCI.

INTRODUCTION

Over the past three decades, physics education research has shown many unexpected results about the difficulties that introductory university students have because they lack the ability to perform formal operations inherent to learning physics (Hestenes, Wells, &

Correspondence author e-mail: rsaaie@ahu.edu.jo © ISSN:1304-6020

Swakhamer, 1992; Kumar, 1994; Savinainen, & Scott, 2002a; Alghamdi & Hassan, 2019). Thus there was need for a more interactive teaching methodology and problem-solving in introductory physics courses (i.e., general physics I course, Physics 101). Many investigations in physics education have been done and have revealed many results about what students know and how they learn and understand basic concepts in physics. Consequently, the misconceptions mainly originate from students' experiences with the real world that seem very logical to them, formal school context, and from each other. However, frequently their intuitive understanding of the world around them does not agree with the scientific explanation. Mostly, these concepts contradict with scientifically accepted physics concepts taught in physics classes. Thus, it is important to take into consideration while planning for instruction to focus on how these naïve conceptions differ from the scientific explanation, and why students construct these ideas. Many researchers have given these preconceptions different names, such as spontaneous knowledge, alternative conceptions, misconceptions, naïve conceptions, and children's science (Driver, & Easley, 1978; Helm, 1980; Gilbert, Watts, & Osborne, 1982; Pines& West, 1986; Demirci, 2005;YudiKurniawan et. al., 2016).

There are many methods of gathering information about understanding the common difficulties students exhibit in learning conceptual physics. The most frequently used methods: the open-ended questions (Eisen &Stavy, 1988), two-tier diagnostic test (Haslam & Treagust,1987) concept mapping (Hazel & Prosser,1994), prediction-observation-explanation (Liew& Treagust,1995), interviews about instances and events (Osborne&Cosgrove,1983), interviews about concepts (Scaife&Abdullah,1997;Martín-Blas,Seidel& Serrano-Fernándeza,2010), drawings (Martlew& Connolly, 1996), interactive engagements versus traditional methods (Hake,1998), word association (Bahar, Johnstone, & Sutcliffe, 1999), analogies (Yerrick et al. 2003),web-based physics software program (Demirci, 2005), the force concept inventory (FCI) (Hestenes et al,1992; Savinainen & Scott,2002),attitude treatment interaction (ATI)(Demirci,2001),tacit and explicit knowledge (Taber, 2013; Collins, 2010),conceptual change oriented interactive lecture demonstrations (YudiKurniawanet al., 2016), cluster analysis (C. Fazio et al, 2018), item response theory(Wang & Bao, 2010; Scottand & Schumayer, 2015),discrepant event (Anggoro, Widodo, Suhandi, & Treagust, 2019), and Modified Module Analysis (MMA) (James Wells et al., 2019).Recently, researchers applied network analytic techniques to explore the structure of the incorrect responses to the Force Concept Inventory (FCI) test by identifying communities of incorrect responses which could be mapped on to common misconceptions (De Vico et al, 2014; Lop´ezPe˜na et al, 2012;Newman, 2018).Numerous studies documenting the students' misconceptions in many specific topics in physics education(Viennot, 1979; Hake,1998; Trumper, 1999; Mestre,2001; Demirci, 2001; Neşet Demirci, 2005; Wang & Bao, 2010; Azita Seyed Fadaei & César Mora, 2015; YudiKurniawan et al, 2016; NadiSuprapto, 2016; Fazio & Battaglia, 2018; Wells et al., 2019; Yang et al, 2019) by introducing the multiple-choice conceptual instruments that measure students' understanding of mechanics such as the Force Concept Inventory(FCI)(Hestenes, 1992) and the Force and Motion Conceptual Evaluation (FMCE) (Thornton et al, 1998).

Up to this date, substantial efforts have been made to collect the most of the students' misconceptions in the Newton's laws of motion, which are the most basic topic of classical mechanics (Clement,1982; Hammer, 1996; Trumper & Gorsky, 1997; Preece, 1997; Muller et al., 2007; Trundle et al., 2007;AzitaFadaei & César Mora, 2015; NadiSuprapto, 2016). As an example of misconceptions in classical mechanics, students believe that a continuous action of a force is necessary to keep an object moving. That is, students think that if an object is moving, there should be a net force acting on it, and if an object is not moving, there is no force acting on it (Gilbert&Zylbersztajn,1985;Sadanand & Kess,1990;Gulcan,2007). There are more incorrect ideas such as a force will produce motion; a constant force produces constant velocity, the magnitude of the velocity is proportional to the magnitude of the force (a linear relationship between force and velocity), acceleration is due to an increasing force, and in the absence of forces, objects are either at rest or slowing down, and so on (Helm,1980;Gilbert et al., 1982; Pines & West,1986; Hestenes et al., 1992; Kumar,1994; Savinainen & Scott, 2002; Tunç et al, 2012). Different educational backgrounds, different ages, language, preconceived notions, non-scientific beliefs, naive theories, mixed conceptions, tradition, gender, and cultural upbringing are influencing factors on students' conceptual understanding in science (Docktor & Heller, 2008; Tunç et al, 2012). The literature on the relationship between secondary school students' conceptual change learning and their epistemological beliefs about science shows that students who hold certain immature beliefs are less likely to acquire an integrated understanding of particular science concepts and they are also less likely to change their conceptions once they are formed (Qian & Alvermann, 2000). In these findings, they emphasized the need for further research on the relationship between epistemological beliefs and conceptual change. Researchers used open-ended questions to investigate students' epistemological self-reflection (May &Etkina, 2002; Guven, Mugaloglu, Doganca & Cobern, 2019), Their study probed the relationship between students' epistemological self-reflection and conceptual learning in general physics classes. In addition, they concluded that commonsense beliefs about motion and force are incompatible with Newtonian concepts in most respects and conventional physics instruction produces little change in these beliefs.

Docktor and Heller (2008) found that there was a significant gender gap in pre-test FCI scores that persist post-instruction although there was essentially no gender difference in course performance as determined by course grade. Attitude Treatment Interaction (ATI) was performed for the dependent variable of misconceptions by (Demirci,2001). The ATI between pre-test and gender relative to misconception was found to be significant. The study showed that incorporating the web-based physics program with traditional lecturing had a significant effect on dispelling students' misconceptions about force and motion concepts. The perceived link between force and motion was investigated in a longitudinal and cross-cultural study involving 2326 pupils in schools of the Republic of South Africa using a multiple-choice questionnaire by Enderstein and Spargoa (1996). They showed that students in South Africa schools did not differ greatly in the belief that a force in the direction of motion was necessary to maintain motion. Also, they found that the recognition of the presence of the gravitational force depended on the situation presented. Male students appeared to be affected by the situation to a greater extent than females.

Comparing the different cultural backgrounds of students, some studies found out that the misconceptions of some topics in physics were universal in nature (CİTE). Bogdanov and Viiri (1999) compared undergraduate students' conceptions of force and motion in Finland and Russian by using the Force Concept Inventory (FCI) as a diagnostic tool. The average score for the Russian and the normal Finnish groups appeared to be almost equal, whereas the students in the experimental Finnish group achieved a significantly higher level, close to the well-known threshold of 60%. Also, the Russian students had the impetus misconception less frequently than Finnish students, but they were more dominance-minded than Finnish students.

Yudi Kurniawan and colleagues (2016) studied the influence of the implementation of interactive lecture demonstrations conceptual change-oriented (ILD-CC) toward the decreasing of the number of students that had misconceptions on the Newton's First Law in Indonesia. They concluded that the implementation of the ILD- CC model could be used to decrease the number of students that had misconceptions on the Newton's First Laws (Demirci, 2005) by incorporating a web-assisted program to normal traditional classroom instruction with the Force Concept Inventory (FCI) as pre- and post-tests, in order to study students' misconceptions in force and motion concepts in physics. The study showed that the use of computer-based instruction dispelled students' misconceptions about force and motion. Based on the data from the Demirci study, incorporating the web-assisted physics program was significantly effective on high school students' Force Concept Inventory (FCI) pre-and post-test mean difference scores, and this incorporation increased students 'achievements in force and motion concepts in physics. NadiSuprapto and colleagues (2016) were possessed the conception profile college physics students at Surabaya State University, Indonesia in mechanics by using: Force Concept Inventory (FCI) and Mechanics Baseline Test (MBT). Their results indicated that students' conceptions on Newtonian mechanics based on FCI performed that students at Junior level better than Sophomore and Freshman and the overall level of misconception among college students was moderate (68.86%). Also, they found that the students performed a high level in misconception in general principles such as energy conservation, superposition of force, free fall, and action-reaction. AzitaFadaei and César Mora (2015) examined how the traditional teaching method was being able to investigate misconceptions in force and motion concepts using the FCI diagnostic test for high school students in Tehran, Iran. The average percentage reported in their study suggests that the traditional teaching method was successful in promoting learning in some parts of the subject, but in other parts, it was not successful and they found unsuccessful cases of FCI items, so some commonsense misconceptions were independent to traditional instruction.

However, to the best of our knowledge, there are no systematic studies on the misconceptions that science and physics student-teachers (pre-service teachers) have about the terms force and motion at Jordanian Universities. Therefore, the aim of this work is trying to answer the following question:

Do Jordanian physics students in pre-service training to be high-school teachers hold correct scientific views that will eventually allow them to plan and implement instructional strategies? Also, do they lead their future students to achieve correct scientific concepts of the introductory physics?

The answer to this question is motivated us to know the Jordanian students' understanding of the basic mechanics' concepts (force and motion) by obtaining misconceptions or alternative conceptions in this topic of science. Hence, this study reveals the pattern of the pre-service physics teachers' misconceptions in force and motion concepts in Jordanian universities by using the Force Concept Inventory (FCI).

The FCI is a conceptual test consisting of 30 multiple choice items focusing on the core concepts of force and motion (Hestenes & Halloun, 1995). Also, this study will investigate whether students' gender and background influence their misconceptions. In addition, another contribution of this research will be to distinguish whether the geographical place of the university in Jordan affects on the students' misconceptions. Thus, the data were collected from different Jordanian universities: Al-Hussein Bin Talal University, University of Jordan, and Al-Yarmouk University. These universities are chosen very carefully, to cover three different geographical areas (south, middle, and north) of Jordan. Accordingly, this division could help to suggest possible reasons for these misconceptions in the fields of force and motion in those universities. In addition, determine whether there is a common about the insufficient (or incorrect) ideas of the Jordanian pre-service physics teachers have about these concepts. Consequently, the misconception about force and motion concepts that affect student' further learning or achievements has to be reduced because students that hold on misconceptions tend to ignore the related concepts with their misconception (Azman, et.al, 2013; Anggoro et al., 2019)and the misconception could be widespread to the next generation of pre-service physics teachers.

METHODS

The sample group of this study was selected from pre-service physics teachers in physics departments at the three universities in Jordan. The data was collected from Al-Hussein Bin Talal University (AHU), which is located in the south, the University of Jordan (JU), which is situated in the middle, and Al-Yarmouk University (YU), which is located in the north. These universities were chosen very carefully, in order to cover three different geographical areas of Jordanand to study their results on the FCI test to identify the possibility of an impact of the geographical distribution on their performance on the test. Also, the chosen Jordanian universities in this study have a different academic ranking of world Universities which could be reflected a real impact on students' performance on the test. A total of 97 pre-service teachers (26.8% from AHU, 46.4% from JU, and 26.8% from YU) participated in the study. The sample under study had a mixed ability with the age ranging from 21 to 22 years old (total distribution of students: 8.2% of the students was 21 years-old and 91.8% was 22 years old). This age usually reflects the fourth year or the last year in the program of Bachelor of Science (BSC). 71.1% of the students were female and 28.9% were male. Therefore, the composition of the sample allowed us to compare students' response according to: (i) background level, (ii) gender, (iii) major attitude, and (iv) geographical area: South (AHU), Middle (JU), and North (YU) areas. Accordingly, this division could help to suggest possible reasons for the misconceptions in the fields of force and motion which could be held by physics students' in the Jordanian universities. We inspected some of the misconceptions in pre-service physics teachers about force and motion concepts at universities in Jordan by using the Force Concept Inventory (FCI) which is developed by Hestenes and colleagues (1992) and validated by Wang and Boa (2010) and Fazio and Battaglia (2018). The FCI is considered to be one of the most reliable and useful physics tests available for physics teachers who teach at introductory level.

Physics teachers (Wells et al, 2019). It is a conceptual test consist of 30 multiple choice questions, which are focusing on the core concepts of force and related kinematics. The Newtonian concepts in the Inventory: Kinematics, the first law of motion, the second law of motion, the third law of motion, superposition principle of forces, and other kinds of forces (solid contact, fluid contact, and gravitation). The score on the FCI test reflects the degree of students' understanding of Newtonian concepts. Also, each wrong choice for any question, which has five alternative answers, reflects a specific misconception about the concepts of force and motion. The wrong answers are carefully chosen to correspond to common sense beliefs (misconceptions). The multiple-choice format of the FCI makes it feasible to do controlled large-scale educational studies. It has been shown by their developers to be reliable and valid measures of students' conceptual understanding of basic Newtonian mechanics (Hestenes et al,1992;Wells et al, 2019). Hestenes and Halloun (1995) argued that the entire FCI test should be used for the purposes of course and teaching evaluations. They stated that the total FCI score is the most reliable single index of student understanding, because it measures coherence across all dimensions of the Newtonian force concept. Single FCI items cannot be used to make reliable conclusions, but several items addressing the same dimension of the force concept can provide valuable information about specific learning difficulties that students may have (Thornton &Sokoloff, 1998; Savinainen& Scott,2002 b; Yang et al, 2019). Therefore, the total score of the test is the best single measure of a student's coherence of the force concept. One of the most important features of the FCI is that it can be used to find the common-sense misconceptions that students have when trying to apply Newtonian mechanics ideas. A complete classification of these misconceptions can be found in the original articles of Hestenes and colleagues(1992), Wangand Bao (2010) and Savinainen and Scott (2002b). However, the strength and limitations of the FCI in measurement are systematically discussed in the other researchers' articles (Savinainen & Scott, 2002a; Wang & Bao, 2010). The present work will show how to characterize students' results in specific FCI questions to find out. To know the University of Jordan that requires more attention to changing or modifying its teaching methods, plans, and building evaluation strategies and tools that the university uses in evaluating the learning process in its educational programs.

Thus, the study could be contributed to drawing the attention of the physics departments at Jordanian Universities to the level of their students in important physical concepts and compared them with international students over the world.

a) Data Collection

The sample of pre-service physics teachers consisted of 97 students (Male: 28 and Female: 69) at the undergraduate level in physics at three universities of Jordan (Al-Hussein Bin Talal University (AHU), University of Jordan (UJ) and Al-Yarmouk University (YU)). In order to have valuable information, all the students at the selected universities were not notified prior to the FCI test, and were given one hour to finish that test. Also, the students were told that the test was not an achievement test, and they should not to copy one another's work during the test, in order to adapt the validity and reliability. The students were asked to answer all 30 questions of the test, to be able to avoid students answering questions at random. Misconception scores were graded on a scale from one to 30 points. Each correct response is given one point, and each incorrect response is given zero, with a maximum score of 30 points. For each question, participants were required to choose between Newtonian concepts and common-sense alternatives.

b) Data Analysis

The results of the FCI Test were analyzed using t-test and one-way analysis of variance (ANOVA) test. The t-test and ANOVA are widely used statistical methods to compare group means. Both are parametric statistical techniques. These tests involve a number of assumptions, including: normally distributed population; dependent variable measured on a continuous interval or ratio level; a random sampling of data; and homogeneity of variance. The t-test is used to test differences in means between two groups. It is used when the dependent variable is a continuous interval/ratio scale variable (such as total self-esteem) and the independent variable is a two-level categorical variable (such as gender). While the ANOVA is used to determine whether there are any significant differences between the means of three or more independent (unrelated) groups.

FINDINGS AND DISCUSSION

The general description of the sample of pre-service physics teachers is shown in Table 1. From the Table, it can be seen that the University of Jordan group is the largest one (46.40%) with the highest grade point average (GPA) in high secondary school. This is because the University of Jordan is the biggest university in Jordan (50,000 students at all). Also, the competitive admission system for students in Jordanian universities and their acceptance depend on the GPA of the high school. Since the UJ and YU are ranked as the top academic and research universities in Jordan, they often receive more students than the AHU, which has a lower academic rank than those universities in Jordan. Thus, high school student with an intermediate academic achievement (GPA ~ 65-70%) has a full admission at the department of physics-AHU. Nevertheless, the university GPA of students' at the three universities was almost the same and no significant difference was found (see Table 1), which could be attributed to the similarity of the academic system in all Universities in Jordan. Also, the university GPA is calculated for all the subjects that the student takes at the university, including physics classes as specialization subjects.

Table 1. *General description of the sample of pre-service physics teachers*

University Name	Geographical Area in Jordan	Frequency	Percent (%)	High school GPA	University GPA
Al-Hussein Bin Talal	South	26	26.80	70.81	65.89
Jordan	Center	45	46.40	84.00	68.30
Al-Yarmouk	North	26	26.80	78.50	66.89

To fully understand the academic achievement of the pre-service physics teachers in the universities of Jordan, the FCI test was therefore applied. The results of the FCI test were summarized in Table 2. According to the Table, it can be seen that there are significant differences in the results of the university students on the FCI test. In order to find out if these differences were statistically significant, the one-way analysis of variance (ANOVA) test was used. The ANOVA test is a statistical procedure used to compare means between three or more groups (Pallant, 2007). In addition, the ANOVA statistical procedure examines what the variation (difference) is within the groups, then examines how that variation translated into variation between the groups, taking into account how many subjects there are in the groups (degrees of freedom) (Moore& McCabe,2003;Pallant, 2007). If the observed differences are greater than what is likely to occur by chance, then there is statistical significance. The statistic computed in the ANOVA test to generate p-values is the F-ratio, which is the ratio of the mean of the squares between the mean of the squares within: $F = MSb/ MSw$ (each of the means = SS/ df) (Moore& McCabe, 2003; Pallant, 2007). Also, the F-ratio depends on degrees of freedom to determine probabilities and critical values. The F-ratio statistic and the p-value depend on the variability of the data within groups and the differences among the means (Moore& McCabe,2003; Pallant, 2007). Thus, the ANOVA puts all the data into one number (F) and it gives one P-value for the null hypothesis. However, it is common to declare a result as significant if the P-value less than 0.05.

The analysis of the ANOVA test that applied to the FCI results of the pre-service physics teachers at the universities of Jordan (Table 2) was summarized in Table 3. From Table 3, it can be noticed that the F-ratio and P-value were found to be 1.311 and 0.274, respectively ?.Thus, the differences among the studied universities were not statistically significant in the subjects of force and motion. Moreover, the degree of understanding of the concepts of force and motion was approximately identical at the studied universities. This result could be explained by the fact that the physics students at the Jordanian universities are learning the concepts of force and motion from the same textbook (physics for scientists and engineers with modern physics by Serway and Jewett's). Also, physics professors follow the same teaching methods inside their classrooms.

Table 2. *Comparing the academic achievement of the pre-service physics teachers via the FCI test*

University	Students No.	Mean	Std. Deviation
Al-Hussien Bin Tala	26	29.230	12.121
Jordan	45	30.000	13.725
Yarmouk	26	25.128	10.508
Total	97	28.488	12.555

Table 3. *The ANOVA results*

Source of variation	Sum of squares	Degree of freedom)df(	Mean squares	ratio-F	value-P
betweengroUps	410.715	2	205.357	1.311	0.274
withingroups	14723.077	94	156.628		
total	15133.792	96			

In recent years, researchers have shown great interest in the relationship of gender to participation and performance in physics education. Addressing the factors related to gender that are involved in school performance is important to ensure that all students will succeed to the best of their ability. In addition to this, much gender research in physics has focused on increasing female participation and promoting their success in physics (Erickson & Erickson, 1984; Lee & Burkam, 1996; Häussler & Hoffmann, 2002; Kahle & Lakes, 2003;Demirci, 2005; Docktor & Heller, 2008;Azman et al, 2013). Thus, the effects of the gender on different categories of the pre-service physics teachers' misconceptions about force and motion have been investigated. Based on table 4, the t-test analysis shows that there were no significant differences among the responses of males and females in the level of misconceptions at a significant level (P = 0.05). Therefore, it shows that the level of misconception among male respondents and female respondents were almost the same. Although, there was a slight difference in the mean between male respondents (13.204) and female respondents (12.374), the level of misconceptions between both genders was still the same. This result could be attributed to the fact that they are learning the concepts of force and motion in the similar academic conditions. Based on the previous studies which investigated the effect of gender on different categories of students' misconceptions about force and motion (Docktor & Heller, 2008), there was no significant difference between male respondents and female respondents at the significant level (P = 0.05). A recent study by Azman and colleagues (2013) showed that there were no significant differences in the level of misconception between the male respondents and the female respondents (t = 0.290 and P-value = 0.468). Also, the researchers found that there was a slight difference in the mean value between both genders, as one gender exceeds another (male students mean = 21.667 whereas female students mean = 22.095).

Table 4. *The misconceptions among pre-service teachers on the topic of force and motion across gender*

Gender	No.	Mean	Std. Deviation	t	Sig.
Male	28	29.0476	13.20485	0.278	0.781
Female	69	28.2609	12.37498		

In recent years, there have been several studies conducted related to the relationship between students' epistemology, attitudes and the learning of Physics (Redish et al., 1998; Stathopoulou &Vosniadou, 2007; Adams et al., 2006). Although epistemological beliefs and attitudes have been the subject of extensive research for many years over the world, it has not widely researched in Jordan. So far there has not been any known detailed study or education research to probe students' epistemological beliefs towards learning Physics among our Jordanian students. Thus, this study is initiated with the aim of probing the Jordanian Universities attitudes towards learning Physics and their conceptual understanding of the Newtonian force concept in Physics.

Table 5 shows the comparison of the performance of the physics pre-service teachers at the studied Jordanian Universities on the FCI test according to their attitude to study physics as a main major by asking the students the following question "Do you have an aspiration to study physics?". The t-test was used to investigate the effect of attitude on different categories of students' misconceptions about force and motion. As can be seen from table 5, the t-test analysis shows that there was no significant difference according to their attitude to study physics (t = 0.510 and P – value = 0.611). Thus, the attitude of the Jordanian students toward studying physics did not affect the level of their understanding of the concepts of force and motion in the level of misconceptions at the significant level (P = 0.05). This result could be explained as follows; the process of understanding of these concepts is mainly affected by mental abilities such as analysis, interpretation, understanding, and classification.

Table 5. *The misconceptions among physics pre-service teachers on the topic of force and motion across attitude*

Attitude to physics	No.	Mean	Std. Deviation	t	Sig.
Agree	58	29.023	13.49332	0.510	0.611
Non-agree	39	27.6923	11.13852		

Table 6 shows the performance of the Jordanian students on the FCI test according to their GPA at high school and university. The Pearson correlation coefficient (PCC) was used to investigate the effect of GPA at high school and university on different categories of students' misconceptions about force and motion. As can be seen from the table 6, there was no correlation between the GPA of the students at high school and their performance on the FCI test (r = - 0.001, p-value = 0.993). This result was expected because the GPA of the students at high school is the sum of various educational subjects and the physics subject is one of them. On the other hand, a statistically significant correlation was found between the GPA of the students at university and their performance on the FCI test (r = 0.265, p-value = 0.009). This can be attributed to the many reasons such as an increase in math skills critical thinking and problem-solving skills for students accompany practical and theoretical applications in many courses of physics. In addition, the university GPA in the physics department is mostly the sum of many courses in the field of physics and hence the students aspire to be physics teachers.

Table 6. *The misconceptions among physics pre-service teachers on the topic of force and motion across the GPA at high school and university*

GPA	No.	Mean	Std. Deviation	R	Sig.
High School	97	78.999	8.730	-0.001	0.993
University	97	67.363	8.919	0.265	0.009

Table 7 and figure 1 show the descriptive statistics for physics students' conceptual understanding in the Jordanian universities corresponding to the individual test items of the FCI test. The students were asked to answer all 30 questions of the test, in order to avoid random answers or leaving the question without answers. For each of the 30 questions, the mean percentage of the students that were answered correctly is given in the table 7. Regarding the number of correct answers per question (see Table 7), the mean percentage of correct answers per student was found to be 28.49% with 12.55 as a standard deviation for all students at Jordanian universities (see Table 2). This result shows a clear difference from the other studies on the same topics under investigation using FCI test (Bayraktar, 2009; Martín-Blaset al.,2010;Sahin,2010; Yusof et al,2013;Mercadoet al.,2014). Bayraktar (2009) investigated the misconceptions of Turkish pre-service teachers about force and motion using the FCI test. He found that the correct response rate on the FCI test of the beginner physics students (first year) is considerably lower (33.4%) than that of fourth year students (fourth year) with 42.1%. Martín-Blaset and colleagues (2010) studied the enhancing force concept inventory diagnostics to identify dominant misconceptions in first-year engineering physics at Universidad Politécnica de Madrid in Spain. The researchers analyzed the results of the FCI test, which was administered to two different groups of students at the college of engineering. The first group was the industrial engineering school students (110) and the second group was the forestry engineering school students (33). The mean percentage of correct answers per student was found to be 53% for the first group while this number was dropped to 32% among the second group. Mercadoet and colleagues (2014) presented research results about the effectiveness of (IDEA)strategy on the problem-solving classes of Newtonian mechanics, energy, work and movement quantity in Physics I for a group of students in the first year of the engineering courses at(Ferramentas de Identificação e Combate ao Abandono) FICA. In their study, two groups were formed with pre-test/ post-test type: the experimental group receiving the intervention and the control group serving as a reference and receiving traditional training in the subject. The FCI analysis produced these results: at the control group, 21 % for the pre-test and 30 % for the post-test, while at the experimental group, 22 % for the pre-test and 51 % for the post-test. Sahin (2010) investigated the effects of problem-based learning on students' beliefs about physics and physics learning and conceptual understanding of Newtonian mechanics. Participants were (124) Turkish university students (problem-based learning (PBL) group = 55 and traditional group = 69). The PBL group showed significantly higher conceptual learning gains in the FCI than the traditional group. At the PBL group, the mean score on the FCI test was 56.29 % for the pre-test and 70.71 % for the post-test, while at the traditional group; it was 45.83 % for the pre-test and 56.01 % for the post-test. Also, the PBL approach showed no influence on students' beliefs about physics; both groups displayed similar beliefs. Yusof and colleagues (2013) studied the level of understanding of students and teachers in the concept of force and motion in four universities in Johor Bahru, Malaysia. They found that 60.4% of the students fail to understand the force and motion concept with a mean of 19.23% and a standard deviation of 11.09. Also, their data showed that 75% of the teachers reached the level of poor understanding of force and motion concept and 25% of the teachers failed to understand the concept with a mean and a standard deviation of 21.88% and 10.83, respectively. Furthermore, the analysis of the conceptual understanding in the Jordanian universities corresponding to the individual test items of the FCI test showed that the correct response rates for most questions were significantly low and showed very obvious indications of various misconceptions (see Table 7 and Fig.1). The following questions with the respective correct response rates: Q.11 (14.43%), Q13 (14.43%), Q23 (8.25%), Q25 (14.43%), Q26 (8.25%), and Q 30 (12.37%), exhibited student difficulties according to the all dimensions of the FCI test (see Table 7), which were related to the taxonomy developed by Hestenes, Wells, and Swakhamer (1992). This result showed an obvious difference from other studies on the topic under investigation (Bayraktar, 2009; Cayhadi, 2004). The previous studies, Turkish pre service physics teachers (Bayraktar, 2009), Indonesian undergraduate engineering students (Cayhadi, 2004; Nadi Suprapto, 2016), and Russia and Finland undergraduate students(Bogdanov & Viiri,1999) showed that their student-teachers have analogous misconceptions about impetus and active force: (1) force parallel to velocity vector, (2) non-equal action-reaction pairs, (3) constant gravity does not imply constant acceleration, (4) constant force implies constant acceleration, and (5) acceleration of gravity is independent on weight .

Figure 2 shows the achievement of the Jordanian students in different conceptual dimensions of the FCI test. From the figure, it can be seen that nearly 35% of the students correctly answered the questions related to Newton's second Law as well as the superposition principal. However, the correct response rates were lower than 30% for all other dimensions. Also, it can be seen that nearly 20% of the students correctly answered the questions related to Newton's third law. Therefore, the third law dimension of the FCI test in comparison with the other dimensions of the test shows a comparatively low achievement level. However, complexities in students' understanding of Newton's third law were also observed in numerous other research studies (Hestenes et al., 1992; Savinainen & Scott, 2002a; Cayhadi, 2004; Yusofetal, 2013; YudiKurniawan, 2015; NadiSuprapto; 2016; Wells, 2019). Authors of the previous publications showed that misconceptions about Newton's Third Law were found within many students who believed that Newton's Third Law can be held only in dynamic conditions.

Table 7. *The FCI results for individual test items of 97 students at Jordanian Universities*

Question No.	Mean (correct response rate (%))	Conceptual Dimension
Q1	41.24	Kinds of Force
Q2	27.84	Third Law

Q3	30.93	Kinds of Force
Q4	37.11	First Law
Q5	17.53	Kinds of Force
Q6	47.42	First Law + Second Law
Q7	39.18	Second Law
Q8	23.71	First Law
Q9	50.52	Kinds of Force + superposition
Q10	25.77	First Law
Q11	14.43	Third Law
Q12	51.55	Kind of Forces
Q13	14.43	Third Law
Q14	25.77	Third Law
Q15	31.96	Kinds of Forces
Q16	29.90	Kinds of Forces
Q17	17.53	Kinds of Force
Q18	29.90	Kinds of Force + First law + superposition
Q19	23.71	superposition
Q20	18.56	Kinematics
Q21	30.93	Kinematics
Q22	19.59	Kinds of Force
Q23	8.25	Kinds of Force + Kinematics
Q24	42.27	Kinematics + Second Law
Q25	14.43	Kinematics + Second Law
Q26	8.25	First Law
Q27	35.05	First Law
Q28	49.48	First Law
Q29	35.05	Kinds of Force
Q30	12.37	Kinds of Force

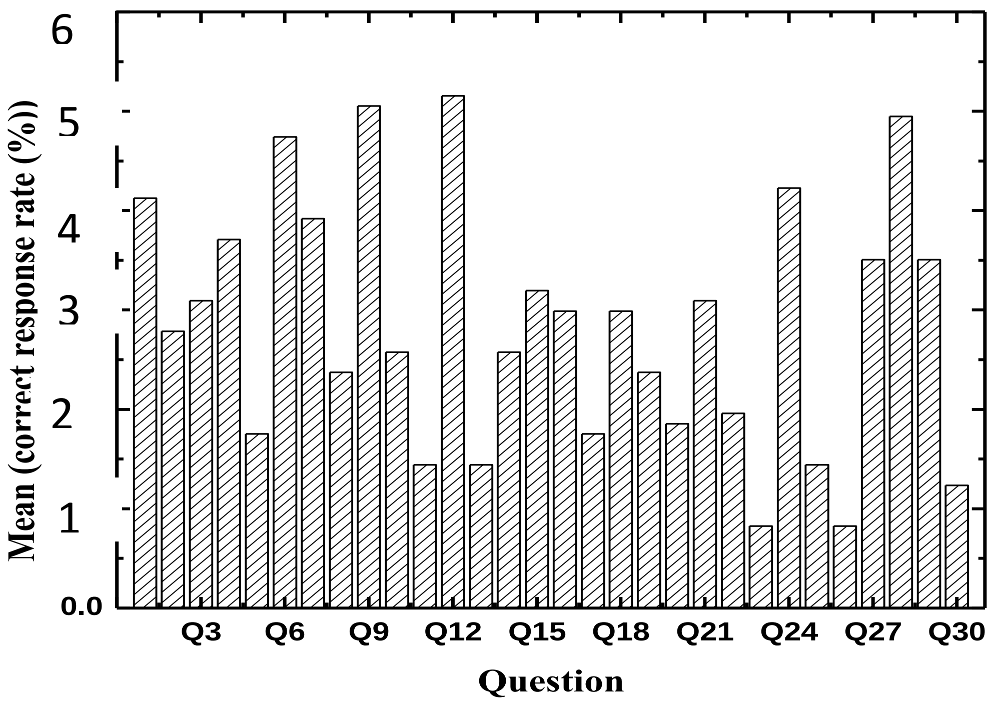

Figure 1. Descriptive statistics for physics students' conceptual understanding in the Jordanian Universities corresponding to the individual test items of the FCI test

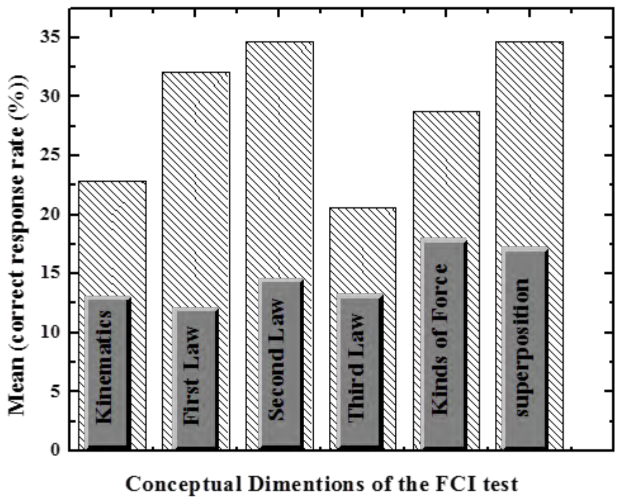

Figure 2. FCI scores on different conceptual dimensions

CONCLUSIONS

The level of understanding among pre-services teachers at Jordanian universities on the physics concepts of force and motion across gender, attitude, and GPA at high school and university has been investigated. According to the t- test analysis, the level of misconceptions across the gender showed that there was no significant mean difference between male respondents and female respondents in the level of misconceptions at the significant level. Also, the t-test analysis (t = 0.510 and P – value = 0.611) showed that the attitude of the Jordanian students toward studying physics did not affect the level of their understanding of the concepts of force and motion in the level of misconceptions at the significant level. Based on the Pearson Correlation Coefficient, there was no correlation between the GPA of the students at high school and their performance on the FCI test (r = - 0.001, p-value = 0.993) whereas a significant correlation was found between the GPA of the students at university and their performance in the FCI test (r = 0.265, p-value = 0.009). In addition, the analysis of the ANOVA test that applied in the FCI results of the Jordanian Universities showed that the F-ratio and P-value were found to be 1.311 and 0.274, respectively ?. Thus, the differences between the universities in the subjects of force and motion are insignificant. Regarding to the number of correct answers per question, the mean percentage of the correct answers per student was found to be 28.49% with 12.55 as a standard deviation for all students at studied Jordanian universities. However, nearly 35% of the students correctly answered the FCI questions related to Newton’s second Law as well as the superposition principal while 20% of the students correctly answered the questions related to Newton’s third law. Thus, it can be concluded that the pre-services teachers' misconceptions on the concepts of force and motion at the studied universities is somehow high. Hence, the results could help teachers and physics curriculum planners not only in Jordan universities, but also at any University over the word to revise the teaching methods and contents of textbook for related unsuccessful parts in the subjects of Newton’s laws and their misconceptions. In addition, this study could help teachers and physics students to hold of several ideas in improving, learning, and understanding in physics and ultimately achieving meaningful learning. However, traditional instructions and inappropriate instructions might add more to the students’ alternative conceptions and thus new instructional strategies based on conceptual change must be considered and carried out carefully in physics classroom to motivate deep understanding of concepts among pre-services teachers.

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