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EXAMINING THE PHYSICS CONCEPTIONS, SCIENCE ENGAGEMENT AND MISCONCEPTIONS OF UNDERGRADUATE STUDENTS IN STEM

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Abstract. *Exploring students' physics conceptions, science engagement and misconceptions in physics together with their association to certain variables (gender, educational background, and program of study) are essential in improving physics teaching and learning. However, few studies have been conducted to explore these three measures and almost none among STEM undergraduate students in the domain of Newtonian mechanics. To explore these measures, the Force Concept Inventory (FCI) and the Science Engagement Survey (SES) were administered to 281 STEM undergraduate students. Various statistical tools (ANOVA, t-test, correlations, etc.) have been utilized in the data analyses. The result revealed that gender and previous upper-secondary school strand have no significant effect on physics conceptions but have a significant effect on science engagement. The results also revealed a weak correlation between physics conceptions and science engagement, suggesting that interest becomes more effective when it was developed during the learning process. Finally, the results also revealed that more than 80% of the participants have a misunderstanding about the force direction of a thrown object, confirming that the dominant features of force and motion students have less conform to problems that involve non-contact force.*

Keywords: *conceptual change, misconceptions, physics conceptions, science engagement.*

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Introduction

Factors like gender, educational background and program of study are often associated with students' physics conceptions since these factors are believed to affect students' ability to develop concepts in physics. As a result, various studies have been conducted to evaluate how these factors affect students' conceptions in physics (Mears, 2019; McCullough, 2002; Said, 2015). In most cases, results often reveal a favorable agreement with the purpose, which is to prove that gender, educational background, and program of study influence the performance of students in conceptual test. In some cases, when results indicate a non-significant effect of the said variables on physics conceptions, researchers tend to discontinue their research design and disregard other factors that have contributed to the non-significant results. To figure out how these variables affect students' physics conceptions, the main effects of these variables to physics conceptions were evaluated. On the other hand, the effect of students' gender, educational background and study program on science engagement is somewhat interesting to study since these variables including the level of engagement of the students in science were linked to physics conception. However, the participation of students in science activities is much more related to interest rather than on physics conceptions. Thus, advancing women's participation in science is one of the common themes of studying the effect of gender to science engagement (Allegrini, 2015; Marcus, 2020). Moreover, it is expected that those students who were enrolled in STEM strand during their upper-secondary school study gained more science engagement than those students who were not enrolled in STEM strand during their upper-secondary school (Wang, 2013). The term 'upper-secondary school strand' in this research refers to a group of disciplines in a certain area. STEM strand, for example, consists of related disciplines in the field of science, technology, engineering, and mathematics, which upper-secondary students need to enroll to prepare them in higher education studies in STEM field (Sarmiento & Orale, 2016).

Engagement in science, in this research, was defined as how frequently someone has engaged in activities related to science because of one's own

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interest in it. These science-related activities, associated with interest in science, pertain to reading science fiction books, watching movies related to science, or participation in activities related to science (French et al., 2019; Ryder et al., 2015). However, interest in science becomes more effective in learning when it was developed during the learning process or within the context to which the learning happened (Rodriguez et al., 2019). This indicates that developed interests from early learning experiences become more effective in learning if it engages learners in activities that develop conceptions (e.g., designing experiments, testing hypotheses, or analyzing data). Thus, the development of physics conceptions is much more related to the interest formed during the learning process than to the interest developed from previous learning experiences. Rather than claiming that early science engagement has a positive impact on learning new concepts, the author will instead associate physics conceptions with 'schema theory'. The theory explains that learners internalize the dominant features of force and motion they have in interpreting situations new to them (Graham et al., 2013; Rowlands et al 2007).

Misconceptions, which are often described as 'misunderstanding', have been one of the main topics in research in science education for the past three decades. The said alternative framework is often described as a 'theory-like' way of interpreting the world or an alternative way of thinking (Rowlands et al 2007). The framework suggests that pre-instructed learners carry alternative frameworks that is different from the frameworks accepted in the scientific community. One example of physics misconception is the dissipation idea (a force is needed to push a tossed object upward), another is the dominant framework (a greater mass or a greater velocity imparts a greater force). Various frameworks have been articulated to describe how misconceptions occur in physics. Among these frameworks, which the research had focused on, is the framework of spontaneous responses to unfamiliar problems (Graham et al., 2013; von Aufschnaiter & Rogge, 2010). Describing how learners end up with misconceptions, there are facts of evidence showing that unfamiliar problems in Newtonian mechanics are interpreted based on the dominant features of force and motion that students have. These dominant features of force and motion, which students utilized in making sense of the world, are intuitively derived from daily life experiences, and in some situations, fail to conform to the mechanics context to which students need to conceptualize. Thus, one of the main objectives of this research is to confirm that physics problems that conform to the dominant features of force and motion students have (e.g., the direction of force in a pushed object) are more likely to be answered correctly by the students, while problems that less conform to the dominant features force and motion they have (e.g., direction of force in a tossed object) are less likely to be answered correctly by the students.

Physics Conceptions

Concepts about Newtonian mechanics are considered the foundational knowledge in the field of physics. For example, the concepts about energy and momentum, which are considered as important concepts in physics, are derived from the concept of force and motion. Thus, one question that needs to be asked is, how does someone acquire conceptions in force and motion? To answer that, there should be one condition that needs to be met, that is, learners need to associate existing concepts in order to develop new concepts, which usually happens during the process of learning (Graham et al., 2013; Rowlands et al., 2007). Consider, for example, the idea about 'flower', the concept of 'rose' can be associated with the concept of 'plant', which then is associated with the concept of 'flower'. However, the conception of force, which is highly dependent on situations, is more than knowing the concepts associated with force (e.g., tension, gravity, or friction). Thus, every understanding of force is unique regarding what situation the problem is showing. For example, the direction of the force of a thrown object is downward even if its upward velocity slows down and becomes zero upon reaching the highest point. Another is, an object with higher mass is heavier than an object with lower mass, but this does not mean that an object with higher mass will exert a greater force than the lower mass when they collide. These suggest that understanding of force does not only involve understanding about concepts related to force, but also involves the situations or the contexts to which the concept was formed.

Science Engagement

In general, engagement in science is often linked to science interest. The likelihood to engage in activities related to science (e.g., visiting science center; joining science competitions) is related to interest in science (Regan & DeWitt, 2014). Although science engagement may have a significant contribution to the academic performance and students' retention, engaging in learning processes, as a result of interest, becomes more effective in learning

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if the interest, which led to the engagement process, was formed during the learning process or during the actual learning engagement. Renninger and Hidi (2011) articulated that interest, which has been linked to science engagement in this research, is specific to a particular event and requires specific association between a person and their environment. Since some of the problems in Newtonian mechanics are context dependent and specific to a certain situation, building the interest of the students during the learning process or during the meaning making process is one of the objectives of physics education. In this research, the term engagement will be treated as how often someone had participated in science related activities, as what Atkinson and Mason (2014) articulated.

Misconceptions in Newtonian Mechanics

Works in the field of conceptual change started from the idea of 'misconceptions' in the field of mechanics. The concept about 'misconception' explains that students carry ideas in force and motion that are odd to the ideas accepted in the scientific community (Brown & Hammer, 2008; Peter 1982). These ideas, which derived from intuitive daily life experiences, conform to the beliefs of students and are difficult to change (Reinke et al., 2019). But what does the term "misconception" really mean, does it pertain to an alternative concept, a different point of view, or a misunderstanding. The concept about 'misconceptions' is somewhat, originated from the early literature "theory-like ideas", which students depend on when confronted with new physics problems (Rowlands et al., 2007). The idea also suggests that misconceptions are alternative frameworks or pre-conceptions that students carry, which do not conform to the accepted scientific conceptions. However, do misconceptions really exist prior to physics learning or spontaneously develop during the learning process or sense making process? The framework of spontaneous responses suggests that misconceptions spontaneously occur during the sense making process or during the confrontation of unfamiliar problems. This framework, supported by schema theory, explains that 'learners' resort to use established schemas when explaining and interpreting unfamiliar situations. 'Schema', which is acquired from daily life experiences, consists of concepts that are interconnected to each other, whereas a group of 'schema' is called 'schemata' (Graham et al., 2013; Howard, 1987; Rowlands et al., 2007). The framework explains that misconceptions occur when the dominant features of force and motion that students have don't conform to the physics problems, which students need to explain.

Research Questions

Evaluating the conceptual understanding of students relative to some variables may reveal a deeper understanding of how students develop conceptual understanding in physics. Associating the physics conceptions of students with other measures like science engagement and misconceptions in Newtonian mechanics, may establish a clearer idea of when students develop effective conceptual understanding in physics. To deal these notions, the following research questions were addressed:

1. What is the main effect of gender, upper-secondary strand, and current study program on the conceptual understanding and science engagement of the STEM undergraduate students?
2. Is there a correlation between the students' physics conceptions and science engagement?
3. Based on the students' distribution of the responses to the FCI items that were identified as concealer of students' misconceptions, why do most of the students rely on the most dominant feature of force and motion they have when solving problems in Newtonian mechanics?
4. How does engagement in science influence conceptual learning in Newtonian mechanics?

Research Methodology

General Background

This research employed an exploratory design in evaluating the physics conceptions, science engagement and mechanics misconceptions of the STEM students. The conceptions of the STEM students in Newtonian mechanics and science engagement were evaluated using the Force Concept Inventory (FCI) and the Science Engagement Survey (SES). The measures were further evaluated in terms of gender, upper-secondary school strand, and study program. The correlation between the two measures were evaluated, as well as the students' misconceptions in force and motion. The research activities that include validation of research instruments and gathering of data were conducted at the different moments of school year 2018/2019. The research is focused on the physics conceptions

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and science engagement of undergraduate students enrolled in the STEM program from the two higher education institutions that specialized in the field of science and technology.

Participants

The research utilized a purposive sampling method in evaluating the physics conceptions and science engagement of undergraduate STEM students relative to gender, upper secondary school strand, and program of study. Prior to the conduct of the research, permission to administer research questionnaires to the participants was sought first to each head of the higher education institutions in the Philippines through a letter of request. These two institutions specialized in the field of science and technology courses. Through proper coordination to the heads of the institutions as well as to the deans of the respective colleges, a total of 281 STEM students, enrolled in an introductory physics course in which force and motion are part of the syllabus, have participated in the research. In the work of Karadağ and Aktaş (2012), it has been argued that the effect size value is very significant in estimating an appropriate sample size in ANOVA design. According to Cohen (1988), the computed *f* value of 0.10 is interpreted as a small effect size, the computed *f* value of .25 is defined as a medium effect size, while the computed *f* value of 0.40 is defined as a large effect size. The computed Cohen's *f* value for the three independent variables (gender, educational background, and program of study) at .01 level of significance exceeds .5, thus consider a large effect size. Furthermore, survey revealed that 46% (128) of the participants were men, while 54% (152) were women. In terms of the program of study, 38 of the participants are enrolled in computer engineering program, 39 are enrolled in civil engineering program, 32 are enrolled in electronic engineering program, 58 are enrolled in mathematics program, 41 are enrolled in psychology program, 43 are enrolled in physics program, and 40 are enrolled in computer science program. Although the 'study programs' students enrolled during the time of study are all in the field of STEM, they have different upper-secondary school background: 58% (162) of the participants are not in the STEM strand during their upper-secondary school study, while only 42% (119) are in the STEM strand. Based on the current policy, learners who weren't able to take STEM strand in upper-secondary school can still be accepted in STEM programs at college, provided that students will credit STEM subjects that will make them qualified to enroll in STEM programs at college. Furthermore, the age of the participants ranged from 19 to 21.

Instrument and Procedures

The research has utilized the Force Concept Inventory (FCI) developed by Hestenes et al., (1992) in measuring the physics conceptions of the students in Newtonian mechanics. The instrument is appropriate because it does not only measure students' conceptual understanding in Newtonian mechanics, but also reveals students' misconception in Newtonian mechanics (Martin-Blas et al., 2010). FCI consists of 30 multiple-choice questions that feature topics in Newtonian mechanics. To establish the appropriateness of the instruments in the local setting, the instrument underwent the validation process. Through 113 undergraduate students in the STEM program, the coefficient of reliability was computed. As a result, the computed scale reliability is ($\alpha = .87$) good reliability. To determine how frequently the students have participated in science activities from their previous studies and to know the level of interest they acquired in the field of science, the study had also utilized the Interest & Recruitment in Science Survey (IRIS-Survey). The said instrument was developed to understand the interest of the students in the field of STEM (Henriksen, 2015). Since the research intends to measure the level of interest in terms of how often the students have participated in activities related to science, only those items that represent science activities were chosen. A total of 10 items were extracted from the IRIS-Survey and restructured so that each item (pertaining to a science activity) can be rated based on how frequently the students have engaged in the activity. Each item is rated from "5-always" to "1-never". To establish the reliability of adopted survey instrument, the questionnaire was also administered to 113 STEM program for undergraduate students. Cronbach's alpha was also computed giving a coefficient of ($\alpha = .83$) good reliability.

Data Gathering

Initially, permission to administer the research questionnaires was sought from the two higher education institutions that offer courses programs that specialize in the field of STEM. Requests letters were sent to the head of the institutions asking permission to conduct the study. Upon the approval of the request, the researcher co-

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ordinated with the respective deans of the colleges to determine programs and the list of the students who can participate in the research. A list of students enrolled in 'introductory physics course' was given to the researcher together with their class schedule. Upon completion of the instructions in Newtonian mechanics, participants were given a consent letter indicating the purpose of the research and the confidentiality of the research results. A set of questionnaires (FCI and IRIS-Survey) was given to the students, which was then followed by an explanation of the instructions. The participants were given 40 minutes to answer the test questions, good enough to complete the questionnaire. All the test questions were gathered and tallied by the researcher after the students completed the task.

Data Analysis

Various statistical tools have been utilized to explore the physics conceptions, science engagement and misconceptions of the students in Newtonian mechanics. Analysis of variance (ANOVA) and *t*-test were considered to know the main effect of the variable such as gender, upper-secondary background, and program of study on the physics conceptions and science engagement of the students. Furthermore, the association between the physics conceptions and science engagement was further analyzed using Pearson *r* correlation through intercorrelations. The distributions of the responses of the participants in SES items were further analyzed based on percentage. The number of students who selected options identified as concealer of students' misconceptions in Newtonian mechanics for each item was tallied to determine which among the identified misconceptions was selected by the greatest number of the students.

Research Results

The conceptions of the students in Newtonian mechanics and their level of engagement in science related activities were evaluated in terms of gender, upper-secondary school background, and program of study. Table 1 presents the number of participants, the standard deviation, and the computed *F* and *p* values. The results revealed that gender, previous upper-secondary school strand, and program of study have no effect on the FCI scores of the students. This indicates a non-significant difference between the gender, a non-significant difference between the strands (STEM and Non-STEM strands), and a non-significant difference between the study programs. Furthermore, the results revealed that gender and upper-secondary school strands have an effect on the engagement of the students in science, however none when it comes to the program of study.

Table 1
Mean Scores Comparisons in Terms of Gender, Previous Strands, and Program of Study

Variables	Force Concept Inventory					Science Engagement Activity				
	n	*M*	*SD*	*F*	*p*	*n*	*M*	*SD*	*F*	*p*
Gender										
Male	128	5.55	1.93	2.30	> .01	128	1.98	0.65	6.25	< .01
Female	152	5.82	2.27			152	2.33	0.96		
Total	281	5.68	2.14			281	2.17	0.84		
Previous-Strand										
STEM	119	5.84	1.97	1.11	> .01	119	2.48	0.97	30.0	< .01
Non-STEM	162	5.57	2.25			162	1.95	0.65		
Total	281	5.68	2.14			281	2.17	0.84		
Program										
Computer Eng.	38	5.55	1.84	1.16	> .01	38	2.17	0.96	2.53	> .01
Civil Eng.	29	5.66	1.61			29	2.39	0.92		
Electronics Eng.	32	5.97	2.82			32	2.58	0.77		

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Variables	Force Concept Inventory					Science Engagement Activity				
	n	*M*	*SD*	*F*	*p*	*n*	*M*	*SD*	*F*	*p*
Mathematics	58	5.16	2.08			58	1.94	0.79		
Psychology	41	5.59	1.99			41	2.05	0.70		
Physics	43	6.09	2.18			43	2.15	0.78		
Computer Sci.	40	6.03	2.25			40	2.17	0.91		
Total	281	5.68	2.14			281	2.17	0.84		

Table 2 presents the correlation between the FCI mean score and the SES overall mean score. The result revealed a significant and positive weak correlation between the measures. In addition, the correlations between the FCI mean score and the individual mean score in the SES items were also presented in Table 2. The results gave varying positive correlations between the mean scores, ranging from strong positive to weak positive correlations.

Table 2
Correlations between the Mean-Score/Items in the Science Engagement Activity and the Mean-Score in the Force Concept Inventory

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11
1	2.45	1.095											
2	2.23	1.108	.67**										
3	2.17	1.069	.44**	.60**									
4	2.31	1.096	.35**	.39**	.60**								
5	2.65	1.075	.31**	.36**	.42**	.65**							
6	2.07	1.169	.50**	.51**	.48**	.48**	.50**						
7	2.36	1.109	.40**	.44**	.49**	.51**	.57**	.50**					
8	2.09	1.135	.35**	.52**	.55**	.53**	.54**	.54**	.66**				
9	1.53	1.371	.37**	.49**	.52**	.43**	.27**	.50**	.43**	.51**			
10	1.85	1.341	.38**	.58**	.55**	.38**	.25**	.53**	.40**	.49**	.71**		
11	2.17	0.845	.65**	.76**	.77**	.72**	.65**	.76**	.73**	.78**	.74**	.74**	
12	5.68	2.137	.01**	.15*	.18**	.12*	.12	.13*	.12	.14*	.21**	.21**	.20**

Note. 1 = Experiments or laboratory works, 2 = Science field works or excursions, 3 = Read popular science books and magazines, 4 = Read science fiction or fantasy books, 5 = Watch science fiction or fantasy movies, 6 = Visit museum or science center, 7 = Watch popular science television channels/programs (e.g. Discovery Channel, Horizon), 8 = Watch science films on television (e.g. CSI, Numbers, Grey's Anatomy), 9 = Join Science, Technology or mathematics competitions, 10 = Participate in science outreach activities (e.g. science festivals, science summer schools), 11 = overall mean score of the SES, 12 = overall mean-score of the FCI, *N* = 281, *M* = mean, ** significant at .01 level, * significant at .05 level.

FCI items that were identified as concealer of students' misconceptions in mechanics were presented in Table 3. Among all the items that were identified as concealer of alternative conceptions in Newtonian mechanics, the number of students who selected choices that were considered as misconceptions is always higher than the number of students who selected the right choice. Comparing the items in terms of the number of students who selected choices that were considered as misconceptions, the misconception "impetus dissipation" has been selected by most of the students (231, 82%) while the misconception "force cause acceleration to terminal velocity" has been selected by the few students (90, 32%). Furthermore, comparing the items in terms of the number of students who answered correctly, item 22 "force cause acceleration to terminal velocity" has been answered correctly by most of the students (79, 28%) while item 26 "resistance oppose force/impetus" has been answered by the least number of students (17, 6%).

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Table 3
Frequency of Students' Responses to FCI items that Reveal Misconceptions in Force and Motion

FCI item	Misconceptions	NSSMA		NSSCA		NSSL	
		n	%	*n*	%	*n*	%
2	The heavier fall nearer	99	35	45	16	137	49
4	Greater force implies greater mass	154	55	24	9	103	37
5	Active force in the direction of motion	181	64	62	22	38	14
11	"Hit" produces impetus	192	68	41	15	48	17
13	Impetus dissipation	231	82	31	11	19	7
15	Most active agent produces greater force	161	57	35	12	85	30
17	Largest force determines motion	147	52	47	17	87	31
18	Circular impetus	184	65	61	22	37	13
20	Velocity-acceleration indiscriminate	141	50	40	14	100	36
22	Force cause acceleration to terminal velocity	90	32	79	28	112	40
25	Motion when force overcomes resistance	99	35	69	25	113	40
26	Resistance opposes force/impetus	114	41	17	6	150	53
30	Impetus supplied by hit	163	58	68	24	50	18

Note. N = 281, NSSMA – Number of students who selected misconception answers, NSSCA – Number of students who selected correct answers, NSSL – Number of students who selected other answers

Discussion

The effect of gender, upper secondary strand, and study program on students' physics conceptions and science engagement was evaluated. A non-significant effect of gender, upper-secondary school strand, and study program on physics conceptions was revealed. This indicates that gender has no significant effect on the conceptual understanding of the students in Newtonian mechanics. The non-significant effect of gender on FCI scores has been observed also from the study of Said (2015) and Hairan et al., (2019) among undergraduate students. For upper-secondary school background, a small effect of math upper-secondary school background on students' physics conceptions was also observed from the study of McCullough (2002). These results suggest that the other factor aside from the said variable is affecting the conceptual understanding of the students in physics. In a seminal work presented by Graham et al., (2013) and Rowland et al., (2007), it was stated that the absence or presence of schema in solving physics problems is the main factor that affects students learning in physics. It was explained that students hold dominant features of force and motion that they depend on when they encounter problems new and unfamiliar to them. These dominant features of force and motion students have, often derived intuitively from daily life experiences, could be the main reason why gender, upper-secondary school background, and study program did not affect the physics conceptions of the students. Since the responses of the students in the FCI questions are often derived from the dominant features of force and motion students have, which occur spontaneously during the process of analysis, it is less likely that early upper-secondary strand significantly affects the physics conceptions of the students. Furthermore, the effect of gender, previous upper-secondary school strand, and study program on students' science engagement is somewhat interesting since science engagement in this research was correlated with the physics conceptions of the students. Based on the results, a significant effect of gender and upper-secondary school strand on students' science engagement was revealed in the outcomes. The significant level of interest in science activities among female students as compared to male students is a positive indication of improved science participation of female students and declining gender inequality in the field of science (Marcus, 2020). Similarly, a significant effect of 'upper-secondary school strand' on students' science engagement was also observed. It is more likely that those students who took STEM strand during their upper-secondary school study developed a higher level of interest in science activities compared to those students who

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didn't take STEM strand during upper-secondary school study. Thus, the significant effect of gender and secondary school strand on students' science engagement suggests that science engagement is more related to the affective domain, like interest in science, than to the cognitive domain of learning, like physics conceptions. Moreover, the relationship between the FCI scores and the students' level of science engagement was also examined. The results revealed significant, but weak positive correlations between the FCI average score and the levels of engagement in science. This indicates that the interest developed by the students from previous learning experiences is weakly associated with the conception of the students in physics. Thus, based on these findings, it is suggested that interest developed during the learning process or engagement process is much more effective in physics learning than the interest developed from previous learning experiences. The highly situational and contextual characteristic of physics problems can be considered also as one factor of a weak relationship between science engagement and physics conceptions. Problems in Newtonian mechanics are highly situational, in a sense that every problem has a context that needs a high level of analysis. As a result, it appears that the responses of the students to mechanics problem relied strongly on the dominant features of force and motion they have (a higher mass result to a higher force, a state of rest corresponds to zero net force, the direction of force is always the same with the direction of motion, e.g.) rather than on the level of engagement they acquired from the previous learning experiences (Graham et al., 2013). This also supports the assumptions that alternative conceptions or misconceptions are not formed prior to learning but build spontaneously during the sense making process of physics problems (Rowland et al., 2007). Since physics learning is highly situational and context dependent, contextualizing physics learning explicitly is one strategy that can be used to improve physics conceptions. The number of students who correctly and incorrectly answered the FCI items identified as concealer of students' misconceptions in Newtonian mechanics was also evaluated. Based on the outcomes, the misconception "impetus dissipation" was selected by the greatest number of students, while the misconception "force cause acceleration to terminal velocity" was chosen by the least number of students. The notion that 'a slowing motion of a tossed object was due to dissipation of force' has been manifested by the greatest number of students. Relying on the most dominant feature of force and motion in explaining unfamiliar and highly contextualized physics problems is one possible reason for this result. These dominant features of force and motion derived from daily life experiences are considered schema which students use when they encounter problems new to them (Graham et al., 2013; Rowland et al., 2007). The idea that a decreasing velocity will result in a decreasing force is an example of intuitive idea used by the students in describing the motion of objects. Another dominant feature most students use in describing the motion of a tossed object is "moving-up" which students often mistakenly choose to describe the direction of the gravitational force. These dominant features of force and motion students have, which usually formed from daily life experiences, are applicable with contact force situations, in most cases, but not with situations that involve non-contact force. It was observed from the results that although all the participants are enrolled in STEM program, many still rely on intuitive force and motion ideas derived from daily life experiences when interpreting problems that require higher level analysis, like throwing object. It was seen from the results of the study that the misconception "impetus dissipation" was selected by the highest number of students while the misconception "force result in acceleration to terminal velocity" was selected by the lowest number of students. The distinction shows that 'impetus dissipation', which describes non-contact force situations, often does not conform to the dominant features of force and motion derived from daily life experiences, while 'force result to acceleration to terminal velocity' which describes contact force situations, usually conforms to the dominant features of force and motion derived from daily life experiences.

Conclusions and Implications

Even though students have engaged in various science related activities and established fundamental knowledge in force and motion from earlier learning experiences, it is astonishing that many still develop misconceptions when contextually challenging problems in Newtonian mechanics are encountered. Identifying possible factors that affect physics conceptions is one of the main concerns in physics education research. In this research the conceptions of students in Newtonian mechanics and science engagement were evaluated in terms of gender, previous upper-secondary school strand, and study program. The associations between the two measures were also examined. A non-significant effect of gender, upper-secondary school strand, and study program on physics conceptions was revealed in the results. Problems in Newtonian mechanics are situational and contextually challenging. Thus, in most cases, students depend on the most dominant features of force and motion they have when solving problems that involve force and motion. However, in some cases, these dominant features of force and

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motion, derived from daily life experiences, mislead students in the correct conceptions. This strongly suggests that the dominant features of force and motion students hold are likely more responsible in the conceptions of the students rather than their gender, upper-secondary school strand, and study program. Moreover, a significant effect of gender and upper-secondary school strand on science engagement was also observed in the results. Since science engagement is more associated with the affective domain than the cognitive domain, the significant effect of gender and upper-secondary school strand on the science engagement of students indicates an improved participation of women in the field of science and an improved science interest of those upper-secondary students enrolled in STEM strand. Furthermore, a weak correlation between physics conceptions and science engagement was observed in the results. This implies that although interest gained from earlier science engagement is effective in physics learning, this affective domain will become more effective if it was formed during the learning process or during the engagement process. Since most of the problems in physics are very contextual and require complex analysis, using interventions that explicitly describe physical situations is one possible way to improve physics conception in Newtonian mechanics. Finally, the number of students who selected options that were considered as concealer of students' misconceptions was analyzed. Among the misconceptions identified in this study, the misconception "impetus dissipation" was observed among the highest number of participants, while the misconception "force result in acceleration to terminal velocity" was seen among the least number of students. Even though students have gained basic understanding of force and motion from previous learning experiences, students still rely on the dominant features of force and motion they have when solving physics problems. These dominant features of force and motion, gained from daily life experiences, usually don't conform to problems that don't involve contact force.

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