2010

Misconceptions on force and gravity among high school students

Jane Ragasa Pablico
Louisiana State University and Agricultural and Mechanical College

MISCONCEPTIONS ON FORCE AND GRAVITY AMONG HIGH SCHOOL STUDENTS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
In partial fulfillment of the
requirements for the degree of
Master of Natural Sciences

In

The Interdepartmental Program in Natural Sciences

By
Jane R. Pablico
B.S., University of Northern Philippines, 1996
M.S.T., University of Northern Philippines, 2002
August 2010

ACKNOWLEDGEMENTS

I would like to express my sincerest gratitude and appreciation to everyone who have, in one way or another, contributed for the successful completion of this piece of work. Special appreciation is accorded to:

Dr. Dana A. Browne, my thesis adviser and committee chair, for all his invaluable assistance, motivation and brilliant suggestions;

My committee members, Dr. Steven F. Watkins and Dr. Michael L. Cherry, for their comments and suggestions which contributed much to the improvement of this research;

Dr. James J. Madden, the coordinator of the MNS program for teachers, without whom this program would not have been made possible;

Dr. Jing Wang and Dr. James P. Geaghan, for sharing their expertise in statistics;

Dr. Richard Gunstone, for allowing me to use the survey instrument;

My school administrators, for allowing me to conduct my research; my colleagues, for their assistance in administering the survey; and students, for their participation;

The MNS- Physical Science 2010 cohorts: Ingrid, Beth, Cindy, Micah, Daniel, Danny, Jason, Jonah and John, for their comments and suggestions, especially to Jason, who also patiently edited my manuscript;

Friends, who provided encouragement and joyful company; and

Most of all, my family – Sam, for the love, and assistance in putting together my data; my kids Schuyler James and Shirlene Joyce, for the inspiration which kept me going during those tough times; and, my parents and sisters, for the words of encouragement amidst the distance that separate us.

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ABSTRACT

The goal of this study is to determine prevalent or dominant misconceptions on force and gravity among high school students. A survey instrument consisting of 12 qualitative questions requiring both answers and written explanations was used to gather students' ideas and beliefs in situations involving force and gravity. Furthermore, it examined whether the proportion of students having misconceptions per question are correlated with gender and the type of school Physics background. The results show that the respondents have misconceptions that are similar to the misconceptions found in previous research. The number of misconceptions and the proportion of students having misconceptions per question are not correlated with gender. They are, however, correlated with the amount of Physics instruction. Both the number of misconceptions and the proportion of students having misconceptions diminish as the school Physics background progresses from Middle School Science to High School Physical Science, and finally to High School Physics.

INTRODUCTION

<u>Background of the Study.</u> Students come to school bringing with them some preconceptions that are incompatible with established scientific theories. Such preconceptions are also called misconceptions, naïve conceptions, alternative conceptions, or conceptual misunderstandings.

Lee, et. al (1992) pointed out at least three ways in which alternative conceptions among children differ from generally-accepted concepts. First, children have difficulty with the kind of abstract reasoning used by scientists. Second, children are interested in unique explanations for specific events; unlike scientists, they are not concerned with the need for coherent and non-contradictory explanations for a wide variety of phenomena. Third, the everyday language of our society often leads children to have views that are different from those of scientists, and common speech is often at odds with the precise language used by scientists.

Students usually explain physical phenomena using their knowledge from previous experience or using "common sense" knowledge. But even common sense knowledge often does not agree with scientific fact. According to Halloun and Hestenes (1985), Physics and General Science can be regarded as extensions and modifications of common sense. This gives the science teacher the challenging role of facilitating the modification of common sense.

Some of the students' misconceptions in Physics may be traced back from pre-Newtonian Physics such as the Aristotelian view and the 14th century Impetus Theory by Jean Buridan (Halloun & Hestenes, 1985). For example, Aristotle's views include the ideas that "rest is the natural state" of all objects, that "every motion has a cause", that the "speed of a falling body is proportional to its weight", and that "a constant force imparts to an object a constant speed", to

name a few. On the other hand, Jean Buridan proposed that motion was maintained by some property of the body, called “impetus”. Impetus is conceived to be an inanimate “motive power” or “intrinsic force” that keeps things moving (Hestenes, et.al., 1992). Buridan further held that the impetus of a body increased with the speed with which it was set in motion, and with its quantity of matter (New World Encyclopedia). Clearly, Buridan anticipated Isaac Newton when he wrote:

...”after leaving the arm of the thrower, the projectile would be moved by an impetus given to it by the thrower and would continue to be moved as long as the impetus remained stronger than the resistance, and would be of infinite duration were it not diminished and corrupted by a contrary force resisting it or by something inclining it to a contrary motion”.

Tenacity is another characteristic of misconceptions. Children do not just drop their ideas and beliefs just because someone says so, or because an event disproves what they have come to believe (Worth, 2000). In a research conducted by Gunstone and White (1981), the students exhibited a strong tendency to observe their prediction regardless of what actually happened in the lecture demonstrations. Even adults have trouble changing theories that are well-grounded in experience (Worth, 2000).

Misconceptions can have serious impact on student learning. The prevalence of those misconceptions hinder students from learning more advanced concepts, and as they continue to build up knowledge, it becomes more difficult to rectify the misconceptions. If their initial understanding is not engaged, they may fail to grasp new concepts and information presented in the classroom, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom (Donovan, et. al., 1999). It is then important that the science teacher

should find ways to identify and carefully address those misconceptions that students bring to class.

The primary aim of this study is to determine the prevalent or dominant misconceptions on force and gravity that need to be addressed in the science classroom. Furthermore, it also examined if the number of misconceptions and proportion of students having misconceptions are correlated with gender and the type of school Physics background.

The results of this study will provide data to teachers and curriculum developers on the prevalent misconceptions of the students on force and gravity. Moreover, the findings will serve as a guide for teachers in planning classroom activities that could address misconceptions, and thus, improve their students' conceptual understanding and facilitate the acquisition of advanced knowledge.

Scope and Delimitation. This study is limited to the misconceptions associated with the situations on force and gravity covered in the instrument used. The 12-item survey instrument was adapted from the Asia-Pacific Physics Teachers and Educators Association (APPTEA) research report (Gunstone, et.al., 1989) which was published in 1989. The misconceptions gathered were also limited to the students' written responses to the questions, and no further interviews were conducted. The high school students in the study were 9^{th} to 12^{th} graders from a public high school in East Baton Rouge Parish, Baton Rouge, Louisiana.

Related Studies. The following paragraphs report past studies designed to improve science instruction by identifying students' misconceptions.

Halloun and Hestenes (1985) surveyed and analyzed "common sense" beliefs of college students. The researchers used multiple-choice diagnostic pretests and posttests, and

conducted interviews. Examples of misconceptions are: that under no net force, an object slows down; that under a constant force, an object moves at constant speed; and, that an impetus is required to maintain the motion of an object. From the result of the survey, a taxonomy of “common sense” concepts which conflict with Newtonian Theory was developed as a guide to instruction. This is part of a sequence that led to the development of the Force Concept Inventory (FCI).

The Force Concept Inventory (Hestenes, et.al., 1992) is a probe of belief systems originally consisting of 29 questions which were developed from the taxonomy of commonsense misconceptions. The inventory has been used in different research studies for purposes of lesson planning and monitoring student learning from different teaching approaches. In a research study conducted by Savinainen and Scott (2002), the FCI was used to evaluate student learning after Interactive Conceptual Instruction was used in teaching Mechanics in a Finnish upper secondary school. The most common specific conceptions found after instruction were the ideas that the last force to act determines motion, velocity is proportional to applied force, and greater mass implies greater force. On another occasion, Viiri (1996, as cited by Savinainen and Scott), compared the FCI scores of Finnish and American Students and concluded that the results are very similar.

Another research-based assessment instrument that probes conceptual understanding of Newtonian Mechanics is the Force and Motion Conceptual Evaluation, or FMCE (Thornton and Sokoloff, 1998). It was developed as an assessment tool of students’ understanding of Newton’s Laws of Motion, and was used to assess students’ conceptual learning after the implementation of microcomputer-based laboratory (MBL) curricula. Thornton and Sokoloff found out that, after

students' exposure to active learning strategies supported by the MBL curricula, students' conceptual learning had improved, based on the test.

Trowbidge and McDermott investigated student understanding of the concept of velocity (1980) and acceleration (1981) in one dimension. Individual demonstration interviews, conducted with 200 university students, indicated that even after instruction, many students confused position with velocity and velocity with acceleration. A long-term study was also conducted to identify student difficulties in relating kinematical concepts, their graphical representations, and the motions of real objects (McDermott, et.al., 1987). The result of this study was used as a guide in developing a conceptual approach to teaching kinematics (McDermott & Rosenquist, 1987). Other studies were conducted by McDermott, et.al such as the investigation of student understanding of the work-energy and impulse-momentum theorems (1987), of the Atwood's machine (1994), of light (1987), and of DC circuits (1992), which led to the development of the "Physics by Inquiry" modules (1996) and "Tutorials in Introductory Physics" (1996). These modules and tutorials have emphasis on the development and application of concepts and scientific reasoning skills.

Gunstone (1987) conducted a survey of student understanding in mechanics in Australia. On a multiple-choice test given to 5500 high school students, a majority predicted that two equal masses on an Atwood's machine would "seek" the same level.

Lee, et.al. (1992) surveyed some of the common misconceptions of force, gravity, heat and electricity among Malaysian pupils. The survey revealed that more than half of the pupils had the misconceptions that if a body is moving, then a force is acting in the direction of the motion, and if a body is stationary then there's no force acting on it. They also associated gravity with the earth's atmosphere, deducing that an object would be weightless on the moon because

there is no atmosphere. About one-third of the pupils perceived heat as some form of a substance that can move. They also believed that some electric current is used up after it has flowed through a bulb in a circuit. This study showed that pupils still held certain misconceptions even after receiving classroom instruction.

Prior to instruction, more than 100 students in an introductory university mechanics course were given a short-answer test on concepts of force and motion (Champagne et al., 1980 as cited by McDermott, 1998). The test used a technique abbreviated as D.O.E. (demonstration, observation, explanation). The results revealed that the students, who had previously studied physics, had many incorrect ideas: a force will produce motion; a constant force produces constant velocity; the magnitude of the velocity is proportional to the magnitude of the force; acceleration is due to an increasing force; and in the absence of forces, objects are either at rest or slowing down. In another study that involved written tests and interviews about a pendulum and a coin tossed in the air, the results indicated that both before and after an introductory course in mechanics, many students seemed to believe that motion implies a force (Clement, 1982 as cited by McDermott, 1998).

In a study entitled “Gender Difference, Misconceptions and Instruction in Science” (Khang, 1995), the relationship between gender and students’ misconceptions in science was analyzed. The study was conducted on two groups of secondary three students (third year high school) from Singapore, both of which consisted of males and females. The two groups were subjected to different teaching strategies for six weeks, namely, teaching strategy 1, which is basically didactic in nature, and teaching strategy 11, which incorporates students' misconceptions and applies the Generative Learning Model. A constructed and validated diagnostic instrument was used as a means to measure the effectiveness of these two teaching

strategies. The findings showed that gender differences did not relate well to students' misconceptions in science.

Another study investigated relationships between gender, interest and experience in electricity, and conceptual change text manipulations on learning fundamental direct current concepts (Chambers, 1997). Conceptual change text has been shown to lead to better conceptual understanding of electrical concepts than traditional didactic text. When interest level, experience, and prior knowledge were not included in the analysis, both gender and text type produced significant main effects. When interest level, experience, and prior knowledge were included in the analysis, conceptual change text led to better understanding of electricity concepts than did the traditional text, and the effect of gender was eliminated. This finding supports the hypothesis that prior interest level, experience, and knowledge mediate apparent gender differences in learning about electricity. It suggests that conceptual change text manipulations are likely to be effective for both men and women.

A research study was also conducted to find what kind of changes in student understanding of motion can occur and at what age (Dykstra & Sweet, 2009). The subjects of this study were 4^{th}, 6^{th} and 8^{th} grade students. Prior to and after instruction, the students were asked to carefully describe several demonstrated accelerated motions. The 4^{th} and 6^{th} grade students gave similar pre-instructional descriptions of the motion, but the 4^{th} grade students did not exhibit the same degree of change in descriptions after instruction. The findings of the study suggests that students as early as 6^{th} grade can develop changes in ideas about motion needed to construct Newtonian-like ideas about force. Furthermore, this study suggests that students' conceptions about motion change little under traditional physics instruction from these grade levels through college level.

The Asia-Pacific Physics Teachers and Educators Association (APPTEA) also conducted a survey of students' conceptions in mechanics in seven Asia-Pacific countries (Gunstone, et.al., 1989). The survey covered 12 qualitative questions on force and gravity. It was found out that students in the countries involved (India, Korea, Malaysia, Philippines, Thailand, Australia and Singapore) use ideas other than those taught in Physics to interpret situations. These ideas appeared to have been derived from students' interpretation of the world around them and from students' attempts to construct meaning from their everyday experiences. The idea that force is needed for motion was widely held. What was found to differ across some countries was the nature of some commonly misapplied physics principles. These include association of spinning with gravity (Australia), the invoking of an inertial force (Thailand), and the assertion that gravity exists only on earth (Malaysia). The findings may reflect something specific about physics education in the country – curriculum, textbook, or teacher knowledge - which can be determined only by further investigations.

The following were the common misconceptions on force and gravity found in the APPTEA research report: On the situation involving a ball thrown into the air, the students believed that the direction of motion is the direction of the force; that the force of throw still acts on the ball thrown; and the use of "push of gravity". On the situation where the bicycle is slowing down, the students believed that the force used to speed up is still there, and that there is force because there is motion, but there were also some who said that there is no force because it is slowing down. On gravity, the following were the misconceptions found: gravity decreases with height; floating equals weightlessness; the higher you are, the harder you hit the ground, so gravity is greater; no gravity when object is falling freely; no gravity on moon; moon has no atmosphere, so it has no gravity; less gravity on moon because it is far from earth; no gravity in

space; floating means no gravity; and, gravity underwater makes you drown if you were not swimming. On the Atwood's machine, students believed that the blocks will move to the same level because they have equal mass.

To sum up, various researches have already been conducted to investigate students' misconceptions in science and to test the effectiveness of different teaching strategies in altering those misconceptions. In this study, the researcher wishes to investigate misconceptions on force and gravity among high school students in a public high school in East Baton Rouge Parish, Baton Rouge, Louisiana, and compare these with the findings of previous research studies, particularly with the result of APPTEA research, where the survey instrument has been adapted.

MATERIALS AND METHODS

This study made use of a descriptive research method. A survey instrument adapted from Asia-Pacific Physics Teachers and Educators Association (APPTEA) research published in 1989 was used in gathering the profile of the respondents and in soliciting their ideas in response to questions on some situations involving force and gravity. The survey was administered in December 2009 to science classes with the help of their respective teachers.

Population and Sample. The respondents in this study consisted of students at a public high school in East Baton Rouge Parish. Samples were taken from different science classes in order to obtain information and ideas that are representative of different school Physics backgrounds.

At the time of the survey, the school had a population of 1,140 students, 337 (30%) of which were freshmen, 320 (28%) were sophomores, 272 (24%) were juniors and 211(18%) were seniors. The freshmen were taking the Physical Science class which consisted of Chemistry in the Fall semester and Physics in the Spring semester. Since the survey was administered in December, Physics had not yet been discussed in class, so the freshmen were considered to have "Middle School Science" as their school Physics background.

There were 135 (12%) students who were taking Physics at the time of the survey. Since they had already learned about force and gravity in this class, they had "High School Physics" as their source of school Physics background.

The rest of the respondents (58%) were taken from Biology and Environmental Science classes which mostly consisted of sophomores and juniors. Since they had taken Physical Science in their freshmen year, "High School Physical Science" was considered as their source of school Physics background.

With the school population of 1,140 students, and at a confidence level of 95% with a 5% margin of error, this study needed a sample size of at least 288. Interactive online sample size calculators were used (www.surveysystem.com and www.raosoft.com) and found to obtain the same sample size as the formula below.

$$ss = \frac{Z^2 * (p) * (1 - p)}{c^2}$$

Where :

ss = sample size
Z = Z value (e.g., 1.96 for 95 % confidence interval)
p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed)
c = confidence interval, expressed as decimal (e.g., 0.05 = ± 5)

For a finite population, a correction is made by the following formula.

$$\text{New sample size} = \frac{ss}{1 + \frac{ss - 1}{pop}}$$

Where: pop = population

Stratified random sampling was employed to obtain samples from the different groups based on "school Physics background". Proportionate stratification was used to determine the number of samples for each group.

Table 1 shows the distribution of the sampled respondents in terms of school Physics background and gender. Among the 288 samples in the study, 86 of them belonged to the Middle School Science group, 167 to the High School Physical Science group, and 35 to the High School Physics group. These numbers are proportional to the total number of students who

belonged to each group. The random sampling also resulted in the sample being 51% male and 49% female subjects.

Table 1. Frequency and Percentage Distribution of the Respondents in Terms of School Physics Background and Gender.

School Physics Background	**Male**		**Female**		**Total**	
	f	**%**	**F**	**%**	**f**	**%**
Middle School Science	43	15	43	15	86	30
HS Physical Science	87	30	80	28	167	58
HS Physics	18	6	17	6	35	12
Total	**148**	**51**	**140**	**49**	**288**	**100.00**

Data Gathering Instrument. The instrument was a 12-item qualitative test that requested student answers and the reasoning used to arrive at those answers. It aimed to find out students' ideas and beliefs relevant to aspects of force and gravity. This instrument was formulated in Australia in 1987 for the Asia-Pacific Physics Teachers and Educators Association (APPTEA) project. It was the result of the collective efforts of the representatives of the countries who attended the inaugural meeting of the APPTEA in a workshop sponsored by UNESCO in 1986 in Manila. The pilot testing of this instrument was done in seven countries namely India, Korea, Malaysia, Philippines, Singapore, Thailand and Australia.

Questions 1, 2 and 3 asked about the total (net) force (whether up, down or no force) on a ball thrown straight up into the air at three positions: on the way up (after leaving the hand of the thrower) ; at the top of its flight ; and on the way down. After each question, a space was given for students to write their reasons in choosing their answer.

Questions 4 and 5 focused on a ball thrown up in a parabolic path. The students were

asked to consider “all the forces on the ball” at two positions - the ball at its highest point and the ball on its way down. In order to avoid student confusion on pull of gravity and push of gravity, the original six alternative responses were reduced to four, eliminating the choices that involve “push of gravity”. The alternative responses involved one or two of: “pull of gravity” ; “force of throw” ; “no force” . Students’ reasoning was also asked. The third part of questions 4 and 5 asked if there were other forces not shown in the choices.

Question 6 showed a bicycle being ridden with no brakes and no pedaling, but slowing down. Students were asked if there was a force on the bicycle, and to explain their answer.

Questions 7, 8, 9, 10 and 11 asked about the presence or absence of gravity in five situations : standing on the earth ; falling from an airplane ; standing on the moon; spaceman near a satellite ; and swimming underwater. In some of these cases, the perceived magnitude of any gravity was also probed.

Question 12 showed two equal blocks at rest on a pulley (Atwood’s machine) with the left hand block lower than the right hand block. Students were asked whether, one minute later, the blocks would be in the same position, or at the same height with each other, or if the right hand block would be lower. Their reasoning for their answer was also asked.

In all questions, line drawings were used to illustrate the situations. The final version of the instrument is shown in Appendix E.

A correct conception corresponds to a correct answer with correct reason. Students with misconceptions did not include those who did not express ideas, those who gave the correct answers but with no reasons, and those who gave the correct answers but restated their answers instead of giving their reasons.

Statistical Treatment. Frequency counts and percentages were used to present students' ideas and misconceptions in the situations involving force and gravity.

In determining the association between gender and the number of misconceptions found per situation, Fisher's Exact Test was utilized. The null hypothesis was tested at 0.05 level of significance. The same statistical test was used to determine whether there was a significant difference in the proportion of male and female students having misconceptions. To further validate the result of Fisher's Exact Test, a t-test was also used to determine significant differences between the number of misconceptions of male and female students, and between the proportion of male and female students having misconceptions.

Kendall's Coefficient of Concordance was calculated to determine agreement in the ranking of the number of misconceptions held according to school Physics background. The same statistical tool was also used to determine agreement in the ranking of the proportion of students having misconceptions according to school Physics background. The values of Kendall's coefficient of concordance range from 0 to 1 and is treated same way as coefficient of correlation. Higher values denote a stronger correlation. The chi-square statistic was used to test the significance of the Kendall's coefficient at the 0.05 level of significance.

RESULTS AND DISCUSSION

Data on students' ideas and beliefs about force and gravity were gathered with the use of the survey instrument consisting of 12 qualitative questions. The ideas and beliefs gathered were limited to the situations included in the survey and to the students' written responses. After a thorough collection, tabulation, and analysis of students' responses, the following results were obtained.

Students' Responses and Misconceptions. Questions 1, 2 and 3 in the survey asked about the total or net force on a ball thrown straight up into the air at three positions, namely: on the way up ; at the top of its flight ; and, on the way down. Tables 2, 3 and 4 summarize the students' responses to each of the three positions, and figures 1, 2 and 3 present a bar graph of these misconceptions. The data were derived from the students' responses but only the alternative ideas and beliefs were used. Correct responses, answers with no reasons, and inconsistent answers that did not provide a logical clue to students' thinking, were not presented in these graphs.

On ***question 1*** (the ball is on its way up), only 20 or 7% of the total number of students got the correct answer and correct reasons (see Table 2). Five students believed that the force is downward because "gravity pushes it down". Although the vocabulary used is not appropriate, this response was not considered to be a misconception in this study. The students who wrote this answer may only have a wrong choice of word for "push" when they actually meant "pull" of gravity. The respondents in the APPTEA research also presented an idea about "push of gravity".

A majority of the students (69%) thought that the total force is directed upward. This result is consistent with the findings of the APPTEA research in 1989 where a majority of the

students also answered the same thing. Ninety-nine students (or 59%) from the Physical Science group responded that the force is directed upward when the ball is on its way up, but were not able to reason out their conceptual belief. Some students based their response on the idea that the direction of motion is also the direction of the force. Others believed that the force from throw still existed when the ball was rising in the air.

Table 2. Students' Answers to Question 1 – If a ball is thrown straight up into the air, then the total force on the ball on its way up is a) down, b) up or c) zero?

Answers and Reasons	Middle School (n=86)		Physical Sci. (n=167)		Physics (n=35)		Overall (n=288)		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
A) Down	**7**	**7**	**25**	**15**	**10**	**7**	**42**	**29**	**71**
Reasons:									
*gravity pulls it down	5	3	0	0	7	4	12	7	19
*ball is decelerating	0	0	0	0	1	0	1	0	1
gravity pushes it down	0	2	0	0	2	1	2	3	5
ball is leaving the hand	2	1	0	0	0	0	2	1	3
ball will eventually fall	0	1	0	0	0	0	0	1	1
force is directed down	0	0	15	8	0	0	15	8	23
what goes up must come down	0	0	2	1	0	0	2	1	3
force is directed up(inconsistent)	0	0	3	5	0	0	3	5	8
don't know	0	0	0	0	0	1	0	1	1
no reason given	0	0	5	1	0	1	5	2	7
B) Up	**35**	**33**	**57**	**57**	**8**	**9**	**100**	**99**	**199**
Reasons:									
force from throw	15	10	0	0	3	4	18	14	32
force from throw is greater than gravity	0	0	0	0	2	0	2	0	2
ball is going up	18	20	0	2	2	5	20	27	47
gravity makes the ball go up	1	0	0	0	0	0	1	0	1
force is directed up	0	0	52	47	0	0	52	47	99
gravity makes the ball come down(inconsistent)	0	1	1	0	0	0	1	1	2
common sense	0	1	0	0	0	0	0	1	1
right answer	0	0	0	3	0	0	0	3	3
no reason given	1	1	4	5	1	0	6	6	12
c) Zero	**1**	**3**	**4**	**6**	**0**	**1**	**5**	**10**	**15**
Reasons:									
no force when the ball goes into the air	0	2	0	3	0	0	0	5	5
force of throw and gravity cancel	0	0	0	0	0	1	0	1	1
ball will stop at its peak	1	0	2	2	0	0	3	2	5
don't know	0	1	0	0	0	0	0	1	1
no reason given	0	0	2	1	0	0	2	1	3
No Answer Given	**0**	**0**	**1**	**2**	**0**	**0**	**1**	**2**	**3**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* Correct answers

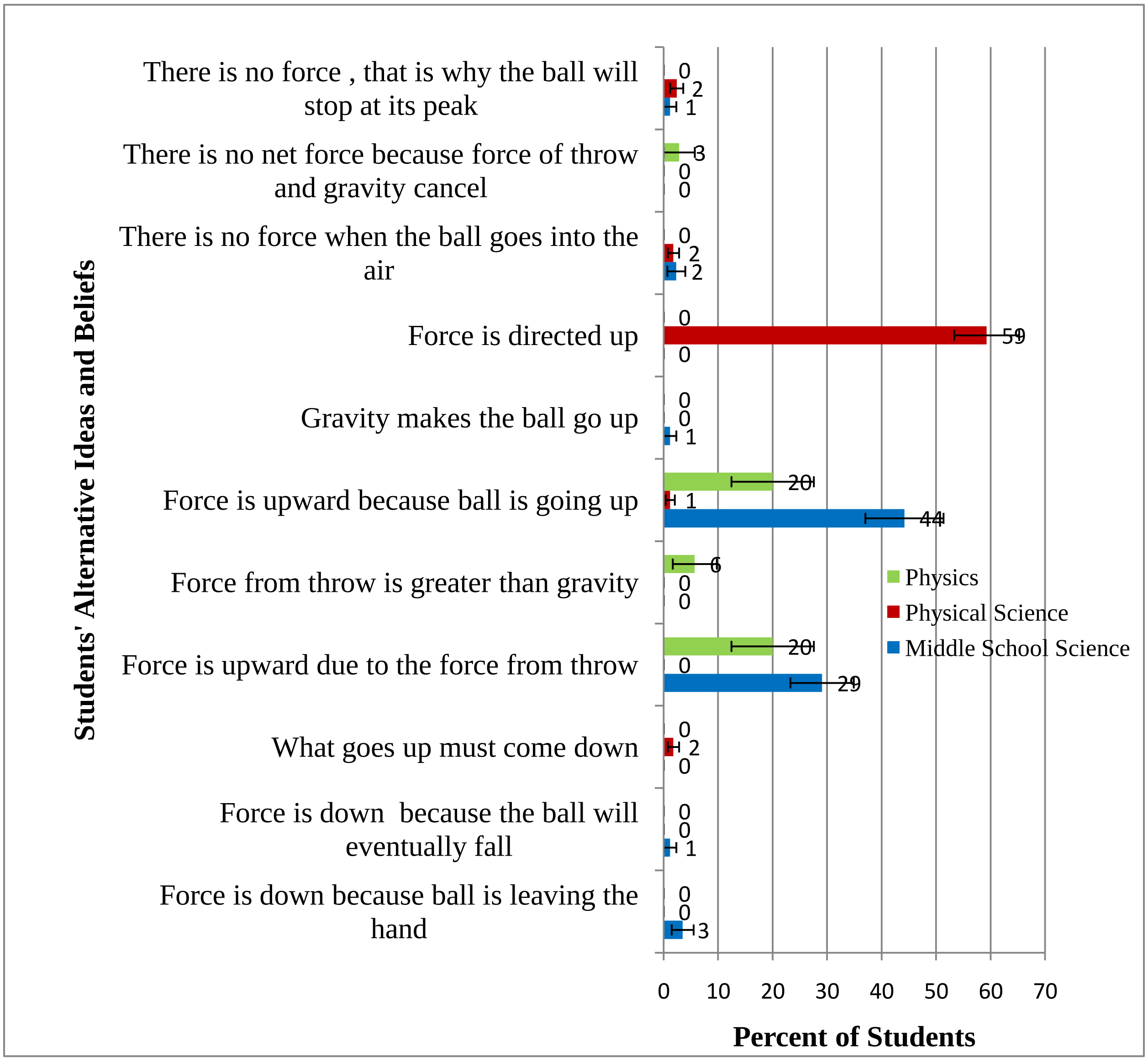

Figure 1. Alternative Ideas of Students on the Total Force on a Ball Thrown Vertically While Rising.

Figure 1 shows the misconceptions held by the students. The idea that the direction of motion is also the direction of force, and the idea that the force of throw is still in the ball on its way up, are dominant misconceptions among students with Middle School Science background and students with Physics background.

Students who answered that there is no force when the ball is going up, believed that there is no force when the ball is in the air. Some believed that gravity and force of throw cancel,

and a few reasoned out that the ball will eventually stop on top because there are no forces acting on it.

Table 3. Students' Answers to Question 2 – If a ball is thrown straight up into the air, then the total force on the ball just at the top of its flight is a) down , b) up or c)zero?

Answers and Reasons	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Total**
A) Down	**9**	**11**	**16**	**26**	**7**	**7**	**32**	**44**	**76**
Reasons:									
*gravity pulls it down	2	2	0	0	6	4	8	6	14
*the ball is accelerating down	0	0	0	0	1	3	1	3	4
gravity pushes it down	3	0	0	0	0	0	3	0	3
mass of the ball makes it go down	1	0	0	0	0	0	1	0	1
force is directed down	0	0	13	18	0	0	13	18	31
what goes up must come down	0	0	0	3	0	0	0	3	3
ball starts to come down	3	8	0	0	0	0	3	8	11
it's the right answer	0	0	0	2	0	0	0	2	2
no reason given	0	1	3	3	0	0	3	4	7
B) Up	**3**	**6**	**14**	**13**	**0**	**0**	**17**	**19**	**36**
Reasons:									
ball is up in the air	3	3	1	0	0	0	4	3	7
force is directed up	0	0	7	8	0	0	7	8	15
ball will come down(inconsistent)	0	2	0	0	0	0	0	2	2
no reason given	0	1	6	5	0	0	6	6	12
c) Zero	**31**	**25**	**55**	**38**	**11**	**10**	**97**	**73**	**170**
Reasons:									
ball stops on top of its flight	12	12	35	8	8	5	55	25	80
gravity didn't force it down yet	1	0	1	1	0	0	2	1	3
force of throw has run out	3	1	0	0	0	0	3	1	4
getting ready to go down	1	0	0	1	0	0	1	1	2
no force on top of flight	14	9	10	22	0	0	24	31	55
has potential energy on top	0	1	0	0	0	0	0	1	1
ball is weightless at the top	0	0	1	0	0	0	1	0	1
ball loses momentum at the top	0	0	1	0	0	0	1	0	1
force of throw and gravity balance	0	1	0	0	3	4	3	5	8
the right answer	0	0	0	1	0	0	0	1	1
don't know	0	0	0	0	0	1	0	1	1
no reason given	0	1	7	5	0	0	7	6	13
No Answer Given	**0**	**1**	**2**	**3**	**0**	**0**	**2**	**4**	**6**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* Correct answers

Table 3 reveals the students responses on ***question 2***, which asks about the total force on the ball when it is just at the top of its flight. Seventy-six or 26% of the students answered that the force was downward, but only 18 or 6% supported their answers with correct reasons.

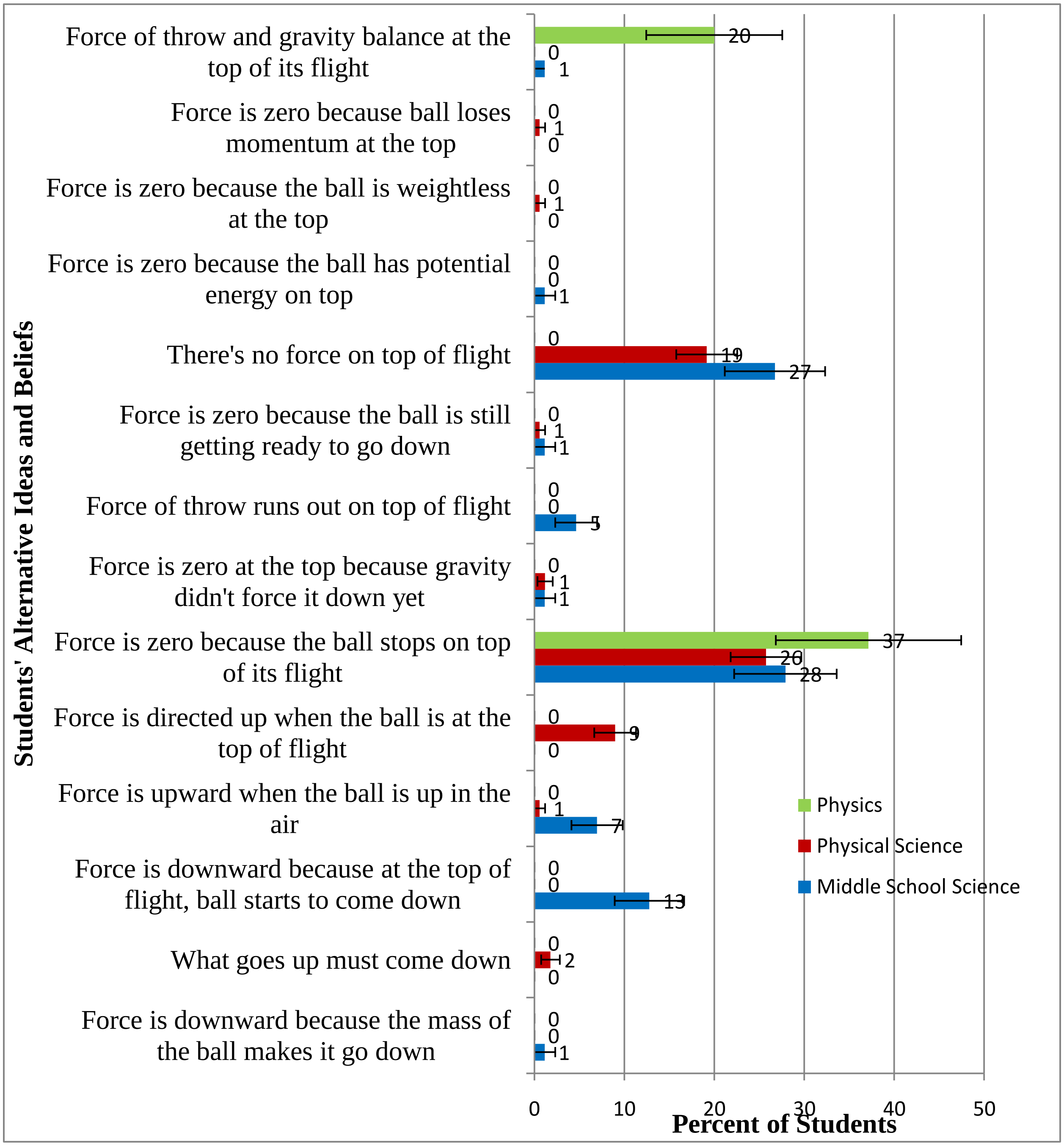

Figure 2. Alternative Ideas of Students on the Total Force on a Ball Thrown Vertically at the Top of its Flight.

Figure 2 shows a comparison of the misconceptions held by each group of students. The most common misconception for all the three groups (28% of Middle School Group, 26% of Physical Science Group, and 37 % of the Physics group) is that “the force is zero because the ball stops on top of its flight”. The students thus believed that there is no force when there is no motion. This very persistent misconception exists in higher percentage of students who had received advanced Physics instruction in the Physics group. Twenty-seven percent of the Middle School group and 19% of the Physical Science group believed that there is no force on top of flight, but they did not provide an explanation for their belief. Among the Physics group, 20% believed that there is no force at the top of the ball’s flight because the force of throw and gravity balance at that point. This probably comes from the idea that when the ball is momentarily at rest at the top of its flight, it is in instantaneous positional equilibrium, and there must therefore be a balance of forces.

On ***question 3***, which asks for the total force on the ball on its way down, 233 or 81% answered that the total force is downward, but only 54 or 19% answered with correct reasons (see table 4). The majority (53%) of the Middle school students answered that the “force is downward because the motion is downward”. Five percent from the Physical Science group and 17% from the Physics group also answered the same. This is another persistent and common misconception (Driver, 1994). Nine percent of the Physics group believed that the force is upward because of air resistance. Other misconceptions include “no force when the ball is in the air by itself”, “no force when falling”, “force is up when ball is coming down”, “force on the ball is pressured down”, and “there’s a force above the ball that pushes it down”. The responses “the force of the ball is pulling it down” and “force is downward because gravity is greater than the force of the ball” is indicative of students’ belief that the ball has a motive force. Table 4

presents the answers provided by the students and figure 3 presents the misconceptions and a comparison of the percent of students from each group having those misconceptions.

Table 4. Students' Answers to Question 3 – If a ball is thrown straight up into the air, then the total force on the ball on its way down is a) down , b) up or c) zero?

Answers and Reasons	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
A) Down	**40**	**36**	**66**	**59**	**16**	**16**	**122**	**111**	**233**
Reasons:									
*gravity pulls it down	16	5	5	8	9	9	30	22	52
*ball is accelerating down	0	0	0	0	2	0	2	0	2
gravity pushes it down	2	1	3	2	1	2	6	5	11
ball goes down so force is down	21	25	0	9	3	3	24	37	61
force of the ball is pulling it down	1	0	0	2	0	0	1	2	3
gravity is stronger than force of the ball	0	1	0	0	1	0	1	1	2
a force above will push it down	0	1	0	0	0	0	0	1	1
force on the ball is pressured down	0	1	0	0	0	0	0	1	1
force is directed down	0	0	52	28	0	0	52	28	80
the right answer	0	0	0	3	0	0	0	3	3
common sense		1	0	0	0	2	0	3	3
no reason given	0	1	6	7	0	0	6	8	14
B) Up	**2**	**2**	**8**	**4**	**2**	**1**	**12**	**7**	**19**
Reasons:									
when it's coming down, force is up	0	1	0	3	0	0	0	4	4
air resistance	0	0	0	0	2	1	2	1	3
inconsistent reasons	2	0	2	3	0	0	4	3	7
don't know	0	1	0	0	0	0	0	1	1
no reason given	0	0	2	2	0	0	2	2	4
c) Zero	**1**	**5**	**10**	**13**	**0**	**0**	**11**	**18**	**29**
Reasons:									
no force when falling	0	3	5	7	0	0	5	10	15
ball is in the air by itself	0	2	0	0	0	0	0	2	2
inconsistent reasons	1	0	3	3	0	0	4	3	7
don't know	0	0	0	0	0	0	0	0	0
no reason given	0	0	2	3	0	0	2	3	5
No Answer Given	**0**	**0**	**7**	**0**	**0**	**0**	**7**	**0**	**7**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* Correct answers

Figure 3 shows the dominant misconception that the direction of motion is also the direction of force. This is a widely-known misconception (Driver, 1994) and is also consistent

with the findings in the APPTEA research (1989). The APPTEA research found that 86% of the Asia-Pacific students jointly believed in the presence of the force of throw and that the direction of motion is also the direction of the force.

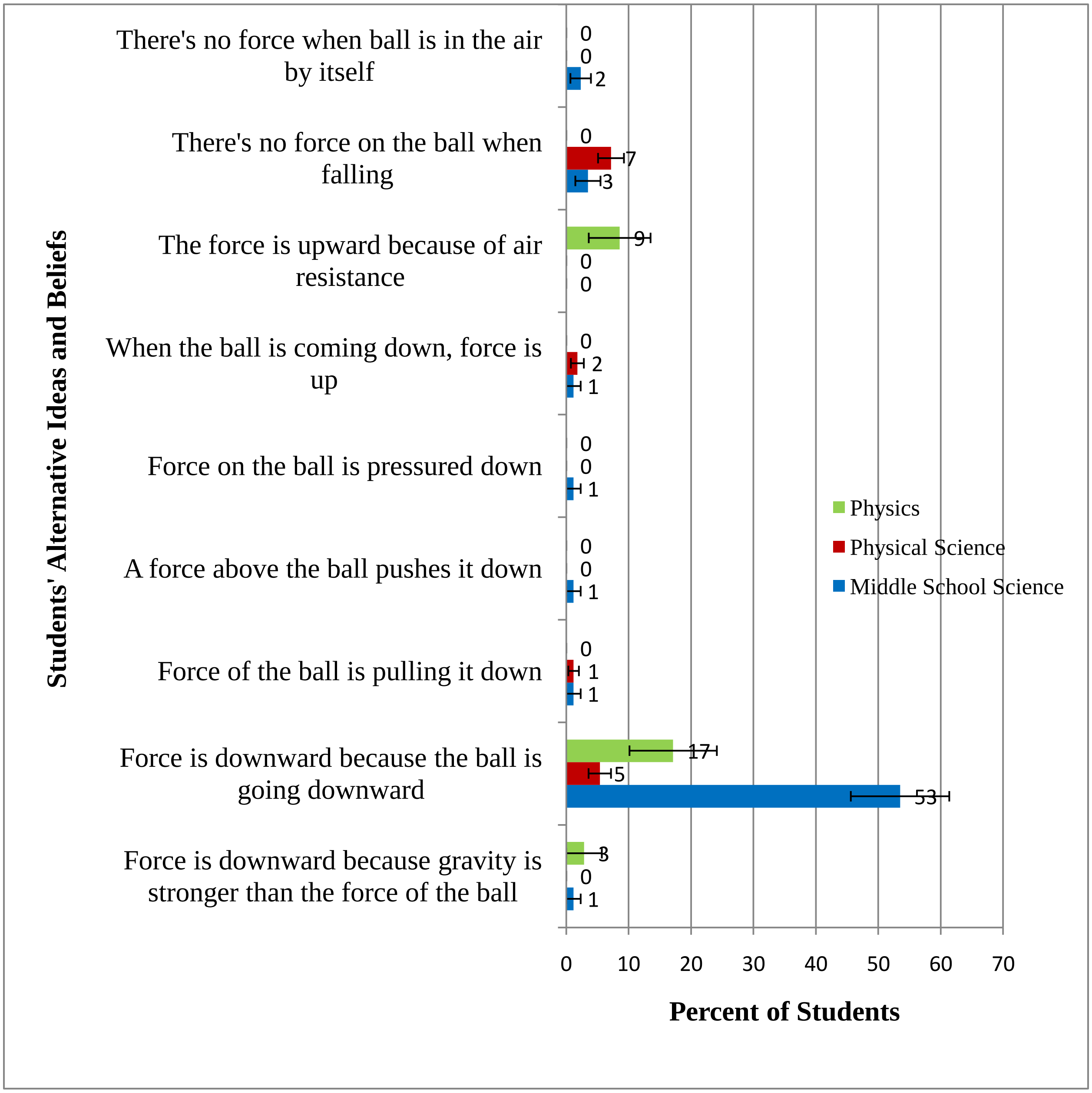

Figure 3. Alternative Ideas of Students on the Force on a Ball Falling Vertically

Table 5 presents the students' responses to ***question 4***, which asks about the total force on a ball thrown obliquely at the top of its parabolic path. It can be seen from the table that only 20 students or 7% answered and reasoned correctly.

Table 5. Students' Answers to Question 4 – If a ball is thrown obliquely to travel along a parabolic path, what forces act on the ball at its highest point?

Answers and Reasons	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
A) Pull of Gravity	**1**	**4**	**12**	**7**	**4**	**1**	**17**	**12**	**29**
Reasons:									
*only gravity acts on the ball	1	2	7	5	2	1	10	8	18
* ball has already left the hand	0	0	0	0	1	0	1	0	1
*throw is no longer a force after leaving the hand	0	0	0	0	1	0	1	0	1
inconsistent/no reason given	0	2	5	2	0	0	5	4	9
B) Force of Throw	**6**	**12**	**8**	**18**	**2**	**1**	**16**	**31**	**47**
Reasons:									
no gravity at the highest point	0	1	0	0	0	0	0	1	1
only force of throw exists at the highest point	5	11	4	10	2	1	11	22	33
inconsistent/no reason given	1	0	4	8	0	0	5	8	13
c) Pull of Gravity + Force of Throw	**27**	**23**	**57**	**35**	**11**	**12**	**95**	**70**	**165**
Reasons:									
force of throw combines with gravity	25	21	16	10	0	0	41	31	72
the force has horizontal and vertical components	0	0	17	7	5	10	22	17	39
inconsistent/no reason given	2	2	24	18	6	2	32	22	54
D) No Force	**9**	**4**	**7**	**14**	**1**	**3**	**17**	**21**	**38**
No Answer Given	**0**	**0**	**3**	**6**	**0**	**0**	**3**	**6**	**9**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* correct answers

It can be seen from the table above that 165 or 58% of the students believed that the force of gravity and the force of the throw both act on the ball when it is at the top of its flight. When the number of students answering b (force of throw) and c (gravity +force of throw) are combined together, this sums up to 212 or 74 % of students who believed that the force of the throw is still present on the ball. In the APPTEA research, 78% of the younger students (15-16 y/o) and 71% of the older students (17-18 y/o), or 75% of all the students also believed in the

presence of the "force of throw". This conceptual belief coincides with the Impetus Theory (as cited by Halloun and Hestenes, 1985) which was formulated in the 14th century.

A detailed comparison of students' misconceptions and percent of students per group having the misconceptions is presented in figure 4.

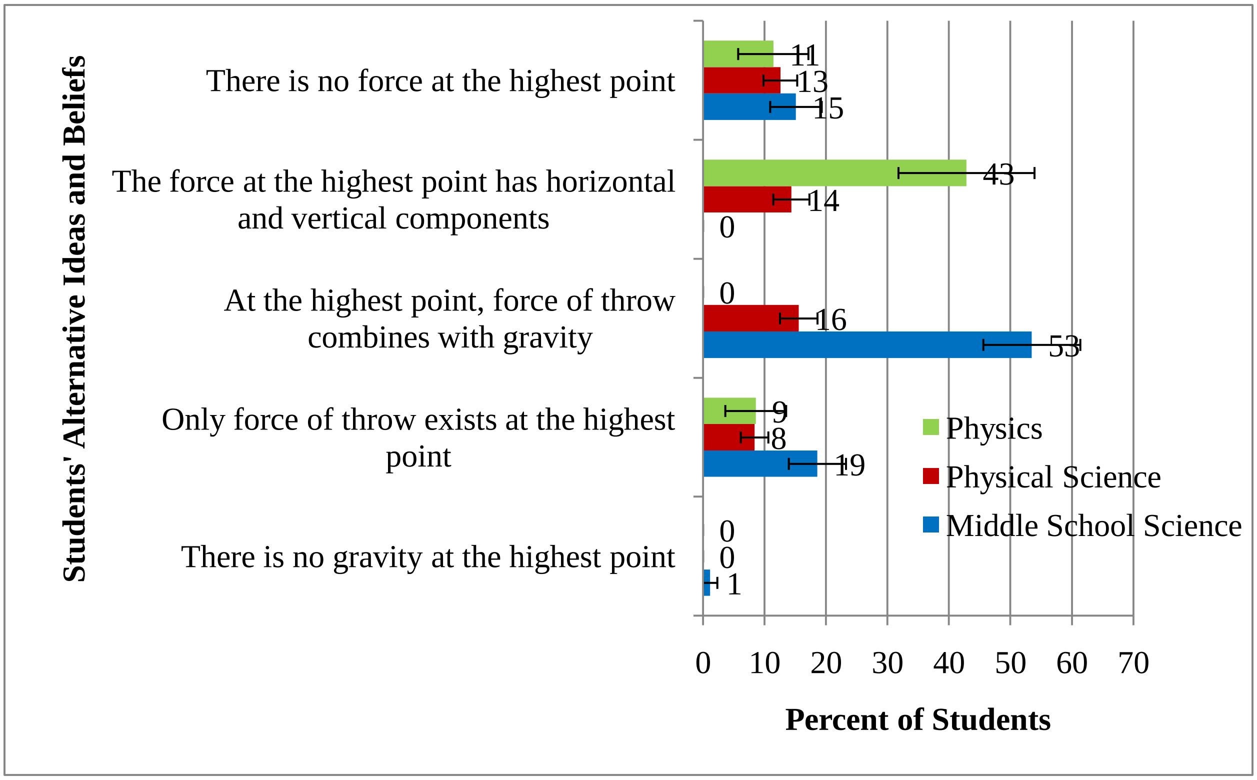

Figure 4. Alternative Ideas of Students on the Force on a Ball at the Top of its Parabolic Path.

Figure 4 shows that the misconception on the presence of the "force of throw" is more common among the Middle School group (total of 72%) and decreases to 24% among the Physical Science group, and to 9% among the Physics group. It noted however, that 43% of the Physics group believed that the force at the highest point has horizontal and vertical components. Since they had received more advanced Physics instruction, their knowledge of vectors and the horizontal and vertical components of velocity in projectile motion has probably caused

confusion with the concept of force. Some students also believed that “there is no force at the highest point” of a parabolic path.

Table 6. Students’ Answers to Question 5 – If a ball is thrown obliquely to travel along a parabolic path, what forces act on the ball when it is coming down?

Answers and Reasons	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
A) Pull of Gravity	**10**	**6**	**17**	**24**	**7**	**2**	**34**	**32**	**66**
Reasons:									
*only gravity acts on the ball on its way down	7	4	10	15	7	2	24	21	45
*force of throw is over after leaving the hand	2	1	0	0	0	0	2	1	3
inconsistent/no reason given	1	1	7	9	0	0	8	10	18
B) Force of Throw	**9**	**14**	**21**	**17**	**0**	**0**	**30**	**31**	**61**
c) Pull of Gravity + Force of Throw	**23**	**19**	**40**	**23**	**11**	**15**	**74**	**57**	**131**
D) No Force	**0**	**4**	**5**	**7**	**0**	**0**	**5**	**11**	**16**
No Answer Given	**1**	**0**	**4**	**9**	**0**	**0**	**5**	**9**	**14**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* Correct answers

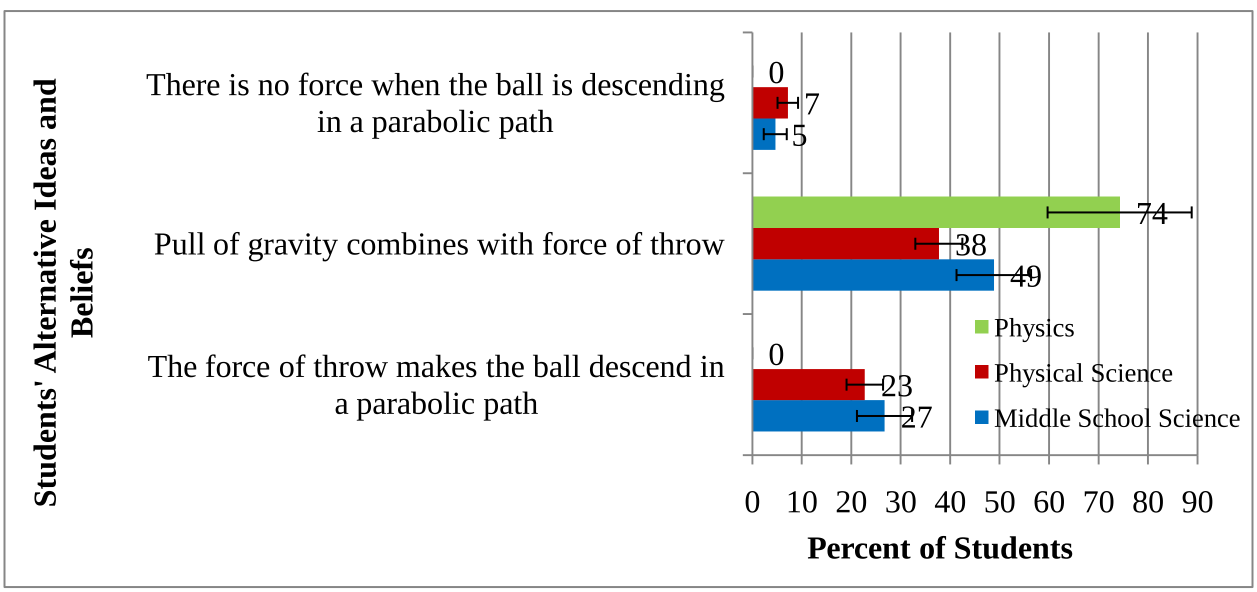

Figure 5. Alternative Ideas of Students on the force on a Ball in a Parabolic Path While Descending.

Question 5 asks about the forces that act on the ball (described in question 4) when the ball is on its way down along a parabolic path. Table 6 reveals the students' responses.

There were 66 or 23% of the total number of students who claimed that only the pull of gravity acts on the ball when it is coming down. However, only 48 or 17% provided consistent reasons. As in the case of question 4, a majority (67%) of the students believed that the force of throw was still acting on the ball, either alone or combined with gravity. This is again consistent with the APPTEA research where 62% of all the respondents believed in the presence of force of throw. A visual comparison of the misconceptions is shown in figure 5.

Table 7. Students' Responses to Second Part of Questions 4 and 5 - If a ball is thrown obliquely to travel along a parabolic path, are there other forces acting on the ball aside from those given in the options?

Answers	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
Question 4									
*Yes, air resistance	2	0	0	0	4	4	6	4	10
Yes, upward force	3	4	1	0	1	0	5	4	9
Yes, diagonal force	1	1	0	0	0	0	1	1	2
Yes, weight of the ball	0	1	0	0	0	0	0	1	1
Yes, (no reason given)	0	0	17	9	0	0	17	9	26
No	37	35	60	52	0	13	97	100	197
No answer given	0	2	9	19	0	0	9	21	30
Question 5									
*Yes, air resistance	0	0	0	0	6	2	6	2	8
Yes, upward force	0	2	0	1	0	0	0	3	3
Yes, (no reason given)	0	0	9	5	0	0	9	5	14
No	38	38	62	54	12	15	112	107	219
No answer given	5	3	16	20	0	0	21	23	44

* Correct answer

Table 7 reveals that only 10 out of 288 students recognize air resistance as another force acting on the ball while it is at the top of its parabolic path. For question 5, only 8 recognized it as a force that should be included.

Question 6 asks about the force on a bicycle when brakes and pedals are not used and the bicycle is slowing down. Out of the 288 students, only 46 or 16% answered correctly and with correct reasons. One hundred twenty-three of the students also agreed that there is a force on the bicycle but they provided no or wrong explanation.

Table 8 provides the detailed data on students' responses to question 6. The misconceptions involving this situation are also summarized and compared per group in a bar graph (figure 6).

Table 8. Students' Answers and Reasons to Question 6 – Is there a force on the bicycle if the person riding it is not using the brakes or pedals but the bicycle is slowing down?

Answers and Reasons	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
YES with correct reason	**6**	**3**	**12**	**5**	**12**	**8**	**30**	**16**	**46**
Reasons:									
*friction	5	1	7	5	10	6	22	12	34
*air resistance	1	2	5	0	2	2	8	4	12
YES with incorrect reason	**22**	**19**	**21**	**22**	**6**	**7**	**49**	**48**	**97**
Reasons:									
force used to speed up is still there	9	8	0	0	0	0	9	8	17
still moving so there's force	4	4	8	12	3	0	15	16	31
inertia	0	2	0	1	0	0	0	3	3
gravity	7	5	13	9	2	5	22	19	41
normal reaction	2	0	0	0	0	0	2	0	2
inconsistent reason	0	0	0	0	1	2	1	2	3
YES, no explanation given	**3**	**0**	**15**	**8**	**0**	**0**	**18**	**8**	**26**
NO	**8**	**20**	**35**	**36**	**0**	**2**	**43**	**58**	**101**
Reasons:									
no pedalling and/or no brakes	1	12	0	0	0	0	1	12	13
slowing down	4	5	7	3	0	2	11	10	21
tires are just rolling	1	0	0	0	0	0	1	0	1
no pressure applied on the bike	0	1	0	0	0	0	0	1	1
inertia caused the motion	0	1	0	0	0	0	0	1	1
inconsistent reasons	2	1	11	17	0	0	13	18	31
no force (restatement)	0	0	9	11	0	0	9	11	20
no reason given	0	0	8	5	0	0	8	5	13
							0	0	0
No answer given	**4**	**1**	**4**	**9**	**0**	**0**	**8**	**10**	**18**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* Correct answers

It is observed from figure 6 that 26% of the Physics group believed that gravity slows down the bicycle, together with 13% and 14% of the Middle School and Physical Science groups respectively. Twenty percent of the Middle School group also believed that the force used to speed up is still present. Students also reasoned out that there is force on the bicycle since it is still moving. Students argued that there's no force because there's no pedaling and no brakes applied, because it is slowing down, because tires are just rolling, and because inertia just caused the motion. Others also believed that inertia and normal force slowed it down. Three of these were found similar to the misconceptions found in the APPTEA research, namely: force used to speed up is still there; there's a force because it is still moving; and, there's no force because it is slowing down.

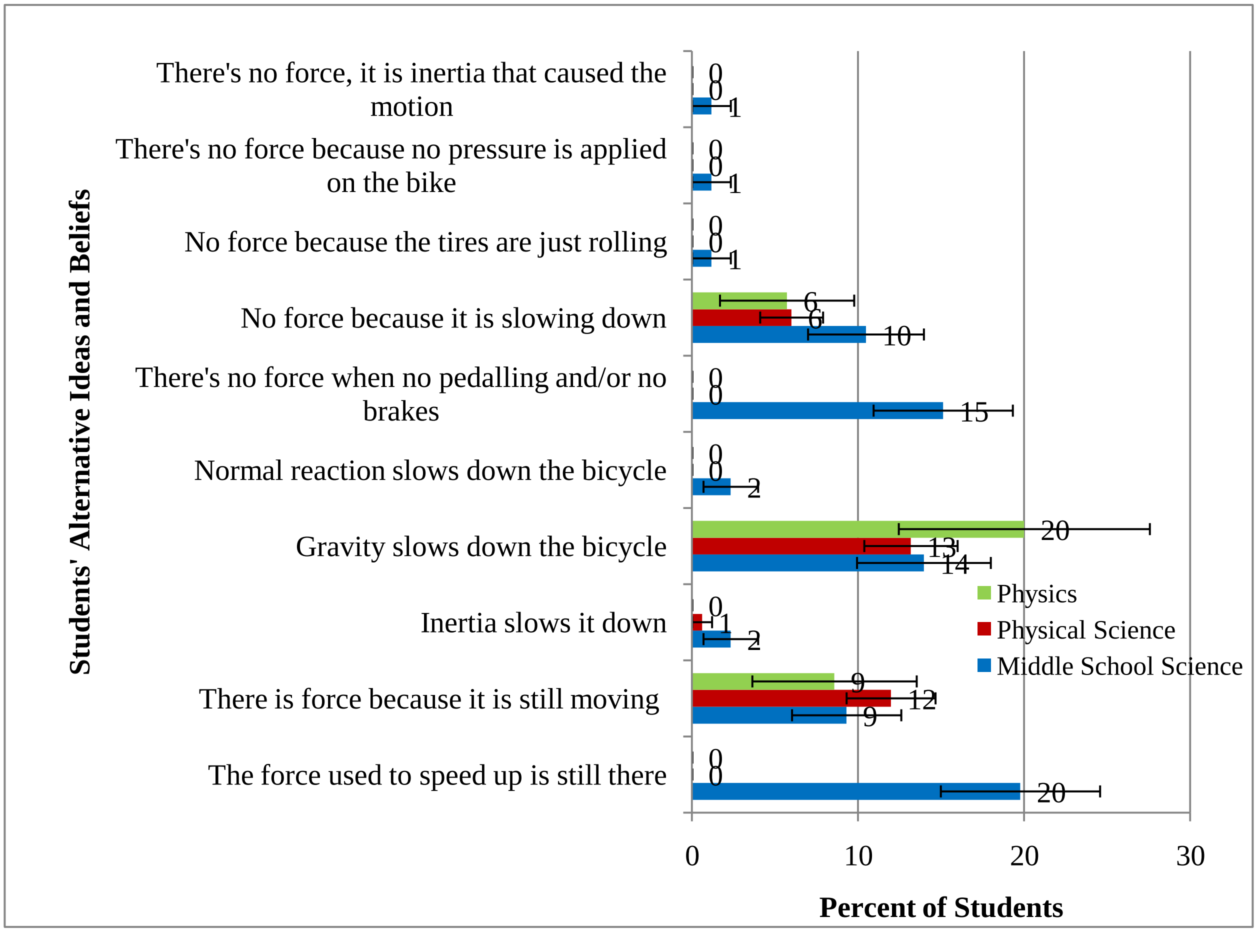

Figure 6. Alternative Ideas of Students on the Forces on a Bicycle That is Slowing Down

Table 9. Students' Answers and Reasons to Question 7 – Is there gravity when you are standing on the earth?

Answers and Reasons	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
YES with consistent reason	**35**	**31**	**57**	**55**	**15**	**15**	**107**	**101**	**208**
Reasons:									
*gravity keeps us standing on earth	26	24	38	35	9	9	73	68	141
*gravity keeps us from floating	7	6	19	20	6	6	32	32	64
*mass of earth causes gravity	2	0	0	0	0	0	2	0	2
*you have weight	0	1	0	0	0	0	0	1	1
YES with incorrect/inconsistent reason	**0**	**2**	**1**	**0**	**3**	**0**	**4**	**2**	**6**
Reasons:									
there's gravity because of the air	0	2	1	0	0	0	1	2	3
gravity pushes you down	0	0	0	0	3	0	3	0	3
YES with no reason given	**6**	**1**	**14**	**6**	**0**	**2**	**20**	**9**	**29**
NO	**2**	**9**	**8**	**12**	**0**	**0**	**10**	**21**	**31**
Reasons:									
no gravity when you're not moving	0	2	0	0	0	0	0	2	2
no gravity when you're just standing	1	5	2	3	0	0	3	8	11
earth's atmosphere	0	0	0	2	0	0	0	2	2
inconsistent reasons	1	0	0	1	0	0	1	1	2
no reason given	0	2	6	6	0	0	6	8	14
							0	0	0
No answer given	**0**	**0**	**7**	**7**	**0**	**0**	**7**	**7**	**14**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* Correct answers

Questions 7 to 11 were aimed to determine students' ideas about gravity at various locations. ***Question 7***, which asks about gravity when someone is standing on earth, had the greatest percentage of students getting the correct answer. A total of 208 students or 72% answered correctly with consistent reasons. The consistent idea about the gravity of the earth that "pushes" you down persists for three or 9% of the Physics group. There are also noted misconceptions about gravity when standing on earth. Figure 7 provides a summary of those misconceptions as well as a comparison of the percentage of students from each group who had each of those misconceptions.

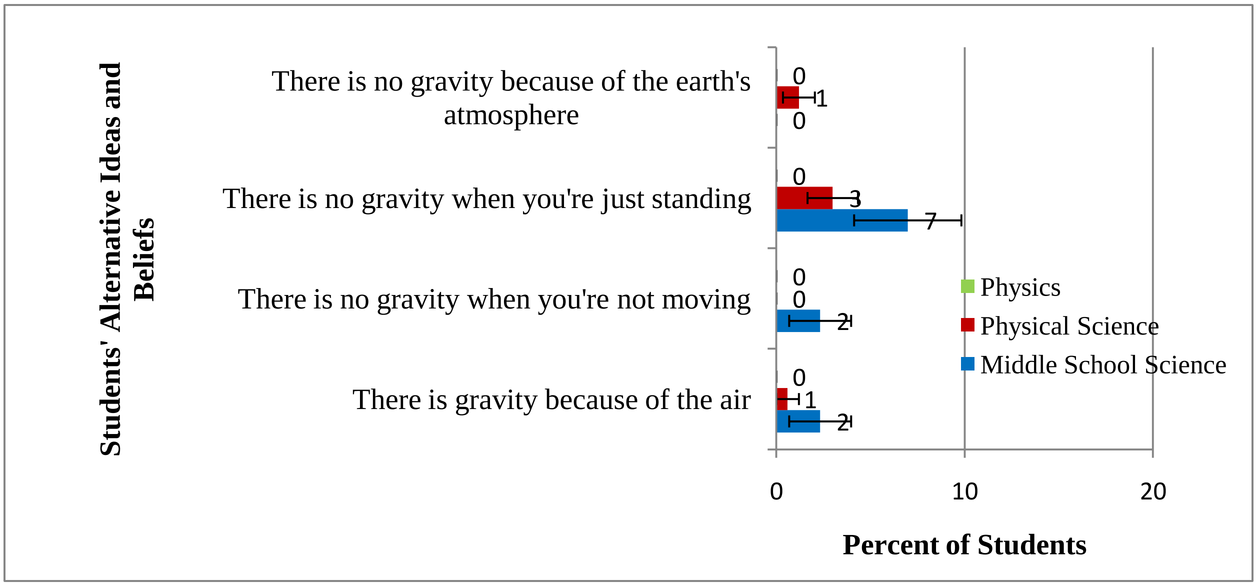

Figure 7. Alternative Ideas of Students on Gravity When Standing on Earth

Students who answered that there is no gravity claimed that there is no gravity when you're just standing, when you're not moving, and no gravity because of the earth's atmosphere. One student from the Physical Science group and 2 students from the Middle School Science group believed that there is gravity when you are standing on earth because of the air.

Q***uestion 8***, with a drawing of a person falling from an airplane, asked whether or not gravity was present. There were four alternatives given: gravity present was "the same", "much less", or "much more" than on the ground; and "no gravity". Table 10 shows the number of students who answered each of the alternatives given, together with their reasons.

Eighty-two students answered that gravity is about the same as on the ground. However, only 60 or 21% gave correct reasons. The misconceptions are presented in figure 8.

A total of 16 misconceptions were found for question 8. Similar to the previous research by APPTEA, the most common response was that "gravity is much more than on the ground". Students who answered this presented the following reasons: "gravity pulls more when falling"; "gravity increases at high altitudes"; "the weight of the person adds to gravity", "the force of

the wind adds to gravity", "gravity on your back pushes you down", "higher pressure at higher altitude makes gravity greater, and "gravity is greater which makes you fall faster as you hit the ground".

Table 10. Students' Answers and Reasons to Question 8 – If someone falls from an airplane, is there any gravity?

Answers and Reasons	**Middle School (n=86)**		**HS Physical Sci. (n=167)**		**HS Physics (n=35)**		**Overall (n=288)**		
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Total**
A) Yes, about the same as on the grou	**12**	**7**	**20**	**25**	**11**	**7**	**43**	**39**	**82**
Reasons:									
*gravity is constant here/near earth	9	5	12	16	9	7	30	28	58
*little change in gravity for this altitude	0	0	0	0	2	0	2	0	2
he is falling(restatement)	1	0	3	3	0	0	4	3	7
gravity slows down the aeroplane	0	1	0	0	0	0	0	1	1
no reason given	2	1	5	6	0	0	7	7	14
B) Yes, but much less than on ground	**11**	**10**	**15**	**17**	**3**	**2**	**29**	**29**	**58**
Reasons:									
gravity decreases with altitude	4	2	0	0	3	2	7	4	11
air is pushing against gravity	1	0	0	0	0	0	1	0	1
less gravity when falling	2	5	11	5	0	0	13	10	23
sky has no gravity	1	0	0	0	0	0	1	0	1
gravity is less in air	0	0	2	6	0	0	2	6	8
no reason given	3	3	2	6	0	0	5	9	14
C) Yes, but much more than on groun	**16**	**21**	**37**	**21**	**4**	**7**	**57**	**49**	**106**
Reasons:									
gravity pulls more when falling	8	10	13	6	0	5	21	21	42
weight of the person adds to gravity	1	0	0	0	0	0	1	0	1
gravity increases at high altitudes	1	2	0	0	4	2	5	4	9
force of wind adds to gravity	1	2	0	2	0	0	1	4	5
gravity on your back pushes you down	0	2	0	0	0	0	0	2	2
gravity makes you fall faster from higher altitude	2	2	0	0	0	0	2	2	4
higher pressure at higher altitude	0	0	1	1	0	0	1	1	2
gravity is less in air(inconsistent)	0	0	12	8	0	0	12	8	20
no reason given	3	3	11	4	0	0	14	7	21
D) No, there is no gravity	**3**	**5**	**9**	**7**	**0**	**0**	**12**	**12**	**24**
Reasons:									
no gravity when falling	0	5	3	3	0	0	3	8	11
weightless when falling	1	0	2	0	0	0	3	0	3
no force to keep the person stay in air	1	0	1	2	0	0	2	2	4
no reason given	1	0	3	2	0	0	4	2	6
NO answer given	**1**	**0**	**6**	**10**	**0**	**1**	**7**	**11**	**18**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* Correct answers

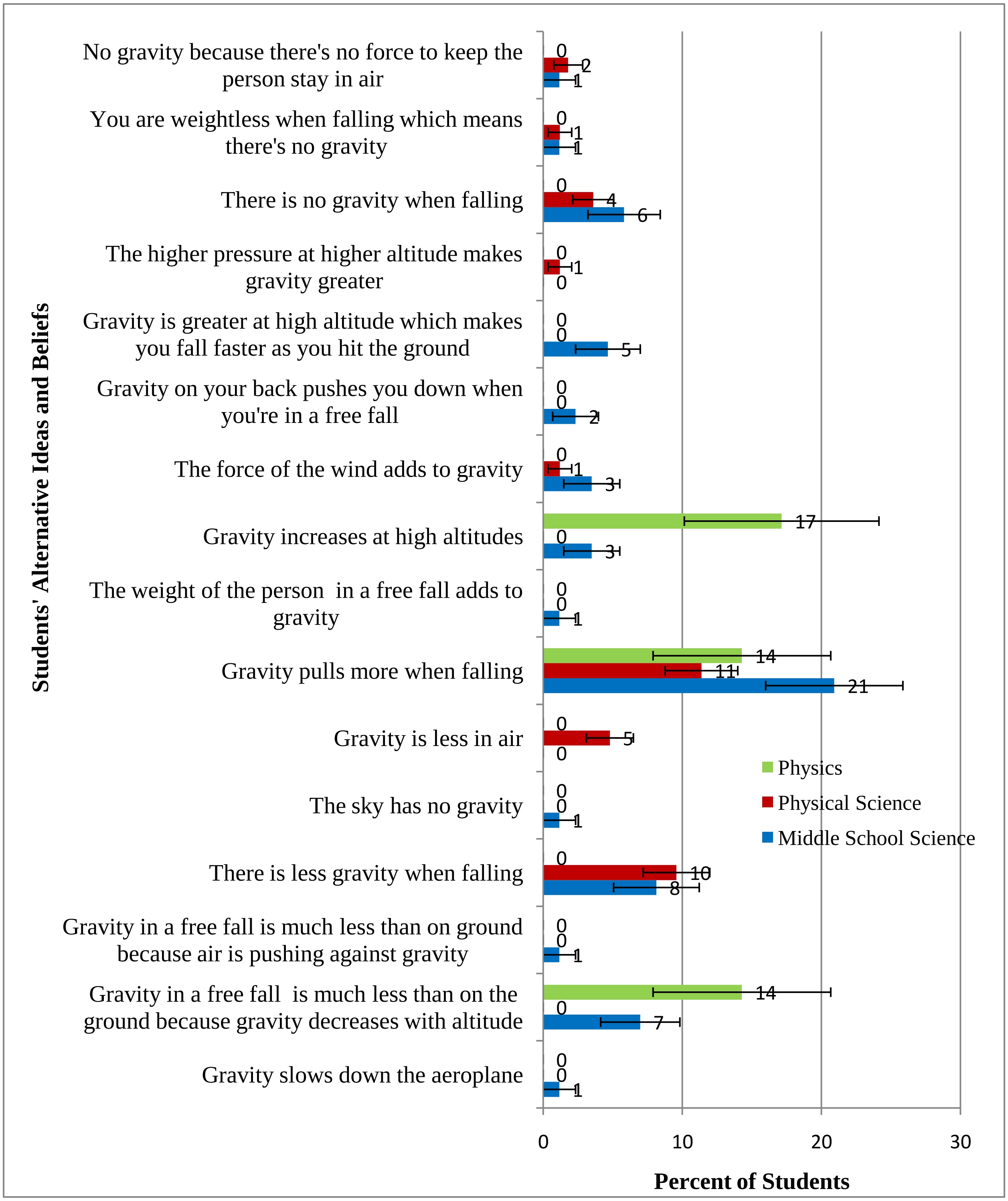

Figure 8. Alternative Ideas of Students on Gravity in a Free Fall

Seven percent of the Middle School group and 14% of the Physics group believed that gravity in a free fall from an airplane is much less than on the ground because gravity decreases

with altitude. Just like the respondents in the APPTEA research, this is an indication of a blind application of a learned fact. The students didn't realize that it takes extraordinary altitude (about 32,000 m) to have a 1% decrease in gravitational force (Gunstone, et.al., 1989). This is supported by a research by Ruggiero, et.al. (as cited by Driver,1994) who found that students who hold the view that gravity decreases with height tend to expect a far bigger decrease in the force of gravity with increases in height than is actually the case.

A small portion of the students believed that "there is no gravity when falling", that "you're weightless when falling, so there's no gravity", and that "there's no gravity because there is nothing to keep the person stay in air".

On ***question 9***, students were asked if there is gravity on the moon and how, if any, would the moon's gravity compare with earth's gravity. Seventy-six or 26% of the students answered correctly with
consistent reasons. In the previous research, 44 % of the respondents got the correct answer and reasoning. One hundred twenty-nine or 45% of the students believed that there is no gravity on the moon. This number consists of 44% of the Middle School Science group, 47% of the Physical Science group and 11% of the Physics group. A detailed distribution of students' responses is presented in table 11, and a comparison of the misconceptions is found in figure 9.

A dominant misconception is the notion that there is no gravity on moon. A total of 129 or 45% of the students were found to have this misconception. Students who answered that there is no gravity on moon based their answer on ideas such as "man floats on moon", "no gravity in outer space", "no atmosphere on moon" , "weightless on moon", and "only earth has gravity". Seven percent of the Middle School group suggested that there is less gravity on moon because it

is difficult to walk. A variety of other misconceptions were given by a small number of students. Figure 9 shows all those misconceptions.

Table 11. Students' Answers and Reasons to Question 9 – If someone is standing on the moon, is there any gravity?

Answers and Reasons	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
A) Yes, but much more than earth	**6**	**6**	**7**	**12**	**0**	**0**	**13**	**18**	**31**
Reasons:									
the higher you go, the more gravity	2	2	0	0	0	0	2	2	4
more gravity in outer space	1	1	0	0	0	0	1	1	2
moon has more gravity than earth	1	1	5	9	0	0	6	10	16
no reason given	2	2	2	3	0	0	4	5	9
B) Yes, about the same as on earth	**0**	**1**	**3**	**7**	**0**	**0**	**3**	**8**	**11**
Reasons:									
moon and earth have same gravity	0	1	1	4	0	0	1	5	6
no reason given	0	0	2	3	0	0	2	3	5
C) Yes, but much less than on earth	**20**	**12**	**28**	**18**	**16**	**8**	**64**	**38**	**102**
Reasons:									
*moon has less mass than earth	3	0	2	3	3	0	8	3	11
*objects weigh less on moon because of less gravity	8	6	20	10	13	8	41	24	65
moon has no atmosphere, so less gravity	1	0	0	0	0	0	1	0	1
difficult to walk on moon	5	1	0	0	0	0	5	1	6
earth is harder, so more gravity than moon	0	1	0	0	0	0	0	1	1
moon is far from earth	0	1	0	0	0	0	0	1	1
heavy uniform pulls them down on moon	0	1	0	0	0	0	0	1	1
moon has smaller orbit	0	0	0	1	0	0	0	1	1
no reason given	3	2	6	4	0	0	9	6	15
D) No, there is no gravity	**17**	**24**	**44**	**34**	**2**	**8**	**63**	**66**	**129**
Reasons:									
no gravity on moon	9	14	28	26	1	3	38	43	81
no gravity in outer space	3	2	0	0	0	3	3	5	8
man floats on moon	1	3	2	3	0	0	3	6	9
weightless on moon on moon	1	2	0	0	0	0	1	2	3
only earth has gravity	0	1	0	0	0	0	0	1	1
no atmosphere on moon	0	1	5	0	0	0	5	1	6
that's what i learned	0	0	0	0	1	2	1	2	3
no reason given	3	1	9	5	0	0	12	6	18
NO answer given	**0**	**0**	**5**	**9**	**0**	**1**	**5**	**10**	**15**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* Correct answers

Among the 12 questions in the survey, question 9 has the longest list of misconceptions. Similar misconceptions in small percentages were also found in the APPTEA research. Also in relation to the result of this study, Stead and Osborne (as cited by Driver, 1994) found that 44% of the 258 13-year old kids believed that there is no gravity on the moon.

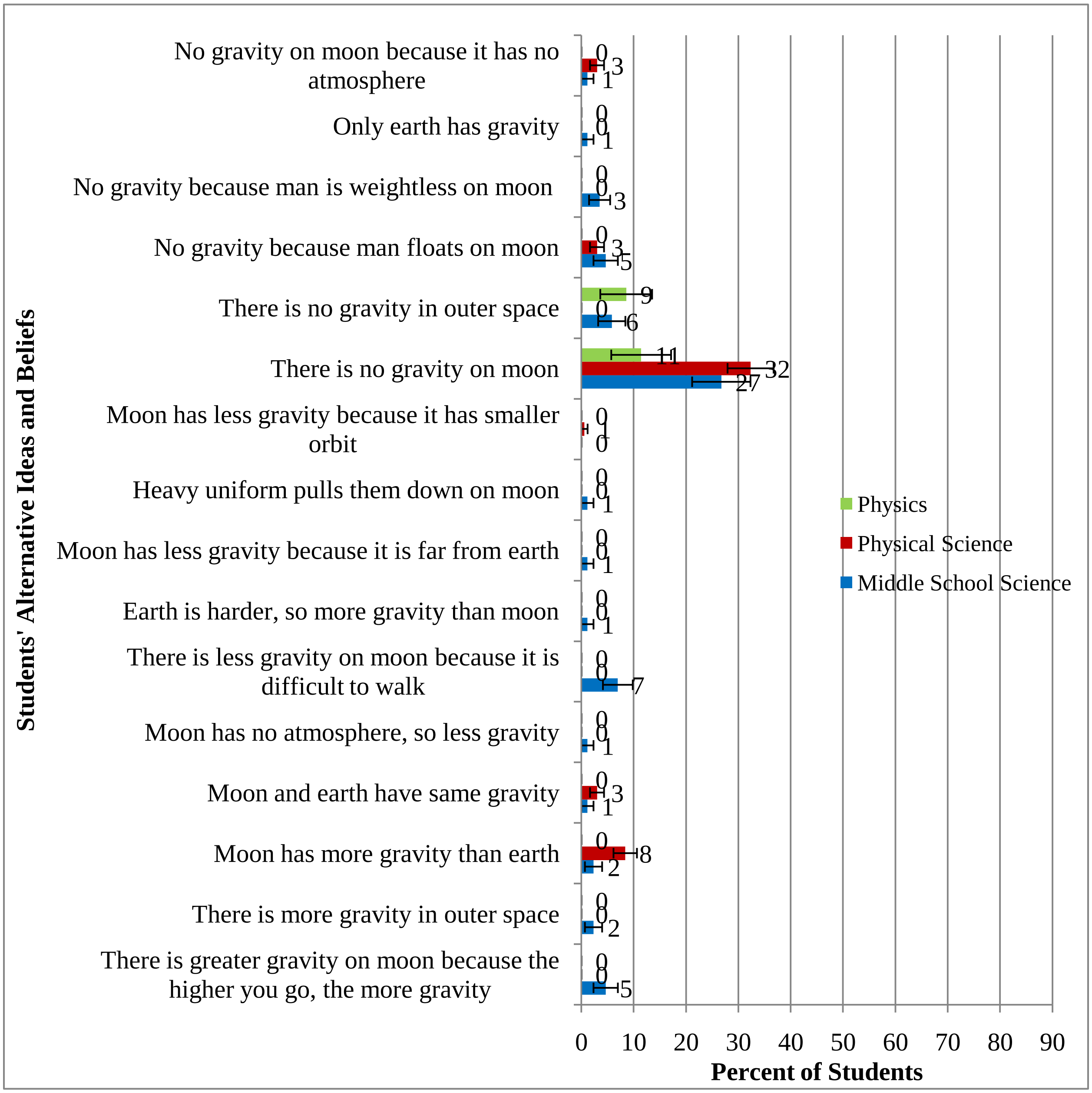

Figure 9. Alternative Ideas of Students on Gravity on Moon

Question 10 was intended to collect students' ideas about gravity when in orbit around the earth. Only forty-eight students or 17% agreed that there is gravity and supported it with consistent reasons. In the previous research, 21% of the students gave correct responses with consistent reasons. A dominant misconception that "there is no gravity" in orbit around the earth is evident on the data. Table 12 presents the students' answers and reason to question 10.

Table 12. Students' Answers and Reasons to Question 10 – Is there any gravity up where the spaceman is if he is near a satellite going around the earth?

Answers and Reasons	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
YES, with correct reasoning	**8**	**9**	**7**	**11**	**9**	**4**	**24**	**24**	**48**
Reasons:									
*gravity keeps it in orbit	6	4	2	3	0	0	8	7	15
*gravity is everywhere in the universe	2	5	5	8	9	4	16	17	33
YES, with incorrect reasoning	**0**	**1**	**3**	**2**	**0**	**0**	**3**	**3**	**6**
Reasons:									
astronaut is just floating	0	1	3	2	0	0	3	3	6
YES, with no reason given	**3**	**3**	**7**	**3**	**2**	**0**	**12**	**6**	**18**
NO, there's no gravity	**32**	**29**	**60**	**54**	**7**	**11**	**99**	**94**	**193**
Reasons:									
no gravity in space	24	14	38	29	7	11	69	54	123
astronaut is just floating	3	9	10	12	0	0	13	21	34
no air in space	0	1	2	2	0	0	2	3	5
no reason given	5	5	10	11	0	0	15	16	31
NO answer given	**0**	**1**	**10**	**10**	**0**	**2**	**10**	**13**	**23**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* Correct answers

A summary and comparison of misconceptions among groups is also revealed in figure 10. It is seen that the misconception that "there is no gravity in space" is very persistent since it is even seen in 51% of the Physics group. Students could have based this idea on science fiction which often depicts zero gravity in space. Students also view "floating" as an indication of no gravity. A small number of the respondents also believed that "there is no gravity because there is no air in space". Similar to this, the APPTEA research also reported that 15% of the Thai

students also had the misconception of associating the absence of atmosphere to the absence of gravity. This idea also came out in a study conducted by Stead and Osborne (as cited by Driver, 1984) in New Zealand among students aged 11 to 17. The students claimed that "there must be air for gravity to act".

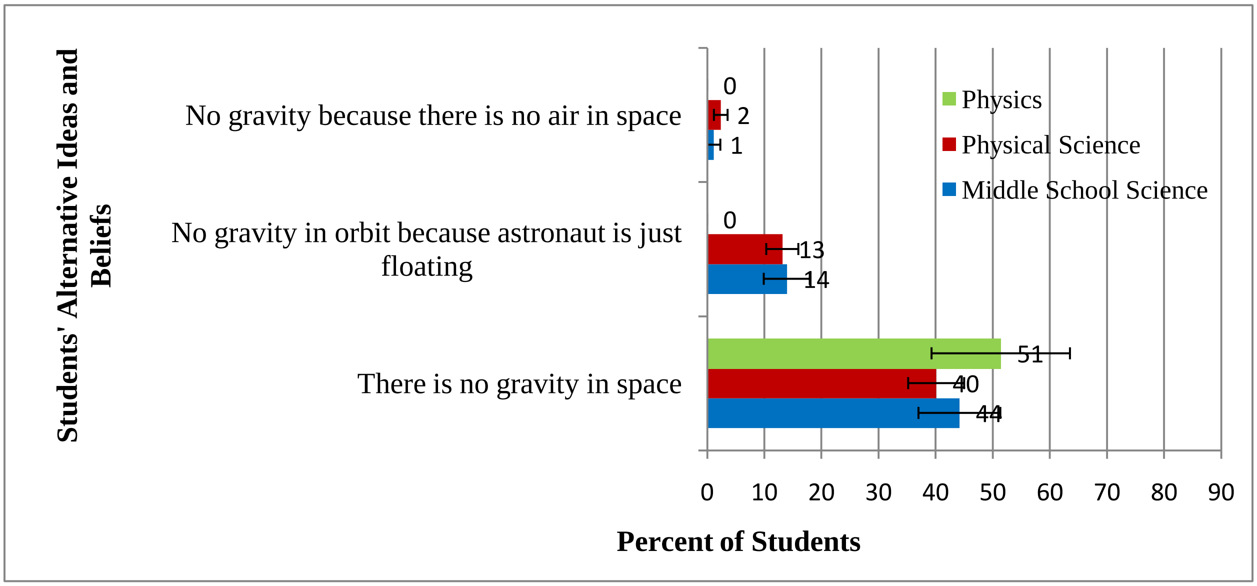

Figure 10. Alternative Ideas of Students When in Orbit Around the Earth

As shown in table 13, although 114 or 40% agreed that there is gravity when swimming underwater, only 57 or 20% have the correct conception. In the previous research, 21% of the students gave correct responses.   The table above shows a summary of the students' responses, and figure 11 shows a visual display of students' misconceptions.

A dominant misconception among the Middle School Science group is the idea that "there is more gravity when swimming down". Eighteen percent of the Physical Science group and 3 percent of the Physics group believed that "there is no gravity underwater". This misconception also came out in the study conducted by Stead and Osborne (as cited by Driver, 1984). Students also associated floatation with the absence of gravity. Students from the Middle School Science group and Physics group supported their idea of the presence of gravity by the

experience that “a man would drown if he doesn’t swim”. This reasoning also came out in the APPTEA research. It is also interesting to note that there were students from the Physics and Physical Science group who claimed that “there’s more gravity when you swim deeper because you’re closer to the center of the earth”. This could be a result of Physics instruction and a learned fact about the Law of Universal Gravitation. Other misconceptions were reported from small number of students. The misconceptions are presented in figure 11.

Table 13. Students’ Answers and Reasons to Question 11 – Is there any gravity when a person is swimming underwater?

Answers and Reasons	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Total**
A) YES	**21**	**13**	**23**	**27**	**16**	**14**	**60**	**54**	**114**
Reasons:									
*gravity is constant anywhere on earth	7	1	10	11	11	10	28	22	50
*gravity is the same, but buoyant force pushes you up	4	0	0	1	2	0	6	1	7
man will drown if he doesn't swim	3	8	0	0	2	1	5	9	14
gravity underwater is less than in air	2	0	0	1	1	0	3	1	4
viscosity lessens gravity	0	1	0	1	0	0	0	2	2
pressure of the water	0	0	2	2	0	0	2	2	4
no gravity underwater(inconsistent)	0	0	1	1	0	0	1	1	2
no reason	5	3	10	10	0	3	15	16	31
B) NO	**5**	**7**	**33**	**17**	**1**	**1**	**39**	**25**	**64**
Reasons:									
no gravity underwater	0	0	20	9	0	1	20	10	30
you float in water	3	5	5	2	0	0	8	7	15
man is weightless in water	0	0	0	0	1	0	1	0	1
water takes up your share of gravity	1	0	0	0	0	0	1	0	1
no reason given	1	2	8	6	0	0	9	8	17
C) Depends whether up/down	**15**	**20**	**21**	**28**	**1**	**1**	**37**	**49**	**86**
Reasons:									
more gravity when swimming down	9	13	4	3	0	0	13	16	29
more pressure when swimming up	1	0	0	0	0	0	1	0	1
buoyant force makes you float	1	1	0	0	0	0	1	1	2
depends on person's weight	0	0	2	3	0	0	2	3	5
water has less gravity	0	0	5	5	0	0	5	5	10
more gravity when you swim deeper	0	0	0	4	1	1	1	5	6
no reason given	4	6	10	13	0	0	14	19	33
NO answer given	**2**	**3**	**10**	**8**	**0**	**1**	**12**	**12**	**24**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

*Correct answers

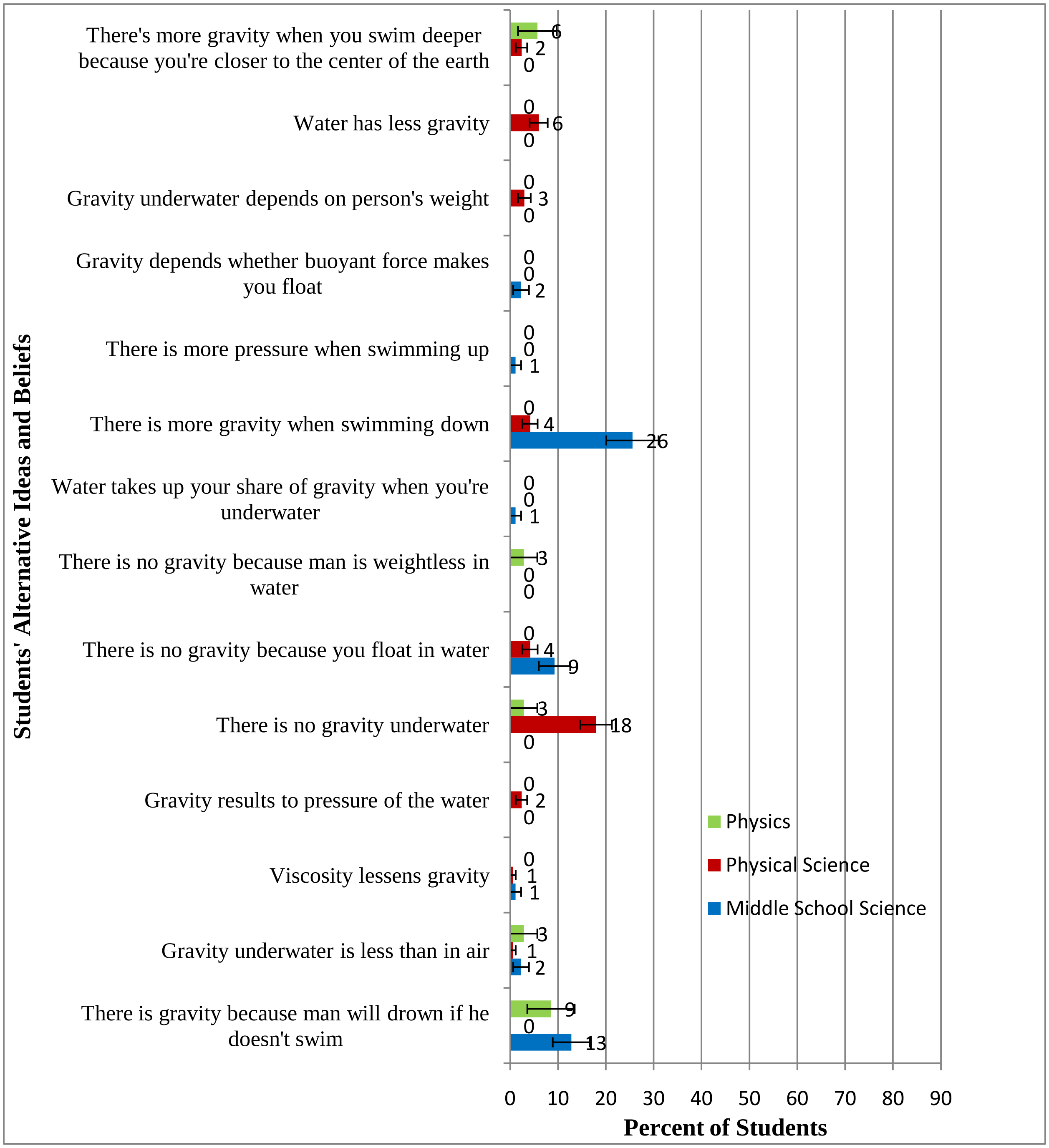

Figure 11. Alternative Ideas of Students on Gravity When Swimming Underwater.

On ***question 12***, two blocks described as "equal" were shown connected by a string and suspended "at rest" from a pulley. Students were asked what to predict the position of the blocks one minute later. Table 14 shows the students responses.

Table 14. Students' Answers and Reasons to Question 12 – Two equal blocks are linked by a piece of string. The string is placed over a pulley, so the blocks are at rest in the position that the left hand block is lower than the right hand block. What will be the position of the blocks one minute later?

Answers and Reasons	Middle School (n=86)		HS Physical Sci. (n=167)		HS Physics (n=35)		Overall (n=288)		
	Male	Female	Male	Female	Male	Female	Male	Female	Total
A) Blocks remain unchanged	**8**	**10**	**18**	**16**	**10**	**5**	**36**	**31**	**67**
Reasons:									
*blocks are at rest, so no change in position	3	2	3	1	0	3	6	6	12
*blocks have equal weight, so no net force to move them	1	2	2	4	6	2	9	8	17
*equal tension on both sides, so no net force to move them	0	0	0	0	1	0	1	0	1
more gravity on the left since lower	1	2	4	5	0	0	5	7	12
blocks will stay the same	2	4	4	2	3	0	9	6	15
no reason given	1	0	5	4	0	0	6	4	10
B) Blocks move so both at the same level	**31**	**26**	**54**	**44**	**8**	**9**	**93**	**79**	**172**
Reasons:									
blocks are equal	23	15	37	32	8	9	68	56	124
gravity pulls the blocks with same force	1	2	5	2	0	0	6	4	10
when one block falls, the other rises	0	3	0	0	0	0	0	3	3
no reason given	7	6	12	10	0	0	19	16	35
C) Blocks move so right hand block is lower	**2**	**7**	**8**	**8**	**0**	**2**	**10**	**17**	**27**
Reasons:									
blocks will switch around	1	7	4	2	0	2	5	11	16
equal weight	0	0	0	3	0	0	0	3	3
no reason given	1	0	4	3	0	0	5	3	8
NO answer given	**2**	**0**	**7**	**12**	**0**	**1**	**9**	**13**	**22**
Total	**43**	**43**	**87**	**80**	**18**	**17**	**148**	**140**	**288**

* Correct answers

Table 14 reveals that only 30 students or 10% of the students answered and reasoned correctly. Most of the students believed that the blocks would move to the same level after one minute. Forty-four percent of the Middle School Science group, 41% of the Physical Science group, and 49% of the Physics group claimed that the "blocks will move to the same level because they are equal". This belief is consistent with the findings of the APPTEA research (44% of students) , and with the findings of Gunstone and White (as cited in the APPTEA research). This could be due to students' unfamiliarity with the situation presented. Figure 12 presents a visual display of the misconceptions.

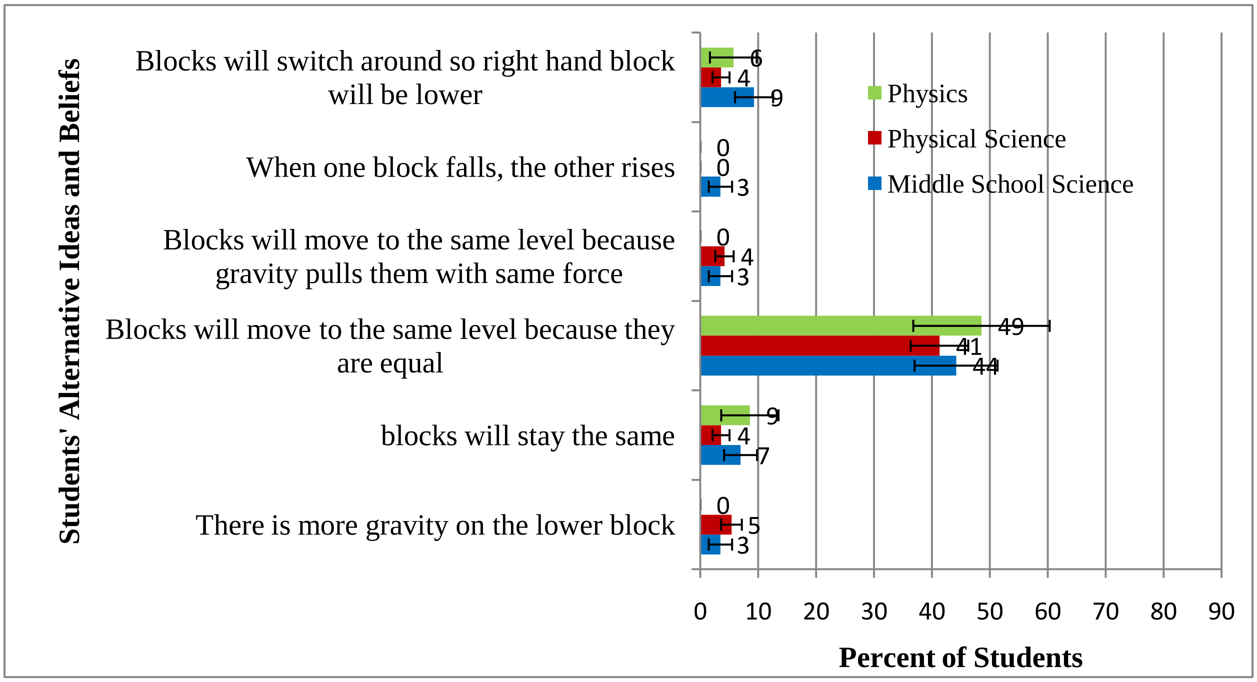

Figure 12. Alternative Ideas of Students on Blocks on a Pulley.

Summary of Prevalent Misconceptions. In this study, the misconceptions held by at least 10% of the students in any group of school Physics background are referred to as "prevalent misconceptions".

Prevalent misconceptions on question 1, 2 and 3 were grouped together because they all involved the force on a ball that is thrown vertically upward. A summary is provided in figure 13.

Misconceptions 1, 6 and 7 in the figure reflect the idea that "the direction of motion is also the direction of the force". Misconceptions 2 and 3 suggest the presence of a "force of throw", the "impetus" view of motion. Misconceptions 4 and 5 present the persistent idea that "there is no force when there is no motion". All these are known common misconceptions.

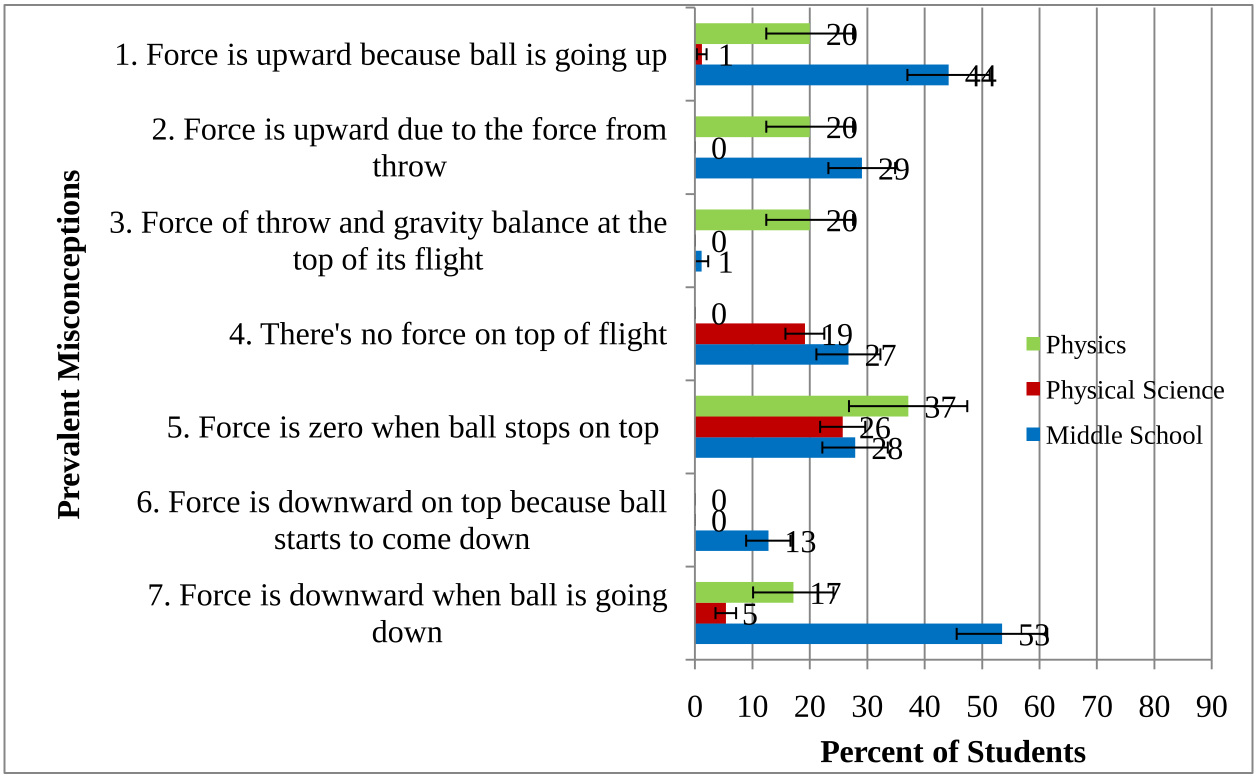

Figure 13. Prevalent Misconceptions on the Force on a Ball Thrown Vertically Upward

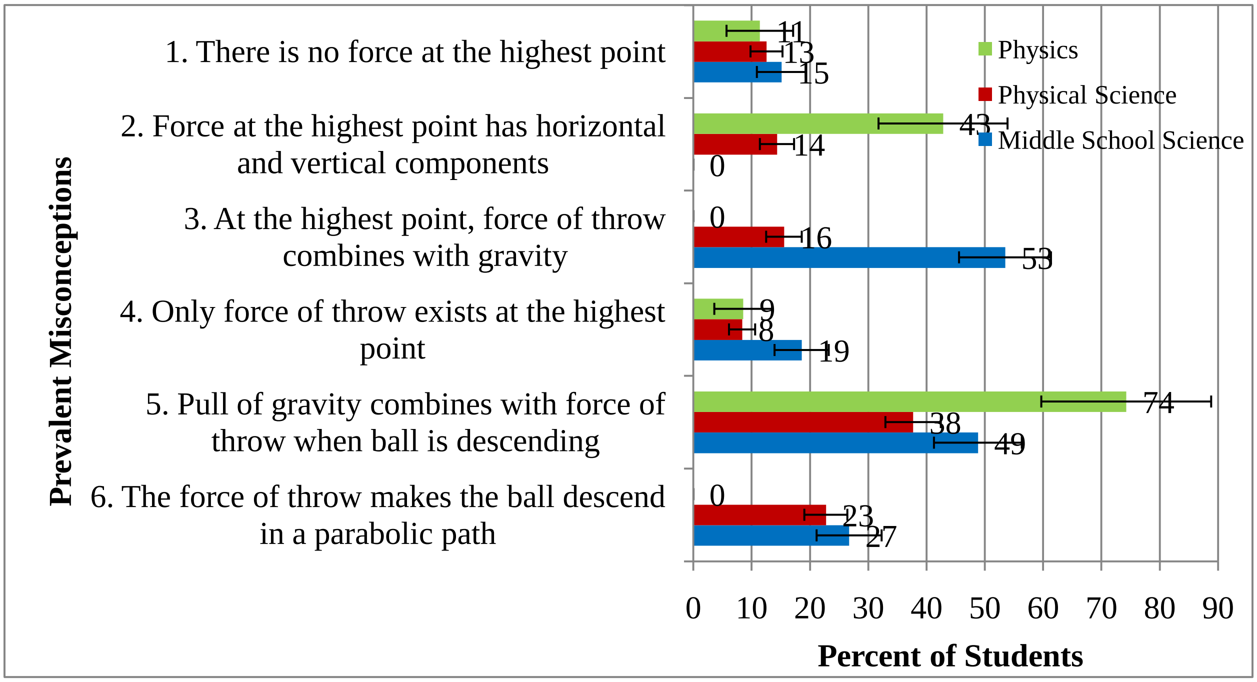

Figure 14. Prevalent Misconceptions on a Ball Thrown Obliquely to Travel Along a Parabolic Path.

Figure 14 presents a strong persistent view of the presence of "force of throw" on a ball travelling along a parabolic path. This idea is evident on misconceptions 3, 4, 5 and 6. Misconception 1 also agrees with misconceptions 4 and 5 from figure 13. The Physics group and Physical Science group also revealed an idea that the force at the highest point has horizontal and vertical components, which made them chose the answer with gravity + force of throw.

The prevalent misconceptions about a bicycle that is slowing down are shown in figure 15. The impetus view of motion is the most common misconception among the Middle School Science group. The idea that gravity slows down the motion is also the most common misconception among the Physics group, but is also consistent with the Middle School Science and Physical Science groups. Misconceptions 1 and 2 on figure 15 reflect the idea that force is needed in order to maintain motion.

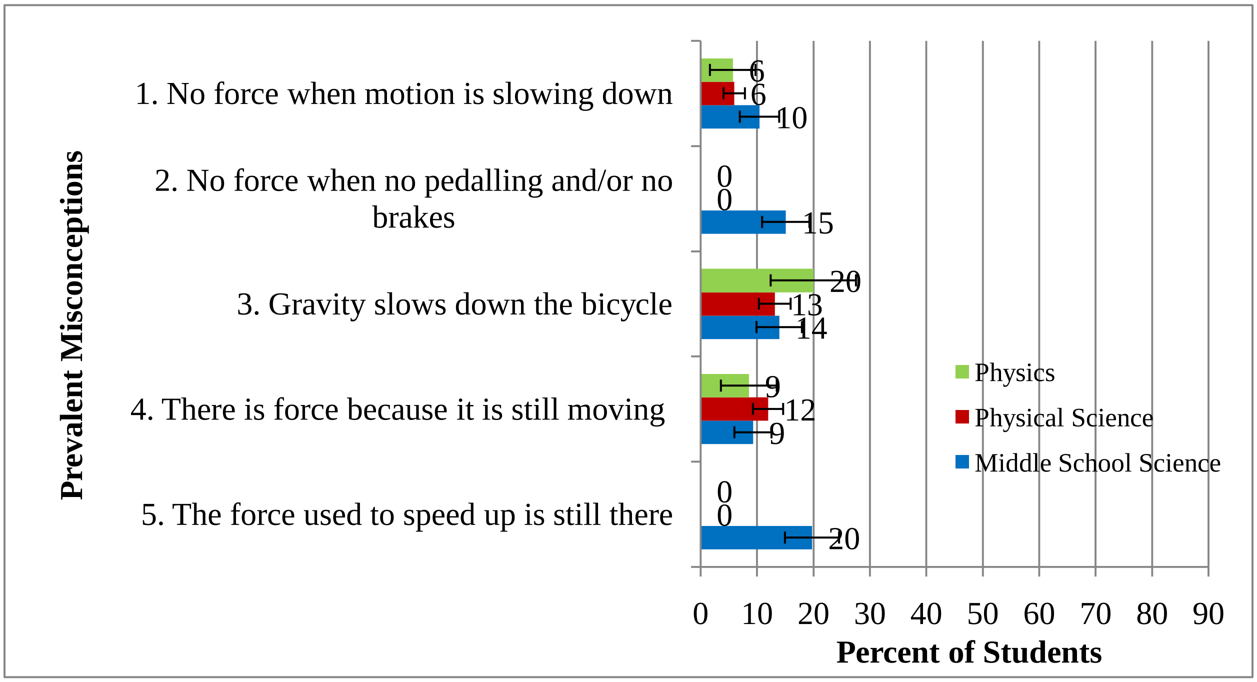

Figure 15. Prevalent Misconceptions on a Bicycle that is Slowing Down

Figure 16 presents a summary of students' prevalent misconceptions about gravity at various locations, and in some case, its relative magnitude. The most persistent misconception is the notion that "there is no gravity in space". This misconception, together with misconceptions 5 and 7, could be due to the influence of science fiction movies. Misconception 1 implies an incorrect association of gravity with altitude among Middle School Science and Physics group. Misconceptions 2 , 3 and 9 are reflections of students' beliefs. Misconception 4 appears to be a blind application of a learned concept in science, and misconceptions 8 and 10 are misconceptions developed by students from experience. These misconceptions are displayed in visual form on figure 16.

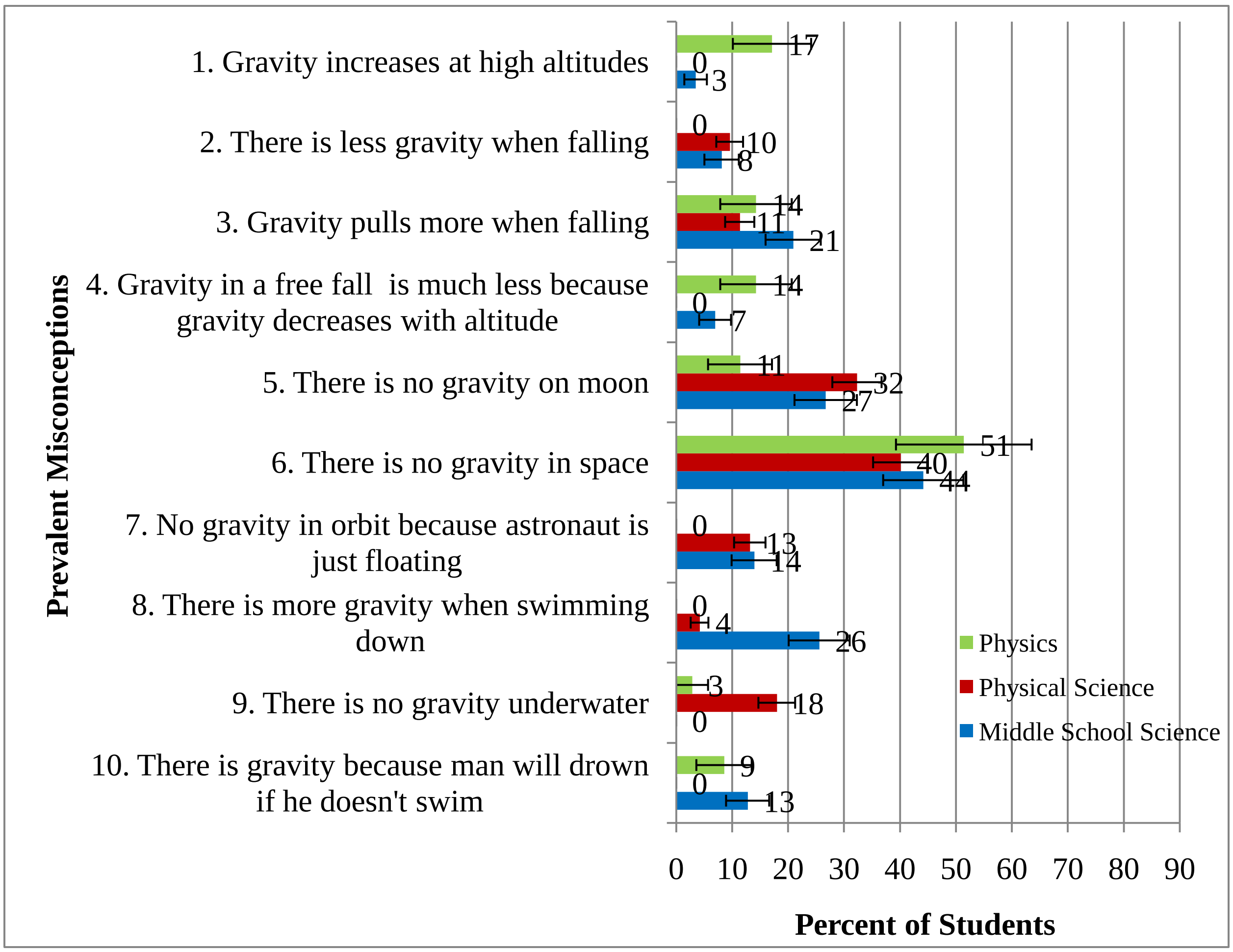

Figure 16. Prevalent Misconceptions on Gravity.

Gravity is a very familiar word to everyone , but in this study, it appears that this is the science concept with which students have the greatest number of misconceptions. Another prevalent misconception is the belief that equal blocks will move to the same level on a pulley.

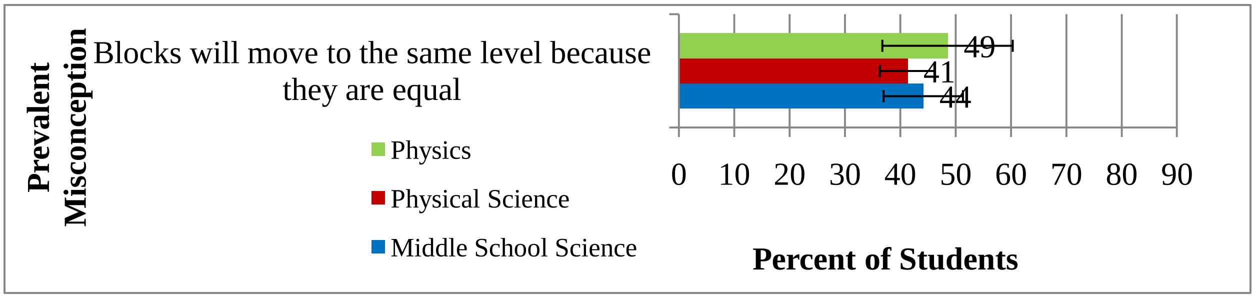

Figure 17. Prevalent Misconception on Blocks on a Pulley.

Comparison of Misconceptions Held by the Students According to Gender. Figure 18 presents a comparison of the number of misconceptions held by gender. There is no significant association between the number of misconceptions and gender.

According to figure 18, the greatest number of misconceptions was seen among female students in the situation involving gravity on the moon where 15 misconceptions were noted. The male students showed the greatest number of misconceptions (14) in the situation involving gravity and free fall. Both male and female students showed 3 misconceptions in the situations involving the force on a ball falling along a parabolic path, and on gravity in orbit around the earth. These items have the smallest number of misconceptions among the female students. For the male students, the situation involving gravity when standing on earth has the lowest number of misconceptions.

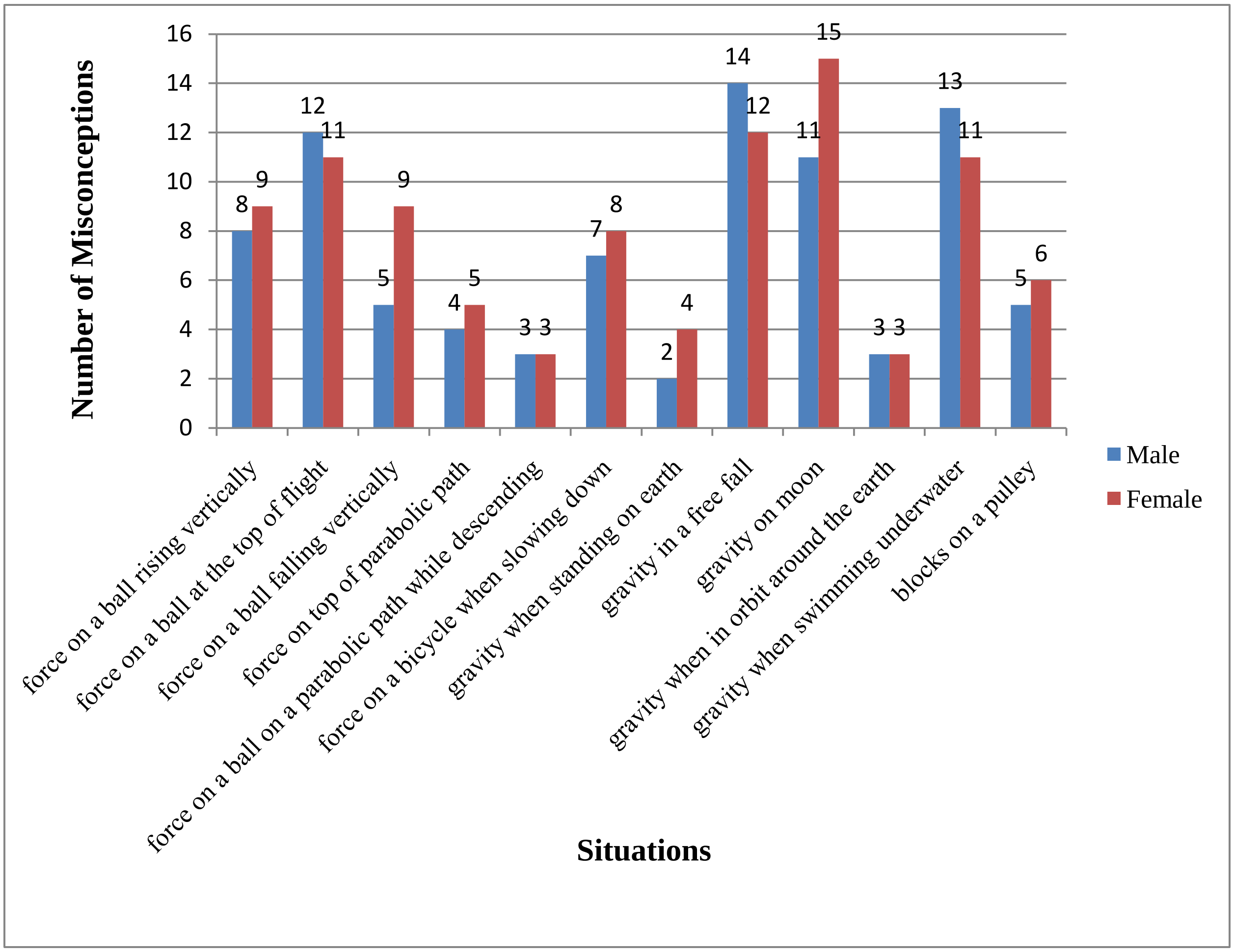

Figure 18. Comparison of the Number of Misconceptions Held According to Gender

A null hypothesis that "there is no significant association between the number of misconceptions and gender" was then formulated and tested at 0.05 level of significance using Fisher's Exact Test. Data Analysis was done using Microsoft Excel and the result is presented and interpreted in table 15. The contingency table used for this test is presented in Appendix F.

The result of Fisher's Test leads to the conclusion that indeed, there is no significant association between gender and the number of misconceptions held. It also implies that the proportion of misconceptions held by the male students does not significantly differ from the proportion of misconceptions held by the females. The result of Fisher's Test was further

Table 15. Result of Fisher's Exact Test of Association Between the Number of Misconceptions Held and Gender.

2-tailed p	Level of Significance	Result	Decision
0.68	0.05	$p > 0.05$	Do not reject null

validated by using a t-test, where the means of the number of misconceptions of males and females were compared and their difference was found to be insignificant with a p-value of 0.68.

The percentage of male and female students having misconceptions was also considered and treated using Fisher's test. A comparison of the proportion of male and female students (in terms of percent) having misconceptions is shown in figure 19. The situation posed by question 5 has the greatest proportion (74%) of male students having a misconception. Question 5 was about the total force on a ball thrown obliquely in a parabolic path when it is on its way down. The situations on questions 1 and 5 have the greatest proportion (71%) of female students having misconceptions. For both genders, the fewest students with misconceptions was in question 7 , which asked about gravity when standing on earth. Only 3% of the male students and 10% of the female students have noted misconceptions on this situation. Thus, gravity on earth is the situation best understood by the students among the 12 situations in the questionnaire.

Table 16 reveals the result of Fisher's Exact Test of difference in the proportion of male and female students with misconceptions. From this result, it can be concluded that at a 0.05

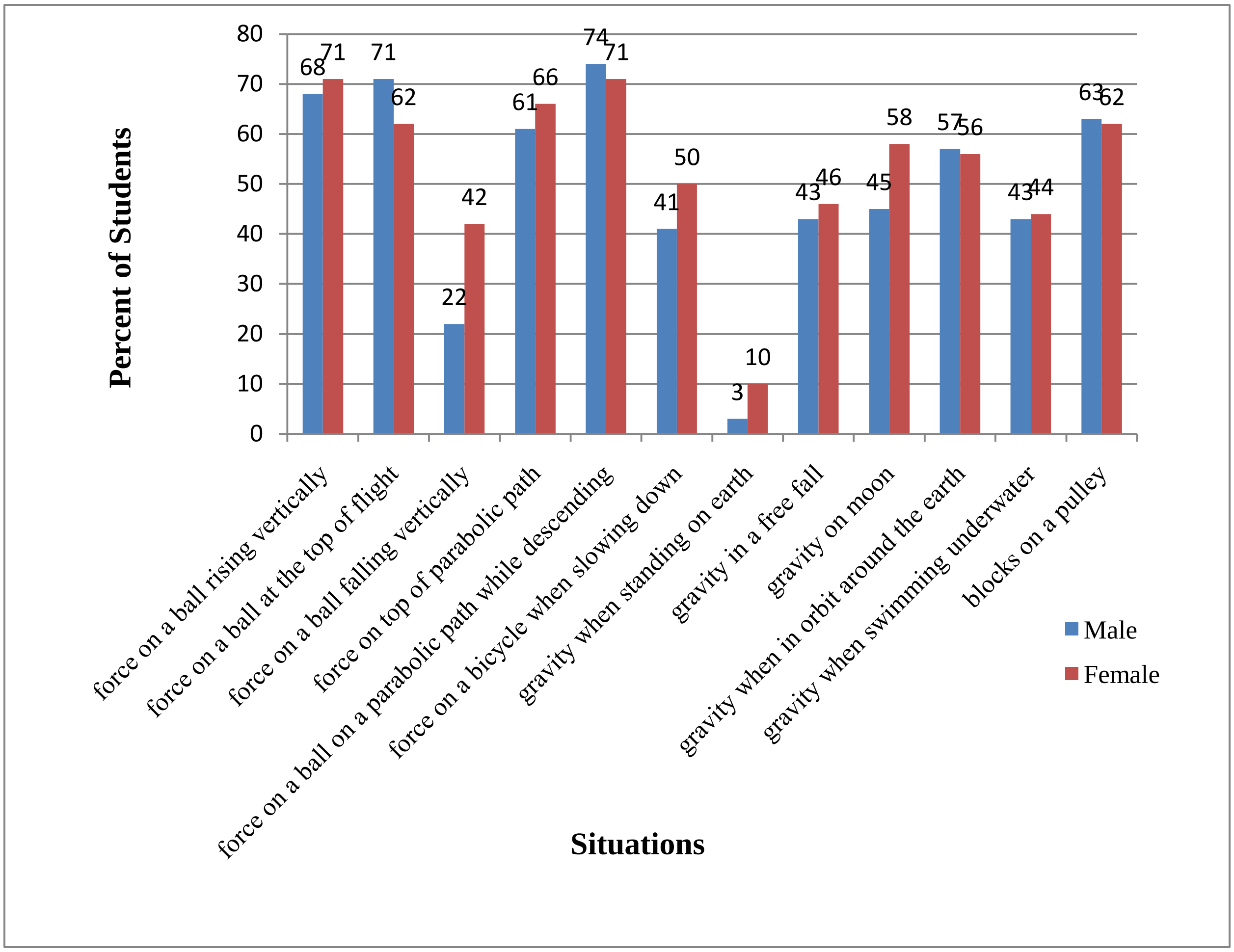

Figure 19. Comparison of the Proportion of Male and Female Students Having Misconceptions.

Table 16. Result of Fisher's Exact Test of Difference in the Proportion of Male and Female Students with Misconceptions.

2-tailed p	Level of Significance	Result	Decision
1.00	0.05	$p > 0.05$	Do not reject null

level of significance, the proportion of male students with misconceptions does not significantly differ from the proportion of female students with misconception. This means that students' misconceptions are not correlated to gender. T-test was also used to test the difference between the means of the proportion of male and female students having misconceptions. The test resulted in a p-value of 1.00, which is greater than 0.05, from which it can be inferred that the there is no significant difference between the two means.

Comparison of Misconceptions Held by Students According to School Physics Background. The number of misconceptions was also compared to school Physics background (see figure 20). As seen in the figure, the Middle School Science group has the highest number of misconceptions in most situations, while the Physics group has mostly the least. The greatest number of misconceptions (15) for the Middle School Science group is on the question about gravity on the moon. For the Physical Science group, the greatest number of misconceptions (9) is a tie between questions 2 and 11, which are about the total force at the maximum height of a ball thrown vertically upward, and about gravity underwater respectively. The Physics group has also the greatest number of misconceptions (5) on question 11, which is about gravity underwater.

Kendall's coefficient of concordance (W) was used to see if there is a significant agreement in the ranking of the number of misconceptions among the three groups of school Physics background. The numbers of misconceptions were converted into ranks among the three groups for each of the 12 situations, and the coefficient of concordance W was calculated. Table 17 summarizes the results of the statistical test. The calculation of the W is shown in Appendix G.

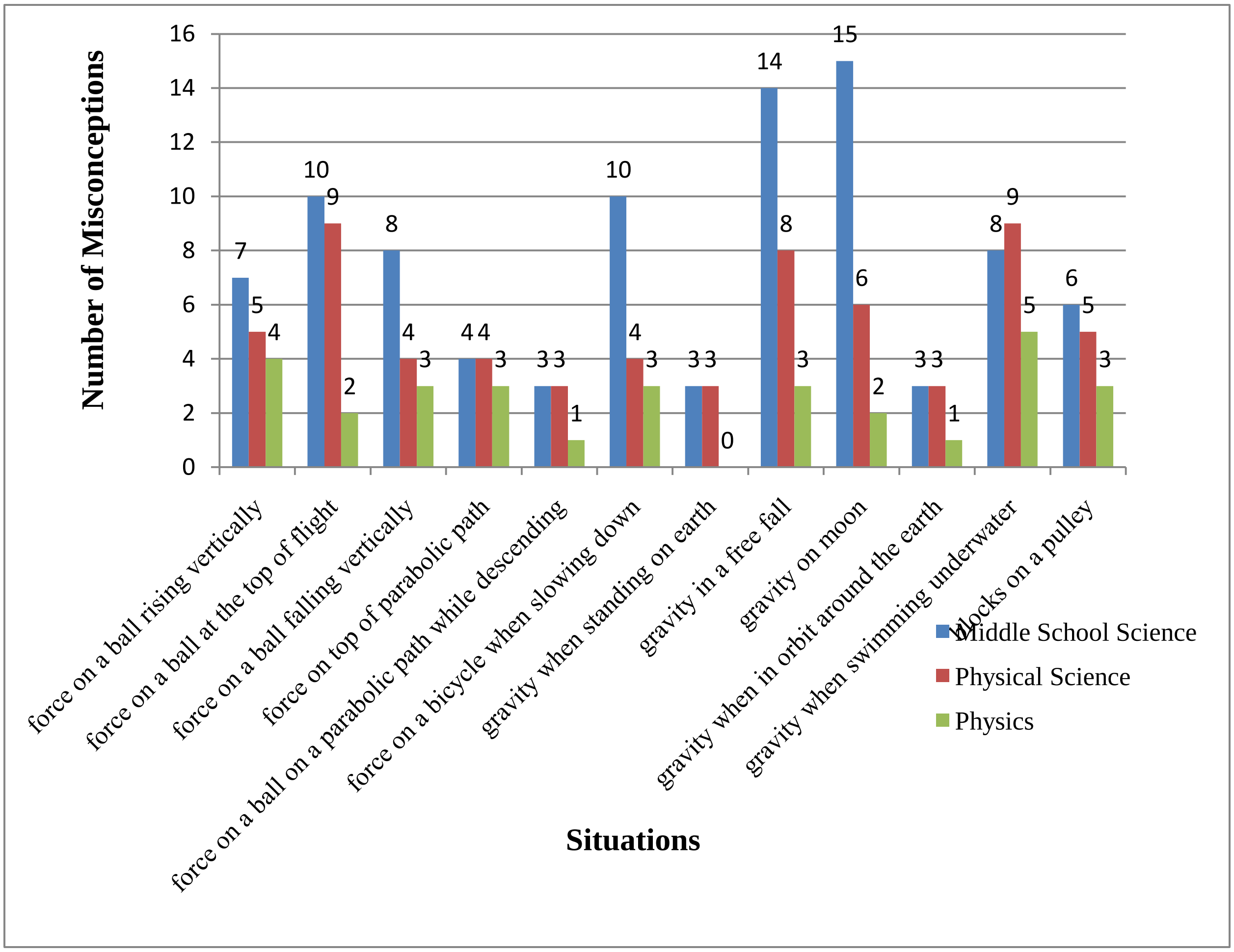

Figure 20. Comparison of the Number of Misconceptions Held by Students According to School Physics Background.

From the coefficient of concordance, a chi-square statistic was calculated , and the p-value was determined to be less than 0.001 which means that the result is highly significant. The null hypothesis is therefore rejected, and the statistical test leads to the conclusion that "there is a significant agreement in the ranking of the number of misconceptions according to school Physics background". This implies a strong correlation between the number of misconceptions and the school Physics background. It is evident from the data that the number of misconceptions is greatest for the Middle School Science group and lowest for the Physics group. This result also

Table 17. Test of Agreement In the Ranking of the Number of Misconceptions According to School Physics Background

W	Chi-Square	Df	p-value	Decision
0.886	21.3	2	$p < 0.001$	Reject Null

implies that students from middle school bring a wide variety of alternative ideas and beliefs as they go to high school, but those misconceptions are diminished as the students receive more Physics instruction in Physical Science and Physics classes.

Figure 21 also shows a comparison of the proportion of students having misconceptions according to school Physics background. It is evident from the figure that the Middle School Science group has the greatest proportion of students having misconceptions in all the 12 situations presented in the questions. There were situations where the proportion of Physical Science group having misconceptions was higher than the proportion of students from the Physics group. There were, however, situations where the Physics group had a larger proportion of students who have misconceptions than the Physical Science group.

The Kendall's coefficient of concordance and chi-square statistic were again used to determine any significant agreement in the ranking of the proportion of students having misconceptions according to school Physics background.

Table 18 supports the decision to reject the null hypothesis. Thus, there is a significant agreement in the ranking of the proportion of students having misconceptions according to school Physics background. It also implies a strong correlation between school Physics

background and the proportion of students having misconceptions. This means that as students' school Physics background progresses, the proportion of students having misconceptions becomes lower.

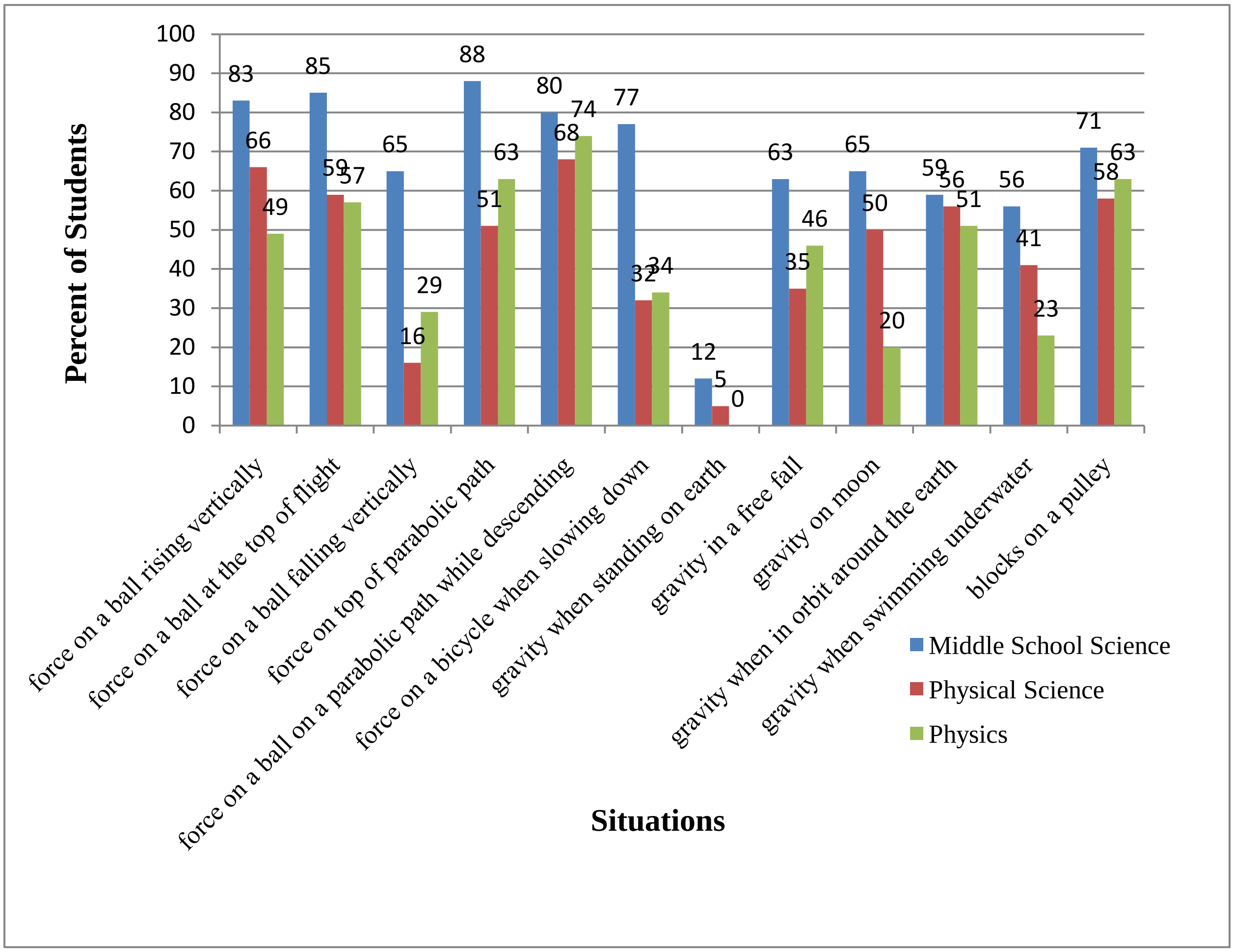

Figure 21. Comparison of the Proportion of Students with Misconceptions According to School Physics Background.

Table 18. Test of Agreement In the Ranking of the Proportion of Students Having Misconceptions According to School Physics Background

W	Chi-Square	Df	p-value	Decision
0.750	18.0	2	$p < 0.001$	Reject Null

SUMMARY AND CONCLUSIONS

Summary. This study determined the misconceptions of high school students aged 14 to 18 on force and gravity and compared the misconceptions according to gender and according to school Physics background. The results suggest that the subjects of this research study hold misconceptions that have been reported by other similar research studies.

Three prevalent misconceptions were found on questions 1, 2 and 3, concerning the force on a ball thrown vertically upward. One of these is the idea that the direction of motion is also the direction of the force. Another prevalent misconception is the belief that the force of throw is still present in the ball even after leaving the hand. The third prevalent misconception is the idea that there is no force when there is no motion. These misconceptions were found to be persistent because they were present in students of the three types of school Physics background, which means that they exist in the minds of students even after Physics instruction.

In the situation where the ball was thrown in a parabolic path (questions 4 and 5), a dominant misconception seen was the belief in the presence of the force of throw. The Physics group showed a strong belief in the combination of force of throw and gravity in the motion of the ball in a parabolic path, which they associated with the horizontal and vertical components of the force. Another prevalent misconception seen was the belief that there is no force when the ball is at the top of its parabolic path.

Question 6 asked about the force on a bicycle that is slowing down. The most common misconception among the Physics and Physical Science group is the idea that gravity slows down the motion. Among the Middle School Science group, the most common misconception was that the force used to speed up is still there. Other prevalent misconceptions include the following

ideas: there is force when there is motion; there is no force when motion is slowing down; and there is no force when no pedaling and no brakes are applied.

The concept of gravity, which is covered on questions 7-11, has the most prevalent misconceptions found in this study. The most common misconception was the belief that there is no gravity in space. Students from the Physics group were found to be the largest proportion having this misconception. Other misconceptions reported are the following: gravity increases at high altitudes; gravity is less in air; gravity is less when falling; gravity in a free-fall from an airplane is much less because gravity decreases with altitude; there is no gravity on the moon; there is no gravity in orbit because objects just float; there's more gravity underwater when swimming downward; there's no gravity underwater; and gravity makes the man drown if he doesn't swim. Some lines of reasoning were found to be similar between the students of the Middle School Science and Physics groups.

A prevalent misconception found by question 12 is the belief that the blocks will move to the same level because they are equal. Question 12 involved a situation in which two equal mass blocks were tied to ends of a string that was passed over a pulley.

The misconceptions found in this study are very similar to the misconceptions found among Asia-Pacific students in the APPTEA research. This is an indication that misconceptions are universal, and although it is often believed and quoted in the popular press that Asian students are "better" than American students, the findings of this study show that they have similar conceptual difficulties on force and gravity. This is also consistent with my own experience as a teacher for 12 years in the Philippines and as a teacher here in East Baton Rouge Parish for two years.

Aside from gathering students' misconceptions, this study also included a comparison of the number of misconceptions held according to gender and according to school Physics background. There is no significant association between gender and the number of misconceptions; the proportion of misconceptions held by the males does not significantly differ from the proportion of misconceptions held by the female students. The Kendall's coefficient of concordance (W) between school Physics background and the number of misconceptions held suggests a strong agreement in the ranking of the number of misconceptions held by students according to school Physics background.

The proportion of students having misconceptions is also compared to gender and to school Physics background. The difference in the proportion of male and female students having misconceptions is not significant at the 0.05 level of significance. Thus, the proportion of students with misconceptions is not associated with gender. The coefficient of concordance (W=0.750) suggests a strong correlation between school Physics background and the proportion of students having misconceptions. This is also found to be significant with a p-value < 0.001.

Conclusions . Based on the findings of this study, the following conclusions are drawn:

1. Students in this study have misconceptions similar to the misconceptions found in previous research. American students have similar conceptual difficulties on force and gravity as the Asia-Pacific students.

2. There is no significant association between the number of misconceptions and gender (p=0.68).

3. There is no significant difference in the proportion of male and female students having misconceptions (p=1.00).

4. There is a strong correlation between the number of misconceptions held and the type of school Physics background ($W=0.886$ and $p<0.001$). That is, the number of misconceptions held diminishes as school Physics instruction progresses.

5. There is a strong correlation between the proportion of students having misconceptions and the type of school Physics background ($W=0.750$ and $p<0.001$). The proportion of students with misconceptions decreases as school Physics instruction progresses.

Recommendations. The researcher recommends that:

1. The findings of this study be used by teachers and curriculum developers in designing classroom activities and teaching strategies that could address the students' misconceptions found;

2. Teachers find ways of identifying students' misconceptions, such as the use of probes or formative assessment, to motivate students and to guide in the teaching process; and

3. Similar researches be conducted, with emphasis on testing teaching strategies that could effectively alter students' misconceptions.

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APPENDIX A
LETTER OF REQUEST TO USE SURVEY INSTRUMENT

August 1, 2009

Richard Gunstone, Ph.D.
Emeritus Professor of Science and Technology Education
Faculty of Education
Monash University
Vic 3800, Australia

Dear Prof. Gunstone,

I am a graduate student at Louisiana State University, Baton Rouge, Louisiana, USA and I am doing a research on Students' Misconceptions on Force and Gravity for my Master's thesis. I have seen the APPTEA Research Report entitled "Conceptions in Mechanics: A Survey of Students' Beliefs in Seven Asian Countries" which was published in 1989 and I found your findings interesting. The survey instrument you developed would be a perfect instrument I could use for my research.

I would like to request your permission to allow me to use the said survey instrument. I have a hard copy of the research report. However, I would so much appreciate it if you could send me an electronic copy or a revised version (if available) of the instrument.

Thank you sir. Your assistance will surely be a great help in the pursuit of my study.

Respectfully yours,

Jane R. Pablico (sgd)
MNS Student
Louisiana State University
Baton Rouge, LA

APPENDIX B
LETTER OF PERMISSION TO USE SURVEY INSTRUMENT

August 5, 2009

Dear Jane,

Nice to know that the APPTEA report still exists somewhere besides my office!!
Of course I am very happy for you to make use of that instrument. It was developed with specific concern for being able to be used by others with whom I would only have postal (snail mail) contact - this was all before the existence of email (yes, there was such a time).
Unfortunately I do not have an electronic version of the instrument - I put this together so long ago that I did not use a pc; indeed we had only 2 word processors in the whole faculty (not pcs, but desktop machines that ONLY were word processors) and they operated only with a typing program ('wordperfect') that had no diagram capabilities. That's a roundabout way of explaining why I don't have a handy file to email you I am afraid.

While I have used various forms of some of the question structures in other contexts on many other / later occasions, the instrument as a whole was not ever refined / developed beyond the form you have in the APPTEA report.

Good luck with your research, sorry I can't help in the way that would be most valuable to you.

Dick Gunstone (sgd)

Richard Gunstone
Emeritus Professor of Science and Technology Education
Faculty of Education
Building 6
Monash University
Vic 3800, Australia
Phone & Voicemail: +(int)(61)(3)99052857
Fax: +(int)(61)(3)99059197
http://www.education.monash.edu.au/profiles/dgunston

APPENDIX C

APPLICATION FOR EXEMPTION FROM INSTITUTIONAL OVERSIGHT

Application for Exemption from Institutional Oversight

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/projects using living humans as subjects, or samples or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

Institutional Review Board
Dr. Robert Mathews, Chair
203 B-1 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu | lsu.edu/irb

- Applicant, Please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://www.lsu.edu/irb/screeningmembers.shtml
- A Complete Application Includes All of the Following:
  - (A) Two copies of this completed form and two copies of parts B thru E.
  - (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
  - (C) Copies of all instruments to be used.
    - •If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
  - (D) The consent form that you will use in the study (see part 3 for more information.)
  - (E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://phrp.nihtraining.com/users/login.php.)

1) Principal Investigator: JANE R. PABLICO **Rank:** ________ **Student*? Y/N** Y

Dept.: BASIC SCIENCES **Ph:** 225-302-4631 **E-mail:** jpabli1@lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each
* If student, please identify and name supervising professor in this space
DR. DANA A. BROWNE

3) Project Title: MISCONCEPTIONS ON FORCE AND GRAVITY AMONG HIGH SCHOOL STUDENTS

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 8-12-2012

4) LSU Proposal?(yes or no) NO **If Yes, LSU Proposal Number** ________
Also, if YES, either ◯ **This application completely matches the scope of work in the grant**
OR
◯ **More IRB Applications will be filed later**

5) Subject pool (e.g. Psychology Students) STUDENTS AT MCKINLEY HIGH SCHOOL
•Circle any **"vulnerable populations"** to be used: (children <18; the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature ________ **** Date** ________ (no per signatures)
****I certify my responses are accurate and complete.** If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

IRB# E4666 **LSU Proposal#** ________
☒ Complete Application
☒ Human Subjects Training

Screening Committee Action: Exempted ✓ **Not Exempted** ____ **Category/Paragraph** 1
Reviewer Mathews **Signature** [signature] **Date** 8/13/09

APPENDIX D
APPROVAL FROM SCHOOL DISTRICT TO CONDUCT RESEARCH

EAST BATON ROUGE PARISH SCHOOL SYSTEM

Accountability, Assessment, and Evaluation
Christa McAuliffe Center
12000 Goodwood Boulevard
Baton Rouge, Louisiana 70815
(225) 226-7625 FAX– (225) 226-7605

November 18, 2009

Jane R. Pablico
McKinley High School

Ms. Pablico,

Your request to conduct the following research in East Baton Rouge Parish School System is approved.

Misconceptions on Force and Gravity Among High School Students

We require that all data you collect protect the anonymity of participants, unless they specifically provide you with permission to identify them. It is my understanding that you will provide the East Baton Rouge Parish School System a summary of your research findings, once your project is completed.

We appreciate the opportunity of working with you. If I can be of further assistance, please contact me at (225) 226-7625 or lfrischhert@ebrschools.org

Sincerely,

Liz Frischhertz

Liz Frischhertz
Chief Officer of Accountability, Assessment, and Evaluation

11/13/09
Date

Approved:

John Dilworth

John Dilworth
Superintendent
East Baton Rouge Parish School System

11/16/09
Date

APPENDIX E
THE SURVEY COVER LETTER AND QUESTIONNAIRE

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 8-12-2012

My dear student,

Greetings!

I am presently conducting a research entitled "Misconceptions on Force and Gravity Among High School Students". This is in partial fulfillment of the requirements leading to the degree Masters of Natural Science. It is aimed to investigate students' ideas about force and gravity and to identify students' misconceptions that need to be addressed in the classroom.

In this regard, may I ask for your assistance by answering completely this questionnaire and test.

Your help will surely spell the success in the pursuit of my study.

Thank you very much.

Truly yours,

Jane R. Pablico
Researcher

I, ______________________________, agree to participate in the study by answering completely the questionnaire and test. I understand that participation in this study is not compulsory. If I have questions about subjects' rights or other concerns, I can contact Robert C. Mathews, Chairman, Institutional Review Board, (225) 578-8692, irb@lsu.edu, www.lsu.edu/irb.

Student's Signature:____________________ Gender(M/F):_____ Age:____
Date:__________________

Highest Source of School-Physics Background: (Please check)

☐ Middle School Science ☐ High School Physics

☐ High School Physical Science ☐ AP Physics

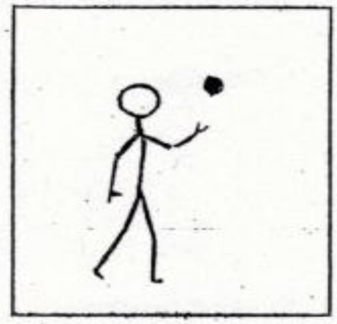
WHAT DO YOU THINK ABOUT FORCE AND GRAVITY?

Directions: For each of the questions, you are asked to select an answer and to write a short explanation of why you chose that answer.

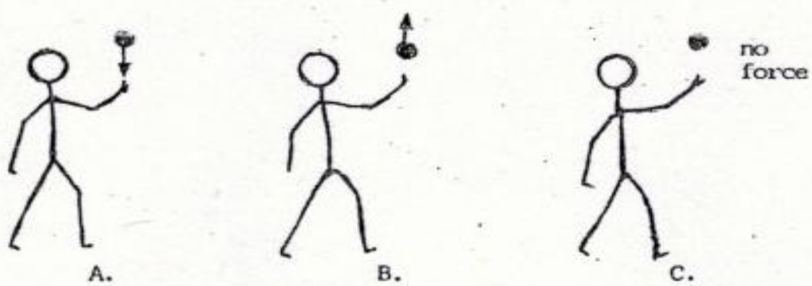
Do not leave an item unanswered. Please patiently answer all the questions.

Questions 1-3

A person throws a ball straight up into the air just a small way. Questions 1-3 are about the total force on the ball.



Q.1 If the ball is on the way up, then the force on the ball is shown by which arrow?



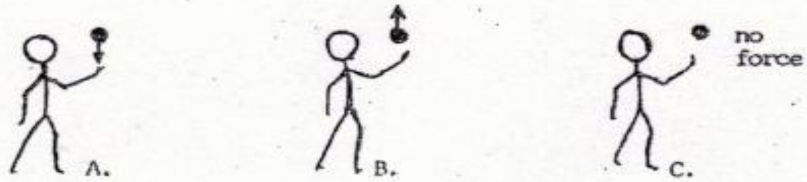
(a). Answer: __________ (write A, B, or C in the space)

(b). Why did you choose this answer? (please write your reasons) ______________

____

____

Q.2. If the ball is just at the top of its flight, then the force on the ball is shown by which arrow?



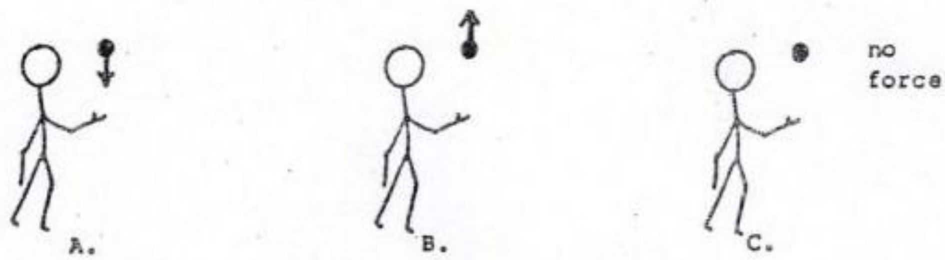
(a) Answer: __________

(b) Why did you choose this answer? ______________

____

____

Q.3. If the ball is on the way down, then the force on the ball is shown by which arrow?



(a) Answer: ____________

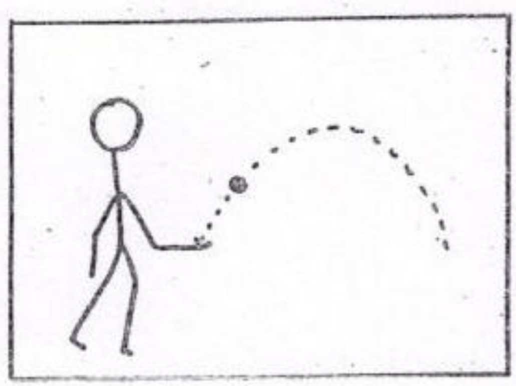
(b) Why did you choose this answer? ____

____

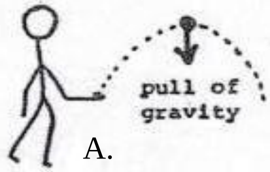
____

Questions 4 and 5

The person now throws the ball to someone else. This drawing shows the path the ball travels along. Questions 4 and 5 are about all the forces on the ball.

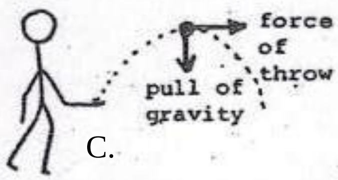


Q.4. When the ball is at its highest point, which of the drawings below best shows all the forces on the ball?

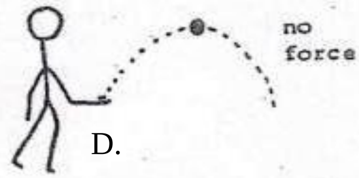


A.

B.



C.



D.

(a) Answer: ______________________

(b) Why did you choose this answer? ______________________

____

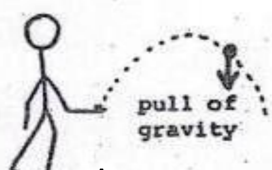
____

(c) Are there any other forces on the ball which are not shown in the diagrams? _____ (yes or no). If you answered yes, please describe the force or forces. ______________________

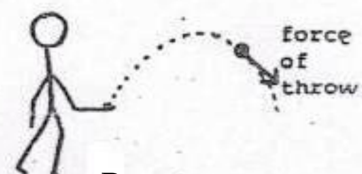
____

____

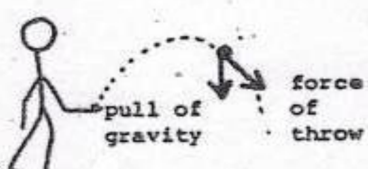
Q.5. When the ball is on the way down again, which of the drawings below best shows all the forces on the ball?



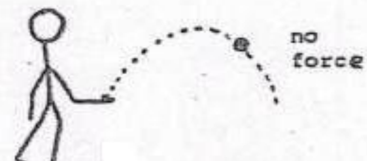
A.



B.



C.



D.

(a) Answer: ______________________

(b) Why did you choose this answer? ______________________________

(c) Are there any other forces on the ball which are not shown in the diagrams? (yes or no). If you answered yes, please describe the force or forces.

____

Question 6.

A person is riding a bicycle. The person is not using the brakes or pedals and is slowing down.

Is there a force on the bicycle?

A. Yes
B. No

(a) Answer: ______________

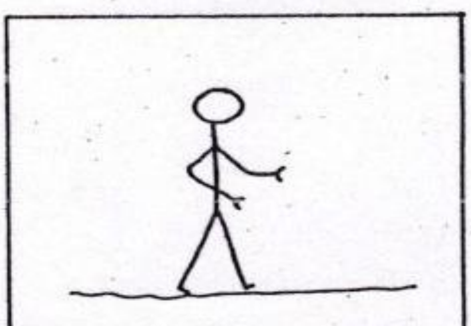
(b) Please explain your answer: ______________________________

Question 7-11

These questions are about whether there would be gravity in different places.

Q.7. Look at picture I. Is there any gravity when you are standing on the earth?

A. Yes
B. No



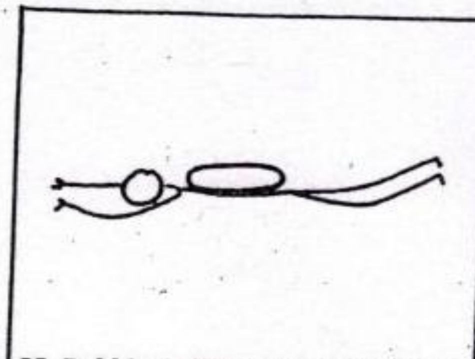
I Standing on the earth.

(a) Answer: ______________

(b) Please explain your answer: ______________________________

Q.8. Look at picture II. If someone falls from an aeroplane, is there any gravity?

A. Yes, about the same as on the ground.
B. Yes, but much less than on the ground.
C. Yes, but much more than on the ground.
D. No, there is no gravity.



II Falling from an aeroplane.

(a) Answer: ______________________________

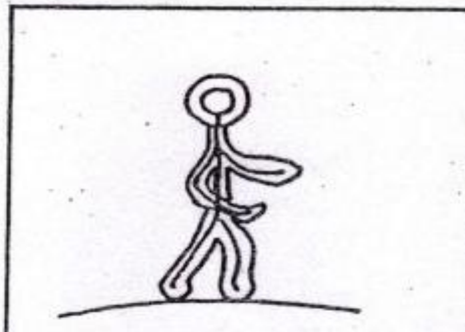
(b) Please explain your answer: ______________________________

____

____

Q.9. Look at picture III. If someone is standing on the moon, is there any gravity?

A. Yes, but much more than on the earth.
B. Yes, about the same as on the earth.
C. Yes, but much less than on the earth.
D. No, there is no gravity.



III Standing on the moon.

(a) Answer: ______________________________

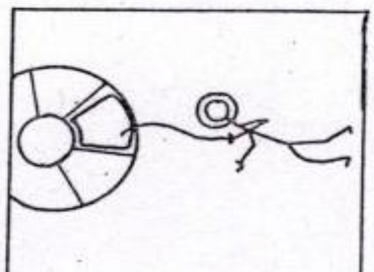
(b) Please explain your answer: ______________________________

____

____

Q.10. Look at picture IV. The satellite is going around the earth. Is there any gravity up where the spaceman is?

A. Yes
B. No



IV. Spaceman near a satellite

(a) Answer: ______________________________

(b) Please explain your answer: ______________________________

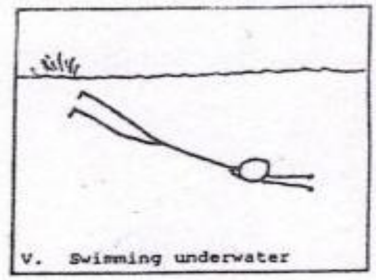
____

____

____

Q.11. Look at picture V. Is there any gravity when the person is swimming under water?

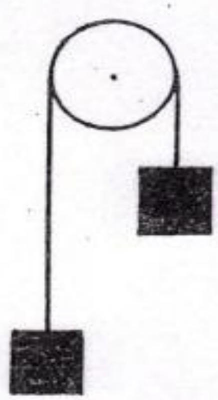
A. Yes
B. No
C. Depends on whether the person is going up or down.



(a) Answer: ___

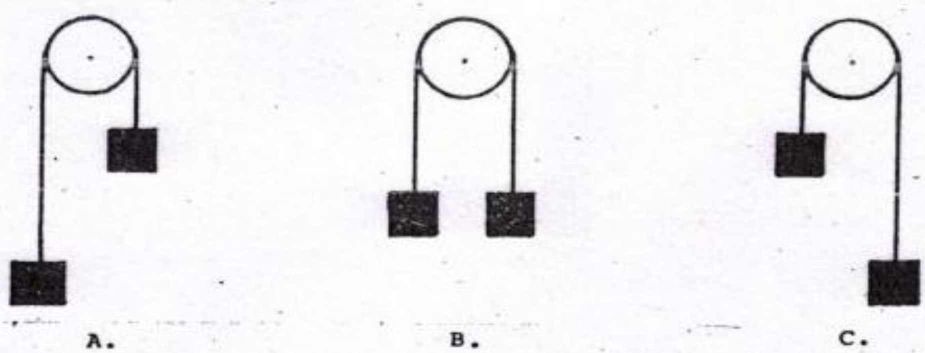
(b) Please explain your answer: ___

Question 12



Two equal blocks are linked by a piece of string. The string is placed over a pulley, so the blocks are at rest in the positions shown in the picture above.

When we look at the blocks one minute later, which of the three pictures below best shows the positions of the blocks now?



(a) Answer: ___

(b) Why did you choose this answer? ___

Thank you for your help.

APPENDIX F
CONTINGENCY TABLES FOR FISHER'S EXACT TEST

A) Ho: There is no significant association between the number of misconceptions and gender in the 12 situations.

# of Misconceptions	**Gender**		**Total**
	Male	**Female**	
0-7	7	5	12
8-15	5	7	12
Total	12	12	24

Result: 2-tailed p = 0.6843
2-tailed p > 0.05

Decision : Do not reject Ho

B) Ho : There is no significant difference in the proportion of male and female students having misconceptions.

Percent of Students	**Gender**		**Total**
	Male	**Female**	
3 – 39	2	1	3
40 - 74	10	11	21
Total	12	12	24

Result : 2-tailed p = 1.00
2-tailed p > 0.05

Decision : Do not reject Ho

APPENDIX G

CALCULATION OF KENDALL'S COEFFICIENT OF CONCORDANCE (W)

A) Ho: There is no significant agreement in the ranking of the number of misconceptions according to the type of school Physics background.

Background (n)	**Questions (p)/Ranking of the Number of Misconceptions**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**	**D**	**S**
Middle Sch	1	1	1	1.5	1.5	1	1.5	1	1	1.5	2	1	15	9	81
Physical Sc	2	2	2	1.5	1.5	2	1.5	2	2	1.5	1	2	21	3	9
Physics	3	3	3	3	3	3	3	3	3	3	3	3	36	12	144

Mean = 24 $\sum S = 234$

$$W = \frac{12\,S}{p^2(n^3 - n) - pT}$$

T = correction for ties
$= (2^3-2) + (2^3 - 2) + (2^3-2) + (2^3-2)$
$= 24$

$$= \frac{12\,(234)}{12^2(3^3 - 3) - 12\,(24)}$$

$W = 0.886$

Where: W = Kendall's coefficient of concordance

D = deviation from mean

S = square of the deviation from mean

p = number of questions (judges)

n = number of items to be ranked

T = correction for ties

$\chi^2 = p\,(n-1)\,W$
$= 12\,(3-1)\,(0.886)$
$= 21.3$

χ^2 tabular = 5.99

Results : $\chi^2 >$ tabular
p-value = 0.000024

Decision : Reject Ho

B) Ho : There is no significant agreement in the ranking of the proportion of students having misconceptions according to the type of school Physics background.

Background (n)	**Questions (p)/ Ranking of Proportion of Students Having Misconceptions**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**	**D**	**S**
Middle Sch	1	1	1	1	1	1	1	1	1	1	1	1	12	12	144
Physical Sc	2	2	3	3	3	3	3	2	2	2	2	3	30	6	36
Physics	3	3	2	2	2	2	2	3	3	3	3	2	30	6	36

Mean = 24 $\sum S = 216$

$$W = \frac{12\,S}{p^2\,(n^3 - n) - pT}$$

$$= \frac{12\,(216)}{12^2\,(3^3 - 3) - 12(0)}$$

$$= 0.750$$

$\chi^2 = p\,(n-1)\,W$ χ^2 tabular = 5.99

$= 12\,(3-1)\,(0.75)$

$= 18.0$

Results: $\chi^2 >$ tabular

p – value = 0.000123

Decision : Reject Ho

VITA

Jane Ragasa-Pablico was born in 1976 in the Philippines. She earned her Bachelor of Science in physics and Master of Science in teaching in the years 1996 and 2002, respectively, from the University of Northern Philippines. She started teaching science and math in the Philippines in the school year following her graduation in 1996. In February 2008, she moved to Baton Rouge, Louisiana, to continue a more challenging teaching career. She started pursuing her master's degree at Louisiana State University in summer 2008. She is employed by the East Baton Rouge Parish School System and is currently assigned as a science teacher at McKinley High School.