REMEDIATING ALTERNATIVE CONCEPTIONS IN INTRODUCTORY PHYSICS

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ABSTRACT: *This study was conducted to remediate students' misconceptions in physics using ConcepTests of Mazur's Strategy, interactive engagement pedagogy. Specifically, it identified students' misconceptions in Newton's Laws of Motion as probed by the Force Concept Inventory (FCI). It also determined the concepts with the most and least misconceptions, the most and least remediated concepts among the identified misconceptions, and the extent of the remediation addressing the identified misconceptions using McNemar Change Test for Significance.*

The result revealed that students possessed misconceptions before remediation on nine (9) specific concepts related to Newton's Laws of Motion as probed by the FCI and validated by an interview. These items were related to concepts (a)'that greater mass implies greater force'; (b) 'ego-centered reference frame'; (c) 'only active agents exert forces'; (d) 'circular impetus and centrifugal force'; (e) 'acceleration implies increasing force', 'gravity increases as object falls', and 'gravity acts after impetus wears down'; and (f) /last force to act determines motion', and 'velocity-acceleration undiscriminated'.

It was discovered that among the nine specific misconceptions identified by the FCI, an only concept related to greater mass implies greater force students performed significantly much better on the posttest with Chi sq = 8.1, $p(\alpha) = 0.0044$ than the items who performed worse.

Introductory physics students believed about the concept that greater mass implies greater force was identified with the most (56%) misconceptions and the concept about the force compromise determines motion was identified with the least (8%) misconceptions.

Among the identified misconceptions, the concept related to 'greater mass implies greater force' yielded as the most remediated which 10 out of 14 students (71%) with misconceptions shifted to scientific conception after remediation. and the concepts about' acceleration implies increasing force' and 'ego-centered reference frame' both yielded the least concepts remediated which none of the students changed their answers from wrong to correct rather have chosen another answer other than the identified choice with misconception.

INTRODUCTION

In physics instruction, conceptual understanding is one of the most serious problems often overlooked. Instructors are often challenged with the problem that students leave their courses without a good understanding of the concepts in some cases even in spite of having achieved good grades in the course[1].

Conceptual learning in physics has been continuing problems for more than thirty years[2] and students are compelled to finish the course not for personal gain but for curricular requirements. Research communities in a different part of the world are doing their best for the development of different strategies and methods to help solve problems in conceptual learning.

Unfortunately, only very few related studies about misconceptions were conducted in the

Philippines. It will take hard work and involvement by both learners and teachers to remedy

misconceptions or alternative conceptions in physics[3]. Similarly emphasized that learning physics will necessarily take by doing physics[4]. Most of the studies were focused on students' conceptual knowledge rather than the mathematical know how [5]. This leads to questions such as, what teachers actually teach? and what students really learn?

This study will augment and enhance students' conceptual grasps and address students' alternative conceptions in Newtonian Mechanics specifically on *Newton's Laws of Motion* with the introduction of a conceptual test called ConcepTest which was developed and used by Mazur. Peer Instruction of Mazur is an interactive-learning technique that works well for instructors teaching both small and large classes. ConcepTest is part of this technique which was used for this study in a small class.

As a result, there is an immense need to remedy misconceptions in an introductory physics course. And to address this important need, this study proposes an alternative strategy, the ConcepTest, a remediation strategy is an interactive engagement pedagogy that could uphold conceptual learning by remediating students' misconceptions in *Newton's Laws of Motion*.

This study aimed to identify and subsequently remediate students' misconceptions in *Newton's Laws of Motion*. Specifically, this research sought to answer the following questions: 1.) What are the misconceptions of students in Newton's Laws of Motion as probed by the FCI?; 2.) In which concepts do students have the most and least misconceptions?; 3.) To what extent does the remediation address the identified misconceptions?; 4.) In which concepts were misconceptions most and least remediated?

The results of this study can significantly contribute to physics teachers, administrators as well as to the curriculum developers. Teachers will be able to find satisfaction in every physics topic they teach by allowing students to involve actively in the discussion and conceptual knowledge is gained as a result. Moreover, alternative conceptions are remedied if not eliminated using the ConcepTest. This technique can be included in the preparation of the course syllabus and lesson plan of the teacher.

This study was focused on the remediation of the most identified misconceptions of students. The class was selected purposively because this was the only non-physics major class during the time frame. The whole class size was the sample of the study provided all students were present the entire planned sessions.

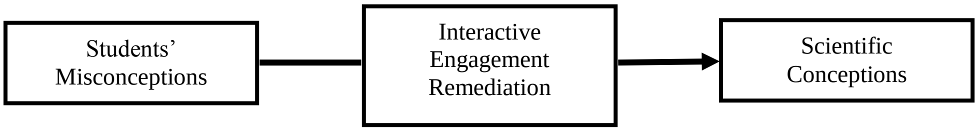


Figure 1 Conceptual Framework of the Study.

Figure 1 shows the framework of the study. It reveals that scientific conceptions (dependent variable) depend on the instructional strategy (Interactive Engagement Remediation – independent variable) of the teacher. Provided strict administration of the subject matter is followed.

The interactive engagement remediation using ConcepTest (CT) is expected to shift students' misconceptions to scientific concepts. It may not eliminate but at least minimize through active learning, not just mere memorization of information. Generally, conventional physics instruction resulted in very minimal help in eliminating students' misconceptions. Related studies revealed that naïve beliefs or preconceptions are very stable and the conversion of a traditional classroom into an interactive one would greatly and strongly contribute in remediating misconceptions. Research results strongly suggest that (1) Traditional courses fail to convey much basic conceptual understanding of Newtonian mechanics to the average student, and (2) Interactive Engagement courses can be much more effective than traditional courses in enhancing conceptual understanding[6].

MATERIALS & METHODS

This study was conducted to Introductory Physics 101 (Fundamental Physics I-Newtonian Mechanics) class. The study employed a pretest-posttest one-group design comparing students' performance in FCI with the interview for validation of responses to remediate students' identified misconceptions using Mazur's Strategy.

a.) Pretest

Diagnostic tests provide a general picture of initial knowledge states, but for instructional purposes we need a classification of initial states that identifies specific misconceptions that need to be corrected[7].

The students were administered the FCI as pretest at the start of the class. The pretest may or may not count towards the course grade. This is to probe students' misconceptions related to *Newton's Laws of Motion* before the remediation.

Since the FCI was published it has been carefully examined by many physics professors around the world. The face validity of the FCI is thus beyond reasonable doubt[20]. It supported by the internal consistency by computing *KR-20* with $r=0.89$ reliability.

b.) The Interview

After the pretest, misconceptions were probed and identified. An interview was carried out to all the students solely to ensure that their answers to the FCI were correctly identified or chosen. During the process, students were asked the same questions in the FCI among the identified items with misconceptions and also asked for a brief explanation of their answers. The class was provided with a handout about Newton's Laws of Motion for advance reading. Remediation using ConcepTests of Mazur's Strategy as interactive engagement pedagogy was carried out as intervention during the process.

c.) The Posttest

At the end of the chapter of the target subject matter, the same FCI was administered as a posttest to the same class which form part of the end-of-the-chapter quiz for grading purposes. The same interview was conducted for validation after the posttest.

A frequency distribution table for pretest was used to determine the identified misconceptions. *McNemar Change Test for Significance* was used to measure the significant difference of the students' conceptual change among the identified misconceptions after the remediation.

McNemar change test for significance studies the change in a group of respondents measured twice on a dichotomous variable. The McNemar's test evaluates changes in related or paired binomial attributes, whether changes in one direction is significantly greater than that in the opposite direction.

If b = the number of positive cases that converts to negative, and c = the number of negative cases converted to positive, then the McNemar test Chi Squares = $[(b-c)-1]^2 / (b+c)$ with the degree of freedom = 1.

Analyses were conducted for the answers of the students in the FCI to determine students' most and least misconceptions. This was focused on the misconceptions of the students related to Newton's Laws of Motion. This was done to closely monitor students' scientific conceptions after the remediation shift from misconceptions at the beginning of the treatment to scientifically known concepts.

RESULTS AND DISCUSSIONS

It consists of two sections, first is the discussion and findings on students' identified misconceptions related to *Newton's Laws of Motion*. Second deals with the subsequent remediation of students' identified misconceptions using Interactive Engagement strategy, the ConcepTests.

Students Misconceptions on Newton's Laws of Motion

Prior to instruction, the pretest of student misconceptions revealed a pattern of misconception frequencies that were comparable to that found by previous studies[8][9]. Table 1 shows the frequency and percentage of students with misconceptions.

Table 1 Frequency and Percentage of Students with Misconceptions

FCI Item #	Frequency (n=25)	Percentage (%)
4	14	56
14	12	48
28	12	48
6	11	44
3	10	40
9	10	40
13	10	40
19	10	40
21	10	40

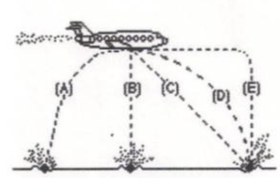
It revealed that about 56% of students believed that objects with greater mass implies greater force, this misconception is related to Newton's 3rd law of motion. FCI item numbers 14a and 28b resulted to 48% where students have the notion that object followed the path opposite to the direction of motion or ego-centered reference frame which is related to kinematics and they also believed that only active agents exert force which is related to Newton's 2nd law of motion.

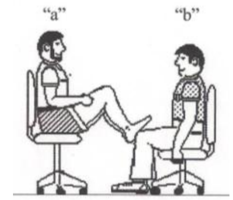
About 44% of students chose item number 6a and believed about circular impetus, that objects would 'remember' the path after it left the constraint. This concept is related to Newton's 1st law of motion. Concepts associated with FCI item numbers 3b, 9b, 13b, 19a, and 21b were identified with the least (40%) misconceptions. FCI items 3b and 19a were both related to Newton's 2nd law of motion and kinds of force. Students believed that acceleration implies increasing force and thought that gravity increases as the object falls. FCI items 9b and 21b were both related to the superposition principle. Students believed that last force to act determines motion. FCI item 19a is related to kinematics and students confused about the concept between velocity and acceleration.

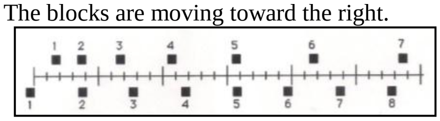
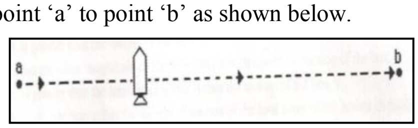
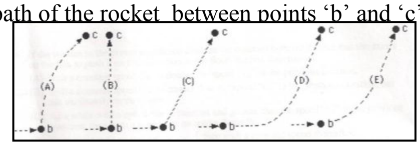
It appeared that the concepts where most students showed misconceptions were related to Newton's 3rd Law of Motion, action-reaction pairs. The result agreed with the findings from different studies[3][9][10][11] conducted.

Based from the results, most of the students have different misconceptions at the start of every physics class, this finding is analogous of that found in similar studies[1][9][12]. Table 2 shows the students' misconceptions based on the pretest responses.

Table 2 FCI Items with the Identified Misconceptions as Supported by Interview Responses and Corresponding Scientific Conceptions

FCI Item Number	Misconception	Scientific Conception
Item 4 A large truck collides head-on with a small compact car. During the collision: (b) the truck exerts a greater amount of force on the car than the car exerts on the truck. (c) the car exerts a greater amount of force on the truck than the truck exerts on the car. (d) neither exerts a force on the other, the car get smashed simply because it gets in the way of the truck. (e) the truck exerts a force on the car but the car does not exert a force on the truck. (f) the truck exerts the same amount of force on the car as the car exerts on the truck.	*56% of students chose:* *(a) the truck exerts a greater amount of force on the car than the car exerts on the truck.* Misconception: ***greater mass implies greater force*** Interview Responses: *Student 1: "the same force"* *Student 2: "malaki yong 'mass' ng truck vs car"* *Student 3: "kasi malaki ang truck"*	**Newton's 3rd Law of Motion: for every action, there's always an equal but opposite reaction** Correct answer: *(e) the truck exerts the same amount of force on the car as the car exerts on the truck.*
Item 14 A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As observed by a person standing on the ground and viewing the plane as in the figure below, which path would the bowling ball most closely follow after leaving the airplane?	*48% of students chose:* *(a)* Misconception: ***ego-centered reference frame*** Interview Responses: Student 1: *"mabigat yong ball"* Student 2: *" it will stay behind when it fall"* Student 3: *"it remain at the back of the plane"*	**Constant acceleration entails parabolic orbit and changing speed.** Correct answer: *(d) figure below* 
Item 28 In the figure below, student 'a' has a mass of	*48% of students chose:*	**Newton's 3rd Law of Motion: for every action, there's always an**

FCI Item Number	Misconception	Scientific Conception
95kg and student ‘b’ has a mass of 77kg. They sit in identical office chairs facing each other. Student ‘a’ places his feet on the knees of student ‘b’, as shown. Student ‘a’ then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching one another: (a) neither student exerts a force on the other. (b) student ‘a’ exerts a force on student ‘b’, but ‘b’ does not exert any force on ‘a’. (c) each student exerts a force on the other, but ‘b’ exerts the larger force. (d) each student exerts a force on the other, but ‘a’ exerts the larger force. (e) each student exerts the same amount of force on the other.	*(b) student ‘a’ exerts a force on student ‘b’, but ‘b’ does not exert any force on ‘a’.* <u>Misconception:</u> ***only active agents exert force*** <u>Interview Responses:</u> Student 1: *“force is at the center”* Student 2: *“kasi ikaw ang nagsipa sa ‘B’”* Student 3: *“‘a’ is bigger than ‘b’”*	**equal but opposite reaction** <u>Correct answer:</u> *(e) each student exerts the same amount of force on the other.* 
Item 3 A stone dropped from the roof of a single story building to the surface of the earth: (a) reaches a maximum speed quite soon after release and then falls at a constant speed. (b) speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the earth. (c) speeds up because of an almost constant force of gravity acting upon it. (d) falls because of natural tendency of all objects to rest on the surface of the earth. (e) falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downwsrd.	*40% of students chose:* *(b) speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the earth.* <u>Misconception:</u> ***acceleration implies increasing force/ gravity increases as object falls.*** <u>Interview Responses:</u> Student 1: *“falling down plus gravity”* Student 2: *“gravity becomes stronger to the stone”* Student 3: *“bumilis kasi lumalakas yong gravity”*	**Constant force implies constant acceleration and acceleration is independent of weight** <u>Correct answer:</u> *(c) speeds up because of an almost constant force of gravity acting upon it.*
Item 9 The figure depicts a hockey puck sliding with constant speed v_o in a straight line from point ‘a’ to point ‘b’ on a frictionless horizontal surface.  Forces exerted by the air are negligible. You are looking down on the puck. When puck reaches point ‘b’, it receives a swift horizontal kick in the direction on the heavy point arrow. Had the puck been at rest at point ‘b’, then the kick would have set the puck in horizontal motion with a speed v_k in the direction of the kick. The speed of the puck just after it receives the kick is: (a) equal to the speed ‘v_o’ it had before it received the kick. (b) equal to the speed ‘v_k‘ resulting from the kick and independent of the speed ‘v_o’. (c) equal to the arithmetic sum of the speeds ‘v_o’ and ‘v_k’.	*40% of students chose:* *(b) equal to the speed ‘v_k‘ resulting from the kick and independent of the speed ‘v_o’.* <u>Misconception:</u> ***last force to act determines motion*** <u>Interview Responses:</u> Student 1: *“force received by puck follow through its direction”* Student 2: *“pag i-kick, hindi derecho yong direction”* Student 3: *“follow the path of kick”*	**Vector sum with canceling forces** <u>Correct answer:</u> *(e) greater than either of the speeds ‘v_o’ and ‘v_k’, but less than the arithmetic sum of these two speeds.*

FCI Item Number	Misconception	Scientific Conception
(d) smaller than either of the speeds ‘v_o’ and ‘v_k’. (e) greater than either of the speeds ‘v_o’ and ‘v_k’, but less than the arithmetic sum of these two speeds.		
Item 13 A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy’s hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is(are): (a) a downward force of gravity along with a steadily decreasing upward force. (b) A steadily increasing upward force from the moment it leaves the boy’s hand until it reaches its highest point; on the way there is steadily increasing downward force of gravity as the object gets closer to the earth. (c) An almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on the way down there is only a constant downward force of gravity. (d) An almost constant downward force of gravity only. (e) None of the above. The ball falls back to ground because of its natural tendency to rest on the surface of the earth.	*40% of students chose:* *(b) a steadily increasing upward force from the moment it leaves the boy’s hand until it reaches its highest point; on the way there is steadily increasing downward force of gravity as the object gets closer to the earth.* Misconception: **acceleration implies increasing force/ gravity increases as object falls** Interview Responses: Student 1: *“increasing gravity as it moves closer to the earth”* Student 2: *“malakas na yong gravity pababa”* Student 3: *“greater pull of gravity”*	**Constant force implies constant acceleration and acceleration is independent of weight** Correct answer: *(d) an almost constant downward force of gravity only*
Item 19 The positions of two blocks at successive 0.20 second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.  Do the blocks ever have the same speed? (a) No. (b) Yes, at instant 2. (c) Yes, at instant 5. (d) Yes, at instant 2 and 5. (e) Yes, at some time during the interval 3 to 4.	*40% of students chose:* *(a) No.* Misconception: ***relationship between velocity and acceleration*** Interview Responses: Student 1: *“because they are all the same”* Student 2: *“pareho pareho lang yong distance”* Student 3: *“no, because they are same space with each other”*	**Acceleration discriminated from velocity** Correct answer: *(d) Yes, at some time during the interval 3 to 4.*
Item 21 A rocket drifts sideways in outer space from point ‘a’ to point ‘b’ as shown below.  Which of the paths below best represents the path of the rocket between points ‘b’ and ‘c’? 	*40% of students chose:* *(b)* Misconception: ***last force to act determines motion*** Interview Responses: Student 1: *“nuay gravity, straight lang ele”* Student 2: *“straight kasi yong rocket”* Student 3: *“because of zero gravity”*	**Vector sum with canceling forces** Correct answer: *(e) figure below*

Remediation from Alternative Conceptions to Scientific Conceptions

This section discusses the extent of remediation relative to the students' identified misconceptions which later changed to scientific conceptions. It can be seen among the nine (9) items with misconceptions, that students who changed the category of their answers (wrong to correct), remediation of misconception in item number 4 performed better (71% of students changed their answers from wrong to correct) after remediation

There was a significant change (chi sq = 8.1; $p(\alpha) = 0.0044$) as supported using McNemar Change Test. FCI item number 4 is related to the misconception that *greater mass implies greater force*. Students changed their notion that regardless of mass, the force exerted on both objects is the same but opposite in direction.

Unfortunately, about 21% of students with misconceptions retained their answers and about 8% changed from wrong to other than the choice identified with misconception as confirmed by McNemar change test.

Relatively, misconception in FCI item 3 shifted 60% to scientific conceptions. Students shifted from their naïve ideas to scientifically accepted notion that *constant force implies constant acceleration* and that *acceleration is independent of weight* of the object. Misconception in FCI item 28 also shifted 58% in which students had acknowledged that for every *force exerted there is always equal but opposite force*, and FCI items 6, 9, 19 & 21 shifted less than 50% as reflected in table 4.3. Furthermore, 75% of students with misconceptions in FCI item 14 retained their answers and 25% changed their answers to other than the identified choice with misconception. And FCI item 13 with 50% of students retained their wrong answers and 50% changed from wrong answers to other than the choice with misconception. The result reveals a very poor grasp of the Newtonian concepts, this implies that students possessed non-Newtonian concepts even before and after introductory physics class, these ideas were the *dominance idea* and the *impetus idea* as also confirmed by previous research findings[13]. Accordingly, this dominance idea means that *bigger or more active body has more force*, and the impetus idea means that a *moving body exercises force within the body*. Students chose to believe that for an object falls from a plane will follow the opposite of the direction of motion. FCi item 28b is related with the superposition principle, students thought that only active agents exert force. This was previously confirmed by Boyle & Maloney (1991). FCI item 6a is associated with Newton's 1st law of motion, students have the notion that objects would 'remember' the path after it left the constraint.

The result may have caused by some factors affecting the swelling of students' misconceptions. This may fall on false negative[15], this is where students select non-Newtonian choices who in fact understand Newtonian mechanics. Students with a strong naïve belief tend to influence other students with a weak foundation of conceptual understanding. Similarly, it is also concluded that conceptual contamination affects student's responses from correct to wrong concepts due to the non-separation of students with misconceptions and students without misconceptions[16]. One of the challenges of this study is students' resistance to the method because most students are unaccustomed to active participation in science classes[17]. Students prefer to deal with sciences by mere paper and pencil strategy. Some feel uncomfortable participating in the discussions or initially consider the discussions a waste of time.

As a result, there are four conditions that must be present to bring about conceptual change, (1) The student must be dissatisfied with the current understanding; (2) The student must have an available intelligible alternative; (3) The alternative must seem plausible to the student; and (4) The alternative must seem fruitful (useable) to the student[18].

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

1. Non-physics major college students have several misconceptions related to *Newton's Laws of Motion* before an introductory physics class. Specific misconceptions were identified among students.
2. Introductory physics students believed about the concept that *greater mass implies greater force* (FCI item 4a) was identified with the most (56%) misconceptions and the concept about the *force compromise determines motion* (FCI item 12a) that was identified with the least (8%) misconceptions.
3. Among the nine specific misconceptions identified by the FCI, only misconception in FCI item number 4 where students performed significantly much better (changed their answer from wrong to correct; Chi sq = 8.1, $p(\alpha) = 0.0044$) than the items who performed worse (retained or changed their answer from correct to wrong).
4. The concept in FCI item number 4 is about the 3rd law of motion for impulsive forces resulted the most concept remediated of which 71% (10/14) students with misconceptions shifted to scientific conceptions. Concepts in FCI item numbers 13 and 14 were both related to Newton's 2nd law of motion and kinematics concepts about *ego-centered reference frame* respectively. In both items, none of the students with misconceptions changed answers to the scientifically accepted concept, but instead 50% & 75% respectively, retained to their prior beliefs and 50% & 25% respectively, chose another answer other than the identified choice with misconception. Thus, misconceptions in FCI items 13 and 14 were considered least remediated.

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