DOES THE USE OF RANKING TASKS INCREASE CONCEPTUAL UNDERSTANDING IN PHYSICS FOR 8TH GRADE STUDENTS?

by

Georgia Nichole Alvarez

A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

Montana State University
Bozeman, Montana

July 2013

STATEMENT OF PERMISSION OF USE

In presenting this professional paper in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

Georgia Nichole Alvarez

July 2013

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This research focused on the use of ranking tasks in a high school level conceptual physics class for the eighth grade. Ranking tasks were used while developing the students' conceptual understanding of force and motion. Many students developed an appreciation for the benefits of using ranking tasks as a tool in their learning strategies toolbox. The ranking tasks were additionally beneficial as an instructional tool in assessing the students' level of conceptual understanding.

INTRODUCTION AND BACKGROUND

Pacific Middle School is in the Evergreen School District located in a suburban, residential area in Vancouver, Washington. Classified as a Title I school, with 43.4% of the current population receiving free and reduced lunch, Pacific's student population is 1,093 and has a 54:46 percent male to female ratio. The majority ethnic group at the school is Caucasian (70.9%). Hispanic (10.9%), Asian/Pacific Islander (15.2%), African American (2.4%), and American Indian/Alaskan Native (1.6%) represent the remaining populations (Washington State Report Card, 2011).

Pacific operates on a modified five-period day. I conducted my research in the 3 sections of physics, with a total of 86 students, during the 2012-2013 school year. My physics students consisted of the mostly EXCEL students that were concurrently enrolled in the Integrated Algebra I math class. The EXCEL program was designed to address the needs of intellectually gifted students in grades two through eight. This program is very similar to the Talented and Gifted (TAG) program offered throughout the country. The physics for eighth graders program has been fully implemented throughout the district for three years. The program allows the eighth graders to take a high school level laboratory science course in middle school where they can earn graduation credits.

In the first two years of teaching physics to eighth grade students, I came to realize that the students could easily substitute numbers into the variables of an equation yet struggled when explaining their understanding of the concept being calculated. Despite intentional, focused efforts to develop the students' understanding through inquiry activities, class discussion, and textbook assignments, I had found that the students struggled to develop deep conceptual understanding and an ability to use scientific terminology. From reading the current research about increasing conceptual understanding, I decided to conduct an action research study on increasing conceptual understanding of physics for eight grade students through the use of ranking tasks. The ranking tasks asked students a conceptual question, for example about acceleration, in which the students had to arrange the six objects in order from greatest acceleration to least acceleration as illustrated in Figure 1.

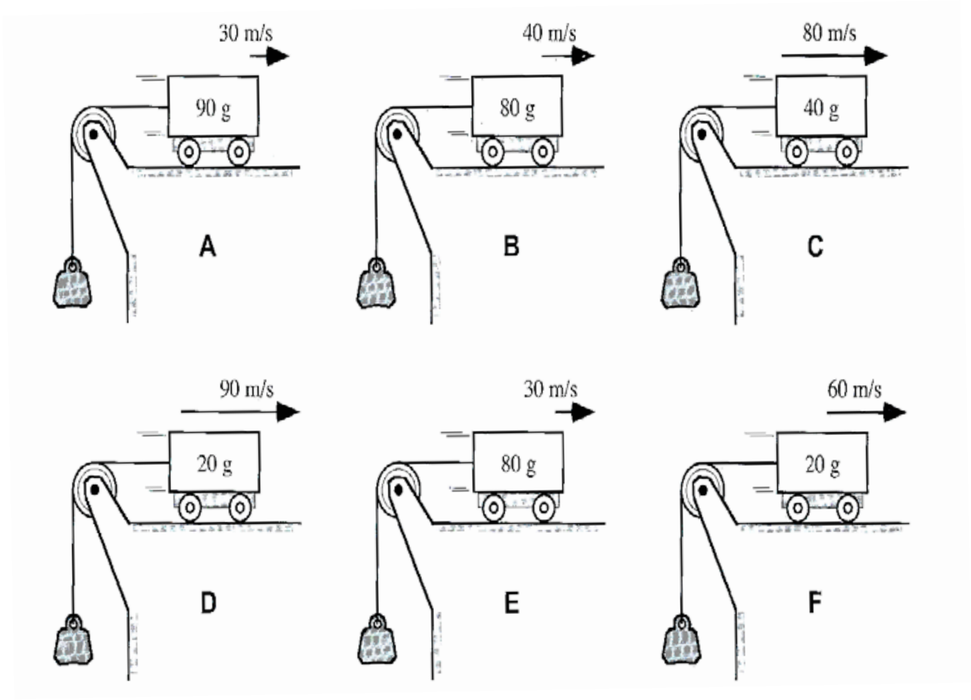


Figure 1. Cart rolling along horizontal surface - acceleration (O'Kuma, Maloney, & Hieggelke, 2000).

The students then had to explain in writing why they chose to place the objects in that order. The combination of ranking the options and explaining their thinking allowed me to gauge the students' genuine understanding of the concept. A sub-question to this research study was to see if the ranking tasks also increased the students' ability to explain their conceptual understanding of physics.

CONCEPTUAL FRAMEWORK

It often comes as a surprise to educators when their students come to the end of the course and discover that many of the original preconceived beliefs the students entered the class with are still intact, despite the varied and intentional instructional methods. While the students perform well on assessments, their conceptual understanding of the material remains low. Once they have left the classroom and are presented with unfamiliar, real-world situations, the students will often revert back to their preconceived beliefs to explain the situation (Eryilmaz, 2002; Hestenes, Wells, & Swackhamer, 1992).

In order to develop conceptual understanding, students need to have an experience that jars their preconceived notion of how the world works. Students will struggle to grasp the concepts unless they intuitively discover the concept first (von Aufschnaiter, 2010). In physics this prior knowledge must be taken into account when attempting to develop new knowledge bases. If conceptual change is to occur, then the instruction needs to first identify the students' beliefs and build their new understanding from these beliefs, not in opposition to them. When students are caught in inconsistencies in their explanations, they are more likely to engage in the learning process to change their understanding (Dykstra, Boyle & Monarch, 1992).

Often in traditional, lecture-based classrooms, the students' prior knowledge is not taken into consideration when determining the best course of action for presenting new concepts. When students' prior knowledge is congruent with the conceptual representations being presented to them, they are more likely to perform better on assessments than when their prior knowledge is incompatible with the representations (Franco et al., 2012). In a Piagetian manner, materials need to be provided for the students to manipulate so that they can develop or "construct" their understanding through concrete learning (Renner, Abraham, Gryzbowski, & Marek, 1990). The constructivist approach to instruction encourages the learner to work through the process of learning instead of simply finding the correct answer. This approach in education also aims at making the present experience more consistent with the learner's experiential memory (Gonan & Kocakaya, 2010).

In order for students to create new knowledge, they must first have their prior experiences challenged and be presented with information that is plausible and intelligible. In physics, students often enter an introductory course with experience-based knowledge about how the world around them seems to work. These everyday observations formulate their understanding about the physical world and students struggle with new information that does not resonate with these realities. Content that is not only engaging and motivating, but also plausible and compelling, is more likely to be incorporated into the students' conceptual schema (Taasoobshirazi & Sinatra, 2011). Hestenes, Wells, and Swackhamer (1992) remind educators that some of the most influential scientists of the past, like Galileo and Newton, began with much the same preconceived beliefs as modern-day physics students before they began their journey of discovery. There are specific knowledge relationships and thinking skills that need to be in place before students can be effectively instructed in new information (Hestenes et al., 1992.) To counteract the students' misconceptions, consideration needs to be taken when designing a unit to provide experiences that will allow students to assimilate the new information in a meaningful way. The interactive experiences of a science class, such as labs and demonstrations, should occur before a textual experience in order to promote conceptual understanding (Renner et al., 1990.) Students of physics have shown that they do not overcome conceptual difficulties even after solving more than a thousand traditional questions without a solid qualitative understanding of the concepts (Kim & Pak, 2001).

A common strategy employed to jar a student's prior knowledge is to present them with an experience that is incongruent to their preexisting beliefs about the situation, causing them to question their beliefs. In the classroom these discrepant events provide a powerful way to challenge and motivate students to change their scientific understanding and stimulate deeper knowledge in a safe environment (Gonzalez-Espada, Birriel, & Birriel, 2010). Many students have already developed strategies allowing them to complete assignments and assessments that are not based on a true conceptual understanding but have proven to be successful in completing the course. It is important to not disregard the students' experiential knowledge about how the world works but to incorporate this into the instructional method as a place to start conceptual developments that better adheres to scientific understanding. As the students' beliefs are challenged, and plausible explanations are provided in the instruction, the students are able to recognize or assimilate the new information and apply it to their understanding. By affording the new information a place in their thinking, the students’ conceptual belief about how the world works is changed (Dykstra et al., 1992; Hestenes et al., 1992.) Motivation is one aspect of student learning that has been researched to determine its effect on a student’s ability to allow this conceptual change to happen (Taasoobshirazi & Sinatra, 2011). According to the constructivist approach to acquiring knowledge, students need to develop their own cognitive awareness through experience, rather than being told the information. This will allow students the chance to change their intrinsic beliefs and therefore increase their motivation and change the confidence in their reasoning abilities (Fischer & Horstendahl, 1997).

In 12 to 16 year-olds, the most common form of reasoning is relationship-based (Driver, Leach, Millar, and Scott, 1996). Ranking tasks require the students to explain their thinking about the relationships represented in the situation rather than ask for a memorized or “plug and chug” response. The use of ranking tasks in physics can be beneficial to eliciting students’ conceptual understanding because they require the students to compare several similar situations to each other and place them in order from greatest value to least value of the concept being illustrated.

Ranking tasks provide both the instructor and student with useful information that enable the instructor to develop the presentation of the curriculum in a manner congruent with the students’ prior experiences. How the students respond to the ranking task can indicate to the instructor how solid the students are in their understanding about the concept. In addition, the students can use the scale at the bottom of the ranking task to self-assess how confident they feel about their understanding of the concept and what they did to work through the problem (O’Kuma et al., 2000).

Ranking tasks have been used to the robustness of the students’ understanding of a concept as it is developed. This is due to the fact that these tasks require the students to really think about and explain why they responded the way they did in each situation. While the ranking tasks do contain numerical information, they have specific values for two variables, and the students need to determine how these factors are affecting the particular situation (O’Kuma et al., 2000; Cox, Belloni, & Christian, 2005).

Robust understanding cannot be constructed from one opportunity to explore the material but is developed through multiple explorations and examinations of the concepts (von Aufschnaiter, 2010). It is a good indication of conceptual understanding if the students have the ability to demonstrate quality, conceptual-based thinking skills in a variety of ways (O’Kuma et al., 2000). Specifically developed to elicit students’ reasoning about the given parameters, ranking tasks enable the instructor to determine the students’ conceptual understanding (Cox et al., 2005).

Ranking tasks can be a productive method to stimulate a class discussion of the concepts being presented. The students can be presented with the ranking task, given time to formulate their thinking, and then asked to demonstrate their thinking via a Classroom Response System (CRS) clicker (O’Kuma et al., 2000; Bruff, 2009). CRS clickers, like the eInstruction clickers, are wireless, handheld devices that enable students to anonymously answer conceptual understanding questions.

The use of clickers also allows time for students to discuss their ideas with their peers. Since the students are answering anonymously, when the results are displayed the students can see how others answered and, therefore, which choice(s) rang true to their experiential beliefs. After each student has seen how their peers have responded, small groups can be formed to discuss the class' thinking about the situation. This leads to a richer class discussion as to why each choice makes sense and why the appropriate choice is the correct response (Bruff, 2009). The use of clickers have been shown to increase student engagement and, by extension, student motivation during knowledge construction because they allow students to engage in questions directed at the students' sense-making skills. Only when students are aware of the gaps in their understanding are they challenged to reach beyond the limits of their knowledge (Beatty & Gerace, 2009).

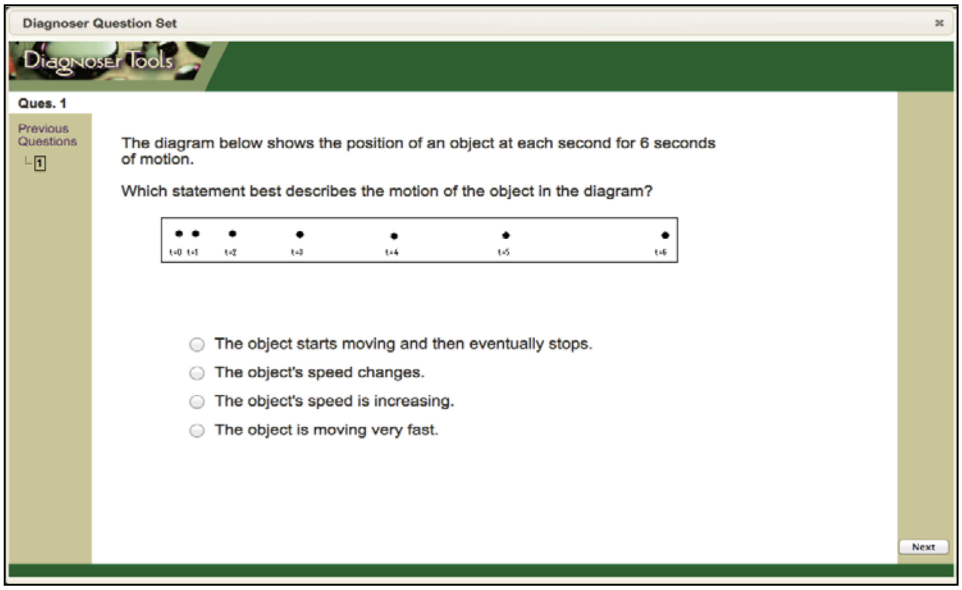
CRS clickers require all students to choose an answer, thereby ensuring that all students actively participate in the discussion. Another benefit of the use of CRS clickers is the sense of camaraderie that develops between the students. The results screen displays a cumulative score for each question. When the correct answer percentage is high the students cheer, and when it is low the students encourage each other (Kenwright, 2009). As social interaction is a key to increasing conceptual understanding, the peer motivation enhanced by the use of the CRS clickers provides a safe environment for the students to modify their conceptual foundations without fear of public humiliation (Martyn, 2007).

The immediate nature of the feedback from the CRS clickers enables the learner to accurately gauge their level of understanding as the lesson/unit progresses. The accountability and participation involved in using the CRS clickers enhances the instruction as well as the learning. The CRS clickers allow the instructor to gauge the number of students that are meeting the expected level of understanding from those who are not (Yourstone, Kraye, & Albaum, 2008). The instructor can then make on-the-spot adjustments to ensure that those students who do not understand the concepts are given multiple opportunities to engage in the material. CRS clicker technology also enables the instructor to capture summary data about that particular class session and use it to guide instruction for the next class. After all, those who do the thinking, reading, writing, and manipulate the materials will be the ones doing the learning (Bennett, 2007). With the aid of the CRS clickers and the use of the ranking tasks, students can increase and improve their conceptual understanding of physics.

METHODOLOGY

Before the unit on kinematics was initiated, the Linear Motion and Ranking Task Pre-Unit Survey was given to the students (*N* = 86) to assess their prior knowledge of five physics concepts: force, speed, velocity, acceleration, and gravity, as well as their familiarity with ranking tasks (Appendix A). The Linear Motion and Ranking Task Post-Unit Survey was given to the students two months after the end of the unit to gauge how their understanding of the five concepts had developed and been retained (Appendix B). The survey also assessed how their understanding of the purpose of ranking tasks had changed since the beginning of the unit. The Force Concept Inventory (Hestenes et al., 1992) was administered before the kinematics unit as well, to assess the students' ability to apply their current thinking about these concepts to real-world situations (Appendix C). The Force Concept Inventory (FCI) is a 29 question multiple-choice assessment. The same assessment was then given at the end of the kinematic unit to gauge the learning progress made by the students.

The kinematics unit was broken down into four subunits: constant linear motion, accelerated motion, projectile motion, and Newton's Laws of Motion. Each subunit began with a pre-unit assessment provided by the Diagnoser website. Diagnoser is a website designed to elicit different facets of student thinking (www.diagnoser.com) using Minstrell, Thissen-Roe, and Hunt's (2004) work to organize learning goals for students based on the student's intuitive ideas about the concepts. Each question set provided feedback to the students as they progressed through the problems that helped them to understand if their thinking was on track or what the program thought might be hampering their grasp of the concepts. I used these data to modify the unit to meet the needs of the students. The first version of the subunit's material was assigned as the Diagnoser pre-assessment. For example, Changes in Speed 1 was assigned to the students at the beginning of the subunit on accelerated motion (Figure 2). Each question set was between six to nine questions, depending on how the student answered the questions.



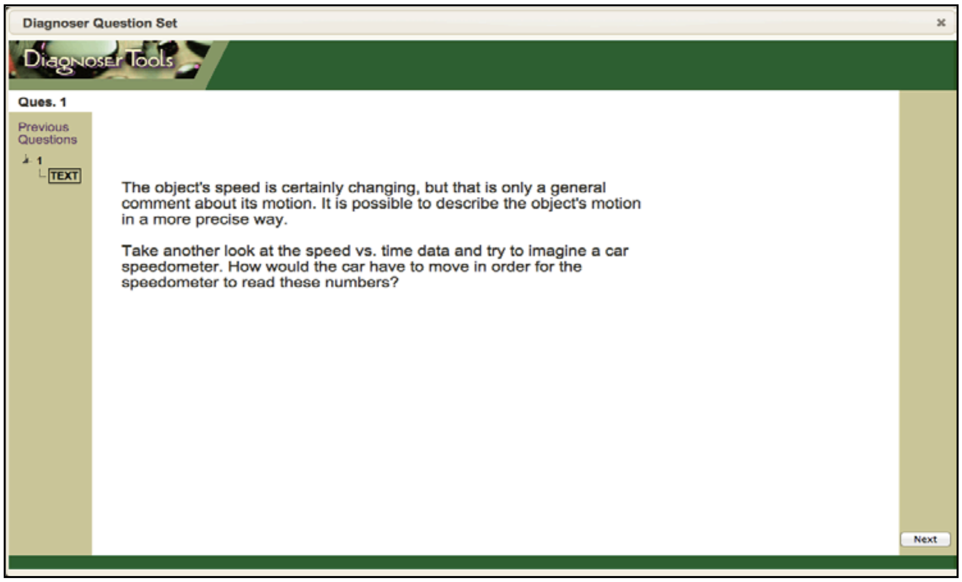
The diagram below shows the position of an object at each second for 6 seconds of motion.

Which statement best describes the motion of the object in the diagram?

○ The object starts moving and then eventually stops.
○ The object's speed changes.
○ The object's speed is increasing.
○ The object is moving very fast.

Figure 2. Diagnoser example: change in speed 1.

If the student chose an option that was consistent with the concept, they received a message that encouraged the student to continue with their line of thinking. However, if the student answered incorrectly, a diagnostic message of what the program assessed their misunderstanding to be appears on the screen. The program explained what might be hampering their understanding and then gave the student more opportunities to adjust their thinking about the concept (Figure 3).



The object's speed is certainly changing, but that is only a general comment about its motion. It is possible to describe the object's motion in a more precise way.

Take another look at the speed vs. time data and try to imagine a car speedometer. How would the car have to move in order for the speedometer to read these numbers?

Figure 3. Diagnoser: diagnostic screen.

Once the students completed the pre-unit Diagnoser questions, I reviewed which facets of the concept were consistently misunderstood and then selected the appropriate ranking task(s) to address those areas. The ranking tasks were incorporated into a minimum of two assignments per week, as starter/exit questions and as a homework problem, though more were used and not collected for analysis. The ranking tasks were scored using levels 0 through 3 based on the following: Level 0 = no answer given; Level 1 = little to no understanding; Level 2 = some understanding; and Level 3 = proficient understanding. To further analyze how the students shifted their conceptual understanding, I tabulated the students' shift in conceptual understanding, changing from a one level of conceptual understanding to different level of conceptual understanding. Students completed an inquiry activity during the subunit prior to the discussion about the concepts. For example, during the subunit on accelerated motion students completed a lab activity, Rolling Marbles, in which they had three differently shaped aluminum tracks and a marble (Appendix D). The goal for the students was to determine which track shape would enable the marble to accelerate the greatest. The students used their ranking task as a hypothesis about the situation and gathered data to investigate whether or not their thinking was supported by the results. This enabled the students to collaborate with one another in a hands-on manner to explore the concepts. Once the inquiry activity was completed, the students were given a reading exercise from the class textbook, *Conceptual Physics* (Hewitt, 1997).

Before using the CRS clickers at the start of the kinematics unit, the students were given a Likert scale survey, To Clicker or Not to Clicker, to determine their prior exposure to the CRS clickers, their interest in using them during class discussions, and their motivation to use the feedback from the CRS clickers to improve their understanding of the concepts (Appendix E). The Likert scale used on the survey was 0 = No, 1 = Maybe, and 2 = Yes. The CRS clickers were used during class discussions to gauge the students' current understanding of the material being covered and during quiz review sessions to gauge how prepared the class was for the assessment. The CRS clickers were also used on the unit quizzes for the multiple choices section in order to provide timely feedback to the students, as I was able to score the short answer section much more quickly without also needing to score the multiple choices section.

At the beginning of the subunit on linear motion, students were given the Displacement Pre-Unit Ranking Task (Appendix F). Students were asked to rank six position-time graphs of moving objects in order from greatest displacement to least displacement, indicating with an equal sign any objects that had the same displacement. When the class was given the clicker-ranking task, they were asked to send their ranking to me via the clicker. The class' overall thinking about the situation was then projected onto the front screen so that the students could see how their peers interpreted the situation. Based on the results, each student discussed the situation with their table group of three to four students. The small group was given five to seven minutes to develop a group response. The table group was directed to write their group ranking on the group's dry-erase board. Each group elected a spokesperson to voice the group's ideas. Once all the table groups had been heard, the students were asked to once again complete the ranking task individually and provide an explanation of how they came to their thinking. The second ranking was collected and analyzed.

A ranking task on the same concept was given as a starter question within two to three days of the first group ranking task activity to assess if the students could apply and explain their understanding of the concepts without the benefit of having the whole class discussion. The ranking task starter question was collected for analysis. I looked for progression in their ranking ability and their explanations from the class-ranking task to the homework-ranking task. I also looked for a shift in the confidence level in their explanations from the self-assessment portion at the bottom of the ranking task worksheet. Two to three ranking tasks were given throughout each subunit. At least one ranking task was also included in the subunit quiz. For example, the same ranking task, Displacement Post-Unit Ranking Task was given on the subunit quiz about linear motion (Appendix F).

The ranking task assignments, inquiry activities, and weekly electronic discussion question on the topic, were used to gauge the progress of the students' understanding and readiness for a summative assessment. As a review of the concepts covered in the subunit prior to the administration of a summative subunit assessment, the alternate Diagnoser question set was assigned to the students, so that they could self-assess their level of understanding after they had received focused instruction and time to develop their conceptual understanding. For example, Changes in Speed 2 was assigned to the students as a review before the acceleration motion subunit assessment. At the end of the first semester, the Force Concept Inventory was given a second time to determine how the students' conceptual understanding and their ability to apply that understanding had developed over the course of the kinematics unit (Appendix C).

The data collection triangulation matrix illustrates the multiple and varied methods I employed to gather data about the effectiveness of the ranking tasks as a method to increase the students' conceptual understanding of kinematic physics (Table 1). The research methodology for this project received an exemption by Montana State's University Institutional Review Board and compliance for working with human subjects was maintained.

Table 1
Data Collection Triangulation Matrix

Research Questions	Data Source			
	1	2	3	4
Does the use of ranking tasks increase the student's conceptual understanding?	Pre Unit and Post Unit Force Concept Inventory Results	Pre and Post Likert Survey	Classroom Quizzes	Pre and Post Diagnoser Website Question Sets
Do ranking tasks increase student ability to explain their understanding of the concepts?	In-class Small Group Ranking Task Activities	Subunit Quiz Ranking Task Questions	Pre and Post Unit Likert Survey	

DATA ANALYSIS

At the beginning of the unit on kinematics, students in each of the three class sections were given the Force Concept Inventory (FCI) to determine their current conceptual understanding of the force, motion, and acceleration. Of the 86 students who were given the FCI, the average pre-unit score was 24%, 27%, and 25%, respectively, for the three class sections (Figure 4).

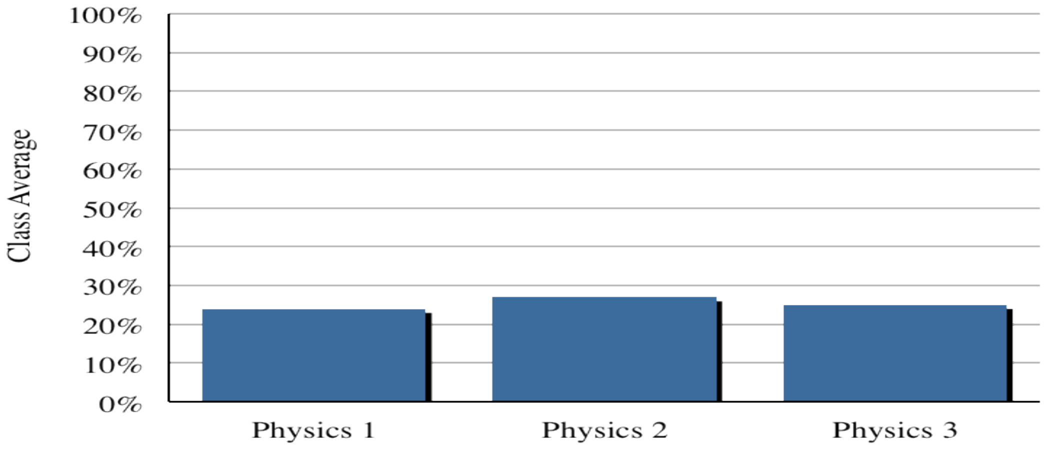


Figure 4. FCI scores: pre-unit class averages, (*N* = 86).

Students (*N* = 86) were then given the Pre-Unit Linear Motion and Ranking Task Survey, which showed the students' knowledge of linear motion vocabulary terms was limited. Fifty percent thought displacement was about an object being in the wrong place, while 69% believed acceleration only occurred if an object was speeding up. The purpose of the ranking tasks was unknown to all of the students. Many students stated that ranking tasks were used for "ranking how I feel about an idea or concept," or "explains how hard or important something is."

The survey about the CRS clickers, To Clicker or Not To Clicker, was given only at the beginning of the kinematics unit as a gauge of how much exposure the students had to them and their use in the classroom. The six categories represented by the survey questions are listed below (Table 2).

Table 2
To Clicker or Not To Clicker Question Categories

Category
Use
Knowledge of how to use clickers
Prior use of clickers
Beneficial
Better understanding through use of clickers
Better quiz prep through use of clickers
Peer learning opportunities through use of clickers
Engagement
Interest in material increased through use of clickers
Engagement with material increased through use of clickers
Confidence in understanding of material through use of clickers
Distracted by the use of clickers
No benefits from using clickers

The student responses were tabulated for frequency. The categories of use, benefits, confidence, and no benefits frequently had a response of maybe (2); while engagement most frequently received a yes (3); and distraction most frequently received a no (1) (Figure 5).

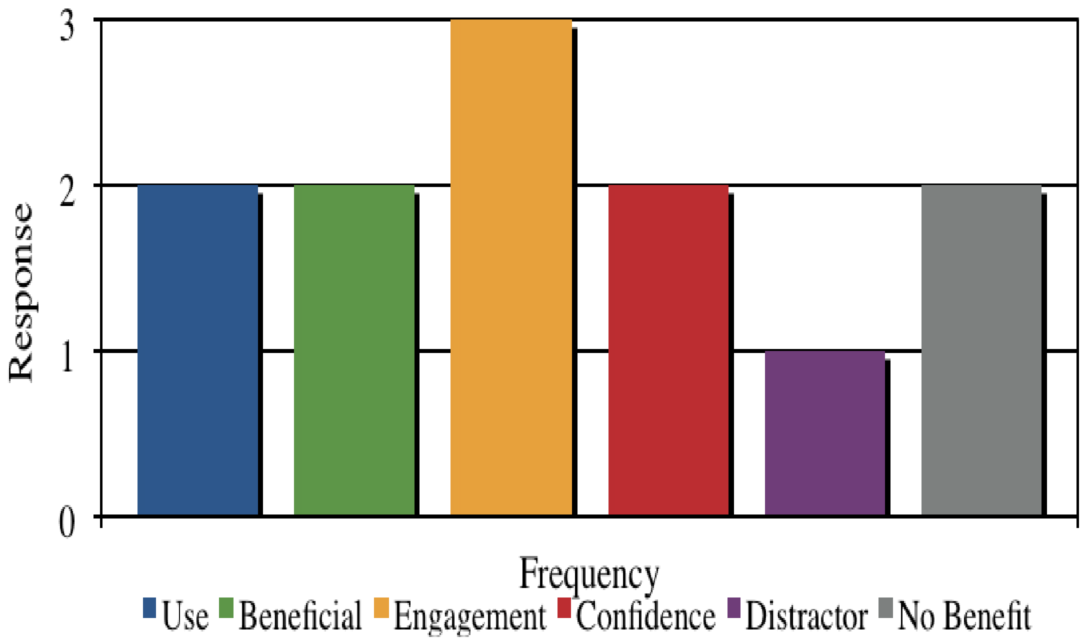


Figure 5. To clicker or not to clicker survey results, (*N* = 86).

The ranking tasks were introduced within the first week of the subunit on linear motion as class problems. For example, students were given the Displacement Ranking Task. On the pre-assessment ranking task, 69% of the students were given a level 1 score because their rankings were incorrect and their reasoning did not accurately explain displacement. Consecutively, 15% received a level 1.5, 13% received a level 2, 2% received a level 2.5, and only 1% received a level 3, indicating accurate ranking and conceptual understanding (Figure 6).

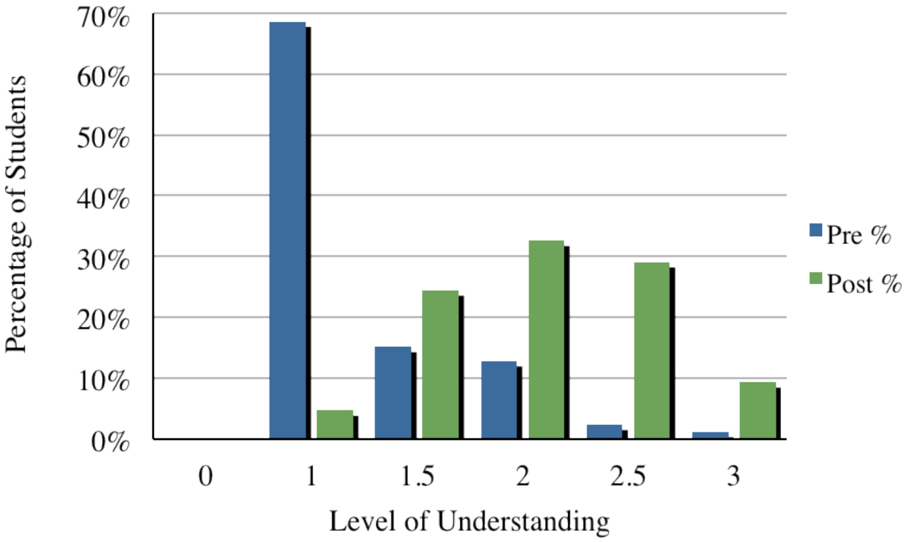


Figure 6. Displacement ranking task: pre and post-unit data, (*N* = 86).

Most students indicated they guessed when deciding how to rank the six objects' displacement. Others had reasoning that did not match the situation. For example, one student stated, "The displacment of the water volume was positive."

After three weeks of building the students' conceptual understanding of displacement, the post assessment ranking task, the exact same ranking task as the pre-assessment, was given to the students (Appendix F). Only five percent of the students were still at a level 1. The remaining 95% fell into the following levels: 24% in level 1.5, 33% in level 2, 29% in level 2.5, and 9% were able to demonstrate accurate Level 3 in their ranking and conceptual understanding.

To further analyze how the students shifted their conceptual understanding, I tabulated the students' gain in conceptual understanding, changing from one level of conceptual understanding to an another level of conceptual understanding. (Figure 7). Four percent of the students had a negative shift in the level of understanding, while 10%

had no shift in level of understanding, and 86% had a positive shift of a half a level of more.

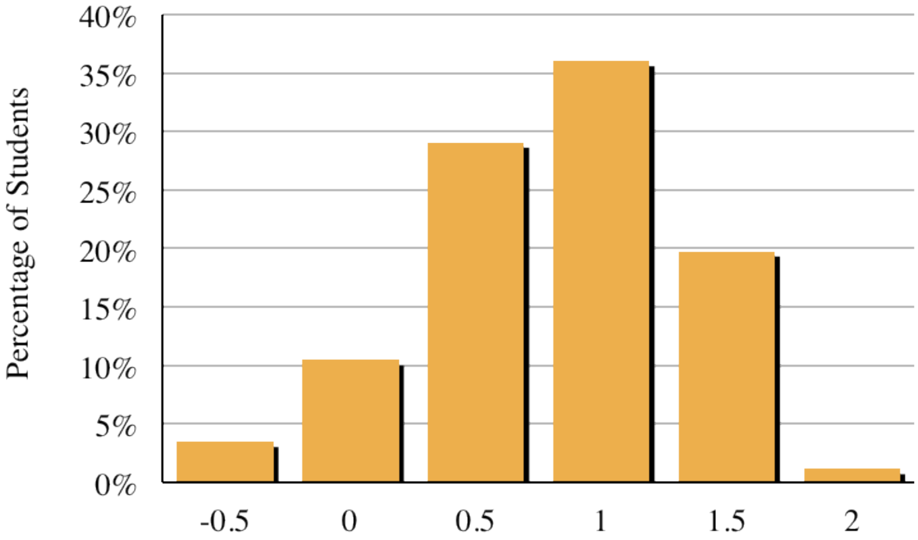


Figure 7. Displacement ranking task: gains in conceptual understanding, (*N* = 86).

As the linear motion subunit continued, the students showed inconsistencies in the pre to post-unit ranking tasks. For example, on the Acceleration Ranking Task on the pre-unit assessment, only two percent of the students showed no understanding of acceleration (Appendix G). While on the post-unit assessment, 12% of the same students showed no understanding of acceleration (Figure 8). Of the remaining students, 29% were assessed at a level 1, and 59% had attained a level 2 or 3.

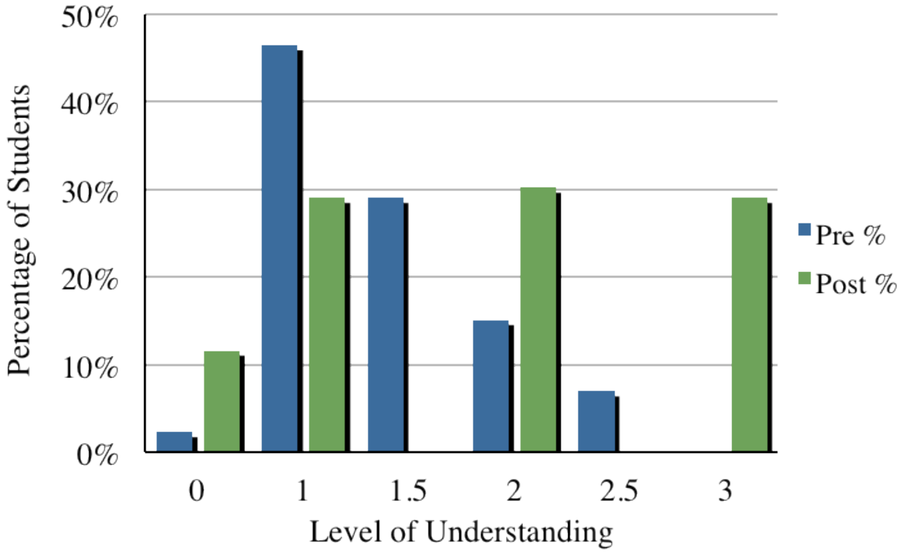


Figure 8. Acceleration ranking task: pre and post-unit data, (*N* = 86).

When the gains in conceptual understanding were calculated, 27% of the students overall had a negative gain in conceptual understanding; 21% showed no gain; and 52% gained a half a level or more (Figure 9). When those students that had a negative gain in conceptual understanding were interviewed, several indicated that they had not looked at which direction the arrow under the ramp was pointing when deciding if the ball was accelerating or decelerating. One student exclaimed, “Oh man! That is such a stupid mistake to make.”

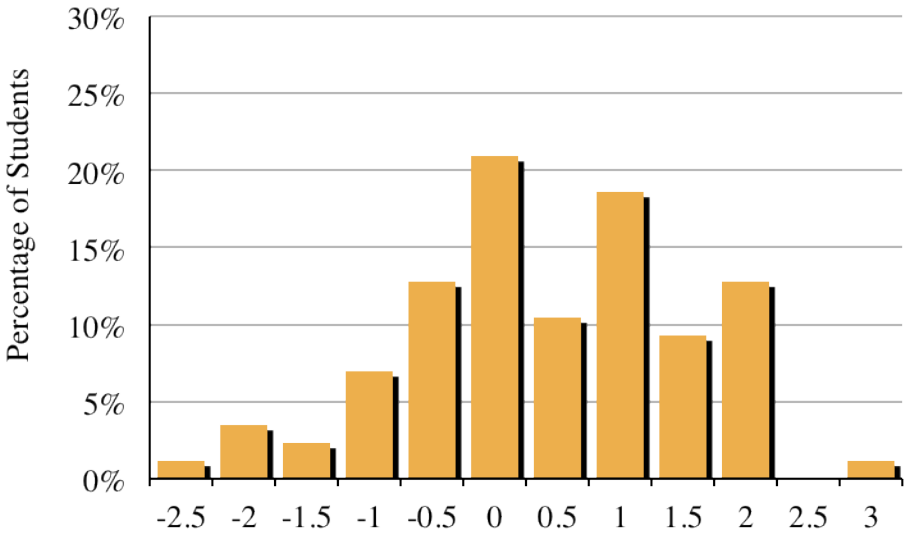


Figure 9. Acceleration ranking task: gains in conceptual understanding, (*N* = 86).

As the kinematics unit progressed in to the Newton's Laws subunit, the majority of the students continued to show overall gains in their conceptual understanding of the material. For example, during the Newton's Laws subunit, the students were given the Normal Force Ranking Task (Appendix H). On the pre-assessment, 28% of students had no understanding of the concept, and only 7% of the students demonstrated a proficient level of understanding (Figure 10). The remaining students were at the following levels on the pre-assessment: 0% received a level 1; 27% received a level 1.5; 24% received a level 2; and 14% received a level 2.5.

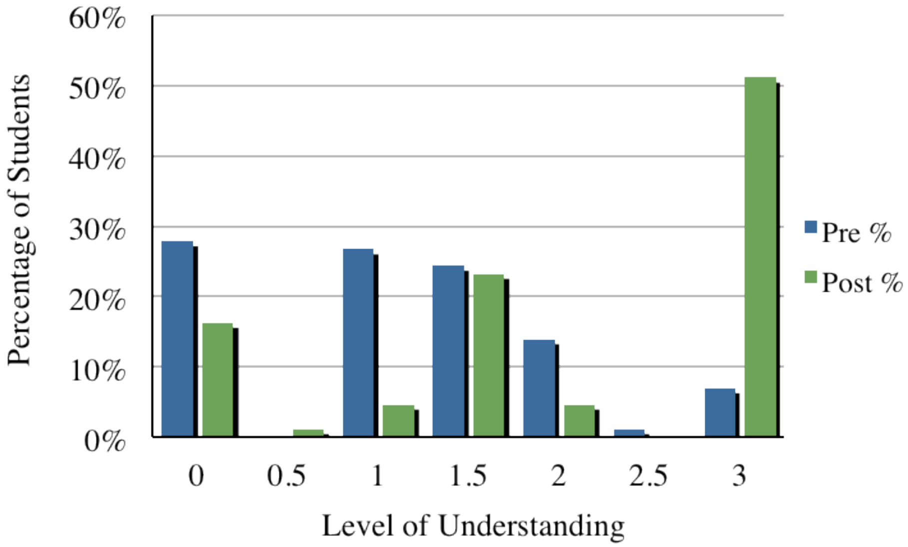


Figure 10. Normal force ranking task: pre and post-unit data, (*N* = 86).

By the close of the Newton's Laws subunit, only 13% had a negative shift in their understanding; 15% had no shift in their understanding; and 62% had a positive shift in their understanding (Figure 11).

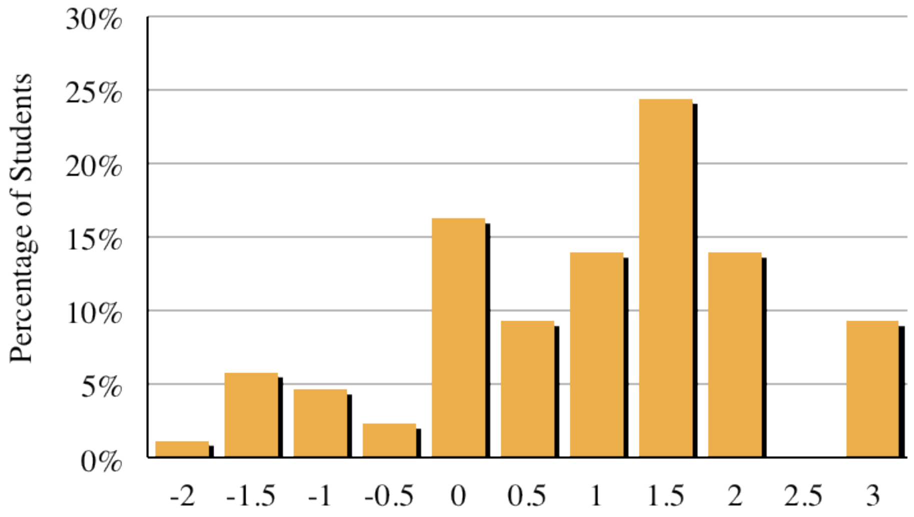


Figure 11. Normal force ranking task: gains in conceptual understanding, (*N* = 86).

At the end of the kinematics unit, the FCI was once again given (Appendix C). The average post-unit score was 52%, 61%, and 61% (Figure 12).

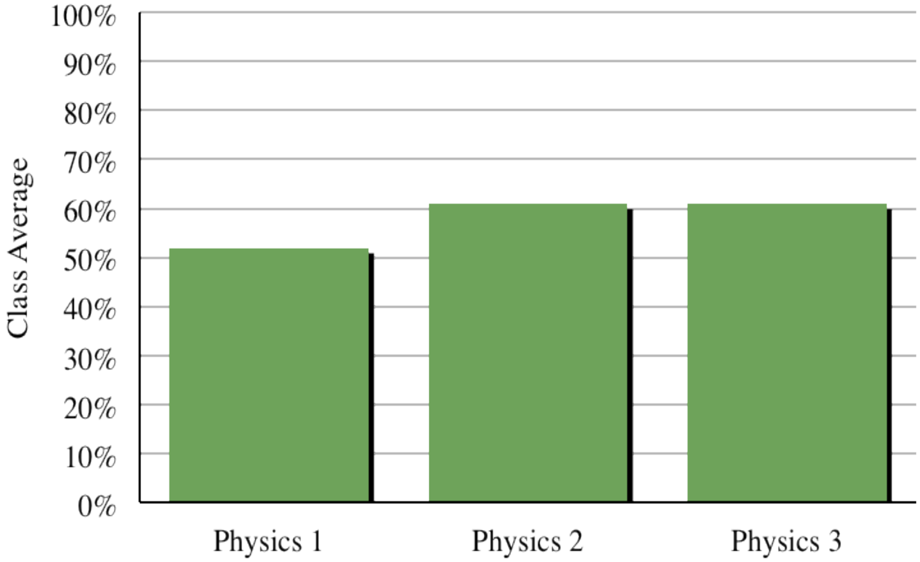


Figure 12. FCI scores: post-unit class averages, (*N* = 86).

When the pre and post-unit FCI results for the three class sections were compared, Physics 2 and Physics 3 had gained more conceptual understanding than Physics 1, with Physics 3 gaining 36% compared to a 34% gain in Physics 1 (Figure 13).

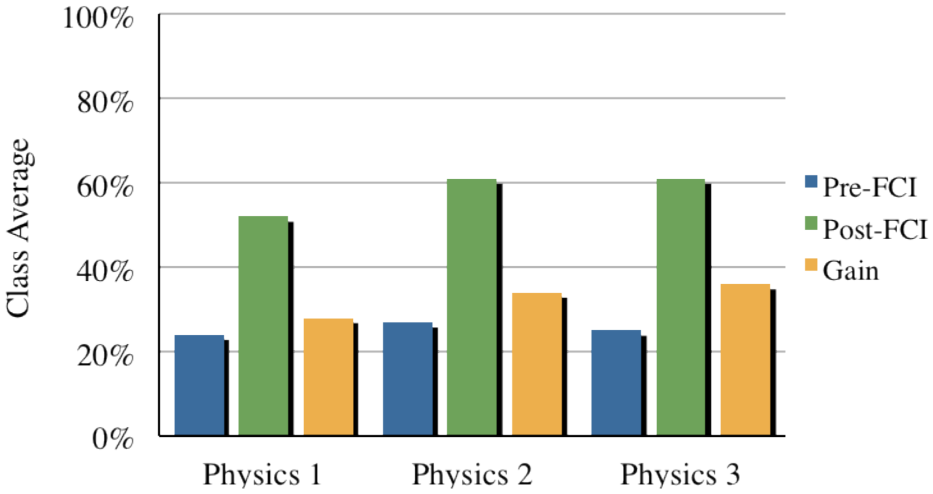


Figure 13. FCI Scores: Pre and Post-Unit Class Averages and Gains, (*N* = 86).

I then calculated the normalized gain of the three class sections compared to the post-FCI class averages (Figure 14). The students' normalized gain in conceptual understanding had a positive trend, with a range of 0.01 to 0.73 normalized gain on average.

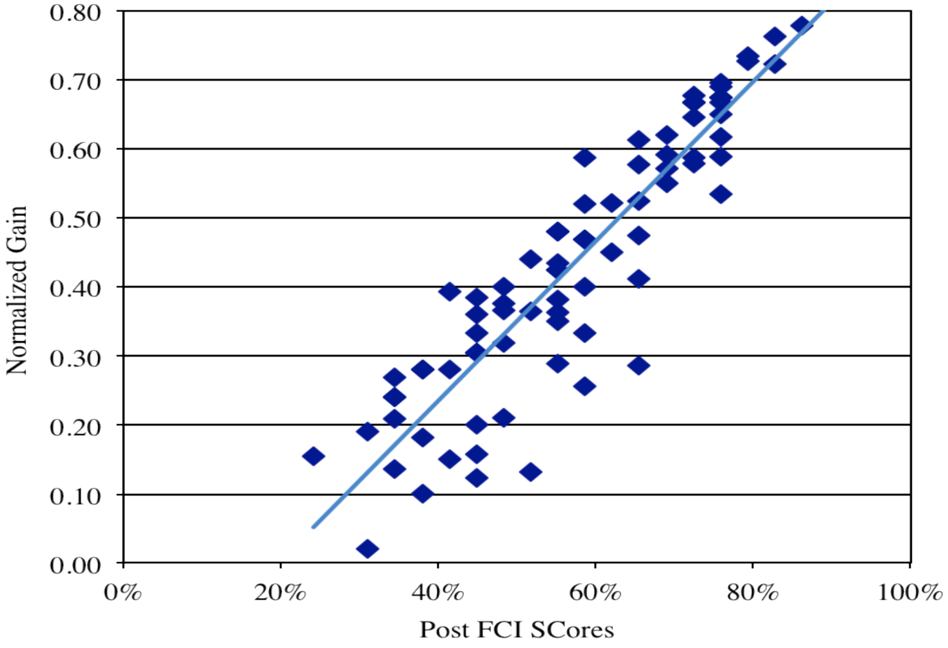


Figure 14. FCI scores: post-FCI normalized gain, (*N* = 86).

The Post-Unit Linear Motion and Ranking Task Survey was given two months after the kinematics unit was completed (*N*=86). The students were divided on the benefits of using ranking tasks to increase their conceptual understanding. Sixty-eight percent of the students felt the ranking tasks were helpful for various reasons including: increasing their understanding of the concept, representing relationships between concepts, applying the concepts in real world situations, and by providing feedback on their areas of struggle (Figure 15). One student commented that, "I had to order them in a specific way, which sometimes was difficult but helped me understand the topic better than just, say, multiple choice question." While another student felt that the ranking tasks, "...were helpful because they required me to think instead of memorizing facts."

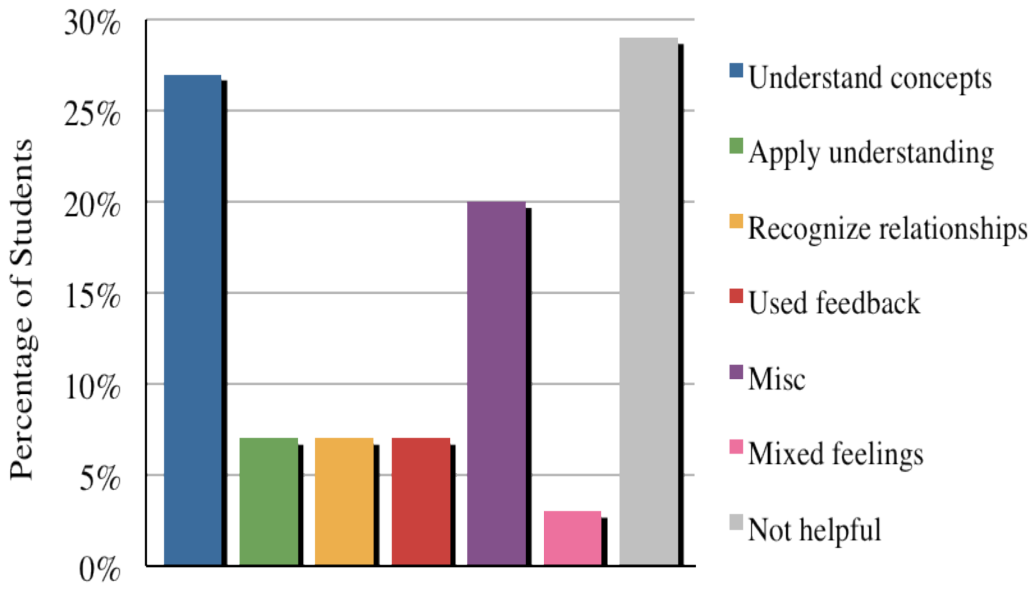


Figure 15. Post-unit linear motion and ranking task survey results, (*N* = 86).

Of the remaining 32%, 29% of the students felt the ranking tasks had no benefits in increasing their conceptual understanding and only 3% said that some of the ranking tasks were helpful but others were not. A few students were mixed in their opinion about ranking tasks. "They helped me know how to rank the order of the subjects, but didn't really help me understand them more than just reading an article or something." Another student stated, "Some just confused me and others I did get. Some were good and some were not."

INTERPRETATIONS AND CONCLUSIONS

Upon completing my analysis I realized, while the increase in conceptual understanding was not as big as I was anticipating, the increase was still substantial for the first year of using ranking tasks. The data confirmed my main focus on the use of ranking tasks to increase conceptual understanding of physics for eighth grade students. I analyzed the class averages of the FCI post scores, which showed gains in conceptual understanding over 20%. I think in the future I would look at individual student scores so that I could analyze where gaps in understanding may have occurred and used the information to assist the at-risk students in closing those gaps.

When I went over the answers to the FCI, many of the students audibly groaned when they realized how simple the mistake in their thinking had been. When asked, several volunteers stated that they had not read the scenario carefully or inferred information that was not necessary for that question. For example on one question, students did not recognize that the thruster on the rocket had been turned on, thus producing a force that would change the direction the rocket was going. One student said, “I thought the question said the thruster had been turned on and then off again.”

I would consider also re-wording some of the questions. The FCI was originally intended for use with college level students, and my eighth grade students had some difficulty decoding what the question was trying to convey. I would add updated graphics as well, as many as the students had indicated they were visual learners. Also, the graphics would enhance the question itself because any information the students may have missed in their reading of the question would be evident in the graphic.

When I compared this kinematic unit with the ranking tasks to the 2011-2012 school year data, I was disappointed to see that Semester 1 Final, which includes the FCI, average scores for the non-treatment year was 69%, while the average score of the treatment unit's Semester 1 Final was only 62% (Figure 16).

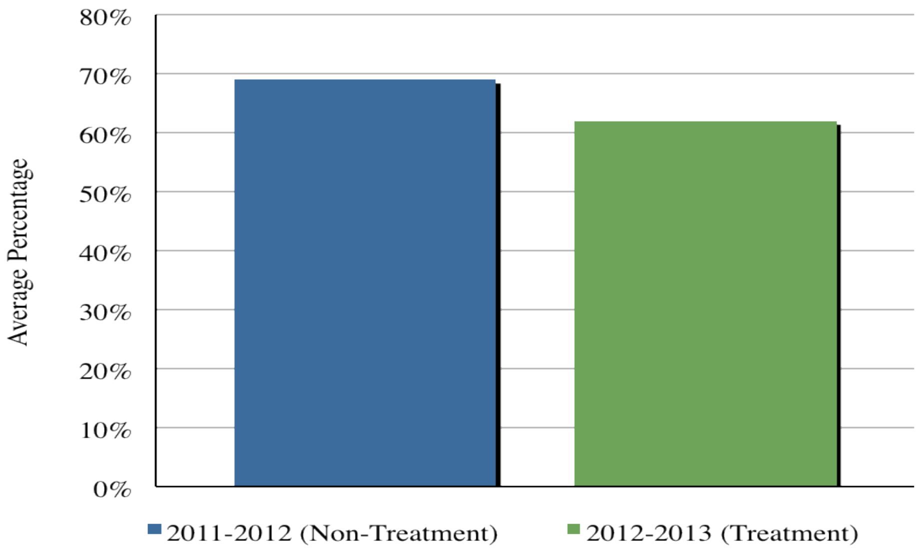


Figure 16. Semester 1 final average scores for 2011-2012, (*N* = 95), and 2012-2013, (*N* = 86).

When I looked back at the student demographics and the entrance requirements for the students to be included in the conceptual physics class, however, I realized that in the 2012-2013 school year any student that had completed the accelerated seventh grade science course, regardless of their grade in the class, was admitted into the course. In 2011-2012 the students were required to have at least a level three score on the state science assessment and a B grade or better in both the seventh grade math and accelerate science courses. Of the 86 students admitted into the 2012-2013 class, only 78 met the 2011-2012 requirements. The remaining eight students had either a level 1 or 2 on the state assessment and had a C+ average in their seventh grade year. I firmly believe, despite best efforts on both the part of the student and myself, these eight students were not cognitively ready for the rigor of the high school level class, and this is demonstrated in the semester final scores.

My second focus question on how the use of the ranking tasks would increase the students' ability to explain their understanding was also confirmed, as the ranking tasks were scored for both the ranking and the explanation. As the treatment unit progressed, the explanations written by the students became more thoughtful and specific to the concept being illustrated in the ranking task. When correlated, the pre and post-unit ranking tasks showed overall gains in the conceptual understanding. Some students had negative gains, unfortunately. As with the FCI, these students stated that they had not read the scenario carefully and had missed important information. This seemed like a standard excuse so I probed further. "I do understand the concept but I can't explain it," was another popular choice from these students. When told this, I responded with one of my favorite Einstein quotes, "If you cannot explain it simply, you don't understand it well enough."

In terms of the use of the clickers, I discontinued their role in my data collection after the second ranking task because the way I had set them up left a lot of room for the students to simply guess at which option was the correct ranking without requiring the students to understand the concept.

With many of the assignments throughout the unit, including the ranking tasks, I offered a revision opportunity to the students. The revisions were based on the feedback they received from me. Often this feedback and the revision opportunity was key to getting the student over the mental "hump." On the Linear Motion and Ranking Task

Post Survey, several students stated that the feedback was particularly helpful. “The ranking tasks were helpful, especially the comments you would leave for me. It helped me understand what I would need to do to get a better understanding.”

VALUE

The take-away from this research is that ranking tasks were a useful tool in increasing the conceptual understanding of physics for my eighth grade students. They did not always appreciate completing the ranking task, but over the course of the unit, they got familiar with how the ranking tasks were designed and how they were beneficial to their learning. For many physics teachers the math, as well as the science, is important for their students to learn. At the eighth grade level, I think it is more important for the students to proficiently develop their conceptual understanding of the science without the fallback of plugging variables into an equation. The ranking task tool was incredibly easy to implement, but in order for students to get the most out of the experience, I could not casually give a ranking task without careful forethought to how they were presented. For example, the first ranking task I assigned to my students could have gone far better if I had read through the scenario with the students and intentionally instructed them on what was the goal of the ranking task. Instead I simply informed them what they were about to do was called a ranking task, to read the directions carefully, and they were only being given participation points for completing the task. I did not want to skew the results by giving the students too much information so that the answer would just be obvious. After that, I chose the ranking tasks very specifically for that group of students and turned to the ranking tasks that were in the newest edition of the textbook I used in class, instead of the college level examples.

Having now written a couple of ranking tasks myself, I feel confident that any teacher, from a novice to a veteran, could incorporate ranking tasks into their curriculum, whether it be science, math, or even physical education. It will be important for me to stay abreast of any new research done in this area in order to further develop my skills at writing my own ranking tasks that will continue to allow my students to increase their conceptual understanding of physics.

In the future I will modify how I use the clickers in conjunction with the ranking tasks. Instead of asking the students to choose the right ranking, I will present them with the graphic illustrating the scenario and then ask which of the illustrations has the greatest value. I think this will reduce the number of students that are guessing because they will only be asked to identify one value not three to five values but will still have to apply the conceptual knowledge to answer the question.

I will continue to use ranking tasks in the future because they have allowed me to add an element of rigor into my curriculum that was lacking in the previous year. The energy unit was my non-treatment unit during this school year, and I could tell by the unit assessment that the level of conceptual understanding was as present as it had been with the kinematics, or treatment, unit. I believe that the ranking tasks were, in part, responsible for the difference because the thinking protocol had been established, as well as the expectation for written explanations during the treatment unit. With that in mind, despite having completed my data collection for this research, I added a ranking task onto the unit quiz for the atomic nature of matter quiz, and the almost all the students received a level 3; it was one of those moments every teacher waits for when their students have their light bulb turn on.

REFERENCES CITED

Beatty, I. & Gerace, W. (2009). Technology-Enhanced Formative Assessment: A Research-Based Pedagogy for Teaching Science with Classroom Response. *Journal of Science, Education, and Technology, 18,* 146-162.

Bennett, S. (2007). *That workshop book: New systems and structures for classrooms that read, write, and think.* Portsmouth, NH: Heinemann.

Bruff, D. (2009-2010). Essays on Teaching Excellence. *Toward the Best in the Academy. 21,* (3). Retrieved February 15, 2012 from http://www.podnetwork.org

Cox, A. J., Belloni, M., & Christian, W. (2005). Teaching Physics with Physlet-Based Ranking Tank Exercises. *The Physics Teacher, 43,* 587-592.

Driver, R., Leach J., Millar, R., and Scott, P. (1996). *Young people's images of science.* Buckingham: Open University Press.

Dykstra, D. I., Boyle, C. F. and Monarch, I. A. (1992), Studying conceptual change in learning physics. *Science Education, 76,* 615–652.

Eryilmaz, A. (2002). Effects of Conceptual Assignments and Conceptual Change Discussions on Students' Misconceptions and Achievement Regarding Force and Motion. *Journal of Research in Science Teaching, 39,* (10), 1001-1015.

Fischer, H.E. & Horstendahl, M. (1997). Motivation and Learning Physics. *Research and Science Education, 27,* (3), 411-424.

Franco, G., M., Muis, K. R., Kendeou, P., Ranellucci, J., Sampasivam, L., & Wang, X. (2012). Examining the influences of epistemically beliefs and knowledge representations on cognitive processing and conceptual change when learning physics. *Learning and Instruction, 22,* 62-77.

Gonan, S., & Kocakaya, S. (2010). A physics lesson design according to the 7e model with the help of instructional technology. *Turkish Online Journal of Distance Education, 11* (1), 98-113. Retrieved September 23, 2012 from http://tojde.anadolu.edu.tr/

Gonzalez-Espada, W. J., Birriel, J., & Birriel, I. (2010). Discrepant Events: A Challenge to Students' Intuition. *Physics Teacher, 48* (8), 508-511.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force Concept Inventory. *The Physics Teacher, 30* (3), 141.

Kenwright, K. (2009). Clickers in the Classroom. *TechTrends, 53,* (1), 74-77.

Kim, E., & Pak, S.J. (2001). Students do not overcome conceptual difficulties even after solving 1000 traditional problems. *American Journal of Physics*, *70*, 759.

Martyn, M. (2007). Clickers in the Classroom: An Active Learning Approach. *The EDUCAUSE quarterly, 30,* (2), 71-74.

Minstrell, J., Thissen-Roe, A., and Hunt, E. (2004). The DIAGNOSER project: Combining assessment and learning. *Behavior research methods, instruments, & computers, 36,* (2), 234-240.

O'Kuma, T., Maloney, D., and Hieggelke, C. (2000). *Ranking task exercises in physics*. (pp. ii-xvi). Upper Saddle River: Prentice Hall.

Renner, J.W., Abraham, M.R., Gryzbowski, E.B., and Marek, E.A. (1990). Understanding and Misunderstandings of Eighth Graders of Four Physics Concepts Found in Textbooks. *Journal of Research in Science Teaching*, *27*, (1), 35-54.

Taasoobshirazi, G. and Sinatra, G. M. (2011), A structural equation model of conceptual change in physics. *Journal of Research in Science Teaching*, *48*, 901–918.

von Aufschnaiter, C. (2010). Misconceptions or missing conceptions?. Eurasia *Journal of Mathematics, Science, and Technology Education, 6,* 3-18.

Yourstone, S. Kraye, H., and Albaum, G. (2008). Classroom Questioning with Immediate Electronic Response: Do Clickers Improve Learning?. *Decision Sciences Journal of Innovative Education, 6,* (1), 75-88.

APPENDICES

APPENDIX A:

LINEAR MOTION AND RANKING TASK PRE-UNIT SURVEY

LINEAR MOTION AND RANKING TASK PRE – UNIT SURVEY

1. What do you think the study of physics is about?

2. How would you describe the following concepts:
   Force -

   Speed -

   Velocity -

   Acceleration -

   Gravity -

3. When you are learning about new ideas or concepts, what strategies help you the most with understanding the new ideas or concepts?

4. How do you know when you understand a new idea/concept?

5. Ranking tasks are used to help people understand new ideas/concepts. What do you think ranking tasks ask you to do?

APPENDIX B:

LINEAR MOTION AND RANKING TASK POST-UNIT SURVEY

LINEAR MOTION AND RANKING TASK POST-UNIT SURVEY

1. Now what do you think the study of physics is about?

2. How would you describe the following concepts:
   Force -

   Speed -

   Velocity -

   Acceleration -

   Gravity -

3. How close was your original thinking about the above concepts to your current thinking about them?

4. Which strategy that you used to help you learn the new ideas/concepts was the most helpful to you. Please explain why it was the most helpful.

5. What level of understanding (1, 2, 3, or 4) do you feel you have about these concepts now? Please explain why you chose the level that you did.

6. Were the ranking tasks helpful to you in understanding the new ideas/concepts? Please explain why or why not.

APPENDIX C:

FORCE CONCEPT INVENTORY

FORCE CONCEPT INVENTORY

1. Two metal balls are the same size, but one weighs twice as much as the other. The balls are dropped from the top of a two story building at the same instant of time. The time it takes the balls to reach the ground below will be:

   (A) about half as long for the heavier ball.
   (B) about half as long for the lighter ball.
   (C) about the same time for both balls.
   (D) considerably less for the heavier ball, but not necessarily half as long.
   (E) considerably less for the lighter ball, but not necessarily half as long.

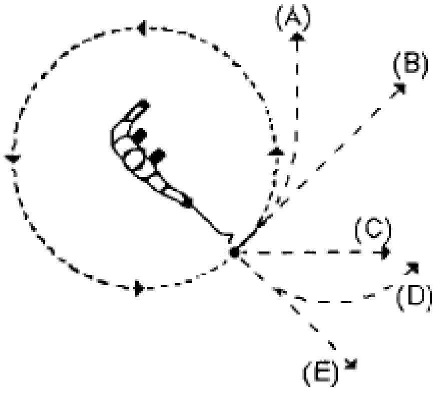
2. Imagine a head-on collision between a large truck and a small compact car. During the collision,

   (A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
   (B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
   (C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
   (D) the truck exerts a force on the car but the car doesn't exert a force on the truck.
   (E) the truck exerts the same amount of force on the car as the car exerts on the truck.

3. Two steel balls, one of which weighs twice as much as the other, roll off of a horizontal table with the same speeds. In this situation:

   (A) both balls impact the floor at approximately the same horizontal distance from the base of the table.
   (B) the heavier ball impacts the floor at about half the horizontal distance from the base of the table than does the lighter.
   (C) the lighter ball impacts the floor at about half the horizontal distance from the base of the table than does the heavier.
   (D) the heavier ball hits considerably closer to the base of the table than the lighter, but not necessarily half the horizontal distance.
   (E) the lighter ball hits considerably closer to the base of the table than the heavier, but not necessarily half the horizontal distance.

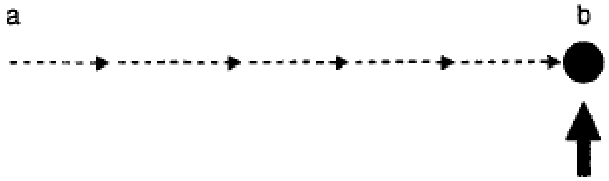
4. A heavy ball is attached to a string and swung in a circular path in a horizontal plane as illustrated in the diagram to the right. At the point indicated in the diagram, the string suddenly breaks at the ball. If these events were observed from directly above, indicate the path of the ball after the string breaks.



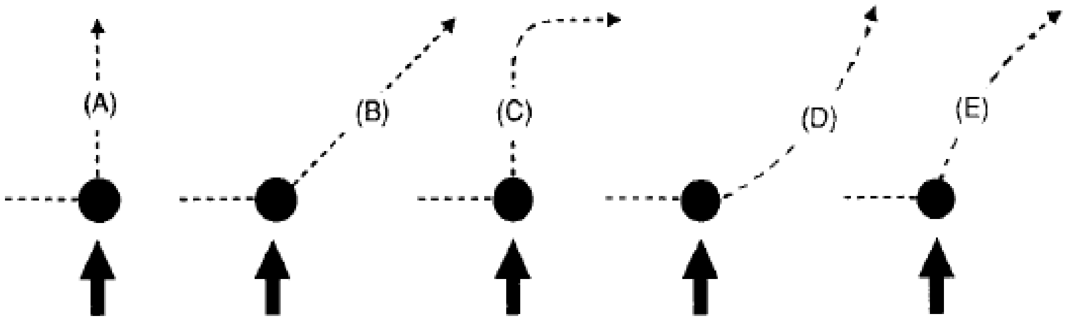
5. A boy throws a steel ball straight up. **<u>Disregarding any effects of air resistance</u>**, the force(s) acting on the ball until it returns to the ground is (are):

   (A) its weight vertically downward along with a steadily decreasing upward force.
   (B) a steadily decreasing upward force from the moment it leaves the hand until it reaches its highest point beyond which there is a steadily increasing downward force of gravity as the object gets closer to the earth.
   (C) a constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point, after which there is only the constant downward force of gravity.
   (D) a constant downward force of gravity only.
   (E) none of the above, the ball falls back down to the earth simply because that is its natural action.

- **Use the statement and diagram below to answer the next four questions:**
- **The diagram depicts a hockey puck sliding, with a <u>constant velocity</u>, from point "a"to point "b" along a <u>frictionless horizontal surface</u>. When the puck reaches point "b", it receives an instantaneous horizontal "kick" in the direction of the heavy print arrow.**



6. Along which of the paths below will the hockey puck move <u>after</u> receiving the "kick" ?



7. The speed of the puck just **<u>after</u>** it receives the "kick"?

   (A) Equal to the speed "v_o" it had before it received the "kick".
   (B) Equal to the speed "v" it acquires from the "kick", and independent of the speed "v_o".
   (C) Equal to the arithmetic sum of speeds "v_o" and "v".
   (D) Smaller than either of speeds "v_o" or "v".
   (E) Greater than either of speeds "v_o" or "v", but smaller than the arithmetic sum of these two speeds.

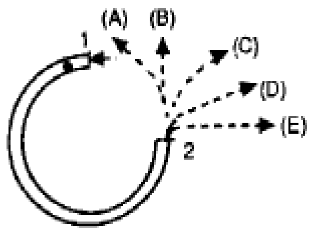
8. Along the **frictionless** path you have chosen, how does the speed of the puck vary **after** receiving the "kick"?

   (A) No change.
   (B) Continuously increasing.
   (C) Continuously decreasing.
   (D) Increasing for a while, and decreasing thereafter.
   (E) Constant for a while, and decreasing thereafter.

9. The main forces acting, **after** the "kick", on the puck along the path you have chosen are:

   (A) the downward force due to gravity and the effect of air pressure.
   (B) the downward force of gravity and the horizontal force of momentum **in the direction of motion.**
   (C) the downward force of gravity, the upward force exerted by the table, and a horizontal force acting on the puck **in the direction of motion.**
   (D) the downward force of gravity and an upward force exerted on the puck by the table.
   (E) gravity does not exert a force on the puck, it falls because of the intrinsic tendency of the object to fall to its natural place.

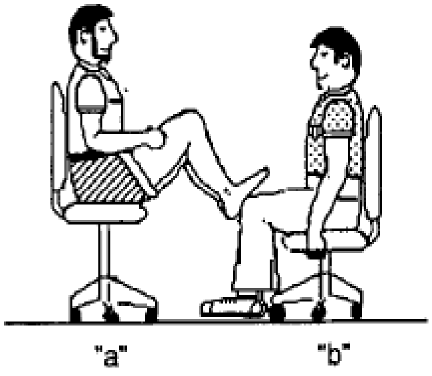
10. The accompanying diagram depicts a semicircular channel that has been securely attached, in a **horizontal plane**, to a table top. A ball enters the channel at "1" and exits at "2". Which of the path representations would most nearly correspond to the path of the ball as it exits the channel at "2" and rolls across the table top.



* **Two students, student "a" who has a mass of 95 kg and student "b" who has a mass of 77 kg sit in identical office chairs facing each other. Student "a" places his bare feet on student "b's" knees, as shown below. Student "a" then suddenly pushes outward with has feet, causing both chairs to move.**

11. In this situation,

   (A) neither student exerts a force on the other.
   (B) student "a" exerts a force on "b", but "b" doesn't 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.



12. A book is at rest on a table top. Which of the following force(s) is(are) acting on the book?

1. A downward force due to gravity.
2. The upward force by the table.
3. A net downward force due to air pressure.
4. A net upward force due to air pressure.

(A) 1 only
(B) 1 and 2
(C) 1, 2, and 3
(D) 1, 2, and 4
(E) none of these, since the book is at rest there are no forces acting on it.

* **Refer to the following statement and diagram while answering the next two questions.**

A large truck breaks down out on the road and receives a push back into town by a small compact car.

13. While the car, still pushing the truck, is **<u>speeding up</u>** to get up to cruising speed;

(A) the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
(B) the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
(C) the amount of force of the car pushing against the truck is greater than that of the truck pushing against the car.
(D) the car's engine is running so it applies a force as it pushes against the truck but the trucks engine is not running so it can't push back against the car, the truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other, the truck is pushed forward simply because it is in the way of the car.

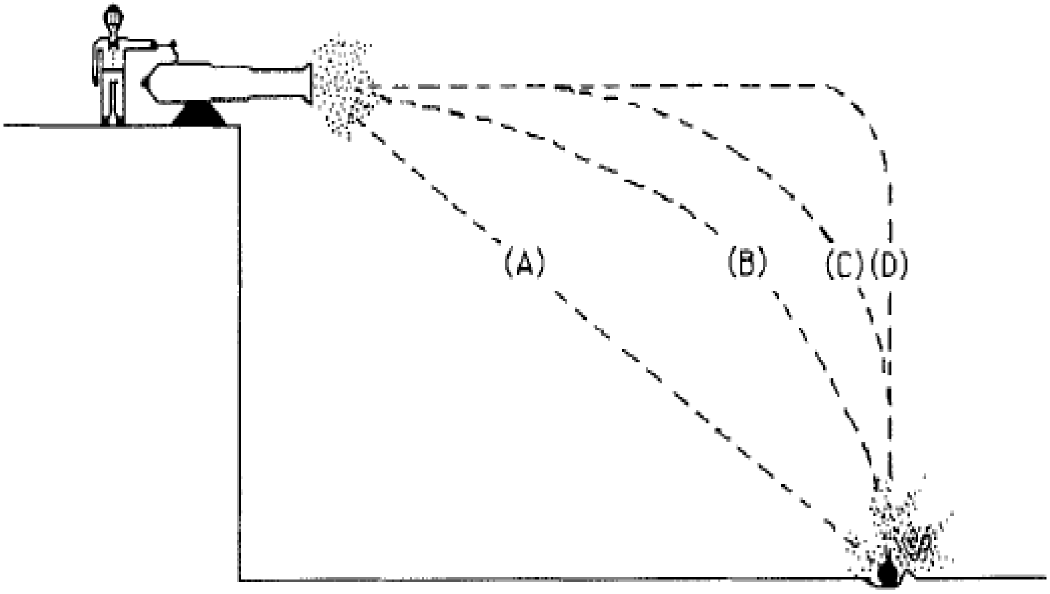
14. After the person in the car, while pushing the truck, reaches the cruising speed at which he/she wishes to continue to travel at a constant speed;

(A) the amount of force of the car pushing against the truck is equal to that of the truck pushing back against the car.
(B) the amount of force of the car pushing against the truck is less than that of the truck pushing back against the car.
(C) the amount of force of the car pushing against the truck is greater than that of the truck pushing against the car.
(D) the car's engine is running so it applies a force as it pushes against the truck but the trucks engine is not running so it can't push back against the car, the truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other, the truck is pushed forward simply because it is in the way of the car.

15. When a rubber ball dropped from rest bounces off the floor, its direction of motion is reversed because;

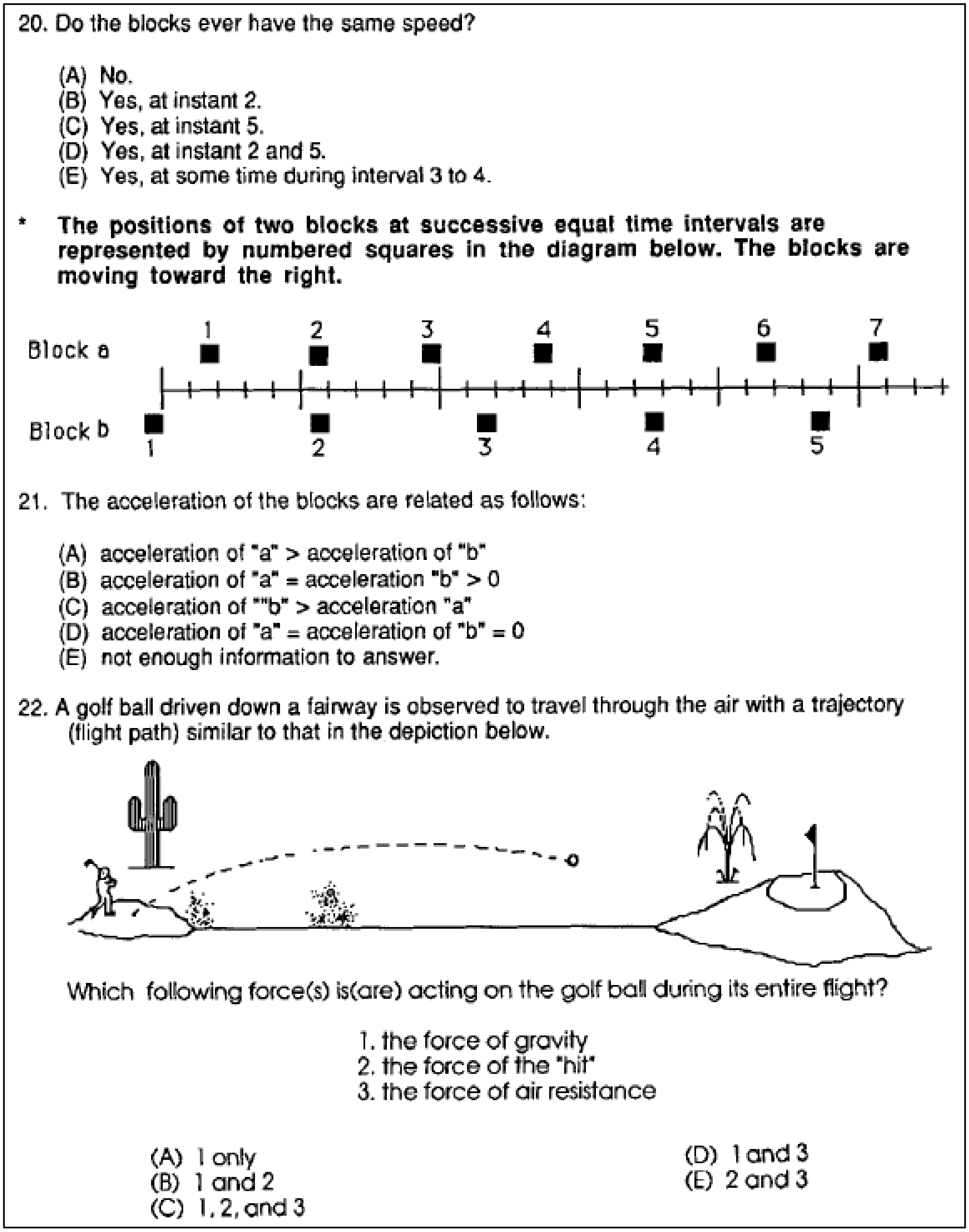
 (A) energy of the ball is conserved.
 (B) momentum of the ball is conserved.
 (C) the floor exerts a force on the ball that stops its fall and then drives it upward.
 (D) the floor is in the way and the ball has to keep moving.
 (E) none of the above.

16. Which of the paths in the diagram to the right best represents the path of the cannon ball?



17. A stone falling from the roof of a single story building to the surface of the earth;

 (A) reaches its maximum speed quite soon after release and then falls at a constant speed thereafter.
 (B) speeds up as it falls, primarily because the closer the stone gets to the earth, the stronger the gravitational attraction.
 (C) speeds up because of the constant gravitational force acting on it.
 (D) falls because of the intrinsic tendency of all objects to fall toward the earth.
 (E) falls because of a combination of the force of gravity and the air pressure pushing it downward.



20. 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 interval 3 to 4.

* **The positions of two blocks at successive equal time intervals are represented by numbered squares in the diagram below. The blocks are moving toward the right.**

21. The acceleration of the blocks are related as follows:

(A) acceleration of "a" > acceleration of "b"
(B) acceleration of "a" = acceleration "b" > 0
(C) acceleration of ""b" > acceleration "a"
(D) acceleration of "a" = acceleration of "b" = 0
(E) not enough information to answer.

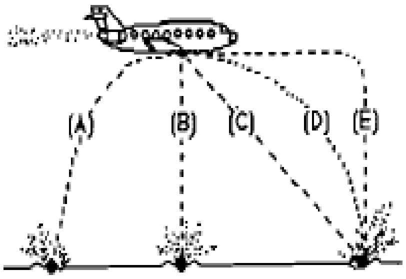
22. A golf ball driven down a fairway is observed to travel through the air with a trajectory (flight path) similar to that in the depiction below.

Which following force(s) is(are) acting on the golf ball during its entire flight?

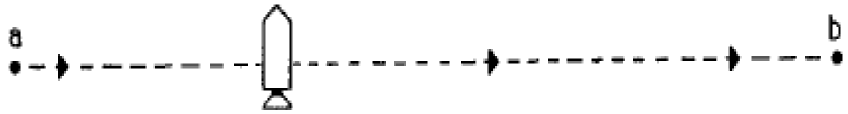
1. the force of gravity
2. the force of the "hit"
3. the force of air resistance

(A) 1 only
(B) 1 and 2
(C) 1, 2, and 3
(D) 1 and 3
(E) 2 and 3

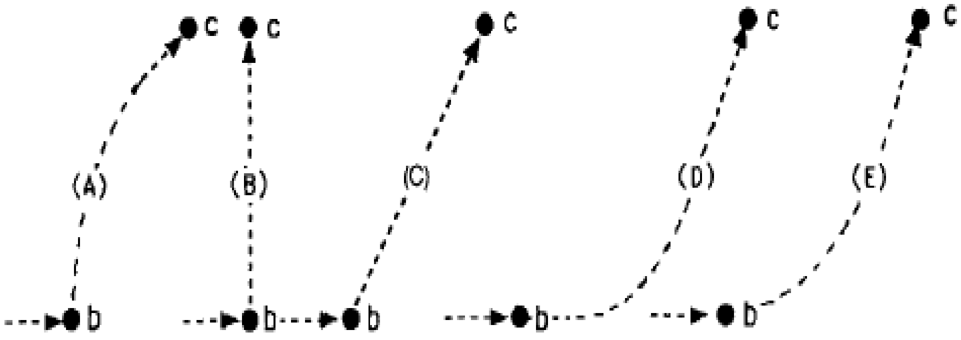
23. A bowling ball accidently falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As seen from the ground, which path would the bowling ball most closely follow after leaving the airplane?



- **When answering the next four questions, refer to the following statement and diagram.**
- **A rocket, drifting sideways in outer space from position "a" to position "b". is subject to no outside forces. At "b", the rocket's engine starts to produce a constant thrust at right angles to line "ab". The engine turns off again as the rocket reaches some point "c".**



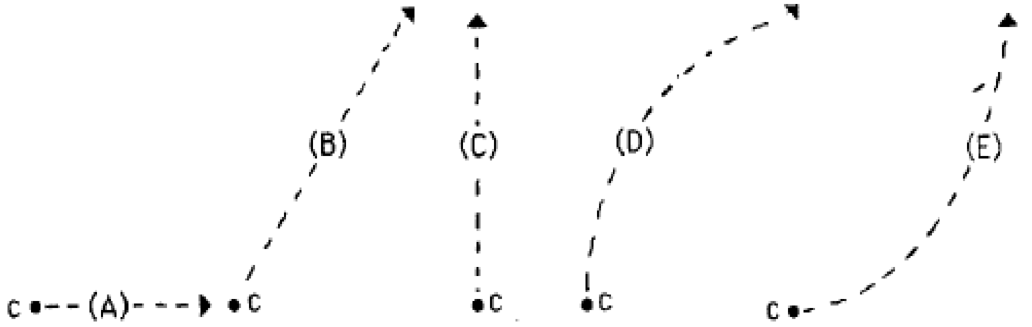
24. Which path below best represents the path of the rocket between "b" and "c"?



25, As the rocket moves from "b" to "c", its <u>speed</u> is

(A) constant.
(B) continuously increasing.
(C) continuously decreasing.
(D) increasing for a while and constant thereafter.
(E) constant for a while and decreasing thereafter.

26. At "c" the rocket's engine is turned off. Which of the paths below will the rocket follow beyond "c"?



27. Beyond "c", the speed of the rocket is;

- (A) constant.
- (B) continuously increasing.
- (C) continuously decreasing.
- (D) increasing for a while and constant thereafter.
- (E) constant for a while and decreasing thereafter.

28. A large box is being pushed across the floor at a **constant speed** of 4.0 m/s. What can you conclude about the forces acting on the box

- (A) If the force applied to the box is doubled, the constant speed of the box will increase to 8.0 m/s.
- (B) The amount of force applied to move the box at a constant speed must be more than its weight.
- (C) The amount of force applied to move the box at a constant speed must be equal to the amount of the frictional forces that resist its motion.
- (D) The amount of force applied to move the box at a constant speed must be more than the amount of the frictional forces that resist its motion.
- (E) There is a force being applied to the box to make it move but the external forces such as friction are not "real" forces they just resist motion.

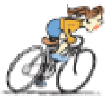
29. If the force being applied to the box in the preceding problem is suddenly discontinued, the box will;

- (A) stop immediately.
- (B) continue at a constant speed for a very short period of time and then slow to a stop.
- (C) immediately start slowing to a stop.
- (D) continue at a constant velocity.
- (E) increase its speed for a very short period of time, then start slowing to a stop.

APPENDIX D:

ROLLING MARBLES RANKING TASK

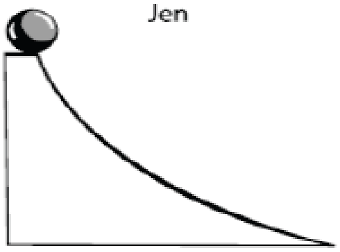
CHAPTER 2

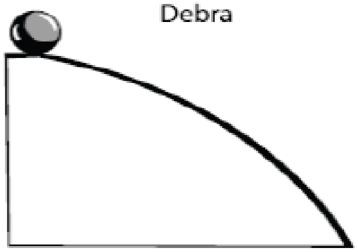


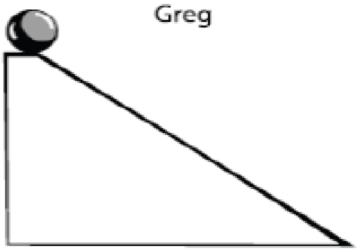
LINEAR MOTION

Acceleration Ranking Task

Jen, Debra, and Greg are playing with ramps and marbles. They decide to have a contest to see who can make a marble roll down a ramp the fastest. Each friend uses the same height and identical marbles. They each let go of their marbles at the top of their ramps. (they do not give their marbles a push.)







Rank the marbles from greatest acceleration to least acceleration at the bottom of the ramp. Use <, >, or = to indicate the order of the marbles.

A Jen's marble

B Debra's marble

C Greg's marble

Ranking: ________ ________ ________

Explain your ranking.

Self Assessment: Please circle one.

Basically Guessed Sure Very Sure

0 1 2 3 4 5 6 7 8 9 10

APPENDIX E:

TO CLICKER OR NOT TO CLICKER SURVEY

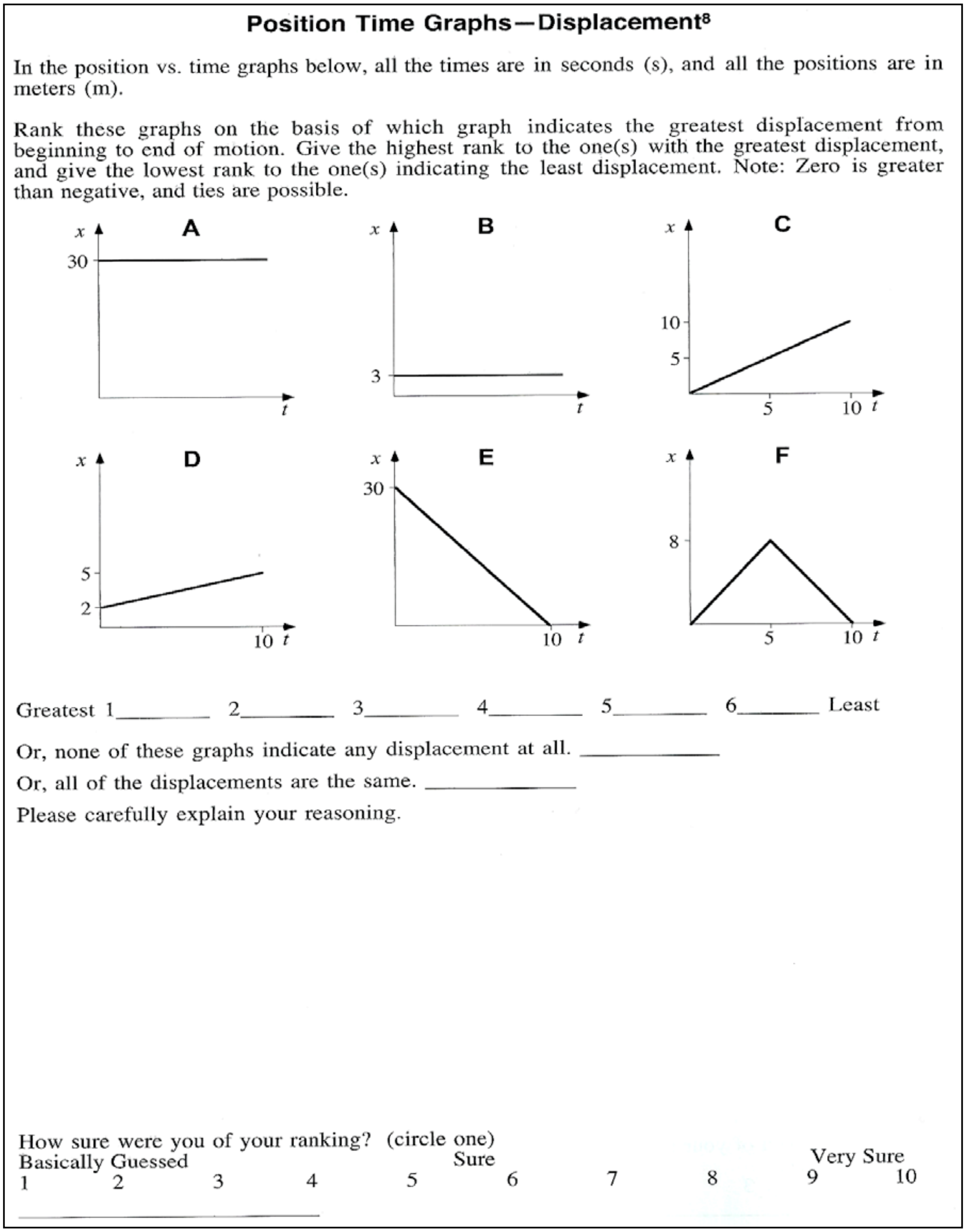
TO CLICKER OR NOT TO CLICKER

Using the scale below, please answer the following questions about Classroom Response System (CRS) clickers by circling the choice that best describes you.

		1 - No	2 - Maybe	3 - Yes
1.	I know how to use a CRS clicker.	1	2	3
2.	I have used a CRS clicker before in another class.	1	2	3
3.	I think using a CRS clicker during class will be interesting.	1	2	3
4.	I think using a CRS clicker will keep me engaged in learning the materials.	1	2	3
5.	I think using a CRS clicker will allow me understand the material better.	1	2	3
6.	I think using a CRS clicker will give me more confident to ask questions.	1	2	3
7.	I think using a CRS clicker will help me better prepare for quizzes & tests.	1	2	3
8.	I think seeing how my classmates responded will be a benefit to my learning.	1	2	3
9.	I think using a CRS clicker during class will take to much time away doing other activities.	1	2	3
10.	I think using a CRS clicker during will not effect how I will the material.	1	2	3

APPENDIX F:

DISPLACEMENT RANKING TASK



Position Time Graphs—Displacement[8]

In the position vs. time graphs below, all the times are in seconds (s), and all the positions are in meters (m).

Rank these graphs on the basis of which graph indicates the greatest displacement from beginning to end of motion. Give the highest rank to the one(s) with the greatest displacement, and give the lowest rank to the one(s) indicating the least displacement. Note: Zero is greater than negative, and ties are possible.

Greatest 1________ 2________ 3________ 4________ 5________ 6_______ Least

Or, none of these graphs indicate any displacement at all. ____________

Or, all of the displacements are the same. ____________

Please carefully explain your reasoning.

How sure were you of your ranking? (circle one)

Basically Guessed · Sure · Very Sure

1 2 3 4 5 6 7 8 9 10

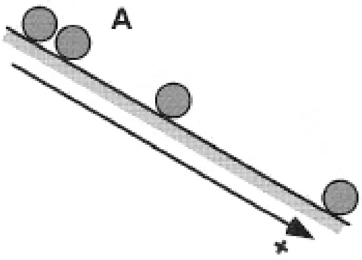
APPENDIX G:

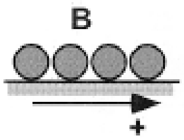
ACCELERATION RANKING TASK

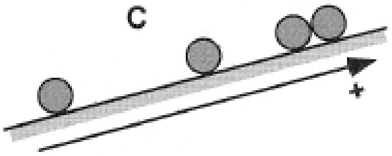
Ball Motion Diagrams—Acceleration I[2]

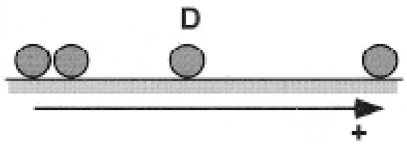
The following drawings indicate the motion of a ball subject to one or more forces on various surfaces from <u>left to right</u>. Each circle represents the position of the ball at succeeding instants of time. Each time-interval between successive positions is equal.

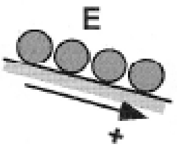
Rank each case from the highest to the lowest acceleration, based on the drawings. Assume all accelerations are constant and use the coordinate system specified in the drawing. Note: Zero is greater than negative acceleration, and ties are possible.

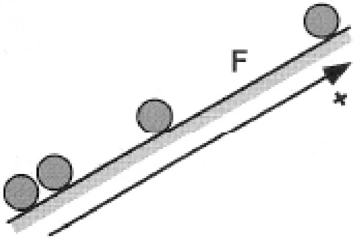












Highest 1________ 2________ 3________ 4________ 5________ 6________ Lowest

Or, all have the same acceleration. _________

Please carefully explain your reasoning.

How sure were you of your ranking? (circle one)

Basically Guessed				Sure				Very Sure	
1	2	3	4	5	6	7	8	9	10

---

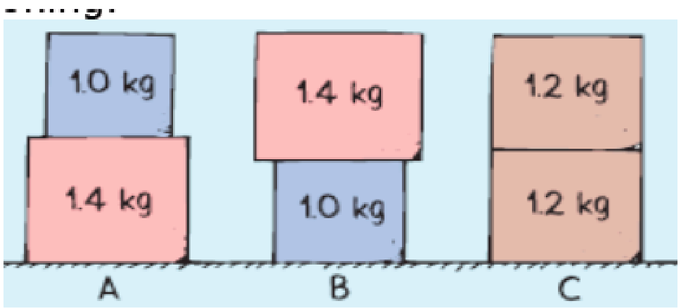
[2] D. Schramme, C. Fang, B. Speers

APPENDIX H:

NORMAL FORCE RANKING TASK

Normal Force Ranking Task

Illustrated below are three sets of boxes sitting at rest on a table. Using the information from the illustration, rank the box sets in order from greatest to least based on the amount of normal force the table is exerting on the box sets. Use <, >, and/or = to indicate the ranking.



Greatest _________ ___________ ___________ Least

Carefully state your reasoning for ranking the box sets in this order.

How sure were you of your ranking? (circle one)

Basically Guessed Sure Very Sure
1 2 3 4 5 6 7 8 9 10