# Order of Instruction as Related to Student Achievement:

# Constructivist Robotics vs. Text-based Curriculum

Kelly Stellmach Castillo

California State University, Northridge

# ABSTRACT

This study addressed the issue of instructional order within a combination constructivist - robotics and traditional instruction curriculum. Student achievement was compared in the two formats of instruction, robotics followed by text, as well as text followed by robotics. Approximately one hundred and fifty eighth grade students received both treatments. A Pre-test as administered prior to the implementation of the curriculum. Quizzes were administered at regular intervals throughout the study. Student projects were also analyzed following each robotics project. A Post-test was used to collect additional data upon conclusion of the curriculum. It was found that students demonstrated statistically significant and immediate gains in the area of content-based achievement when the traditional instruction first treatment was employed first. Findings from this study support the argument favoring content-based instruction prior to the assignment of open inquiry projects when seeking measureable academic achievement.

# Order of Instruction as Related to Student Achievement: Constructivist Robotics vs. Text-based Curriculum

## Chapter 1: Introduction

Science education in America is in the midst of a twenty-year decline. After two decades of worrisome sinking statistics, both in terms of academic achievement and successful employment, our students remain ill prepared and incapable of joining the workforce of the future. In 1983, the United States was perceived to be an international, scientific super power. Citizens and educators alike were shocked by report on the country's achievement, as published in "A Nation At Risk." This study found that, despite the post-sputnik mindset of promoting science education, our country was experiencing a nation wide shortage of physics teachers and specialists. American schools were simply not producing the science oriented graduates that the country needed to remain internationally competitive (A Nation At Risk, 1983).

Reform efforts were made during this time in an attempt to alleviate the epidemic of low performance. While these reform efforts were varied and well funded, future studies proved them generally unsuccessful. Fifteen years from the publication of A Nation At Risk, the 1998 Third International Mathematics and Science Study (TIMSS) showed that American high school seniors ranked third lowest out of the 21 nations evaluated (Pattanyak, 2003).

This low ranking is directly linked to time spent in the science classroom. The National Science Board (2008) reports that under the current curriculum, American high school and middle school students are not receiving an appropriate science education.

The lack of relevant, hands-on classroom material has lead to academic and a dearth of qualified American job applicants worldwide. Physics and engineering have become fields only for the academic elite, and even more so, for the non-American. Currently, fewer than 20% of American High School students actually take a physics course. Half of the high school students in the country take two or fewer years of science. The vast majority of American high school students never even have the opportunity to study physics. In the U.S. approximately one third of bachelor's degrees are awarded in the fields of science and engineering. At the same time, over half of international students graduate with such degrees (National Science Board, 2008).

Reform of science education needs to be a continued priority in order to benefit both students and society. Whether our students become physicists or not, they will need skills related to mathematical applications, manufacturing, and technology to become contributing members to their selected discipline as well as to the economy (Mervis, 1998; Bardeen & Lederman, 1998).

One of the nation's proposed solutions to this crisis was to enact legal parameters to create accountability for the field of education as a whole. In 2002, President Bush signed the "No Child Left Behind" (NCLB) Act. The intent of this law was to create a national goal of improving education and accountability through testing. Regardless of one's stance on this controversial act, there is no denying the fact that enacting NCLB has changed the face and stakes of standardized assessment nationwide. Due to the recent legal pressure, many states have imposed their own standardized guidelines (Slater, 2006).

While California has been using state wide standardized testing since the late 1990s, the introduction of NCLB legislation has imposed greater regulations on these assessments. Upon the enactment of NCLB, California changed the format of its standardized tests to include only questions based on predetermined content standards, or universal, fact based curriculum components. In the Spring of 2006, the California Department of Education began to expand the scope of these tests; the science content of the California Standards Test (CST) was extended to include a pilot section assessing eighth grade physical science. In previous years, science was only evaluated at the high school level. As of 2008, eighth grade students in California are tested in English, Mathematics, History, and Science each spring (Slater, 2006).

In addition to evaluation via standardized tests, educators seek to develop individuals who will be successful on multiple levels, not just academically, but socially as well. Students today are preparing to take on the jobs of tomorrow, many of which do not yet exist. It is the continued hope and goal of educators to produce well rounded, creative, and productive individuals who will be able to succeed at a variety of tasks.

How does a school district strike a balance between test preparation and authentic learning? Arcadia Unified School District (AUSD) finds itself in this predicament on a daily basis. A high achieving district located in a southern California suburb just east of Pasadena, AUSD administrators and teachers work to develop curriculum to achieve the delicate balance required of CST testing. One component of the AUSD mission states that teachers should, “provide quality work that is engaging, results in students learning meaningful content, and challenges every student to learn more” (Leri, 2003, p.3).

Despite increased pressure to achieve test scores, the belief that a commitment to quality and diverse education will lead to success on multiple levels.

AUSD has been successful in fulfilling this mission by incorporating technology into classroom practices. As a district, AUSD states that:

> The rapid advances of our society require that all members of an educational organization participate in ongoing changes. We acknowledge that technology will be a pervasive part of our students' future, both economically and socially. Technology is a resource for learning which must be readily accessible to all students. Not an end in itself, technology is a set of tools which when skillfully used extends students' abilities to communicate effectively, engage actively in their own learning, interact with knowledge, and use information to create and contribute new ideas (Leri, 2003, p.7).

Arcadia Unified School District is using technology as a vehicle to meet the need for students who are both achieving and successful. This is evident based on the implementation of a constructivist-driven, robotics-based eighth science curriculum.

## Purpose of Study

The purpose of this study was to examine the impact of varied sequences of direct instructional practices on a constructivist-learning curriculum. The effect of these differences were measured both in terms of academic achievement and scientific thinking of students. The program in question is a standards-driven, constructivist robotics program, embedded within the $8^{th}$ grade physical science curriculum.

The specific research question is:

- What is the effect on student achievement of instructional order in a curriculum composed of both constructivist robotics as well as traditional instruction?

## Importance of study

The immediate results of this study will influence daily teaching practice in the classroom at hand. Further, results of this study will be used in conjunction with additional research to improve upon the existing eighth grade science curricular program in Arcadia Unified School District. On a larger scale, the results of this study will help to inform curricular development and influence pedagogological policy for those districts and schools wishing to examine the effectiveness of their current eighth grade, standards-based, physical science curriculum.

As the district coordinator and a classroom teacher of this program, I am constantly striving to improve the teaching and learning of physical science via Lego-based robotics. Lego-based robotics programs allow students to explore standards-based, physical science curricula by cooperatively creating, building, programming, and trouble-shooting their own robots. It is my goal to integrate these characteristics into my own classroom in the hopes of bettering the teaching method of constructivist robotics.

## Definition of Terms

- Traditional Instruction- Conventional methods of education tend to be teacher-centered, wherein the teacher will present students with information, usually with lecture as the primary vehicle for information delivery. Students then repeat or replicate the information provided by the instructor (Domin, 1999).

- Constructivism (often referred to as “Discovery Learning” or “Inquiry”)- Constructivist instruction is based on the philosophy that students will learn material when allowed to experience knowledge within a familiar context. Constructivist theorists support the idea that students should approach a topic in a relevant context, or one that has clear real life applications. It is also necessary for students to view the problem from a variety of perspectives. Further, both the learning process and the product are embedded within a social experience and result in an increase of self-awareness (Honebein, 1996).
- Robotics Education- Such programs consist of curriculum in which robotics equipment (LEGO® Mindstroms, for the purposes of this study) is used to demonstrate physics standards in the classroom . LEGO® Mindstorms, the robotics kit designed with “kids in mind (Gura & King, 2007, pg. 39)”, uses a visual, icon based programming system that uses infrared light to program the computer interface found within student developed LEGO® robots (Domin, 1999).

# Chapter 2: Review of the Literature

## Traditional Instruction

Traditional instruction is consistent with the popular perception of school in America. Teachers instruct students to read and study the textbook. The teacher provides information to the students, including concepts, facts, terms, and diagrams. Class periods are lecture based and involve note taking, usually through the use of a chalk board or white board (Sungur & Tekkaya, 2006).

Researchers who have studied the role of traditional instruction demonstrate much consistency in its definition. In one of the earlier comparative studies, the idea of the "passive-student (Hake, 1997, p. 64)" was introduced. Several years after the introduction of traditional instruction, the term had a nearly identical connotation within the discipline of education. The most widespread definition was described as, simply a "lecture and questioning method (Sungur & Tekkaya, 2006, p.310)". In this instructional style, it is expected that students will answer questions generated by their teachers (Sungur & Tekkaya, 2006). Teachers who implement traditional instruction find the method both effective and efficient. With the challenges of reduced budgets and growing class size, traditional instruction allows groups of students to conduct the same experiment at a low price (Sungur & Tekkaya, 2006).

### *Traditional Instruction in the Science Classroom*

Just as in other classrooms, traditional instruction in the science classroom favors activities and labs with a predetermined outcome. Such labs provide students with recipe-like instructions and are used to verify a result that is already known. Sometimes these activities are appropriately referred to as "cookbook labs" (Domin, 1999, pg. 3).

These activities, often called verification labs, exemplify deductive thinking, as students apply a known principle to verify the assertion. Teachers encourage deductive thinking skills by instructing students to prove a principle based on data (Domin, 1999).

## Constructivist Theory

Constructivist theory is the basis for discovery learning. Under constructivism, educators subscribe to the idea that "knowledge cannot be transferred from one person to another (Domin 1999, p. 1)." Instead, a student needs to experience an event in order to make it truly meaningful. This is consistent with developmental educational theory. According to Vygotsky, students in the zone of proximal development benefit from scaffolding tools when facing new material. Completing academic activities within the social context of cooperative learning groups is also beneficial to the cognitive development of these students (Lai, 1993; Robinson, 2005; Wagner, 1999).

Experimentation with discovery learning in the classroom has produced several positive results. A study conducted by Sungur and Tekkaya (2006) demonstrated the favorable outcomes of discovery learning. It was found that students partaking in a discovery style of learning spent much time on task and claimed to be more motivated than when these techniques were not used. While these results are not indicative of learning per se, time on task and increased motivation levels suggest the presence of a more beneficial learning environment than existed prior to the study. (Sungur and Tekkaya, 2006).

In a constructivist classroom, the role of the teacher is less defined than with traditional instruction. The teacher is no longer the focal point of the classroom. Instead, the would-be instructor is now seen as a "facilitator, mentor, coach, or consultant

(Honebein, 1996, p. 22)." During this type of instruction, teachers guide their students to seek contextual, relevant meaning of course content skills. Teachers no longer provide information to "empty vessels," or students with a "blank slate". Instead, teachers offer their students motivation as a tool for learning (Gura & King, 2007).

Constructivism also changes the roles and expectations of the students. Under constructivist theory, the emphasis is not on the amount of content that a student manages to retain, but it is on the manner in which the student learns, or constructs knowledge. As a result, students need to take a more active role in their own learning. In a constructivist classroom, it is the student, not the teacher, who is the focus of education (Honebein, 1996).

*Constructivism in the Science Classroom*

Just as broader studies have found favorable results for constructivism as an instructional method at large, there are also specific implications for the science classroom. A study conducted by Hake (1998) focused particularly on introductory physics and found results in favor of constructivism. It has been established that conceptual understanding is vital to obtaining a working knowledge of Newtonian physics. Hake (1998) found that discovery learning also "enhanced problem solving skills (1998, p. 70)." The discovery-learning classroom favors exploratory labs, or those with a result that is unknown to the students and possibly to the teacher as well. Students then use inductive thinking to construct, or "derive a general principle (Domin, 1999, p.1)" based on their experience.

## Robotics Education

According to the American Association for the Advancement of Science (AAAS), the most effective method for teaching the nature of science is to have students physically engage in the practice of science (1993). The existence of a set method by which all science is conducted is a common misconception in science education. Both the AAAS and Domin's (1999) research regarding verification labs directly dispute the use of a single, formulaic scientific approach. Further, upon the completion of middle school, the AAAS believes that all students should know and understand that, "although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination (AAAS 1993, p. 12)."

Robotics provides experiences that directly correlate with the above philosophy of active science. Robotics-based science teaches students to "problem solve in a realistic way (Wagner, 1999, p. 2)". When working with robotics, students must define a problem, brainstorm possible solutions and then program and test their model. There is not a predetermined correct answer. This method is an example of "pure inquiry (Robinson, 2005, p. 79)," because the lab has no present set procedure or outcome (Wagner, 1999).

In robotics curricula, the technology of the computer interface in combination with the physical manipulatives of the Lego pieces provides this cognitive support. For example, students may explore the abstract relationships between forces and motion by using self made concrete models. Additionally, the critical thinking done by students in robotics engages and promotes an authentic understanding of the broad applications for scientific thinking and knowledge. Experimenting with robotics forces students to "learn from [their] failures (Mauch, 2001 p. 212)." These experiences cannot be gained solely from a textbook. Robotics experiences "illustrate that the real world tends to be much messier, noisier, and more unpredictable than students have come to expect from the idealized view that dominates textbooks (Turbak & Berg, 2002, p. 245)." First-hand knowledge of this aspect of the scientific enterprise contributes greatly to a student's scientific literacy (AAAS, 1993; Mauch, 2001; Turbak & Berg, 2002).

*Existing Research*

Much of the existing research on Lego robotics in the classroom is small in scope, focusing on only a particular segment of the student population. One of the most popular areas of focus has been narrowing the gender based achievement gap in the sciences. Historically, females have struggled with the conceptual nature of physics. Robotics is synonymous with incorporating concrete, physical manipulatives into the curriculum of the hard sciences. Brain-based research and action research demonstrate that hands on modeling greatly increases ability and interest among female students in the conceptual science classroom (Gurian, 2001).

One of the earliest investigations into integrated, computer-driven robotics found that, when using the manipulatives for classroom instruction and investigation, there were no significant cognitive differences measured between genders. This suggests that, in accordance with Gurian (2001), concrete manipulatives provided female students with equal access to abstract concepts. This study also addressed the historical stereotype surrounding the field. Students were asked, at different points in the robotics unit, if computers were easier to learn for boys than for girls. Before their experience with robotics, 27% of students agreed that computers are easier for boys. Upon completion of the robotics unit, the number dropped to 10.7% (Lai, 1993, p. 242). This demonstrated the powerful role that manipulative robotics plays for the perceptions surrounding female students as well as for the students themselves.

More recently, Wellesley College adapted the typical engineering-focused robotics program to include an element of creativity. Also consistent with brain-based research, the instructors at Wellesley felt that their 100% female population would benefit from the tactile nature of robotics without the competitive spirit. Consequently, Wellesley approached robotics as a non-vocational academic exercise, encouraging students to contribute their inventions to a cumulative robotics showcase. This study cemented the developing ideology that robotics promotes equal access across genders (Turback & Berg, 2002).

The history of robotics education includes other prominent universities as well. Carnegie Mellon University (CMU) is world renowned for its contributions to robotics education. Founded in 1965, the CMU robotics institute has grown along with the study of robotics. As robotics-based curriculum made its move to the middle school level, Carnegie Melon University, brought robotics curriculum to the forefront of educational research. In 1998, CMU formed a relationship with LEGO to create a cohesive, robotics based curriculum guide for middle and high school students. In 2006, this relationship was reaffirmed when CMU used LEGO's newest creation, Mindstroms NXT, to extend their curriculum to include this new building kit. Due to it's extensive involvement in the field, CMU is also able to offer teacher training and student experiences across the country (Educational Robotics, 2008; Spice, 2007.)

Similarly, Tufts University later founded their version of the Robotics Institute which they call Robotics Academy. This group also offers curricular support including a K-12 outreach program and opportunities for robotics competitions. Tufts is among the first schools to offer robotics as project-based learning at the undergraduate and graduate levels (Tufts, 2003).

With the introduction of this curriculum, schools began to implement robotics education in the classroom. Some of the first such studies were conducted on gifted and talented students, or those with a predisposition to technology. This homogeneity is explained by the fact that many of the initial pilot programs were conducted in schools on a voluntary basis. Thus, only those students who were interested enrolled in courses. Additionally, these courses were taught by teachers who had also volunteered for the task.

Due to financial constraints of implementing robotics programs on the school or district level, many of the original focus groups were composed of Caucasian students from upper-middle to high socioeconomic backgrounds. While these factors do not devalue the data obtained from such studies, they certainly highlight the current bias in research (Mauch, 2001; Resnick, 1990; Wagner, 1999).

Only recently have such studies shifted their focus to special needs populations. One of the few comprehensive studies surrounding non-mainstreamed students took place in 2005. Robinson (2005) found that a comparable robotics curriculum provided many tools for English language learners to be successful in the area of scientific literacy. Cooperative learning groups enabled these students to practice content vocabulary as well as social and communication skills. The extent to which English language learners have benefited from this program suggests that these techniques will be equally beneficial on a broader scope. Such results have promising implications for all students. (Robinson, 2005).

As previously mentioned, the unique nature of these robotics programs makes widespread implementation difficult on multiple levels. The sparseness of such programs is not reflective of program success. Rather, it is indicative of the many barriers to implementation found in the typical classroom setting. Issues of cost, materials, time, and teacher training have all limited the rapid growth of Lego-based robotics programs in the classroom.

The start-up costs associated with these programs are often not feasible for a school site or school district to fund in whole. Often times, the onus for fund raising falls on the teacher. In 1989, one teacher alone spent $8,900, financed by an independent grant, to implement the program in her classroom. In addition to acquiring the necessary tools, schools need to support and maintain the equipment through the wear and tear resultant of intense daily use. Not only do students need regular access to classroom computers, immediate success is often dependent upon the familiarity students have with technology (Clark, 2002; Robinson, 2005).

Efforts have been made to assess the legitimacy of all variables in the program: building, programming, cooperative learning, and required equipment. Results show that the interdependence of these variables leads to the success of the program. Therefore, eliminating certain components in order to cut costs is not a viable option (Wagner,1999).

In order to properly implement such a program, teachers not only need the proper tools, they also need adequate time. It takes time to train teachers and to train and teach the students. Like all technology, robotics in the classroom "has great potential to enhance student achievement and teacher learning, but only if it is used appropriately (Bransford et al, 1999, Ch. 9 p. 1)." Appropriate use is heavily dependent upon thorough training and careful follow-up, both of which require dedication from the teacher and the school. Students also need blocks of uninterrupted time during which they may complete their projects. Time in school is often in short supply, and when it is available, it is fragmented, interrupted by bells and passing periods (Mauch, 2001).

## Summary

Thus far, the majority of the research provides anecdotal evidence indicating that appropriate implementation and participation in a Lego-based robotics program improves both scientific literacy and cognitive, problem solving ability. Students who partake in these lessons become reflective, metacognitive thinkers and active participants in class. Of the subgroups previously studied, all have shown progress in both the content and process skills needed for scientific literacy. While the link between such cognitive skills and academic achievement has been implied, the correlation between a constructivist, standards driven robotics program and academic achievement in physical science content standards has yet to be explored, particularly in the middle school science classroom. Further, little research has been published documenting the role of direct instruction in the success of such programs (Lai, 1993).

# Chapter 3: Methodology

## Participants

This study was conducted over one 12-week period during the Fall of 2007 at Foothills Middle School in Arcadia, CA. One hundred and sixty eighth grade students were divided into six class periods The six class periods were then further divided into two treatment groups, each consisting of three class periods of students. Each of these two groups were comprised of approximately equal numbers of males and females.

Foothills middle school is one of three middle schools, serving grades six through eighth, in Arcadia Unified School District. Based on the 2005-06 accountability report, Foothills has an enrollment of 817 students. Of this population, approximately 54% of the students are Asian, 32% Caucasian, and 10% Hispanic or Latino. 5% are English language learners and 13% are classified as Gifted and Talented. Of parents surveyed, over 80% have earned either a college or graduate degree. Foothills is considered to be a high achieving school with a 2006 base API (Annual Performance Index) of 930 and a statewide rank of 10$^{th}$ among all middle schools in California (California Department of Education, 2007).

## Materials

Robotics instruction, as well as the physics curriculum, is intended to ensure student competency in the physics and investigation portions of the California standards for eighth grade science listed in Appendix A. The curricular program in question consists of 12 weeks during which students alternated between periods of traditional instruction and building challenges using LEGO-based robotics. Students took part in a total of three robotics projects and three lessons with corresponding content. Student achievement of content standards was evaluated by a both a post-test, as well as multiple choice quizzes and free response questions at regular intervals during the experimental period.

## Procedures

This study took place during the first three months of the 2007-2008 school year, beginning in October and ending late December. Students in six periods of eighth grade science took part in the same robotics curriculum. Each period, however, received direct instruction and constructivist challenges in a different order.

Quantitative data, taken via standardized content driven assessments, were used on eight separate occasions. As shown in Figure 1, a pretest was administered prior to the three units of instruction. After students had completed both the robotics and text based instruction for all three units, a comprehensive post-test identical to the original pre-test was administered.

Figure 1: Overview Timeline for Curriculum Implementation

| | | | | |
|---|---|---|---|---|
| Pretest | Unit 1: Motion | Unit 2: Forces | Unit 3: Newton's Laws | Posttest |

*The entire curriculum consisted of three separate units of study. A pretest and posttest were administered before and after the whole curriculum.*

Figure 2 demonstrates that after the pre-test was administered, unit one began. Within each of the three units, midpoint quizzes were given after the each half of a given section (either the robotics challenge or direct instruction). Robotics projects were evaluated upon completion of each robotics segment.

Figure 2: Sample Timeline for Distribution of Curriculum with one Treatment Group

```
Unit 1:                                                        Unit 2:
Motion________________________________________________________Forces____________ETC
   |                         |             |              |                 |
Robotics Curriculum        Quiz      Text-Based         Quiz           Text-Based
 And Project                          Instruction                      Instruction
```

*The group who received robotics first in Unit 1 received text first in Unit 2, and then robotics first again in Unit 3. The other group followed a reverse schedule.*

## Analysis

Standards-based, objective tests were evaluated in the order introduced. Further, data was sorted to include progress of individuals over time as well as across content areas. Mean scores as well as specific questions or topics were evaluated in search of patterns connected to the method of instruction.

# Chapter 4: Findings

In order to determine student achievement, assessments including pre and post-test data, multiple choice quizzes, and coded free response lab projects were analyzed. Multiple forms of statistical analysis were used, namely independent and paired t-tests. The significance of the findings addresses the question as to the role of order of instruction (robotics first versus text first) and its effects on student achievement.

## Pre-test/post-test

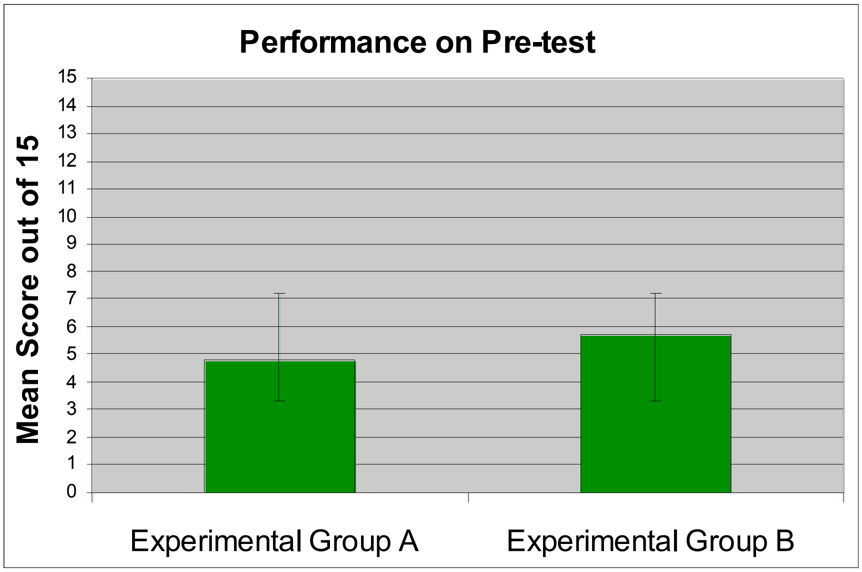
A test consisting of 15 multiple-choice questions, provided in Appendix B, was administered to all students at the beginning as well as upon the conclusion of the study. When analyzed using an independent t-test, the results of the pre-test show that both experimental groups scored a mean of 4.78 and 5.71 (out of 15) respectively. These scores, listed in Table 1 and shown in Fig. 3, are not significantly different from each other, as indicated by a p-value of .123.

Table 1: Pre-test Performance

| Track | N | Mean | Std. Deviation | Sig |
|---|---|---|---|---|
| A | 71 | 4.78 | 3.144 | **P=.123** |
| B | 73 | 5.71 | 2.988 | |

*Both groups of students (tracks A and B) are similar in both size and initial pre-test performance.*

Figure 3: Pre-Test Performance




*Both groups performed statistically significantly similar on the pre-test.*

Results of the post-test, as compared to those of the pre-test, show that significant gains ($p<.001$) were made by those students who completed the implemented curriculum. The statistical analysis of this data is further expanded upon in Table 2.

Table 2: Pre-test to Post-test Achievement

| Mean | Std. Deviation | Upper Lower | Sig |
|---|---|---|---|
| 3.476 | 2.65 | 4.145 2.807 | **P<.001** |

*Upon the completion of both treatments across three units, both groups of students had statistically significant gains in achievement.*

## Quizzes

A five-question quiz, shown in Appendix C, was created for each of the three units of study: motion, forces, and Newton's laws. Each quiz was given to each student twice. The quiz was given for the first time upon the completion of the first treatment for the unit, either a robotics project or the textbook portion. Students then completed the remaining treatment and took the quiz again. Independent t-tests were conducted to determine the significance of treatment order in achievement.

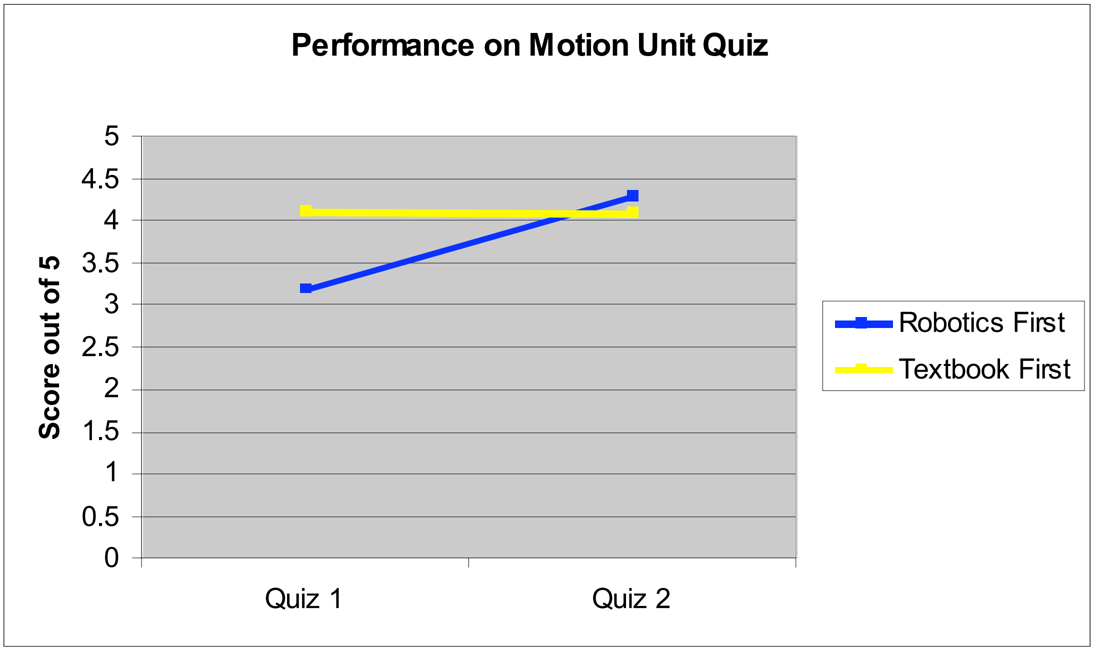
In all three units, the treatment group who received the textbook portion of the curriculum first outperformed the robotics first groups on all three of the first round of quizzes. The significant disparity in performance is noted by p-values for all three quizzes less than .001. Figures 4, 5, and 6 also show the progress of each treatment group over time. In the motion unit and in the unit on Newton's laws, both treatment groups achieved statistically similar scores on the second quizzes, with p-values of .247 and .433 respectively. Quiz data from the forces unit, however, showed that the textbook first treatment group significantly outperformed the robotics first group. Even in the second post-quiz, after both groups had received the same instruction from each treatment, the text first groups showed greater gains with a p-value of .007. Figure 7 depicts this difference in outcomes; P- values are found in Table 3.

Table 3: Quiz Performance

| **Topic**<br><br>**Treatment** | **First Administration of Quiz (Mean)** | **P -value R vs.T** | **Second Administration of Quiz (Mean)** | **P- value R vs. T** |
|---|---|---|---|---|
| <u>Motion</u><br>Robotics 1st<br>Text 1st | <br>3.1667<br>4.0972 | <br>**<.001** | <br>4.2778<br>4.0735 | <br>.247 |
| <u>Forces</u><br>Robotics 1st<br>Text 1st | <br>3.3485<br>4.5000 | <br>**<.001** | <br>4.0204<br>4.5781 | <br>**.007** |
| <u>Newton</u><br>Robotics 1st<br>Text 1st | <br>3.5522<br>4.2286 | <br>**<.001** | <br>4.1692<br>4.3333 | <br>.433 |

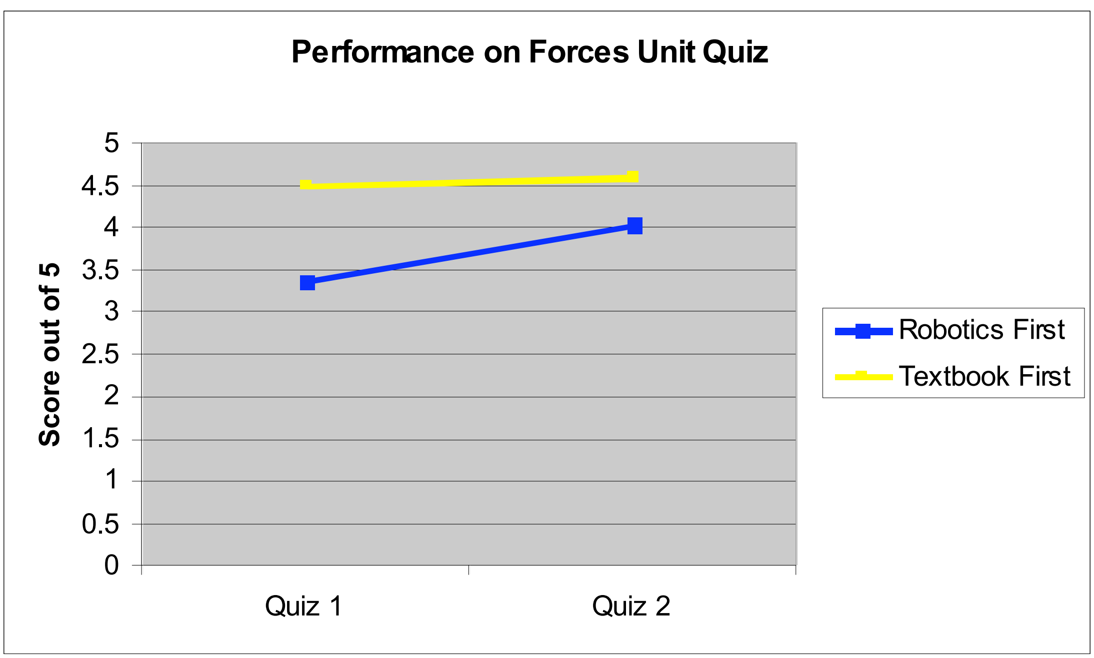
*For all three units, during the first administration of the quiz, the groups who received text-based instruction first outscored the robotics first groups with p-values less than .001.*

Figure 4: Performance on Motion Unit Quiz



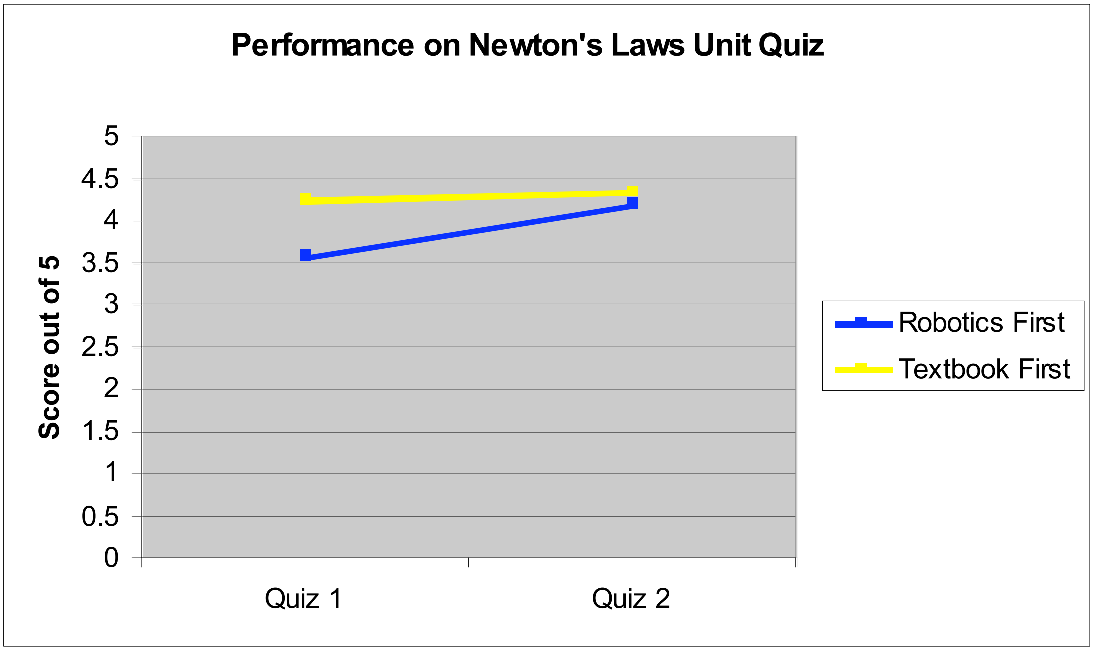

*Results of the first quiz show that the textbook first group significantly out performed the robotics first group (p<.001). After both treatments, both groups showed statistically similar gains in achievement (p=.247)*

Figure 5: Performance on Forces Unit Quiz



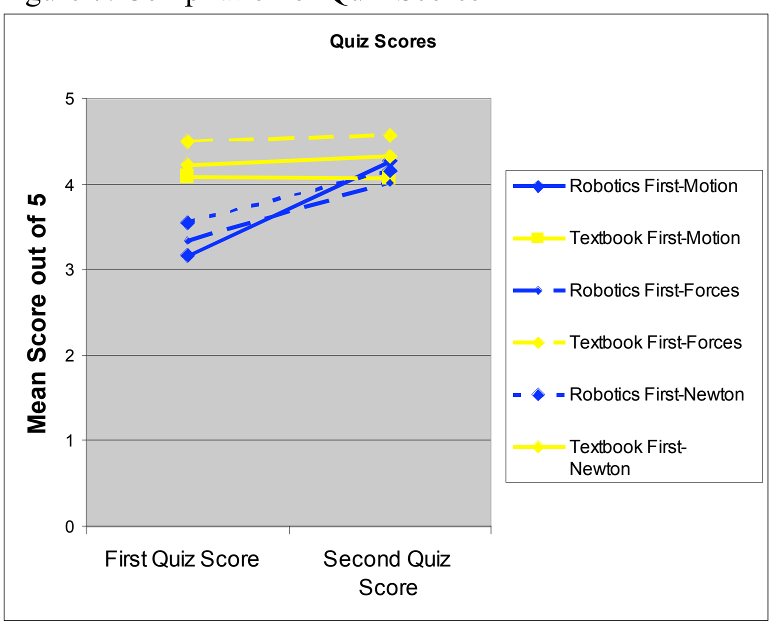

*Quizzes from the forces unit show that the text first group had statistically significant gains in achievement above the robotics first group in both Quiz 1(p<.001) and Quiz 2 (p=.007). .*

Figure 6: Performance on Newton's Laws Unit Quiz




*Results of the first quiz show that the textbook first group significantly out performed the robotics first group (p<.001). After both treatments, both groups showed statistically similar gains in achievement (p=.433).*

Figure 7: Compilation of Quiz Scores




*In all units, the text based treatment significantly outscored those who had robotics first. Groups receiving robotics first demonstrated statistically significant gains on the second quiz, once they completed the textbook portion of the curriculum.*

## Projects

Inquiry based projects, found in Appendix D, were assigned during the robotics portion of each unit. These assignments asked students for a visual and written response to content based material. They were asked to draw a diagram and explain their thinking as it pertained to a main idea in the given content area. Projects were collected from a total of 18 students. These students were selected based on their ability to represent the demographics of the sample group. Information on selected students is available in Appendix E.

Each response was coded on a scale of one to three, and then the values for the diagrammatical and written responses were averaged to result in a score out of three points possible. Reponses received zero points if they were missing. Responses providing no correct information received a score of one. Scores of two points were awarded to those responses who presented a combination of correct and incorrect information provided that they ultimately drew a mostly correct conclusion. Scores of three were reserved for those responses that were scientifically correct and applicable to the question.

While projects were assigned for all three units, only those from the latter two units, forces and Newton's laws, were analyzed. There was not sufficient data available from the first unit, motion, so these assignments were excluded. Additionally, data from both treatment groups was only available from the unit on forces. Adequate data from the same cohort of students across different treatments was available for the unit on Newton's laws. Available data is shown in Table 4.

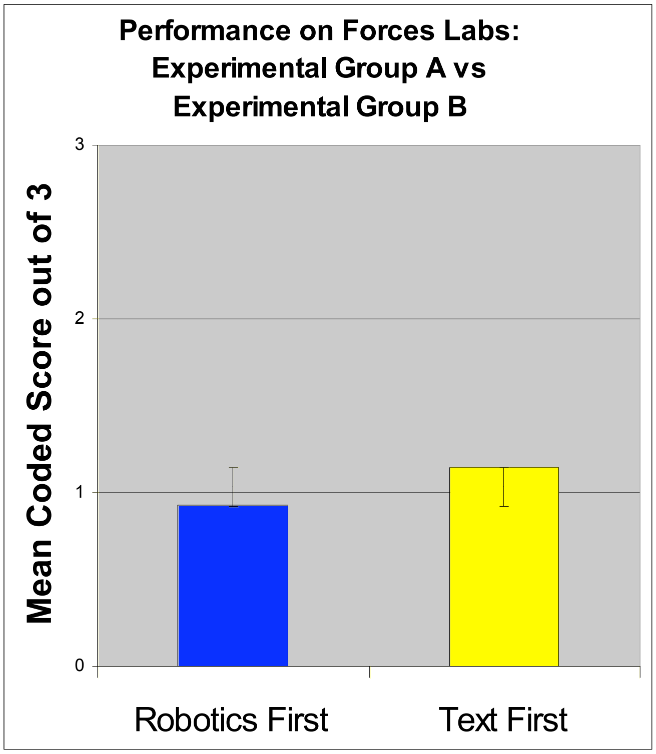
Table 4

| **Track(s)** | **Topic (s)** | **Text 1st & Robotics 2nd** | **Robotics 1st & Text 2nd** | **P value** |
|---|---|---|---|---|
| A vs B | Forces | A<br>Mean= 1.143<br>Standard deviation= .829 | B<br>Mean=.9286<br>Standard deviation= .864 | .509 |
| B: Physics 1st vs. Robotics First | Forces & Newton | Mean= 1.5<br>Standard deviation= .674 | Mean=.9286<br>Standard deviation= .829 | .069 |

*When project data from two groups receiving different treatment within the same unit, it was found no statistical significance in achievement(p=.509). When the same group was followed through, receiving both treatments in two different units, a notable but not significantly statistical difference was found in favor of the text first treatment (p=.069).*

Data on the forces lab from each treatment group was compared using an independent t-test. As shown in Figure 8, both treatment groups scored statistically similarly on the robotics lab, regardless of their sequence of instruction (p=.509). In other words, both groups, those who completed the robotics lab prior to as well as after textbook instruction, performed just as well on the content based laboratory assessment.

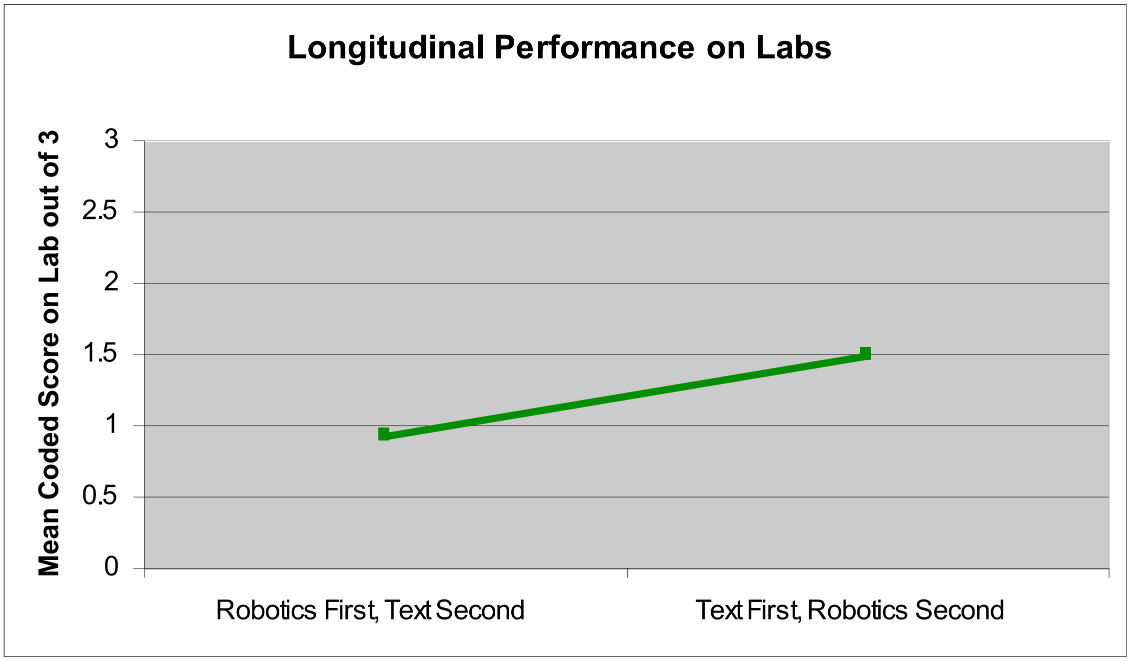
Figure 8: Performance on Forces Project




*Coded results of achievement on the forces project show no statistically significant difference between the group that received robotics first versus that which received text first (p=.509).*

Figure 9 tracks the progress of the same group of students through two different treatments. First, these students completed the forces lab as a part of the robotics first sequence. Next, these same students completed the lab on Newton's laws in the textbook first sequence treatment. Lab scores were compared longitudinally using a paired t-test. Results show that while the difference in achievement was not statistically significant, the group performed remarkably better on the lab assessment when they had the opportunity to study the textbook first.

Figure 9: Longitudinal Performance on Labs




*When the same group of students was followed across both treatments in different units, here was a noticeable, though not statistically significant (p=.069), increase in achievement under the text first treatment.*

# Chapter 5: Findings

## Overview of the Study

The purpose of this study is to examine the relationship between student achievement and order of instruction when using both text based and constructivist robotics curriculum. Treatment groups took part in two different forms of the same content and process skills. Both groups were treated with a both robotics projects followed by textbook instruction and vice versa.

A pre-test and a post-test were given in order to measure the effectiveness of the program as a whole. Quizzes were administered after both the robotics and the text version of the content. The results of the quizzes were compared for each treatment using independent t-tests. Lab work for each robotics project was analyzed via data coding. The results of each treatment were then compared also via independent t-test. Progress of a particular treatment group was also compared over both ordered treatments. This longitudinal data was analyzed using a paired t-test.

## Summary of Findings

Analysis of pre-test and post-test data provided information about the curricular program as a whole as well as the students involved in the study. Quiz results favoring the text first method demonstrated the significance of the difference in achievement between treatment groups. Projects provided insight as to students' thought processes and application of material. Coded project results allowed qualitative data to be compared statistically as a quantitative assessment of performance. Both quizzes and projects point to the text first treatment as providing the greatest gains in academic achievement.

## Conclusions

The significant difference between pre-test and post-test scores, regardless of treatment order, proved that the administered program was effective. Therefore, the program as a whole resulted in greater achievement. This shows that either treatment or the combination of both treatments will result in an increase in achievement. Verifying the effectiveness of the program showed it was evident that some segments of the program lead to its effectiveness. Thus, the data shows that it is legitimate to measure achievement across treatments using the given curriculum. Conversely, if there was no statistically significant difference between pre –test and post-test scores, the curriculum as a whole could not be deemed successful. Therefore, the objective of the study would have been shifted to determining the area of curriculum that is most in need of change.

The statistically insignificant changes in data across both treatment groups demonstrated the initial homogeneity of the students tested. This ensures that both groups started the study with a similar knowledge base. Therefore, comparisons throughout the study were valid, as both groups were statistically equal in the beginning of the study. Should original scores differ, there is the possibility that the data could be skewed by the existence of conflicting previous knowledge.

Quiz scores provided the most comprehensive data with regard to the research question. When students received text-based curriculum first, quiz scores were significantly greater than situations when robotics was administered first. This implies that it is the text, or the content-based material provided before the robotics projects, that resulted in the greatest level of measured achievement.

The conclusions drawn by the project analysis supported the quiz data as well. Project findings demonstrated that the treatment of text first is more achievement oriented. Additionally, the fact that lab analysis was primarily based on qualitative interpretation shows that viewing the results from different angles leads to the same conclusion. Therefore, the argument in favor of the data is strengthened.

The data showed that constructivist robotics projects had a statistically insignificant increased academic outcome when students had the benefit of receiving the academic content before engaging in the project. However, the relatively low p-value of .069 suggests that there may still be a correlation worth exploring. The results show that students needed previous knowledge when approaching guided inquiry assignments.

## Recommendations

The results of this study provide data that is immediately applicable to the way classroom curriculum is implemented. The results of this study make an excellent case on favor of providing information that will create prior knowledge when working with inquiry projects. As a result of this prior knowledge, students will have the information necessary to be academically successful in their projects.

The results of this study have strong implications for curriculum development as well. Not only will the robotics curriculum be structured with the factual information first, other types of inquiry or constructivist projects can be designed in the same way. This structure can be used to increase academic achievement on both the individual and class levels. Greater implications of this research could be extended to the school level, district level and beyond. As schools come to see the connection between instructional order in constructivist projects, this structure may begin to be the norm.

## Limitations of the Study

Despite best efforts, there will always be limiting factors when dealing with human subjects. In this study, the subjects were atypically high achieving students to begin with. Therefore, the results may be skewed because the students did not see robotics as a motivating factor. In a different environment student scores may have improved in the robotics first treatment if the projects served as an external motivating factor.

Initially, this study also included a student survey that gathered information of students' perception of the curriculum both according to engagement and feeling of academic success. As the study progressed it became obvious that there was no real connection between the research question and student opinion. As such, the surveys were not included in the analysis.

The shear number of students involved in the study also served as a roadblock. As a result of the number of students involved, it was not feasible to code and analyze lab projects from each of the students. Instead, a representative group was selected for analysis. As student work from this group was collected and sorted, the fact that these particular students did not submit all of their robotics projects proved to be a problem. As a result, the sample size and available comparisons in the project study does not necessarily prove widespread accurate results.

As the study progressed, student absences began to affect the amount of data collected. Fortunately, the sample size of students quizzed was great enough that the students missing segments of the quizzes or assignments could be removed from the experimental group.

Again, the fact that the students tested tend to do well in school and are high achieving could also affect the outcome of the study's implications. It is a possibility that the text first structure only applies to a population similar to that tested. Additionally, all but five of the students tested have had robotics in the past. With robotics for all students as a district wide initiative, previous experience in the field could down play the engagement and excitement surrounding the seemingly unique robotics curriculum.

In this study, students were viewed as similar and results were addressed on a generalized, whole class level. In order to draw more accurate conclusions, future research will need to analyze sub groups of the population. For instance, resource students and/or English language learners may be affected by the order of instruction in a different way than the majority of the test students. Due to the fact that these groups only represent a small segment of those tested, their scores may not have been accurately reflected in the data.

The percentage of gifted students was also not calculated in this study. Just as the above, where struggling students may have approached the curriculum differently than the norm, the same holds true for the more advanced students. Also, given the demographics and past achievement records of the school involved, the results may have been influenced by a surprising large number of gifted students.

If this topic were to be explored further, issues of subgroups as well as qualitative data would need to be addressed. Due to the uncertain sample size of students in both of these categories, the statistically significant findings do not guarantee comprehensive results. There is also the issue of motivation in different populations outside these particular classes. Broader research is necessary to draw more widespread conclusions.

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## Appendix A

CA 8th grade science standards in question according to the California Department of Education.

Motion

1) The velocity of an object is the rate of change of its position. As a basis for understanding this concept:
   a) Students know position is defined in relation to some choice of a standard reference point and a set of reference directions.
   b) Students know that average speed is the total distance traveled divided by the total time elapsed and that the speed of an object along the path traveled can vary.
   c) Students know how to solve problems involving distance, time, and average speed.
   d) Students know the velocity of an object must be described by specifying both the direction and the speed of the object.
   e) Students know changes in velocity may be due to changes in speed, direction, or both.
   f) Students know how to interpret graphs of position versus time and graphs of speed versus time for motion in a single direction.

Forces

2) Unbalanced forces cause changes in velocity. As a basis for understanding this concept:
   a) Students know a force has both direction and magnitude

b) Students know when an object is subject to two or more forces at once, the result is the cumulative effect of all the forces.

c) Students know when the forces on an object are balanced, the motion of the object does not change.

d) Students know how to identify separately the two or more forces that are acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.

e) Students know that when the forces on an object are unbalanced, the object will change its velocity (that is, it will speed up, slow down, or change direction).

f) Students know the greater the mass of an object, the more force is needed to achieve the same rate of change in motion.

Investigation and Experimentation

9) Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

a) Plan and conduct a scientific investigation to test a hypothesis.

b) Evaluate the accuracy and reproducibility of data.

c) Distinguish between variable and controlled parameters in a test

d) Recognize the slope of the linear graph as the constant in the relationship y=kx and apply this principle in interpreting graphs constructed from data.

e) Construct appropriate graphs from data and develop quantitative statements about the relationships between variables.

f) Apply simple mathematic relationships to determine a missing quantity in a mathematic expression, given the two remaining terms (including speed = distance/time, density = mass/volume, force = pressure × area, volume = area × height).

g) Distinguish between linear and nonlinear relationships on a graph of data.

# Appendix B

Pre-test and Post-test: Both exams were identical.

*Identify the choice that best completes the statement or answers the question.*

1) The **location** of an object at an instant in time is called its:
   a) angle.
   b) origin.
   c) position.
   d) direction.

2) Fully describing a position in two dimensions requires **at least**:
   a) one number.
   b) two numbers
   c) three numbers.
   d) four numbers

3) The quantity that measures the change in position with time in a certain direction is:
   a) speed.
   b) acceleration.
   c) velocity.
   d) dimension.

4) The relationship that allows you to solve for **average speed** is:
   a) distance + time
   b) time × distance
   c) distance ÷ time
   d) time ÷ distance

5) In the phrase "meters per second", the word **per** can mean all of the following EXCEPT:
   a) multiplied by.
   b) for every.
   c) divided by.
   d) for each.

6) A force that always tends to slow the motion of an object on a surface is:
   a) mass.
   b) weight.
   c) friction.
   d) inertia.

7) The force of gravity on an object is called:
   a) mass.
   b) inertia.
   c) weight.
   d) volume.

8) Of the following measurements, the one that would be incomplete without giving a direction is:
   a) time.

b) temperature.
c) length.
d) force.

9) A vector, such as force, can be represented by drawing an arrow. Which of the following statements is CORRECT?
a) The length of the arrow indicates the direction of the force.
b) The length of the arrow indicates the strength of the force.
c) The length of the arrow indicates the unit of force used.
d) The point of the arrow indicates the strength of the force.

10) All of the following are examples of vectors EXCEPT:
a) force.
b) velocity.
c) temperature.
d) acceleration.

11) The action that has the ability to change the motion of an object is:
a) force.
b) velocity.
c) acceleration.
d) mass.

12) The term that means **all of the forces together** is:
a) normal force.
b) net force.
c) frictional force.
d) weight.

13) The property of matter that resists changes in motion is:
a) acceleration.
b) inertia.
c) force.
d) speed.

14) Acceleration is the rate at which ____ changes.
a) distance
b) velocity
c) displacement
d) mass

15) A car traveling around a corner at 18 meters per second is accelerating because it is changing its:
a) mass.
b) speed.
c) direction.
d) displacement.

KEY:
1. C

2. B
3. C
4. C
5. C
6. C
7. C
8. D
9. B
10. C
11. A
12. B
13. B
14. B
15. C

# Appendix C

The pre-test/post-test (see Appendix B) was divided into a series of three five-question quizzes to correspond with each of the three units of study.

Motion Unit:

1) The **location** of an object at an instant in time is called its:
   a) angle.
   b) origin.
   c) position.
   d) direction.

2) Fully describing a position in two dimensions requires **at least**:
   a) one number.
   b) two numbers
   c) three numbers.
   d) four numbers

3) The quantity that measures the change in position with time in a certain direction is:
   a) speed.
   b) acceleration.
   c) velocity.
   d) dimension.

4) The relationship that allows you to solve for **average speed** is:
   a) distance + time
   b) time × distance
   c) distance ÷ time
   d) time ÷ distance

5) In the phrase "meters per second", the word **per** can mean all of the following EXCEPT:
   a) multiplied by.
   b) for every.
   c) divided by.
   d) for each.

Forces Unit:

1) A force that always tends to slow the motion of an object on a surface is:
   a) mass.
   b) weight.
   c) friction.
   d) inertia.

2) The force of gravity on an object is called:
   a) mass.
   b) inertia.
   c) weight.
   d) volume.

3) Of the following measurements, the one that would be incomplete without giving a direction is:
   a) time.
   b) temperature.
   c) length.
   d) force.

4) A vector, such as force, can be represented by drawing an arrow. Which of the following statements is CORRECT?
   a) The length of the arrow indicates the direction of the force.
   b) The length of the arrow indicates the strength of the force.
   c) The length of the arrow indicates the unit of force used.
   d) The point of the arrow indicates the strength of the force.

5) All of the following are examples of vectors EXCEPT:
   a) force.
   b) velocity.
   c) temperature.
   d) acceleration.

Newton's Laws Unit:

1) The action that has the ability to change the motion of an object is:
   a) force.
   b) velocity.
   c) acceleration.
   d) mass.

2) The term that means **all of the forces together** is:
   a) normal force.
   b) net force.
   c) frictional force.
   d) weight.

3) The property of matter that resists changes in motion is:
   a) acceleration.
   b) inertia.
   c) force.
   d) speed.

4) Acceleration is the rate at which ____ changes.
   a) distance
   b) velocity
   c) displacement
   d) mass

5) A car traveling around a corner at 18 meters per second is accelerating because it is changing its:
   a) mass.
   b) speed.
   c) direction.
   d) displacement.

Appendix D

Robotics Projects included in study consist of one project for each of the three units; Motion, Forces, and Newton's laws.

Motion Unit Project:

Motion Activity Lab

- Build the "tracker" found in the first section of the instruction booklet.
- Program your robot to move straight as slowly as possible for 5 seconds.
- Use a flow map to show this program in the space provided.

- You will run your robot along station A on the challenge mat in order to calculate the SPEED.
- You will record the DISTANCE from the REFERNCE POINT that your robot has traveled for each of the 5 seconds.
- Complete the following table to show your data:

| **Time (s)** | **Distance (UNITS? ______)** |
|---|---|
| 0 | |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |

- Use the space below to create a DISTANCE-TIME GRAPH based on your data. Don't forget to label axes and use units.

- What is the slope of your line? Please show your work.

- What is the average speed of your vehicle? How do you know this?

- You will now use the information in your graph and data table to accomplish the challenge.

CHALLENGE: You need to use data to get your robot as close to the Lego man as possible without knocking him down.

- You will begin at station B. Program your robot to complete the above challenge.
- Use a flow map to show your program below.

- What calculations did you use to accomplish this task? Show your work here.

- What was your REFENCE POINT?

- How far was your car from the Lego man?

- You will now begin at station C. Program your robot to complete the above challenge.
- Use a flow map to show your program below.

- What calculations did you use to accomplish this task? Show your work here. Draw diagrams as necessary.

- How far was your car from the Lego man?

Forces Project:

Ramp-bot Challenge
25 points

1. Sketch a drawing of your robot below.

2. Which features (parts) of your original robot made it unsuccessful?

3. Which features (parts) of your final robot made it successful?

4. What is the highest height that your robot climbed. Give the number on the ramp incline.

5. Why is it difficult for a robot to go uphill?

Newton's Laws Unit Project:

**<u>Snail Car Challenge</u>**

Challenge:

You are going to build a racecar of your own design. No building plans will be provided. There's one catch in this race, though: the <u>last</u> car across the finish line wins!

Rules:

- Your car must be built entirely from the LEGO parts in your kit (snail decorations however will be allowed).
- Your car cannot move backwards or sideways.
- The RCX must be part of your car.
- Movement must be measurable and continuous.
- The car must cross the finish line to win.

Hints:

- A successful car will probably include gearing down.
- The worm gear can be very useful.
- In this situation, friction is your friend.

Procedure:

1. Using your scientific knowledge, explain at least 2 physics concepts which will help the vehicle move slowly.
2. Design a gear train and draw it here.
3. Build it.
4. What structural designs didn't work well? Explain in sentences or draw.
5. What structural designs worked well? Explain in sentences or draw.
6. Test it. Approximately how long does it take you car to travel the distance of 1 floor tile? _______
7. Use your physics vocabulary to describe scientifically why your vehicle moved slowly.

Appendix E

The following students were selected to have their projects analyzed. They were selected based on course performance, CST score, and district classification. The rationale behind this method was to obtain a focus group that was representative of the subject base as a whole.

| **Stu #** | | **2007 CST ELA** | **2007 CST Math** | **Combined CST** | **Grade in Science Q1** | **Grade in Science Q2** |
|---|---|---|---|---|---|---|
| | | | | | | |
| 8 | | 505 | 513 | 1018 | A | A |
| 11 | | 480 | 478 | 958 | A | A |
| 57 | | 494 | 513 | 1007 | A | A |
| | | | | | | |
| 26 | | 414 | 449 | 863 | A | A |
| 13 | | 391 | 408 | 799 | B | A |
| 65 | | 372 | 335 | 707 | B | A |
| | | | | | | |
| 32 | RSP stu | 340 | 272 | 612 | A | B |
| 43 | RSP stu | 337 | 310 | 647 | C | C |
| 66 | RSP stu | 302 | 322 | 624 | A | B |
| | | | | | | |

| **Stu #** | | **2007 CST ELA** | **2007 CST Math** | **Combined CST** | **Grade in Science Q1** | **Grade in Science Q2** |
|---|---|---|---|---|---|---|
| | | | | | | |
| 76 | | 539 | 600 | 1139 | A | A |
| 94 | | 468 | 493 | 961 | A | A |
| 139 | | 450 | 585 | 1035 | A | A |
| | | | | | | |
| 84 | | 414 | 466 | 880 | A | A |
| 92 | | 418 | 466 | 884 | A | A |
| 100 | | 400 | 436 | 836 | A | A |
| | | | | | | |
| 94 | EL stu | 228 | 294 | 522 | C | B |
| 98 | RSP stu | 296 | 343 | 639 | A | B |
| 123 | RSP stu | 305 | 248 | 553 | B | B |