MODEL ROCKETRY AND THE HIGH SCHOOL SCIENCE CLASSROOM:
PROJECT-BASED SCIENCE CURRICULUM RESEARCH

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ABSTRACT

The research, conducted fall 2002 and spring 2003 semesters tested the hypothesis that high school students comprehend science principles easier through a project-based science curriculum, which teaches high school science principles through the design, the construction, and the launch of model rockets built from scratch. The ninth grade students at St. Andrew’s Priory and Kaimuki High School participated in this research by taking a pretest based on what the students should learn during the semester. The questions are specifically linked to model rocketry design and construction principles with respect to astronomy, biology, chemistry, computer science, engineering, and physics. During the semester, the students used a scratch rocket manual to build and subsequently launch model rockets while learning various science principles. For example, the students learned how Newton’s second law of motion is used to determine how much force is generated when the model rocket of a specific weight is accelerating (F=ma). At the end of the semester, the students at both schools re-took the pretest. The results showed that the students made the connection between their rocketry experience and the associated science principles with a project-based high-school science curriculum. Consequently, this research supports the claim that a project-based curriculum utilizing model rocketry provided the high school students at St. Andrew’s Priory and Kaimuki High School with a clear sense of science and its various aspects

INTRODUCTION

The science instructor faces stiff competition when trying to retain the attention of high school students. T.V. programming, like MTV and reality shows, perpetuates the short attention span the adolescent student already possesses. Add to this an increasingly “virtual” society where a person with access to a computer or videogame controller can choose to raise a child from birth and develop a society from this beginning complete with pets, social issues, and wars (the Sims) or test engineering principles while building the coolest rollercoaster on the planet. These games are captivating because of the graphics, action, and gratuitous violence, which do teach hand-eye-control, however the learning is passive (conditioned response) and limited to whatever the game’s theme. It is from this stance that the research into the effectiveness of a project-based science curriculum stemmed. The first stage of this research aims at constructing a foundation from which to launch a sustainable project-based science curriculum. The conclusion is that a curriculum that utilizes the hands-on activity and the climatic ending of a video game by incorporating the design, construction—hands-on—and launch—climatic ending—of a model rocket to introduce the high school student to astronomy, basic human biology, chemistry, computer science, engineering, and physics is interesting and therefore promotes a clearer understanding by linking abstract principles and formulas to tangible hands-on activities.
Mr. Dan Nelson and Dr. Jacob Hudson at St. Andrew's Priory offered their classroom testing areas for the research. Mr. Nelson currently uses a scratch rocket manual as one project the students use during the semester. Both instructors administered the concept pretest consisting of science questions directly representative of model rocketry concepts. Hudson administered the conceptual test to his physics class but only his Advanced Placement (AP) students built a two-stage rocket for the Team America Challenge. St. Andrew's Priory's private status affords the study with financially comfortable students.

Lynette Low at Kaimuki High School (KHS), in a low-income district, offered her 9th grade science classrooms as testing grounds. Due to its lack of funding, KHS provided the prime venue to test a revised version of Mr. Nelson's scratch rocket manual. After launching rockets the students from both schools took the post-test (exactly like the pretest) to determine the model rocketry influenced instruction aids in the students' possessing better retention of science concepts introduced during the semester.

**DIAGNOSTIC TEST EXCERPT**

11. A spacecraft experiences a gravitational force of 100 N when at a specific distance from an asteroid. Later the spacecraft is one-fourth the original distance from the same asteroid. What is the gravitational force, due to the presence of the asteroid equal to at this new distance? (Astronomy)
   a. 6.25 N
   b. 25 N
   c. 400 N
   d. 1600 N

12. Weightless environments can cause disorientation because... (Biology)
   a. There is no convection is space.
   b. There is apparently no fixed visual reference frame.
   c. There is apparently no downward directed gravity.
   d. All answers listed.

13. A rocket engine can sometimes be rated by its power output. If a rocket engine can produce 20 kilowatts of power for 7 seconds, how much energy is produced? (Physics)
   a. 2.86 kilojoules
   b. 14.3 kilojoules
   c. 70.0 kilojoules
   d. 140 kilojoules

14. For an electronic ignition system, where a high resistance wire is connected in series to a twelve-volt battery. If the battery can supply 0.012 amps of electric current, what would the resistance of this circuit? (Electronics)
   a. 0.001 ohms
   b. 0.144 ohms
   c. 144 ohms
   d. 1000 ohms
15. Two points of interest on any rocket are the center of pressure, and the center of gravity. The center of pressure is the point in a rocket where all the aerodynamic forces seem to act, whereas the center of gravity is the point where the force due to gravity seems to act. For a stable rocket, we require... (Rocketry)
a. The center of pressure lags the center of gravity.
b. The center of gravity lags the center of pressure.
c. The center of pressure and the center of gravity is located at the same point.
d. None of the above.

SCRATCH ROCKET CURRICULUM

The scratch rocket manual uses basic calculations to determine fin design and body tube length based on the diameter of the paper towel or toilet paper tube selected. If the student selects a tube with a diameter of 2 inches, the student multiplies the diameter by 10, which translates to a 20-inch body tube. The fins are calculated in a similar fashion and then the student selects from a series of designs in which the calculations may require manipulation. The stability of the rocket depends on the student’s ability to manipulate these calculations without exceeding set limits in any one direction while designing a personalized rocket. Once the student completes these calculations and design choices construction begins using a trash bag as the parachute, a plastic egg half as the nose cone and rubber bands as the shock cord. The manual, though basic in its present form, opens up avenues to more advanced calculations such as center-of-pressure and calculating approximate height reached. The final scratch rocket manual will include these formulas among others, a history of science, and links to advanced science concepts.

ST. ANDREW’S PRIORY

St. Andrew’s Priory provided the research with two testing platforms. First, Mr. Nelson’s ninth grade science-challenged class and Dr. Hudson’s four AP students involved in the Team America Challenge. Mr. Nelson currently uses his scratch rocket manual as a supplemental teaching tool in his class. He agrees that the model rocketry projects incorporated in his science instruction make the complex issues comprehensible to these struggling students. Mr. Nelson’s class did not improve their scores on average, and this can only be attributed to Mr. Nelson administering the test as the last exam the students faced, which had no effect on the their grades (table 1). Though not only due to the inclusion of model rocketry, Mr. Nelson believes the students have an easier time learning science principles because of the interest aroused by the hands-on model rocket project.

Dr. Hudson’s four advanced placement girls designed a two-stage rocket with two important requirements: it must reach an apex of approximately 1500 feet, and it must then be recovered without damaging the rocket or the two-egg payload. The five students divided the stages of construction into calculations, design, and construction. The AP students’ scores did increase on the post-test; though less than the students in the same physic class (these girls did not build a model rocket). Dr. Hudson attributes this to the fact the advanced placement students carry a greater workload (table 1). The research at St. Andrew’s Priory suggests that the curriculum utilizing model rocketry motivates the student towards science discovery.
TABLE 1—ST. ANDREW'S PRIORY—MR. NELSON-SCIENCE-CHALLENGED DR. HUDSON-PHYSICS & ADVANCED PLACEMENT—DIAGNOSTIC TEST RESULTS

<table>
<thead>
<tr>
<th>Class / # tested</th>
<th>Pretest Avg. / %</th>
<th>Post-test Avg. / %</th>
<th>+/- %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nelson / 9</td>
<td>4.22 / 28%</td>
<td>3.67 / 24%</td>
<td>(-) 4%</td>
</tr>
<tr>
<td>Hudson physics / 29</td>
<td>5.21 / 35%</td>
<td>11.5 / 76%</td>
<td>(+) 31%</td>
</tr>
<tr>
<td>Hudson AP / 4</td>
<td>6.2 / 41%</td>
<td>9.5 / 63%</td>
<td>(+) 22%</td>
</tr>
</tbody>
</table>

KAIMUKI HIGH SCHOOL

Kaimuki High School is in a low-income area. Its instructors face students lacking skills, interest, and motivation. This marginalized arena provides the project with a true to classroom value. Lynette Low provided her five 9th grade basic science classes, which contain a diverse representation of race and culture, which like the girls of St. Andrew's Priory, recognized for outstanding science skills. Due to the limited funding available, I decided to a revised edition of Mr. Nelson's scratch rocket manual. Ms. Low gave her students the pretest I visited the classroom weekly throughout the semester teaching the construction of the rocket and the associated science concepts.

Once the students had the manual and began their exploration into rocket science, collective enthusiasm emerged. The KHS students in groups of four or five designed, built, and launched their rockets at Windward Community College. In an effort to provide parity for St. Andrew's Priory (the instructors are rocketry enthusiasts) and Kaimuki High School, Low never built or launched a rocket, I designed a study guide and walked the students through the process. I ensured that they understood the links between their rocketry projects and the science during the semester. The post-test results show that all the classes improved with the first day showing the least increase (table 2). Overall, Ms. Low's classes improved their scores by 25%. The improved scores suggest the students gained an understanding of through the employment of a project-based instruction.
TABLE 2—KAIMUKI HIGH SCHOOL—BASIC SCIENCE—INSTRUCTOR-LYNETTE LOW—DIAGNOSTIC TEST RESULTS

<table>
<thead>
<tr>
<th>Period / # tested</th>
<th>Pretest Avg. / %</th>
<th>Post-test Avg. / %</th>
<th>+/- %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 / 13</td>
<td>2.85 / 19%</td>
<td>4 / 27%</td>
<td>(+) 8%</td>
</tr>
<tr>
<td>3 / 15</td>
<td>3.27 / 22%</td>
<td>7.8 / 52%</td>
<td>(+) 30%</td>
</tr>
<tr>
<td>4 / 18</td>
<td>2.89 / 19%</td>
<td>7.2 / 52%</td>
<td>(+) 33%</td>
</tr>
<tr>
<td>5 / 19</td>
<td>2.95 / 20%</td>
<td>8.1 / 54%</td>
<td>(+) 34%</td>
</tr>
<tr>
<td>6 / 19</td>
<td>3.58 / 24%</td>
<td>7.5 / 50%</td>
<td>(+) 26%</td>
</tr>
<tr>
<td>Overall avg. / %</td>
<td>3.11 / 21%</td>
<td>6.92 / 46%</td>
<td>(+) 25%</td>
</tr>
</tbody>
</table>

CONCLUSION

This research supports the claim that a High school project-based science curriculum utilizing model rocketry as the tool of instruction is interesting to the student, and therefore motivates the student towards further science discovery. After taking a pretest, the students at St. Andrew’s Priory and Kaimuki High School learned to build a launchable model rocket. During this process the students learned science principles that are directly and indirectly associated with the model rocket’s design and construction. At the end of the semester, the students took a post-test. The post-test for Mr. Nelson’s class does not indicate an improvement due to the inclusion of model rocketry and that can only be recognized as an anomaly, as Mr. Nelson has employed the scratch rocket manual for a number of years and believes it does aid in maintaining the students’ attention and conveying science principles. Dr. Hudson’s AP students did increase their scores, however not as much as his physics students did. He attributed this to test overload since these students are responsible for AP assignments beyond their class load. Though the scores are not conclusive, the overall elevated interest of the St. Andrew’s Priory girls suggests that there is potential for a project-based curriculum in the private school arena.

The telling data is that the students at Kaimuki High, though in a marginalized program, scored 3% higher on average than the students at St. Andrew’s Priory. This suggests that 1) a project-based science curriculum provides accessible and interesting day-to-day science instruction and 2) that model rocketry is a good tool for science concept dissemination. Finally, the students overwhelmingly agreed answering the opinion question, “If you had the choice of taking a project-based science course utilizing model rocketry or a conventional lecture-based science course: Which one would you choose?” that they would choose the project-based course. Though not definitive, the research shows that the curriculum I will finish December 2003 is a good prospect for use in high school classrooms and introducing prospective rocket scientists to the NASA Space Program.