AC 2008-1470: AN IMPACT STUDY OF THE IMPLEMENTATION OF AN INFORMATION TECHNOLOGY RICH PHYSICAL SCIENCE MODULE AT THE FOURTH GRADE LEVEL

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An Impact Study of the Implementation of an Information Technology rich Physical Science Module at the Fourth Grade Level

Abstract

The accelerating advancement in science and technology has made it essential for teachers to gain Information Technology (IT) rich STEM (Science, Technology, Engineering, and Mathematics) content-knowledge. One such attempt is made by SUNRISE (Schools, University 'N' (and) Resources In the Sciences and Engineering), a NSF/GMU GK-12 Fellows Project. The objective of the SUNRISE project is to implement IT rich STEM content knowledge into grades 4-6 education through joint collaboration among elementary and middle schools and George Mason University (GMU). This program also aims to modify science instruction by providing tools that can help teachers enhance learning opportunities for students and also assist in the professional development of the teachers. In this paper, we present a functioning model of a unique partnership that was built between a GMU graduate Fellow and a teacher of a participating elementary school, which has a student population who are 35% on reduced or free lunch and 25% English language learners. Next, we present the development of IT rich innovative instructions and experiments which build interest in STEM topics among students. We describe a case study in which a module was developed for force, motion, and energy through hands-on experiments, presentations, internet research, animation, molecular graphics, and videos. Students were engaged in inquiry-oriented and problem-based learning through real-world application questions to foster critical thinking skills and participation. Both pre-test and post-test assessments were administered to evaluate the changes in students' content knowledge and understanding of force, motion, and energy. A quarterly assessment was administered to determine student retention of knowledge. The results obtained from the assessments are presented which indicated the effectiveness of the enhanced curriculum. Finally, we present the benefits and challenges that were faced in the implementation process of the enriched modules. We conclude the paper by describing how the SUNRISE project serves as one source of evidence that a strong Fellow-Teacher partnership can indeed enhance the excitement in STEM topics among K-12 children, which could benefit the nation's educational enterprise.

Introduction

The rapid change in science and technology has led to the development of advanced technologies such as nanotechnology. The advancement in technology has made a great impact in the scientific community and everyday life. As a result of these advances the necessity to perceive the content knowledge in science and technology has increased. The current science and mathematics curriculum in K-12 need adjustments to get the future generations ready to face the era of advanced technology.

"Recent reports of the performance of America's children and youth from both the Third International Mathematics and Science Study (TIMSS, 1999[1] and 2004[2]) and the National Assessment of Educational Progress (NAEP, 2000[3]) echo a dismal message of lackluster performance"[4]. For example, TIMSS (2004) report "suggests that the performance of U.S.

fourth-graders in both mathematics and science was lower in 2003 than in 1995 relative to the 14 other countries that also participated in both studies"[2]. This study also showed that the U.S public schools from high poverty areas performed low compared to the other public schools[2]. Another report by the National Science Board notes that in the period 1990-2003, most students in grades 4, 8 and 12 did not reach proficient performance levels in both mathematics and science[5]. A recent report by the BHEF (Business-Higher Education Forum 2007) states "…chronic low student interest and achievement in mathematics and science poses an acute challenge to American economic competitiveness"[6]. The BHEF membership is made up of members from business and academia.

"Now three decades old; it is time that the nation heeded it - *before it is too late*"[4]. A National Research Council panel issued a report that urges increased cooperation between universities and GK-12 schools in teacher education and professional development for teachers of science and mathematics[7]. We must give teachers the tools they need to enrich the learning opportunities for GK-12 students in science and mathematics. The NSF GK-12 program offers a unique opportunity to address this need.

National Science Foundation (NSF) has established a GK-12 program that provides fellowships and education pedagogy to graduate students in STEM (Science, Technology, Engineering, and Mathematics) fields. The fellows serve as a resource to teachers, and help to increase students' interest in STEM. The plan is for the partnership between the fellow and teacher remains active for 1 to 2 year/s. NSF has granted funds to SUNRISE project at GMU to initiate partnerships with unsatisfactory-performing schools in 3 school divisions in the Washington Metropolitan area. Eight schools are participating in the SUNRISE project; seven elementary schools and one middle school. The participating schools were selected based on their academic performance, ethnical diversity, and low socio-economic background. One of the objectives of SUNRISE project is to implement Information Technology (IT) rich STEM content knowledge into grades 4-6 by developing innovative modules that incorporates cutting-edge research to enhance current science instructions.

Virginia has adopted the *Standards of Learning for Virginia Public Schools* (SOL) which outlines the content students are to learn. In fourth grade, the Science Standards of Learning is divided into seven topics or units that introduce basic principles. These units are 1) Scientific Investigation, Reasoning, and Logic, 2) Force, Motion, and Energy, 3) Life Processes, 4) Living Systems, 5) Interrelationships in Earth/Space Systems, 6) Earth Patterns, Cycles, and Change, and 7) Resources. According to the Virginia Science SOL, students should know the concepts from these seven units by the end of the school year. Virginia SOL assesses students to measure their "…content knowledge, skills, and understanding…"[8] in Mathematics, Science, English, and Social Science.

This paper discusses the development, format and implementation of an Information Technology rich Physical Science module at the fourth grade level by a graduate student (fellow) in science. Finally, the benefits and challenges of implementing the module are discussed.

Module Development

The *Advanced FME (Force, Motion, and Energy) Module* coincides with the Standards of Learning for Science. The goal of the module is to provide extensive background information to the teacher and increase the understanding of students. The theme of the module is IT (Information Technology), in which students are exposed to computer software (Science Trek, ViewerLite, Microsoft Excel and PowerPoint), interactive websites, videos, and calculators. This module consists of pretest, three lessons, posttest, and quarterly exam. The three lessons were: 1) Force and Motion; 2) Speed and Energy; and 3) Gravity and Inertia. These lessons focus on incorporating basic principles as well as cutting-edge research such as forces involved in stabilizing structure of a protein.

The pretest, posttest, and quarterly exam assessed the students for their understanding of what the fourth graders should have learned after the completion of the unit according to the science SOL. The time devoted to each lesson varied. The time required for the complete implementation of the module was 45 minutes every day for 12 days, and this included presentations, activities, computer lab time, but excluded planning time for the fellow and teacher.

The first lesson, Force and Motion, introduced basic concepts such as determining position of different objects, distinguishing if an object is in motion, and defining force. The use of frame of reference to describe movement and relative motion were also introduced. Illustrations of applying force, motion, and different frames of reference were also presented. Interactive websites showed how force affects motion. Science Trek software refined the understanding of force and motion. Two activities were conducted during this lesson: the first activity consisted of describing the position of a big and small Styrofoam balls before and after the application of force. This activity was conducted on tile and carpet to compare the distance traveled by each ball. The second activity was performed to illustrate different frames of reference in which each student had to write down directions to reach a location. The partner had to follow the directions and decide if he/she reached the correct location.

The second lesson, Speed and Energy, elaborated the concept of speed, acceleration, and the requirement of force to accelerate. This lesson also introduced potential and kinetic energy, transformation of energy, and law of conservation of energy. Animation of racing cars demonstrated acceleration and constant speed. Animations of rollercoaster and pendulum demonstrated transformation of energy. An activity was performed during this unit, which involved determining the speed of a golf ball by dropping the ball from different heights from an inclined plane. Laptops were used to access a stopwatch program from a website, and calculators were used to determine speed.

The third lesson, Gravity and Inertia, introduced gravity, difference between mass and weight, relationship of gravity and inertia, and Laws of Motion. Interactive websites showed the effect of gravity on weight. An activity was also conducted in which a book and pencil were dropped from the same height, and the object that hit the floor first was determined. Along with these lessons, attractive interactions in a protein were also introduced. Students learned that these attractive forces make a protein fold in a certain way. The 3D-solid ribbon model of haemoglobin was used to introduce proteins and their biological functions. ViewerLite software was used to demonstrate the network of hydrogen bonding in haemoglobin and introduce interactions. This demonstrated the presence of strong and weak forces, and the importance of force. The unit of instruction is attached in the appendices.

Implementation

The *Advanced FME module* was implemented in one of the participating schools in SUNRISE/GK-12 program. This public school is one of the unsatisfactory-performing schools with 35% of the student population on reduced or free lunch and 25% of the student population are English language learners.

The sample population consisted of fourth grade students in four classes. One class consisted of some gifted and talented students. Two classes consisted of many English language learners and students with disabilities. The other class was also an unsatisfactory-performing class. The classes were 23, 23, 17, and 11 respectively. The materials in the *Force, Motion, and Energy* unit were new to the students.

The lessons and activities were taught and conducted by the fellow and teacher. Each student was provided with worksheets for each lesson and activity. The worksheets corresponded to the lessons and assessed the student's understanding of the material presented. They were prepared to enhance mathematics skills, critical thinking skills, and problem-solving skills. The worksheets allowed students to draw, calculate, graph, and write about new concepts. They were collected after completion and graded. The worksheets helped to evaluate students' progress, and assessed their ability to apply the concepts learned.

Results

The pre-assessment was conducted before implementing the module to gain information about students' knowledge on different kinds of forces and energies and their applications. Table 1 provides the summary of the averages of the pre-assessment given to the fourth grade students in four classes. The pre-assessment had twelve questions, and students answered 1.0 to 2.78 questions correctly.

Table 1: Summary of Averages for Pre-Assessment

Class	Sample Size	Average Correct Answers	STD
1	23	23%	1.17
2	23	9%	1.18
3	17	13%	1.03
4	11	10%	1.14

The post-assessment was conducted after completion of the module to evaluate students' understanding of the concepts and their applications. Table 2 provides the summary of the averages of the post-assessment. The students answered anywhere from 4 to 8 questions correctly. The class 2 was exposed to the same presentations as the other classes, but they did not get a chance to perform some hands-on activities or participate in post-activity discussion. Class

2 had less time to spend in computer labs and use Science Trek software. For class 2, maximum time was devoted to lectures, while minimum time was given to discussions and activities if the activities were conducted.

Table 2: Summary of Averages for Post-Assessment

Class	Sample Size	Average Correct Answers	STD
1	23	66%	1.27
2	23	37%	2.02
3	17	56%	2.15
4	9	49%	1.47

Hypothesis testing was used to analyze the results, and determine if the pre-assessment and the post-assessment were or were not statistically different. A 95% confidence level was used to evaluate the result. The results were evaluated to determine if the means were equal (H_o) or not (H_a). Table 3 shows the statistical analysis of the pre and post-assessment with 95% confidence level. The comparison of pre-assessment and post-assessment showed that after the implementation of the module, the number of correct answers increased. The H_o was rejected for all four classes with 95% confidence level, and thus can be said that all four classes performed significantly well after the implementation of the module.

Three classes performed similarly in the pre-assessment with the class with gifted and talented students scoring higher. The lower number of correct answers in the post-assessment of class 2 showed the importance of activities and post-activity discussions. This also showed that the application of the concepts learned in class into activities helped to understanding these concepts better.

Table 3: Statistical Analyses

H_o: $\mu 1 - \mu 2 = 0$

H_a: $\mu 1 - \mu 2 \neq 0$

Where $\mu 1$ = mean of pre-assessment
$\mu 2$ = mean of post-assessment

Class	T statistic	Rejection Region	Reject H_o?
1	-14.29	2.02 < ITI < 2.00	Yes
2	-6.86	2.02 < ITI < 2.00	Yes
3	-8.83	2.04 < ITI < 2.02	Yes
4	-7.96	ITI < 2.086	Yes

The quarterly exam was administered forty one days after the completion of the module and posttest. The quarterly exam was conducted to evaluate knowledge retention and content knowledge in fourth grade students. This exam consisted of twenty questions from two units. Thirteen questions related to the *Force, Motion, and Energy* unit were included in this exam. Table 4 shows that the use of hands-on experiments, videos, presentations, internet research, and animation helped students to retain the knowledge, and use their knowledge to answer questions.

Table 4: Summary of Quarterly Exam

Class	Sample Size	Average Correct Answers	STD
1	20	97%	0.60
2	23	79%	2.22
3	21	84%	2.62
4	9	86%	0.66

The results from the module showed that students can succeed and learn better from an advanced module. In general, advanced modules with higher–level activities are beneficial to students. This module challenges students to think critically and solve real-world application problems.

Challenges

Various challenges were encountered while implementing this module. Some of these challenges were limited time, student behavior, and other minor obstacles. Each unit has to be completed within a certain amount of time. The amount of time devoted for the module was limited, and certain lesson and activity had to be rushed.

In some classes, the behavior of some students proved to be disruptive to the whole class. The fellow and teacher had to divert their attention from teaching to dealing with unexpected behavioral issues, which decreased the amount of quality time devoted to the instruction.

This module involved application of students' mathematic skills for addition and division. The students' performances in mathematics were weak, so a separate lesson on addition and division was taught. The incorporation of mathematics lessons for 45 minutes for 2 days in the module, reduced the scheduled time for other lessons and activities.

Impacts of the Module

Developing, designing, and implementing this module had a positive impact on the fellow, teacher, and students. This module fostered a learning environment through strong collaboration and active participation amongst the fellow, teacher, and students.

Designing lessons and activities helped the fellow to simplify complex scientific concepts and research to target different audiences such as elementary school students. The fellow also learned to deliver instructions effectively and modify instructions to meet the needs of all range of students. The fellow also engaged students in higher level thinking by asking real-world application questions and promoting critical thinking skills among students, thus helping the educational enterprise.

The impact on the teacher is evident through the lessons taught, enriched concepts and student-driven lesson plans. The module added to the prior knowledge of the teacher and introduced new concepts in science and engineering. The teacher learned various ways to incorporate technology, new ideas, and activities to lessons, and also gained an overall knowledge to enrich lessons. The teacher participated in discussions and researched to obtain more information on the topics covered in class.

The participating students were involved in active learning and responsive to the material presented in class. The students were enthusiastic to learn new materials including proteins and participated by asking strong application questions. The hands-on activities and use of different information technologies fostered a learning environment. Students were attentive and eager to use different technologies, software, and Medias. The exposure of students to the use of technologies generated appreciation and increased their understanding to the impact of technology in everyday life.

Conclusion

In this paper, designing of an advanced module to enhance the science curriculum of the fourth grade was discussed. The implementation of this module was challenging but very productive for the fellow, teachers, and students.

This module has shown that the use of information technology, hand-on experiments, and discussions can significantly increase the level of understanding of the science concepts as well as applications of those concepts to solve problems. The frequent use of hands-on experiments and technologies in class might interest students to choose science, technology, engineering, and mathematics in the future.

The fellow works at a school for 1 to 2 years, but the lessons and activities that the fellows developed will be left with the teacher. The teacher can use the same lessons after the fellow leaves, and thus continue implementation of expanded STEM lessons in grades 4-6. The lessons created by the fellow can be assessed by other teachers in this participating school. The teachers can implement STEM lessons in other classes, which could help the educational enterprise.

Acknowledgment

This work was supported by a grant from the National Science Foundation. The authors would like to acknowledge the administrators, faculty, and staffs of the participating school. The authors would also like to thank GMU/NSF graduate fellows: Christina Henderson, Catherine Sausville, Matthew Dale, Joseph Cremaldi, Jonathan Malachowski, Melanie Larson, and David Barr, a former GMU/NSF fellow.

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Appendix A

1. Force and Motion

- Lesson:
  - The fellow and teacher will present a PowerPoint presentation with a worksheet.
  - Students will be able to define position, force, motion, frame of reference, and relative motion.
  - Students will draw images that represent force, motion, and relative motion.
  - Students will write a journal entry describing how they will bring an elephant home from the zoo using the vocabulary words mentioned above.

- Activities
  - Students will look at different colored balloons, and determine the position of one balloon with respect to another.
  - Students will be given a big and small Styrofoam balls. The balls will be placed on tile or carpet. Students will determine the position of the balls with respect to the other objects. Student will apply force to make the ball roll. The distance traveled by the big and small balls on tile or carpet will be measured. There will be a class discussion.
  - Student will be given a paper frame and a worksheet. Each student has to write down the directions to reach a location. The partner will follow that direction and decide if he/she reached the correct location.

- Discussion Questions:
  - What happens when you apply force to an object?
  - How can you make an object to speed up and slow down?
  - If an object is massive, will the force have any effect on it? Why?
  - Are you in motion? Explain. Students have to answer this question using two different frames of reference. Student will be shown an animation of an astronaut looking down at the rotating earth, and the other will be the picture of a student sitting in the classroom.
  - Why do the balls travel a shorter distance on carpet than on the tile?
  - What will happen if there is no opposing force?
  - What are some other attractive forces?
  - Why is an airplane a poor reference point?

- Interactive websites:
  - Force and Movement - http://www.bbc.co.uk/schools/scienceclips/ages/6_7/forces_movement.shtml
  - Pushes and Pulls - http://www.bbc.co.uk/schools/scienceclips/ages/5_6/pushes_pulls.shtml
  - Frame of reference - http://www.edumedia-sciences.com/a261_l2-reference-frames.html

Appendix B

2. Speed and Energy

- Lesson
  - The fellow and teacher will present the PowerPoint presentation with a worksheet.
  - Students will be able to define speed, acceleration, energy, forms of energy, law of conservation of energy.
  - Students will draw images representing potential and kinetic energy.
  - Students will use mathematic skills to calculate averages, and speed. They will also make "Speed vs. Time" graph and analyze the results.

- Activity:
  - Students will be given a 45º cardboard inclined plane, a golf ball, and a laptop. There will be three different heights marked on the inclined plane. The distance that the ball will travel is kept constant like 3 meters. The student will place the golf ball on one of the heights and let the ball go. As soon as the ball touches the bottom of the inclined plane, the stop clock is started. The stop clock is stopped when the ball travels 3 meters. This experiment is done on carpet and on tile. Students will record the time in seconds for three trials for each height. They will determine the average time and speed.

- Discussion Questions:
  - What kind of energy does the ball have at the top of the inclined plane?
  - What kind of energy does the ball have when it rolls down the inclined plane?
  - What are some of the energies that potential energy will transform into when the ball rolls down the inclined plane?
  - Give other examples of transformation of energy.
  - Why does the ball travel the fastest when it rolls down from the top of the inclined plane?
  - What are some of the forces that make the ball stop?
  - If a car is moving at a constant speed and in the same direction, is it accelerating? Explain. Students will look at racing cars demonstrating acceleration and constant speed.
  - If the energy can neither be created nor destroyed, the total amount of energy in the universe is a <u>fixed amount</u> and <u>never any more or less</u>. Students will observe the movement of the pendulum to answer this question.
  - What kind of force makes the car go forward?

- Websites:
  - Roller-coaster (Transformation of Energy) – www.physicsclassroom.com/mmedia/energy/ce.gif
  - Acceleration - http://www.glenbrook.k12.il.us/gbssci/insti/acceln.gif
  - Pendulum - http://www.geocities.com/SiliconValley/Station/9139/main/pe.gif

Appendix C

Gravity and Inertia

- Lesson:
  - The fellow and teacher will present a PowerPoint Presentation with a worksheet.
  - Student will be able to define gravity, gravitational force, mass, weight, inertia, and law of inertia.

- Activities:
  - Students will be given a book and a pencil. They will drop the book and a pencil from the same height. The time that each object takes to hit the bottom is recorded.
  - Students will use a balance to measure mass of different objects.

- Discussion Questions:
  - What are the differences between mass and weight?
  - If you were on the moon, would your mass change or your weight? Why?
  - How much (approximation) would you weight if you were on Jupiter?
  - Imagine our world without gravity, how would it be different?
  - What does the gravitational force depend upon? How can you make the gravitational force stronger? Look at the formula.
  - Why do the book and pencil fall at a same rate ignoring air resistance?
  - The heavier object is pulled with <u>a greater force</u> and it <u>resists acceleration</u> more strongly than the lighter object.
  - What is inertia and what does law of inertia state?
  - What will happen to a rolling ball if there was no friction or gravity?

- Interactive Websites:
  - Mass and weight – http://www.edumedia-sciences.com/a222_l2-weight-mass-on-the-moon.html
  - Gravity, mass and weight – http://www.edumedia-sciences.com/a222_l2-weight-mass-on-the-moon.html

- Videos were accessed from "United Streaming".
- "Magic School Bus" videos related to the unit were also shown.
- "Science Trek" software was also used, and students answered questions.
- Students used desktops, or laptops to access interactive websites and different programs.
- Students also used calculators.
- Stopwatch accessed from http://tools.arantius.com/stopwatch