

Classroom Inquiry and Graphics Technology Skills for K-12 STEM Physical Science Educators

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Abstract

This paper describes a methodology used to expand practicing teachers' conceptual understanding of the physical sciences (physics and chemistry), as well as the pedagogy for student learning of critical concepts in the physical sciences utilizing innovative technologies such as computerized laboratory interface tools and 2D graphics based simulations. The development and utilization of 2D simulations using the graphics based Interactive Physics software program is an integral part of this grant to develop STEM teacher technological literacy skills. Over a three year period participating K-12 teacher grant participants were delivered professional development courses, classroom observations were performed, and data was collected and evaluated that indicate that participants significantly improved their abilities to incorporate technology into their instruction.

Introduction

The methodology used to expand practicing teachers' conceptual understanding of the physical sciences was utilized by facilitators of the 2010-11 Tile II grant funded by the State of Michigan Department of Education focusing on the application of classroom inquiry pedagogy and classroom technologies used to improve teaching and student learning for STEM educators (Irwin, et al., 2009). It is well documented that physical science education, specifically physics and chemistry, provides a strategic link to technological fields of study. This prerequisite knowledge in the physical sciences is necessary for most of the STEM fields at the post secondary level. Classroom inquiry, understood as a way to teach science, and think about the nature of science has played a central role in the educational reform agenda in science education (Wee, et al., 2007). Although teachers are recognized as change agents, they often lack clarity about what inquiry means and how it can be translated into classroom practice.

In addition, the use of computer based technologies and acquiring the spatial visualization skills necessary to develop and implement physics-based simulation programs can be a difficult challenge for K-12 teachers without the necessary preparation. Most physical science educators do not have an engineering background which would include this type of training. Also, in most cases K-12 science students will not have had a course in technology or graphics, which makes using graphics-based software for teaching science content especially difficult. So, one method of impacting the preparedness of students entering the post secondary ranks is to assist in the professional development (PD) of K-12 physical science teachers to develop their technological literacy skills.

Method

The goals of this teacher PD project were to strengthen 5-12 grade teachers' ability to engage students in science inquiry and serve as mentors to new and pre-service teachers. The project was designed to improve teachers' ability to; convey knowledge and application of inquiry-based methods, utilize technologies (e.g. computerized laboratory interface tools and graphic simulations), and positively impact student achievement and attitudes toward and engagement with STEM fields.

Specific objectives of the project were: accomplishing goals of state content expectations, STEM, and national standards; classroom use of computer response systems for interactive lesson development; and finally implementing lab projects and demonstrations in science using computerized instrumentation and computer simulations. Sixteen qualifying grant participants enrolled in the 22 month professional development project providing the chance to earn up to 10 graduate credits (94-124 contact hours) to deepen content knowledge and strengthen content-related pedagogy. The focus of this paper is on the graphics content related to the preparation of the STEM educators in the use of the graphics-based simulation software called Interactive Physics (IP).

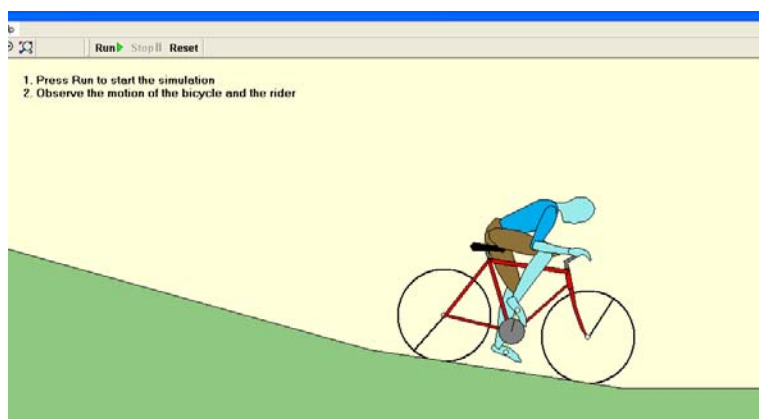


Figure 1. Interactive Physics Software Example

During the summer of 2010 the (2) graduate credit one-week Institute was offered to participants incorporating analysis methods used in engineering and technology occupations. The Institute was designed to strengthen teachers' physics content knowledge. The Institute, "Inquiry and Discovery Learning for Applied Physics," utilized the IP software focusing on three areas: 1) speed, distance, acceleration, and time, 2) weight, mass, gravity, air resistance, the laws of motion, and energy, 3) and heat transfer, waves, and sound. Each topic area was aligned with content expectations and national standards. Lessons were adaptable to teachers of different grade levels, and included lectures, hands-on activities, field work, and group problem solving.

Teachers practiced *Interactive Physics Curriculum Workbook* (provided to each participant with a copy of the IP software) applications, and created discovery learning projects utilizing the IP software (Mitiguy & Woo, 2005). Demonstration followed by practice using tutorials and one-on-one instruction were used to provide assistance for participants who had difficulty visualizing and manipulating the graphics-based software. Participants analyzed data to determine speeds, energy, and temperatures in common industrial applications. They also learned about the capabilities of physics-

based computer aided engineering software first-hand during a tour of a local engineering firm specializing in physics-based simulation analysis.

Graphics Content Knowledge

The Interactive Physics course required participants to not only build lesson plans using the software premade simulations, but challenged participants to build simulations to test designs or experiments of their own. The idea being that with these skills the K-12 teachers could eventually challenge their students to build their own graphics-based simulations in the classroom. After providing a software demonstration and providing time for experimentation with premade simulations, the software graphics instruction process started with a review of the units, grid and snap options in the workspace and overview of the geometry creation options available. The geometry Body toolbar consists of simple 2D shape options such as circle, square, rectangle, polygon, and curved polygon along with an option to anchor or ground the objects in space (see Figure 2).



Figure 2. Interactive Physics 2D Body Toolbar

This was followed by adding velocity vectors to objects, pin joints, spring elements, new controls for inputs such as spring constants, graphs depicting position of objects, changes to gravity constant, air resistance, contact collision coefficients, graphics from a picture library attached to objects, sounds, slot joints, and forces to objects. The graphics created for the simulation in the *Interactive Physics Curriculum Workbook* practice tutorial are shown in Figure 3 (Mitiguy & Woo, 2005).

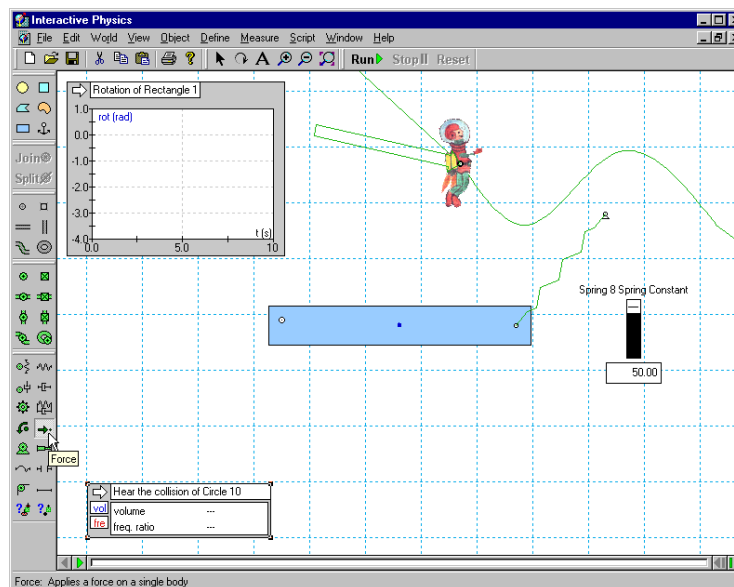


Figure 3. Interactive Physics Introduction Tutorial

Next, the students created simulations by following the step by step procedure in four exercises in a tutorial prepared by an applications engineer, Scott Ziemba (2009), to illustrate physics problems related to Newton's Laws of Motion (Two Dimensions), Newton's Laws of Motion (Circular Motion), and Work and Energy. These exercises required students to model the geometry in the simulations to specific dimensions and at precise locations in the graphics area in order to function properly. For example, the first tutorial is based on this problem statement:

A block of mass =1 lb is placed on a smooth incline plane of 30°. Determine the following after 0.3 seconds:

- A. The acceleration magnitude of the block
- B. The velocity magnitude of the block

Governing equations (1) and (2) (*derived from the basic equations for motion in two dimensions*):

$$A = g \sin \theta \quad (1)$$

$$V = \sqrt{2 g d \sin \theta} \quad (2)$$

where d = displacement magnitude and g = gravity

For the simulation to run properly the 30 degree triangle is made by creating a polygon with the base 14.5 units in length and then using trigonometry calculating the height to be approximately 8.4 units. Then, after sketching a rough polygon of any size the location and size of the polygon can be specified by using the Geometry option specifying polygon points 1, 2 and 3 using absolute coordinates (see Figure 4).

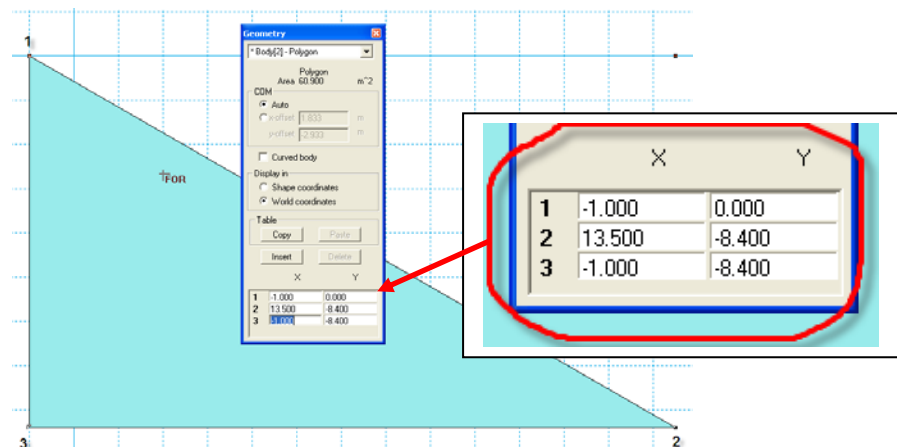


Figure 4. Polygon Body creation using Geometry option

Next, a 1 x 1 unit square can be created with the center at the origin and when rotated -30 degrees the bottom of the square will be tangent to the surface of the triangle. To validate the graphs for acceleration and velocity the displacement of the square body along the 30 degree slope can be measured using the square root of the sum of the squares of the X, Y absolute positions (see Figure 5).

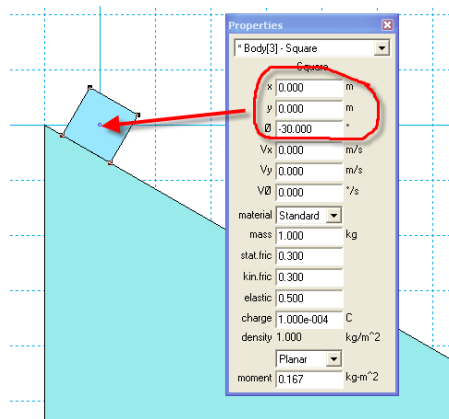


Figure 5. Square Body creation using Properties option

Student Created Graphics for Simulations

After being introduced to the several tutorials creating graphics for additional exercises including an Atwood's machine, centripetal acceleration device, and a mass/spring system the participants were well accustomed to the entry methods and procedures for manipulating the shape and location of objects in the graphics area as well as graphing results and running the simulations. So, at this point they were given the task to create a lesson plan and simulation of their own design.

In this course, students created simulations such as Newton's third law of action and reaction force pairs using graphic representations of billiards balls on intersecting paths, mechanical advantage using pulleys, projectile motion of objects launched into the air with capabilities of changing force and angle of the projectile with the goal of hitting a target, gravity and air resistance on falling objects, and the effect of gravity on the hang time of a basketball player's vertical jump.

Results

The learning objectives for the IP Institute were divided into the three categories; IP for Inquiry Learning, Interactive Lecture Demonstrations (ILD's) using IP Software, and IP for Discovery Learning (DL). Each student first studied techniques of inquiry used for effective science pedagogy, and experienced firsthand the IP inquiry activities. After a review of ILD literature, the participants studied and utilized personal response devices (i-clickers), and then developed lessons using the IP software. Finally, the students prepared their own IP simulation experiments utilizing the software and delivered a practice lesson using DL and science inquiry pedagogy.

The artifacts from the PD activities (lesson plans and IP virtual experiments) were collected and analyzed by the project evaluators. These were used to evaluate the first and most critical goal: "To convey knowledge and application of inquiry-based methods of teaching science in the classroom". Teacher preparation in inquiry-based methodology was measured directly by charting teacher changes in content tests (pre-/post-institute and pre-/post-program) and indirectly via workshop/institute grades (when applicable), self-report surveys, and focus group interviews.

Discussion

The external evaluator reported that "...the participants' scores on pre-/post-workshop and pre-/post-institute content tests showed statistically significant increases." (Irwin & VandenAvond, 2010). Average content scores for all workshops and institutes in which data were collected increased from 48% (pre) to 92% (post). In addition, data from teacher attitudinal surveys suggested that teachers' confidence not only in their understanding of their content knowledge of their disciplines (pre, 5.2; post, 6.1), but in their ability to use inquiry-based methods (pre, 4.9; post, 5.9) increased.

Quantitative findings were supported by open-ended and individual interview data, as well as by evaluation of lesson plans suggesting that teachers used significantly more hands-on activities and had more ideas for teaching units after having participated in a summer institute. Available content knowledge data also suggests that teachers increased their ability to use technology in their classrooms.

More compelling, however, are data pertaining to the evaluation of the lesson plans. The internal evaluator reported that "...teachers planned lessons that used the specified technology of i-clickers interactively. The use of discrepant evens was mostly clear, but was not explicit in one lesson." In addition, teachers "...planned lessons that utilized computer simulation to represent abstract concepts that are difficult to understand." (Irwin & VandenAvond, 2010).

Conclusions

The major findings from the survey data suggest that participants significantly improved their abilities to incorporate technology into their instruction (pre, 4.5; post, 5.8). Interviews corroborate this finding in that participants "learned more about how to use technology than I could have any other way...getting right into it with the people who know it best was the only way that I was going to learn it." (Irwin & VandenAvond, 2010).

Additional graduate courses have been suggested for all grant participants to broaden their knowledge of engineering graphics and STEM related topics and to earn credits toward a Master's of Science degree in Applied Science Education. During the summer 2012, two grant participants participated in a summer graduate course offering of "The Engineering Process" where students study the similarities and differences between the scientific method and the engineering design process as well as broaden their spatial visualization skills. The course is intended to introduce engineering to K-12 teachers by providing them with a meaningful experience about the process that engineers use to solve problems.

During the first half of the course students developed their spatial visualization skills using worksheets and sketching methods, studied the engineering design process, learned the basics of 3D CAD modeling using NX software, and were challenged with an application design problem to develop a design for a Lego Block and/or K'Nex Separator for a child with limited physical dexterity. With the prior training in IP software it provided the students an introduction to 2D graphics software before entering the complex 3D modeling application. The 3D model of the K'Nex separator, (see Figure 6), was modeled by Student "X" in the course and analyzed for functionality by performing

motion simulation and Finite Element Analysis (FEA) with assistance from the instructor to illustrate the iterative design process followed by engineers.

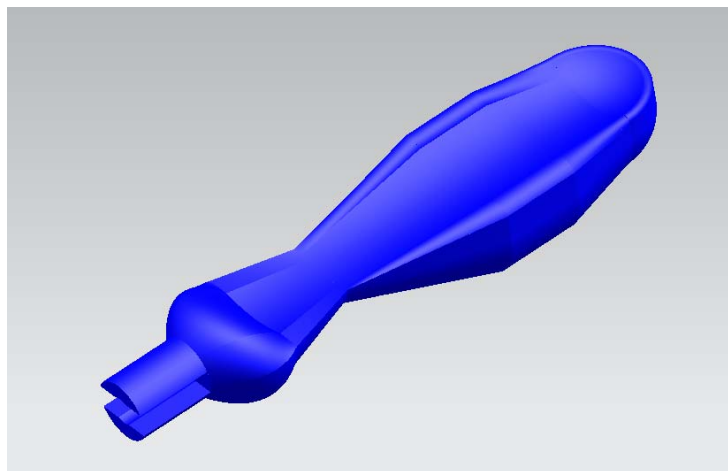


Figure 6. Student “X” NX software 3D CAD Model

Comments provided on a formative feedback survey after the course indicate that developing spatial visualization skills and utilizing the 3D CAD software provided the participants a better understanding of the engineering process. When asked to discuss their thoughts about the application project, one response was that “This was a good vehicle to learn the engineering process”. Further longitudinal study is necessary to indicate how this type of teacher professional development effects students’ decisions to enter STEM fields after high school graduation.

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