TECHNOLOGY ENGINEERING IN SCIENCE EDUCATION: WHERE INSTRUCTIONAL CHALLENGES INTERFACE NONCONFORMING PRODUCTIVITY TO INCREASE RETENTION, ENHANCE TRANSFER, AND MAXIMIZE STUDENT LEARNING

By

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ABSTRACT

Technology Engineering is an innovative component of a much larger arena of teaching that effectively uses interactive technology as a method of enhancing learning and the learning environment. Using this method to teach science and math content empowers the teacher and enhances the curriculum as the classroom becomes more efficient and effective. Although the most modern technology–enhanced content is available for classroom deployment, this study suggests that various challenges arise that can delay a fully productive and successful integration of technology in the science classroom. In this study, seven urban school science teachers, incorporated technology–enhanced inquiry–based modules into their lesson plans to determine the overall effectiveness of technology integration in their classrooms. This paper examines how Technology Engineering helps students to understand scientific phenomena, despite hindrances with in the instructional environment.

Keywords: Instructional Challenges, Technology Engineering, Science Education, Urban School Setting .

INTRODUCTION

The challenge facing both science educators and science teacher educators is how to evaluate relevant applications for information technologies in the science curriculum (Flick and Bell, 2000). This point of view is supported by researchers Flick and Bell who state that flexibility, speed, and storage capacity of contemporary desktop computers is causing science educators to redefine the meaning of hands-on experience and rethink the traditional process of teaching (Flick and Bell, 2000). Technology integration in the science classroom can include a variety of tools. Technology integration includes teacher use of computers (Newman, Bowman, Chapin, Nadherny, and Zhang, 2005), internet, and software (Stevenson, 2005). As a whole technology integration is more than just a means of classroom technology deployment. It is a process wherein computers and other technologies are used as tools to facilitate inquiry-based learning, collaboration, and problem solving (Eib and Mehlinger, 1998). Thus, the integration of technology is a holistic process that encompasses the linkage between technology and curriculum content. Over the past twenty-five years, the coupling of science and technology has lead to efforts to redefine the goals for science courses and support studies that explore the impact of new technologies on student learning (Linn, 2003). Despite the positive impact of educational technology on student learning, its use in the classroom by math and science teachers is still very limited (Ertmer, 2005). A novel approach to technology integration in science classrooms is needed and Technology Engineering may provide the answer.

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"Technology Engineering" is the combination of Learner–Based Tools, Educational Games, Educational Systems, Relevance, and Collaborative Learning Strategies to create an interactive and dynamic cognitive economy. Technology Engineering leads to Product–Based Inquiry. An example of "Technology Engineering" as a methodology is the combination of innovative technology tools such as Instructor–Authored Interactive Metametric Learning Modules with effective teaching strategies and dynamic distance education tools such as Course Management and Learning Management Systems (Osler, 2010). Technology Engineering is an innovative form of interactive technology used as a method of teaching science and math content and curriculum through collaboration with teachers in the classroom (Osler, Hollowell, and Palmer, 2008). The use of Technology Engineering in the science classroom can make challenging science concepts and principles more engaging and thereby aid students in their ability to learn them. A prime example of Technology Engineering in the classroom was the Technology Enhanced Learning in Science (TELS) Center.

Technology Enhanced Learning in Science

The Technology Enhanced Learning in Science (TELS) Center established by the National Science Foundation is a national Center for Teaching and Learning. TELS modules combine dynamic visualization models and real-world scenarios with science and mathematics curricula in an innovative way to empower teachers to enhance student learning. The TELS inquiry-based modules were created by a multidisciplinary team of science teachers, university researchers, and technology specialists. The modules were based on authentic science and mathematical contexts to help students elicit ideas about everyday science experiences and socio-scientific issues and controversies (Linn and Hsi, 2000). These modules, based on the Web-Based Inquiry Science Environment (WISE), included online inquiry maps to guide students, interactive visualizations, electronic discussions, and embedded assessments. Inquiry-based learning is a key component of technology-enhanced learning environments as both teachers and students can become better critics of scientific concepts and materials by engaging the students in inquiry-based projects (Barab and Luehmann, 2003). TELS in the science classroom provided an opportune environment to observe Technology Engineering in action. TELS activities provided a meaningful context for student investigations, by prompting them to consider how scientific knowledge informs everyday decision-making, and presented science as an activity that has real-life relevance. A study was conducted in North Carolina urban schools to determine how effective the implementation of Technology Engineering through TELS in the science classroom could be.

Methodology of the TELS Technology Engineering Classroom Study

In the study, seven teachers from an urban school district in North Carolina used the TELS Biology, Chemistry, Earth Science, and Life Science modules to evaluate technology integration in the science classroom. The class sizes ranged from 18–23 students and the modules were used in both middle schools and high schools. Teachers administered pre and post assessments (based on the Knowledge–Integration (KI) Rubric) for each TELS module to accurately measure student comprehension and evaluate student responses. The Knowledge–Integration (KI) Rubric comes from the research of Linn, Clark, and Slotta (Linn, Clark, and Slotta, 2001). Table 1 provides Knowledge–Integration (KI) Rubric the used in the study.

Table 1 describes the Knowledge–Integration (KI) Rubric. There are seven different variables that indicate knowledge integration of the scientific concepts (in the curriculum areas of Biology, Chemistry, Earth Science, and Life Science) delivered in the TELS classroom study. As illustrated in the Rubric, a score of "0" is indicative of a clear lack of any Knowledge–Integration by the student and each subsequent number relates to the increase in knowledge

Score:	Description:
0	No Answer: - No Response indicated by the student leaving the answer empty.
1	Off Task: - Response is "I don't know" or the student writes some text that is not relevant to the subject matter; especially student does not answer the question being asked.
2	No KI: - Students have isolated ideas, either normative or non-normative, in a given context.
3	Partial KI: - Normative idea without elaboration or multiple normative ideas without connections. - Scientifically valid connections that are not sufficient to solve the problem
4	Limited KI: - Two normative ideas with connections - Scientifically valid connections are made, but no explanation of the answer is given.
5	Complex KI: - High degree of understanding three or more normative ideas with connections. - Scientifically complete and valid connections. Students provide. An explanation for their answer.
6	Systemic KI: - Students have a systemic understanding of science concepts.

Table 1. Knowledge–Integration (KI) Rubric used to Evaluate Student Responses from the TELS Modules Assessment Items

and connection with and between scientific concepts measured in the study. In addition, a qualitative assessment was used to determine teacher perceptions regarding the study. Teacher interviews were conducted after the students completed their respective TELS modules and the teacher thoughts and perceptions were recorded via the qualitative surveys that were administered at the end of the study at the end of the school year.

Technology Engineering through the Implementation of TELS Modules in the Classroom

To gain access to the suite of TELS scientific inquiry modules, teachers that participated in the study were required to register on the TELS WISE website (that was available through http://wise.berkeley.edu or http://www.telscenter.org/curricula/index.html and retrieved from the web during time that the study took place). To implement a TELS module in the classroom, teachers need computers with access to the internet. The minimum software requirements to run a TELS module on the computer platform used by the respective school were found at www. Telscenter. Org/confluence/display/WPSD/Software+Requirements. All of the online resources which included: lesson plans, teachers' guides, assessments, and relevant science standards were made available at the aforementioned website. These resources were available to assist teachers in preparing to run a TELS module in their respective classroom. When registering on the WISE website, teachers had access to over 50 inquiry-based science modules on topics ranging from chemical reactions, mitosis, and kinematics to geological processes. The TELS project library provided information designed to help new users select a module appropriate to their particular science curriculum. Most of the TELS modules were designed to be used entirely online and as a supplement to the traditional lesson activities. For example, middle school earth science students could study global climate change and the rock cycle.

An ideal illustration of how the TELS WISE modules were used to facilitate Technology Engineering during the study occurred when two earth science classes (which each had a sample size of n = 18) were assessed on their comprehension of global warming. This earth science concept was taught using the TELS module "Global Climate Change: Who's to Blame?"(illustrated in Figure 1).

Screenshots of the module are provided courtesy of www.wise.berkely.edu

In this module, students learned about global warming and the greenhouse effect. Interactive animations helped them to understand the relationship between these two phenomena. In addition, the animations aided in helping the students with their understanding of the contributions to global warming made by humans and natural forces. Immediately following the exploration of human and natural contributions resulting in global climate change through the module, students prepared a presentation for classroom debate on whether or not their assigned country should sign the Kyoto Protocol (a key element in the earth science curriculum on global warming). Through their interaction with the TELS module, students learned about the following topics: atmospheric gases, the greenhouse effect, and the ozone layer. They also learned to develop and create an argument, present a position, and revise their position based on scientific evidence and peer feedback (both of which were vital parts of the module and in class assignments related to their experiences).

Student Performance Results

Data Analysis on a single module (in this case the aforementioned TELS WISE module "Global Climate Change: Who's to Blame?") provides deeper insight into the overall effect that Technology Engineering had on the students that participated in the study. Student performance results are illustrated in Table 2 and Figure 2

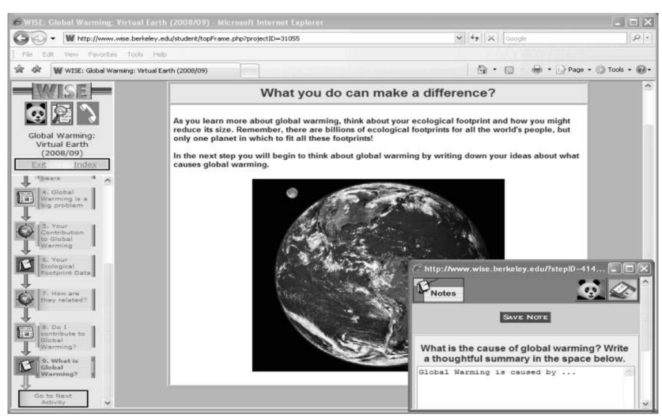

Figure 1. A Screenshot from the TELS Module, "Global Climate Change: Who's to Blame?"

respectively. Table 2 displays the results of the pre and post assessments for "Global Climate Change: Who's to Blame?". Figure 2 illustrates the research outcomes from the individual TELS module "Global Climate Change: Who's to Blame?" in box and whisker plots.

Table 2 contains unedited excerpts from student pre and post assessments, where students were asked to respond to a pre and post-test item that allowed them to explain the difference between the greenhouse effect and global warming. In Example 1, "Joe" is able to not only define both global warming and the greenhouse effect, but is also able to list the chemicals involved in the greenhouse effect. In Example 2, "Kim" is now able to discern the differences between global warming and the greenhouse effect and relate it to life on earth. In Example 3, although "Megan" did not give a response on the pretest, her response on the post-test indicates that she now has an understanding of both global warming and the greenhouse effect. Thus, in all three examples, students were able to demonstrate significant learning gains regarding the subject matter as a result of their experiences with the TELS WISE module.

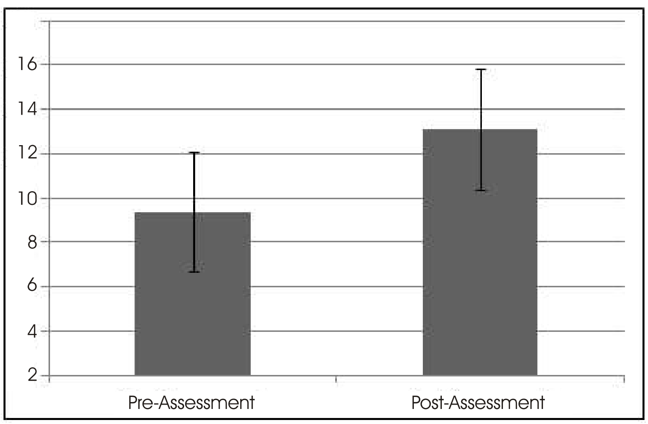

Figure 2. Combined Knowledge–Integration Scores for Three Assessment Items Used To Evaluate Student Learning Gains on "Global Warming" and "The Greenhouse Effect"

Figure 2 contains the combined results of pre and post assessments that were completed during the study regarding the TELS module, "Global Climate Change: Who's to Blame?" indicated that the students gained a significant amount of knowledge about global climate change and the greenhouse effect. Student responses to each question were coded using the Knowledge –Integration (KI) Rubric (Linn, Clark, and Slotta, 2001) that evaluated the quality of each student response (as illustrated in Table 1). Based on this rubric, students were able to better answer questions about global warming and the greenhouse effect as indicated by the combined KI scores for three assessment items. These three assessment items asked students to: (i) describe how the greenhouse effect happens; (ii) define global warming; and (iii) state the difference between global warming and the greenhouse effect. The combined KI pre-assessment score was 7.40 ± 2.71 and the combined post-assessment score was 11.11 ± 2.61 (as indicated in Figure 2). Thus, demonstrating that after experiencing the modules students responses indicated a greater breadth and depth of knowledge that they could clearly articulate regarding the scientific concept.

Pre-test and Post-test responses from three students to the assessment item, "What is the difference between the greenhouse effect and global warming?"

Student Name/Test:	Response to Item:	KI:
Example 1	Comment:	Score:
Joe (pre-test)	The greenhouse effect is one idea while global warming is all the things that raise the temperature.	3
Joe (post-test)	Global warming is a process of the Earth heating up in general. Greenhouse effect is when build up of CO_2, methane, and nitrous oxide trap IR, slowly heating the earth.	6
Example 2	Comment:	Score:
Kim (pre-test)	The greenhouse effect is in relationship with the ozone as on the other hand global warming is in relation with temperature.	2
Kim (post-test)	Although the greenhouse effect and global warming run hand in hand and are popularly spoken of sometime in the same sentence, the greenhouse effect creates an equal balance so that humans and other species may survive on the earth in comfort. Global warming in much respect is the actual rising temperature of the earth.	5
Example 3	Comment:	Score:
Megan (pre-test)	[No No response.]	0
Megan (post-test)	The greenhouse effect deals with infrared energy & solar energy and it's more like a cycle. Global warming is a side effect of the greenhouse effect.	4

Table 2. Student Pre– and Post–assessment responses to the question: "What is the difference between the Greenhouse Effect and Global Warming?"

Instructional Challenges with Technology in the Science Classroom

To assess the perceptions of teachers that participated in the study, interviews were conducted after the students completed the respective TELS modules. The surveys used to ascertain this data were administered at the end of the school year. After interviewing all seven teachers that participated in the study from the North Carolina urban school district, a number of challenges emerged. Teachers revealed instructional challenges (or barriers) that they faced when implementing the TELS modules in their science classroom (illustrated in Figure 3). The teachers that responded included three middle grade science teachers and four high school science teachers (that had each used at least one of the TELS modules as a part of their science curriculum instruction). The results of the data are as follows

Figure 3 illustrates in order of importance, the top three barriers that teachers faced when implementing the TELS modules in their classrooms. The top three barriers were: (i) access to computers and/or the computer lab (at 71%); (ii) apprehension about using technology at (65%); and (iii) network access and outdated computer systems (59%). This data clearly indicates that technological accessibility and readiness along with overall teacher perception about technology are still vital problems that must be addressed when implementing technology as a helpful solution. Figure 4 follows and displays the KI distribution for all students that participated in the similar studies along with North Carolina during the same time period.

Figure 4 describes the distribution of Knowledge–

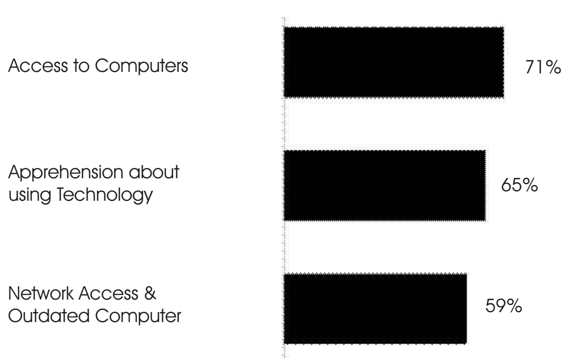

Figure 3. The Top Three Instructional Challenges Teachers Faced When Implementing the TELS Modules

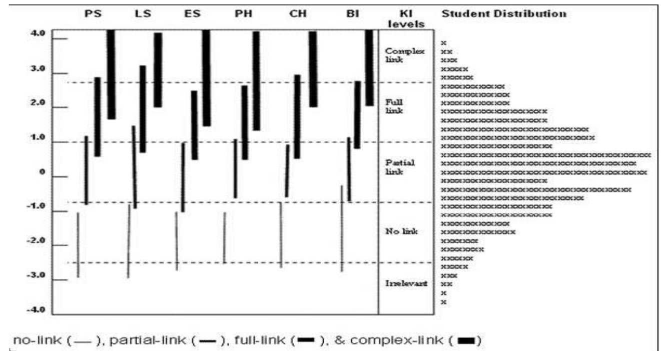

Figure 4. The Distribution of Knowledge Integration Estimates for Students in Three States

Integration (KI) estimates of all students (n = 4745) from three different states, one of which was North Carolina. An individual "x" represents 10 students (note the normality of the overall shape of the distribution). The dark bold lines on the graph represent the item threshold locations for each of four knowledge integration levels. There were thirty-six different versions of tests, six versions for each of the six subject areas across each of the three states that were equated in this sample. Converting from the IRT analysis (with a distribution range of 4 to 4) to the given Knowledge–Integration scale, students whose knowledge integration estimates that were below—2.6 were considered at the "irrelevant" level; from 2.6 to 0.8 at the "no-link" level; from 0.8 to 1.0 at the "partial-link" level; from 1.0 to 2.8 at the "full-link" level; a score of 2.8 or higher was considered to be at the "complex-link" level (each of these are indicated by the lines that become bolder as the scores become higher). A legend for Figure 4 in terms of subject matter area is as follows: PS = 0.25 for Middle School Physical Science; LS = 0.25 for Middle School Life Science; ES = 0.25 for Middle School Earth Science; PH = 0.25 for Middle School Physics; CH = 0.25 for Middle School Chemistry; BI = 0.25 for Middle School Biology; KI = 0.25 for Knowledge Integration. The graph indicates that the overall impact of the TELS module inquiry units is consistent with studies of individual units and show that there are significant pre to posttest gains (as indicated in the North Carolina Urban School Study). The results of the NC study are substantial because the TELS modular inquiry units lasted approximately five class periods and their impact was measured at the end of the school year, not immediately after students were exposed to the modular material.

Technology Engineering and the Future

When implementing technology into science programs, recent data suggest that students and teachers in urban settings face many barriers that are distinct from the barriers experienced by their colleagues in suburban and rural settings (Songer, Lee, and Kam, 2002). Science education in an urban elementary school, revealed that teachers were more poorly prepared than had been anticipated, in terms of both science content knowledge and instructional skills, and the quality of classroom pedagogical and management skills (King, Shumow, and Lietz, 2001). In the NC urban school district study, several teachers reported that they had limited or no access to computers in their classroom, they also stated that there were not enough computers for the entire class unless the students worked in pairs or small groups of 3-4. Teachers also responded that they were apprehensive about using technology in the classroom because there was no 'in-house' technical support to assist them should a computer-related problem arise while the students were completing their work. In addition, one direct impact to study occurred because outdated computer systems could not access firewalled sites, and had restrictions on downloading some of module content coupled with slow downloading times for some of the project models.

Despite all of the setbacks, the study clearly indicates that the Technology Engineered classroom is effective. Many of the problems must be overcome with teach professional development and better regularly updated technology. In many cases, Technology Engineering is only limited to the imagination of the instructor. Further investigation into this interactive engaging realm continues to yield the limitless ways educators have to truly empower students. New pedagogical and andragogical methods are open to development by those who have a passion for teaching students (Osler, 2010). The foundation of Technology Engineering prevailing in the struggles of the urban classroom begins with the strength and sustainability of professional development for the teachers implementing the curriculum. In a traditional top-down approach, the lack of success of many innovative projects is attributed to the failure of teachers to implement the innovation in a way corresponding to the intentions of the developers (Van Driel, Beijaard, and Verloop, 2001).

As this research has indicated through teacher responses "the absence of in-house and customized help has lead teachers to be reluctant to use technology in the classroom" (Salpeter, 2004). Much of research suggests that teacher technology preparedness is the key to unlocking student technology proficiency. Much of research supports this premise as stated in the following: Professional development is one mechanism to improve teacher fluency with technology (Songer, Lee, and Kam, 2002). It seems that long-term staff development programs are needed to actually change experienced teachers' practical knowledge (Van Driel, Beijaard, and Verloop, 2001). Several researchers have documented the support structures needed for teachers to implement technology in their classroom. These structures range from teacher competence in technology, access to the internet, classroom structures that support the use of technology, to professional development opportunities on technology (Czerniak, Lumpe, Haney, and Beck, 1999). Since the successful use of computers largely depends on teacher pedagogy, then efforts must be devoted towards helping teachers understand 1.) the purpose of educational technology, and 2.) the important pedagogy that is needed for its implementation (Mouza and Bell, 2001) (Eib and Cox, 2003).

According to the 2007-08 Digital Content Trends in America's K-12 classrooms, teachers currently use technology for a small percentage of their classroom time (QED Incorporated, 2008). The study also asked teachers to identify barriers to technology use in their classrooms. Some of the key findings included

- 86% of teachers have desktop computers available in their classrooms; 67% of teachers have access to laptops for their students if they need them; and only 5% of teachers have no access to computers of any kind.
- 9% of teachers spend more than 50% of instructional time using technology, while 16% of report no use of technology during classroom time.
- 85% of teachers report not having enough computers

in their classroom as a barrier to using digital content, either always (23%) or sometimes (63%).

"The findings from the new State of Digital Content report underscore the importance of schools across America making a commitment to providing access to up-to-date, relevant technology for both students and teachers," said Andy Lacy, President, (Quality Education Data (QED) Incorporated). "Teachers are telling us that they recognize the importance of technology as both a motivator and an instructional tool and as an essential part of a 21st century classroom." (QED Incorporated, 2008).

Conclusion

Although the North Carolina Standard Science Course of Study mandates that teachers integrate science and technology, teachers are still reluctant to implement technology in their science classroom to help their students achieve scientific literacy. In this article, we have provided examples in which the TELS inquiry-based model can promote authentic understanding of content-specific scientific pedagogy through technological integration in the science classroom. From the research discussed in this article, the students gained significant knowledge from the TELS module on global warming, autonomously of the limitations of their instructors and classroom environment. Teacher beliefs about the importance of technology for teaching are a strong predictor of delivery in the classroom and teacher directed student use (Russell, Bebell, O'Dwyer, and O'Connor, 2003). With the hands-on science movement, digital technologies are changing the ways teachers interact with students in the classroom (Flick and Bell, 2000) and many educational stakeholders understand the value that educational technology adds to the nature of teaching and learning (Groff and Mouza, 2008).

While technology is not able to overcome many of the classroom barriers such as class size or reduced instructional freedom, technology incorporated in the science curriculum can significantly improve students' understanding of difficult science topics (Linn 2003). The teachers in this study not only cited the benefits of using technology in the classroom but also identified barriers they faced that prevented them from the successful integration of technology in their classes. We argue that lack of sufficient technological support and professional development for teachers impeded further possible success in the urban classroom. Teachers are a critical component to the successful integration of technology in the science classroom and a new kind of leadership is required to anchor technology and inquiry–based pedagogy in the science classroom (Linn, Lee, Tinker, Husic, and Chiu, 2006). We must delve further into interactive territories that can cross Multiple Intelligences and Learning Styles. Technology Engineering classrooms through TELS or other educational courseware is both achievable and possible. Once fully implemented, the end results may prove to be as far reaching in education as the early printing press was to global literacy (Osler, 2010).

Resources

TELS: The Center for Technology Enhanced Learning in Science—http://www.telscenter.org

WISE: The Web-Based Integrated Science Environment- http://wise.berkeley.edu

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