Awards for Innovation
Final Report

Title of Research Study

How STEM teachers integrate concepts of PCK

Investigators, Institution

Joshua W. Brown
Assistant Professor of Technology Education
Department of Technology
Campus Box 5100
Illinois State University
Normal, IL 61790-5100
Phone: (309) 438-5874
Fax: (309) 438-8926
Jbrown4@ilstu.edu

Ryan A. Brown
Assistant Professor of Secondary Education
Department of Curriculum and Instruction
Campus Box 5330
Illinois State University
Normal, IL 61790-5330
Phone: (309) 438-3964
Fax: (309) 438-8659
rbrown@ilstu.edu

Strand Project Addressed

Professional development for pre-service and beginning teachers

Overview of Research Study

The Illinois State University Department of Technology Master's Degree program "STEM Education & Leadership Program" provides professional development for teachers on instructional practices that integrate technology and engineering education with mathematics and science at the secondary level. This advanced degree is designed to assist teachers in secondary classrooms of Illinois public schools in discovering how technology education and engineering design can be integrated with science and mathematics. The inaugural cohort of teachers began in the summer 2008 and took a course on Pedagogical Content Knowledge (PCK) during the fall 2008 and a course on Integrated STEM education during the spring 2009 semester. These

courses helped the teachers explore their own pedagogical approaches and provided them with the direct instruction to create a framework to use in their classrooms to improve the integration of Science, Technology, Engineering and Mathematics (STEM).

In the STEM Education & Leadership program the students were introduced to foundational resources in PCK and STEM through instruction from Illinois State University graduate faculty. While the faculty provided resources and instruction focused on PCK and STEM, there was not a clear understanding of the impact of this PCK and STEM on the classroom practices of Illinois public school teachers. This research program will investigated how the teachers integrated the concepts (PCK and STEM) learned into their classrooms. To accomplish this investigation, the teachers enrolled in the PCK course were observed teaching both near the beginning of the program (fall 2008) and following extensive professional development with PCK and STEM at the end of the spring 2009 semester. To complete the observations, the researchers used the "Inside the Classroom: Observation and Analytic Protocol" process for observations.

By using the "Inside the Classroom: Observation and Analytical Protocol," the researchers collected qualitative and quantitative data about both the instructors curriculum and instruction. The teachers were rated on many different standards under the overall headings of lesson design, implementation, content, and classroom culture. From the entire protocol, eleven questions were identified for analysis in this study as they measured specific aspects of STEM integration and use of PCK. Along with the quantitative ratings, the researcher wrote a narrative about the classroom experience and talked with each teacher about their experiences teaching STEM related content. We have summarized our findings in the deliverables section of this report.

Objectives/Research Questions

At the completion of this research project and through the project deliverables, the researchers are able to:

1. Describe how teachers integrated PCK and STEM principles into their classrooms.
2. Illustrate the change in instructional practices after the teachers have professional development on PCK and STEM.
3. Describe the teachers' feelings about how their approach has changed by integrating PCK and STEM into their classrooms.

Project Deliverables

The collected data were first organized by the entire group of teachers and then sorted by each teacher to measure the individual gain or loss of rating in each a category. Below is a summary of our findings related to this research project. The appendix of this document contains the

complete analysis of each rating in all categories, including the qualitative comments written by the researcher during the observation.

Overall Findings

The observation protocol used to summarize the teachers' instructional procedures has over 30 different areas to rate and is organized into four categories, 1) lesson design, 2) lesson implementation, 3) content and 4) classroom culture. Researchers score the lesson by answering questions on a scale of 1 (not at all) to 5 (to a great extent). The observations rated many different areas of instruction, but for the purpose of this study the researchers isolated concepts related to PCK and STEM. The cumulative averages of all Peoria teachers (n=6) observed in our research study are below. The complete analysis is located in the appendix. In the chart below you will see the statement on the left and scoring information on the right.

STEM Concepts

	Fall 2008 Rating	Spring 2009 Rating	Growth
The design of the lesson incorporated tasks, roles, and interactions consistent with investigative technology.	3.0	3.8	0.8
The design of the lesson included STEM integration.	2.2	3.3	1.1
The instructional strategies were consistent with investigative mathematics/science.	3.3	3.7	0.3
The lesson implementation included STEM integration.	2.5	3.0	0.5
Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification.	3.0	3.7	0.7
Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or real-world contexts.	2.0	4.0	2.0
The STEM content was significant.	2.3	3.5	1.2
Average	2.6	3.6	1

Pedagogical Content Knowledge

	Fall 2008 Rating	Spring 2009 Rating	Growth
The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, prior knowledge, and/or learning styles.	3.5	4.0	0.5
The teacher's classroom management style/ strategies	3.0	3.8	0.8

enhanced the quality of the lesson.			
The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/ problem solving (e.g., emphasized higher order questions, appropriately used 'wait time,' identified prior conceptions...).	2.5	3.5	1.0
The mathematics/ science content was appropriate for the developmental levels of the students in this class.	3.7	4.3	0.7
The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).	4.0	4.3	0.3
Average	3.3	4.0	0.7

The overall averages illustrated above show a trend of growth for the teachers in topics related to PCK and STEM instruction in secondary schools. While this trend is encouraging, for the purpose of this study we are equally interested in the individual growth of each teacher in the cohort. Below we summarize the growth of each individual teacher focused on the STEM and PCK related questions while also providing a context for the data by briefly describing the classroom setting based on our corresponding qualitative data collection.

Teacher #1

STEM Concepts

	Fall 2008 Rating	Spring 2009 Rating	Growth
The design of the lesson incorporated tasks, roles, and interactions consistent with investigative technology.	3	2	-1
The design of the lesson included STEM integration.	1	2	1
The instructional strategies were consistent with investigative mathematics/science.	3	3	0
The lesson implementation included STEM integration.	2	3	1
Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification.	2	2	0
Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or real-world contexts.	1	4	3
The STEM content was significant.	1	3	2
Average	2.2	3.2	1

Pedagogical Content Knowledge (PCK)

	Fall 2008 Rating	Spring 2009 Rating	Growth
The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, prior knowledge, and/or learning styles.	4	4	0
The teacher's classroom management style/ strategies enhanced the quality of the lesson.	4	5	1
The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/ problem solving (e.g., emphasized higher order questions, appropriately used 'wait time,' identified prior conceptions...).	2	3	1
The mathematics/ science content was appropriate for the developmental levels of the students in this class.	3	4	1
The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).	3	5	2
Average	3.2	4.2	1

Teacher #1 grew an average of 1 point on the rating scale in both STEM integration and use of PCK. In terms of STEM integration the teacher grew in the majority of areas based content that was designed and implemented. The teacher's first lesson was designed to teach microscope skills and while it was investigative and unique, it included very little integrative STEM content. The second lesson was focused on embryo development and taught science concepts using mathematics skills including measurement and scale. Throughout the lesson the teacher made connections to the medical discipline and to medical technology such as sonogram and ultrasound machines. The second lesson, however, was not as investigative or engaging as the first lesson. In terms of pedagogical content knowledge, the teacher was strong in both observations. The greatest growth in PCK was due to improvement in classroom management and understanding of the concepts that were being taught. Teacher 1 selected content that was appropriate and enhanced student understanding though the use of questions, especially in one-on-one situations.

Teacher #2

STEM Concepts

	Fall 2008 Rating	Spring 2009 Rating	Growth
The design of the lesson incorporated tasks, roles, and interactions consistent with investigative technology.	3	3	0
The design of the lesson included STEM integration.	1	2	1
The instructional strategies were consistent with investigative mathematics/science.	3	3	0
The lesson implementation included STEM integration.	1	2	1
Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification.	4	4	0
Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or real-world contexts.	1	4	3
The STEM content was significant.	1	3	2
Average	2.3	3.5	1.2

Pedagogical Content Knowledge (PCK)

	Fall 2008 Rating	Spring 2009 Rating	Growth
The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, prior knowledge, and/or learning styles.	3	4	1
The teacher's classroom management style/ strategies enhanced the quality of the lesson.	4	3	-1
The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/ problem solving (e.g., emphasized higher order questions, appropriately used 'wait time,' identified prior conceptions...).	2	3	1
The mathematics/ science content was appropriate for the developmental levels of the students in this class.	4	4	0
The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).	4	4	0
Average	3.4	3.6	0.2

Teacher #2 designed and implemented two lessons that were investigative and that included scientific analysis and justification. The second lesson, however, had more STEM content which led to average of a 1.2 growth in STEM integration. The first lesson focused on chemical testing and included no direct connections to other STEM disciplines. In a conversation prior to the second observation, the teacher expressed that it is tough the integrate STEM concepts because of resources (mainly time, materials, and equipment), however in the lesson Teacher 2 made clear connections between math and science by discussing the types of math and are used by scientists. The teacher then created a graph from scientific data that was collected in class and assigned the students the task of using algebra to find the X-intercept of the data. Throughout both lessons Teacher 2 displayed excellent use of PCK. In the second lesson, specifically, the teacher designed a lesson that was based on previous struggles that students were having with gas laws. The lesson that he designed and implemented included a review of several gas laws and teacher demonstrations that enabled the students to visualize the effects of the laws.

Teacher #3

STEM Concepts

	Fall 2008 Rating	Spring 2009 Rating	Growth
The design of the lesson incorporated tasks, roles, and interactions consistent with investigative technology.	3	4	1
The design of the lesson included STEM integration.	1	3	2
The instructional strategies were consistent with investigative mathematics/science.	2	2	0
The lesson implementation included STEM integration.	1	2	1
Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification.	3	3	0
Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or real-world contexts.	1	3	2
The STEM content was significant.	1	2	1
Average	2	3.2	1.2

Pedagogical Content Knowledge (PCK)

	Fall 2008 Rating	Spring 2009 Rating	Growth
The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, prior knowledge, and/or learning styles.	2	3	1
The teacher's classroom management style/ strategies enhanced the quality of the lesson.	1	2	1
The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/ problem solving (e.g., emphasized higher order questions, appropriately used 'wait time,' identified prior conceptions...).	2	2	0
The mathematics/ science content was appropriate for the developmental levels of the students in this class.	4	3	-1
The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).	4	2	-2
Average	2.6	2.4	-0.2

Teacher #3 showed substantial gains related to STEM integration. This is especially true in design of the second lesson. Teacher 3 designed the lesson to include a wide range of math and science concepts, as shown in the teacher's lesson plan and activity sheet. In implementation, however, the teacher omitted much of the math and science content and only focused on the activity for the sake of the activity. It would have been possible to include the STEM content in the activity, but Teacher 3 chose omit the content. From conversations with Teacher 3 it was gleaned that it may be based on the teacher's lack of comfort with the level of mathematics that was required in the lesson. This teacher also appears to struggle with classroom management as evidenced in several ratings related to PCK. Because of the lack of focus on content in the second observation, Teacher 3 demonstration of PCK dropped slightly. It was clear that Teacher 3 values and attempted to include STEM content, but because of struggles with classroom management and other aspects of PCK had trouble implementing the integrated lesson that Teacher 3 had designed.

Teacher #4

STEM Concepts

	Fall 2008 Rating	Spring 2009 Rating	Growth
The design of the lesson incorporated tasks, roles, and interactions consistent with investigative technology.	2	5	3
The design of the lesson included STEM integration.	3	5	2
The instructional strategies were consistent with investigative mathematics/science.	4	5	1
The lesson implementation included STEM integration.	3	4	1
Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification.	2	5	3
Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or real-world contexts.	3	5	2
The STEM content was significant.	3	5	2
Average	2.85	4.85	2.0

Pedagogical Content Knowledge

	Fall 2008 Rating	Spring 2009 Rating	Growth
The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, prior knowledge, and/or learning styles.	4	5	1
The teacher's classroom management style/ strategies enhanced the quality of the lesson.	3	4	1
The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/ problem solving (e.g., emphasized higher order questions, appropriately used 'wait time,' identified prior conceptions...).	3	5	2
The mathematics/ science content was appropriate for the developmental levels of the students in this class.	3	5	2
The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).	5	5	0
Average	3.6	4.8	1.2

Teacher #4 grew an average of 2 points in STEM integration and an average of 1.2 points in application of PCK. The high level of growth is related to the classroom approach incorporated in the high school general science classroom. During the first observation the instructor taught a lesson based on the periodic table of elements and the students solve paper based problems (word puzzles). While the lesson had accurate science content, it was not interdisciplinary with math and technology. Also, the students were not engaged in the lesson. During the second observation, the teacher used an "egg drop vehicle" project to integrate math, science and technological concepts in a "hands-on" activity. By discussing key concepts such as propulsion, velocity, gravity and mass the instructor effectively integrated math while also discussing technological developments that can help passengers safely travel in vehicles. Not only did the scores in PCK and STEM related concepts increase, but the observer noted the student engagement increased. Also, in discussion with the observer, the teacher stated that the students would much rather work on a project and learn conceptually through practical experience than through worksheets and memorization.

Teacher #5

STEM Concepts

	Fall 2008 Rating	Spring 2009 Rating	Growth
The design of the lesson incorporated tasks, roles, and interactions consistent with investigative technology.	4	5	1
The design of the lesson included STEM integration.	5	4	-1
The instructional strategies were consistent with investigative mathematics/science.	4	5	1
The lesson implementation included STEM integration.	5	4	-1
Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification.	5	4	-1
Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or real-world contexts.	5	4	-1
The STEM content was significant.	5	4	-1
Average	4.7	4.2	-0.5

Pedagogical Content Knowledge

	Fall 2008 Rating	Spring 2009 Rating	Growth
The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, prior knowledge, and/or learning styles.	5	5	0
The teacher's classroom management style/ strategies enhanced the quality of the lesson.	4	5	1
The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/ problem solving (e.g., emphasized higher order questions, appropriately used 'wait time,' identified prior conceptions...).	4	4	0
The mathematics/ science content was appropriate for the developmental levels of the students in this class.	5	5	0
The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).	5	5	0
Average	4.6	4.8	0.2

Teacher # 5 had negative growth in STEM content and a very modest 0.2 growth in application of PCK in their classroom. As is evident from the ratings, teacher # 5 scored very high on their first observation, which provides a challenging baseline for growth, but there was still a decrease in effective integration of STEM concepts in the 6th grade science classroom. Through an analysis of the observations and conversations with Teacher #5 it was clear the topic covered in observation 1 was something in which technological innovation was much easier connected to the science classroom. In the first observation, the class was learning about the mummification process and discussed the different technologies used in ancient Egypt to mummify individuals and in observation number two the students worked on making a model “animal” based on DNA and Genotypes. Both could have significant STEM content, but the instructor did not integrate the technology and math concepts to the same degree in observation number 2.

Teacher # 6

STEM Concepts

	Fall 2008 Rating	Spring 2009 Rating	Growth
The design of the lesson incorporated tasks, roles, and interactions consistent with investigative technology.	3	4	1
The design of the lesson included STEM integration.	2	4	2

The instructional strategies were consistent with investigative mathematics/science.	4	4	0
The lesson implementation included STEM integration.	3	3	0
Mathematics/science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis, and/or proof/justification	2	4	2
Appropriate connections were made to other areas of mathematics/science, to other disciplines, and/or real-world contexts.	1	4	3
The STEM content was significant.	3	4	1
Average	2.6	3.8	1.2

Pedagogical Content Knowledge

	Fall 2008 Rating	Spring 2009 Rating	Growth
The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness, prior knowledge, and/or learning styles.	3	3	0
The teacher's classroom management style/ strategies enhanced the quality of the lesson.	2	4	2
The teacher's questioning strategies were likely to enhance the development of student conceptual understanding/ problem solving (e.g., emphasized higher order questions, appropriately used 'wait time,' identified prior conceptions...).	2	4	2
The mathematics/ science content was appropriate for the developmental levels of the students in this class.	3	5	2
The teacher displayed an understanding of mathematics/science concepts (e.g., in his/her dialogue with students).	3	5	2
Average	2.6	4.2	1.6

Teacher #6 had high growth in both areas of STEM integration (1.2 points) and PCK (1.6 points). Teacher #6 worked in a middle school teaching 6th and 7th grade science classes. In the first observation, the teacher struggled with incorporating an activity that effectively integrated math and technology with the students. Teacher #6's planning was rated above average, but had struggles with classroom management and did not engage the students in active learning until the end of the class period. In observation two, Teacher #6 engaged the students early in the class session and encouraged the students to use engineering design to develop a filtration process for

water that simulates how nature filters water. Discussing modern technologies and connecting these technologies with the hands on science activity created a student base excited to design and build their own projects.

Summary

In summary, nearly all six teachers demonstrated growth in both STEM integration and use of Pedagogical Content Knowledge. These findings and corresponding conclusions are currently being written as a manuscript for submission to a national journal. Additionally, the researchers will share these findings at the 2010 Connections Conference and have submitted a proposal to present the findings at the 2010 International Technology Education Conference. The researchers hope to continue this line of research to determine if these teachers continue to grow in the areas of STEM integration and use of Pedagogical Content Knowledge.