Paper ID #18431

Research Design, Data Collection, and Assessment Methods for an Integrated STEM Education Model (Work in Progress)

Mr. J. Geoff Knowles, Purdue University

J. Geoff Knowles is the Executive Director for Ivy Tech Community College in Crawfordsville, Indiana. His background is in environmental engineering and he is a PhD candidate in Technology and Engineering Teacher Education in the Polytechnic Institute at Purdue University. Currently he is doing research on integrated STEM education through the Teachers and Researchers Advancing Integrated Lessons in STEM (TRAILS) NSF ITEST funded project.

Dr. Todd Kelley, Purdue University

Todd R. Kelley is an Associate Professor in Technology Leadership and Innovation. Dr. Kelley joined Purdue in 2008 upon completion of his PhD at the University of Georgia. He was hired as a P-12 STEM educational researcher and technology teacher educator. His dissertation research was on teaching and learning engineering design in secondary education. Prior to graduate school, Kelley was a high school and middle school technology education teacher for nine years teaching in three school districts in New York state and Indiana.

Dr. Kelley's research focus is in design and cognition seeking to better understand how young students learn design and how design improves STEM education. He joined a team of researchers to create a program to improve learning STEM in elementary grades, and the team was awarded an NSF Math and Science partnership called Science Learning Through Engineering Design (SLED). Kelley is currently the PI on an NSF I-Test project called Teachers and Researchers Advancing Integrated Lessons in STEM (TRAILS). TRAILS prepares science and technology education teachers to integrate STEM content through biomimicry inspired engineering design within the context of entomology.

Dr. Kelley the program coordinator for the engineering/technology teacher education program at Purdue. Dr. Kelley is also leading the second year Design Thinking course for the Purdue Polytechnic Institute. The course is a collaboration between the Polytechnic and Anthropology to integrate ethnographic approaches by developing technological and engineering design human centered design solutions.

Mr. Euisuk Sung, Purdue University

Euisuk Sung is a Ph.D. candidate at Purdue University. He is majoring Engineering and Technology Teacher Education. He has computer science degree and worked as a computer software developer for three years. then he served as an engineering and technology educator in high school for 9 years in South Korea. Currently he is working in NSF Funded project, titled TRAILS. His research interests are design cognition, design process model, and all about STEM education.

Mr. Jongseong Choi, Purdue University

Jongseong Choi is a Ph.D. student in the School of Mechanical Engineering at Purdue University, working with Dr. Todd Kelley as a graduate assistant. He has been involved in the field of STEM education since he worked for data collection and analysis in SLED (Science Learning through Engineering Design) NSF-funded project. He is currently in charge of data analysis in TRAILS (Teachers and Researchers Advancing Integrated Lessons in STEM) NSF-funded project. His research focused on evaluating & improving STEM lessons via developing specified curriculum. Individually, his research includes video processing, autonomous monitoring system, computer vision, and robotics. Prior, he worked on dynamic behavior of reinforced ballistic materials and applications, collaborated with U.S Department of Justice.

Research Design, Data Collection, and Assessment Methods of an Integrated STEM Education Model (Work in Progress)

The goal of this research is to assess the effectiveness of an integrated STEM education model. The study is being conducted under a three-year NSF-ITEST funded project (award #1513248), *Teachers and Researchers Advancing Integrated Lessons in STEM* (TRAILS). This research incorporates engineering design as a STEM subject integrator and scientific inquiry to provide an authentic learning context for promoting 21st century skills and connections in STEM learning. In addition, the study seeks to assess effective strategies to increase STEM self-efficacy within science (biology or physics) and engineering technology education (ETE) teachers, and advance students' learning of STEM content at schools in rural settings. In order to evaluate the effectiveness of the TRAILS model, researchers developed and adopted various measures and instruments. Data collection for the study includes utilizing the following: a) instruments measuring STEM lesson content knowledge (knowledge tests), b) attitudinal perceptions of teachers and students (pre/posttest surveys and delayed posttest surveys), c) rubrics for assessing 21st century skills in project based learning, d) classroom observations, and e) student knowledge transfer problems. This variety of quantitative and qualitative data collection provides opportunities for triangulating data and analysis to ensure rigorous evaluation of TRAILS goals and outcomes. The quasi-experimental research design implements an experimental group in which teachers participate in professional development, an online community of practice, and implement integrated STEM lessons. A comparison group of teachers also participate in the data collection process but do not participate in professional development or any of the activities of the experimental group in cohort one. The research design including instruments utilized, the methods for assessing 21st century learning skills, classroom observation, and knowledge transfer problems, will be described, including preliminary analysis procedures.

Introduction

Major concerns have been raised regarding U.S. competiveness within an emerging global economy as our national population rises and a STEM ready workforce decreases (National Center on Education and the Economy, 2006; National Academies Press, 2010). Recent educational reforms and reports (NRC, 2011; NGSS, 2013, National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) respond to the need for increasing achievement in STEM education, with some reports coming from the highest level (President's Council of Advisors on Science and Technology (PCAST), 2010). However, ambiguity remains regarding integrated STEM education approaches (Breiner, Harkness, Johnson, & Koehler, 2012) and many STEM education efforts remain disjointed, teaching science, math, technology, and engineering in isolation (Abell & Lederman, 2007; Sanders, 2009; Wang, Moore, Roehrig, and Park, 2011). Teachers lack access to proven STEM lessons that engage students in technology and engineering practices while improving math and science achievement. This is especially acute in rural school settings with low SES where professional development opportunities are scarce and shortages remain for highly qualified STEM teachers (Arredondo & Rucinski, 1996; Czerniak, 2007; Sipple & Brent, 2008).

TRAILS is a NSF I-TEST funded project that implements a model of integrated STEM instruction and teacher professional development to enhance student learning of STEM content while generating interest in STEM careers (Kelley & Knowles, 2016). TRAILS seeks to increase STEM self-efficacy within science and technology teachers and advance students' learning of

STEM content at schools in rural settings. TRAILS uses engineering design as a STEM subject integrator, providing an authentic learning context to promote 21st century skills, and motivate students to pursue STEM careers. The TRAILS model blends scientific inquiry and engineering design to teach common STEM practices and STEM habits of mind. TRAILS leverages the use of innovative tools such as additive manufacturing technology, 3D scanning technology, and parametric modeling software, allowing students to design and test innovative design solutions (US Department of Education, 2010).

Barriers exist for students to pursue STEM career pathways partially due to lack of STEM role models (National Academies, 2011), deficiencies in career readiness and interest, and general accessibility to post-secondary education opportunities for students from rural settings (Sipple & Brent, 2008), low SES populations, and underrepresented minorities (PCAST, 2010). Additionally, secondary teachers struggle to locate authentic contexts for teaching STEM subjects, lack STEM pedagogical context and content knowledge, and lack awareness of current STEM workforce practices, especially in rural school settings (US Department of Education, 2010). Moreover, students in rural schools are often not taught the multiple ways in which STEM is practiced in industry, thus they may not conceptualize STEM career pathways (Avery, 2013).

TRAILS' vision seeks to enhance high school students' interest and capacity to pursue STEM careers and prepares secondary teachers to provide integrated STEM learning experiences. The TRAILS team hosted a teacher professional development institute which featured an integrated STEM lesson called *Designing Bugs and Innovative Technology (D-BAIT)* that provides a platform for teaching the science of entomology within engineering design (Knowles, Kelley, & Hurd, 2016). To assess the TRAILS project, the investigators are researching the following questions concerning teachers and students:

Teachers

1. How confident are science and technology teachers in teaching an integrated STEM lessons and design activities?
    a. Does their confidence increase with TRAILS professional development?
2. What challenges do science and technology teacher identify when planning integrated STEM activities in rural school settings?

Students

3. To what degree do students demonstrate learning of STEM content knowledge embedded within TRAILS lessons?
4. To what degree do students use 21st century skills when engaged in TRAILS lessons?
5. Does students' confidence in learning STEM subjects increase after engaging in TRAILS lessons?
6. Does students' interest in STEM careers change after engaging in TRAILS lessons?

Data is currently being collected on teachers and students participating in the study through pre/posttest online surveys, STEM content knowledge assessments, classroom observations, teacher interviews, student knowledge transfer problems using think aloud protocol, and rubric results for 21st century learning skills.

Research Design

The research design employs a quasi-experimental nonequivalent comparison group design which utilizes an experimental group and a comparison group with both pretest, posttest, and delayed posttest assessments on non-randomized participants (Ary, Jacobs, Sorensen, & Walker, 2014; Creswell, 2009; Shadish, Cook, & Campbell, 2002). In this research design, two teacher groups of participants were selected from applicants to the TRAILS program. Twelve of the applicants that could attend the professional development institute in June 2016 and met required criteria were selected for the experimental group. Other applicants that could not attend the professional development institute in June 2016, but met the required criteria were invited to participate in the comparison group, which served as a control. The comparison group teachers are encouraged to attend the professional development (delayed treatment) the following summer in 2017 for cohort two. TRAILS required partners to be currently teaching high school biology or physics, and teaching ETE (Project Lead the Way or ETE courses) with experience in parametric modeling software and 3D printing technology. The participants were also carefully balanced in the groups with science and ETE teachers as possible. In the first teacher cohort in 2016, we have nine males and three females participating in the experimental group who attended the professional development institute. In the comparison group, six males and three females participated. All teachers who chose to participate were of Caucasian decent with a diversity of experience, age, and schools in a Midwestern state.

All teachers in the experimental and comparison groups are taking pretest, posttest, and delayed posttest assessments. One group participated in the experimental group which included attendance at the TRAILS professional development institute in June 2016. The other group did not attend the professional development, providing a comparison group. This research approach was not a true experimental design since the participants were not from a random sample but selected from applicants who taught biology or physics, and a partner teaching ETE courses (Creswell, 2009). All teachers were required to have at least two years of experience teaching. The participant STEM teachers were given a pretest (T1) prior to the TRAILS summer professional development workshop. The same participants then took the same assessment for a posttest (T2), after the completion of the TRAILS summer professional development workshop, and then are again later (delayed posttest, T3) during the school year after implementation of the integrated STEM lessons to measure lasting effects. The students of the participant teachers are also being assessed using STEM content knowledge tests and surveys to measure attitudes toward STEM learning and career interest.

Data Collection Instruments and Methods

Several instruments are being used to collect data from teachers. The Science Teaching Efficacy Belief Instrument (STEBI) is designed to assess teachers' perceptions of their effectiveness for teaching science with 25 questions using a 5 point Likert scale, with 1 being "Strongly Disagree," to 5 being "Strong Agree" (Riggs & Enochs, 1990). The Teacher Efficacy and Attitudes toward STEM (T-STEM) survey measures changes in teachers' self-efficacy and confidence in STEM subject content and teaching, 21st century learning skills, using technology in the classroom, and STEM career awareness (The Friday Institute for Educational Innovation, 2012b). The Teaching Design, Engineering and Technology (DET) survey measures teacher perceptions and familiarity with these subjects and perceived barriers to teaching these topics. The DET survey has 40 questions using a 5 point Likert scale (Tao, Purzer, & Cardella, 2011). TRAILS students are being surveyed to assess interest and confidence in learning STEM subjects as measured by the Students Attitudes Toward STEM Survey (S-STEM) for middle and high school students (Friday Institute for Educational Innovation, 2012a). Student participants are surveyed in both the experimental and comparison group, determined by the group of the TRAILS teacher participant (Friday Institute for Educational Innovation, 2012a).

Instruments used to collect data on STEM content knowledge from students and teachers include the D-BAIT knowledge assessment, and a teacher selected STEM lesson content assessment for lessons developed in the TRAILS professional development institute. The TRAILS D-BAIT unit knowledge test includes 24 multiple choice test items with format similar to the work of Fortus, Dershimer, Krajcik, Marx, and Mamlok-Naaman (2004) with a blend of low, medium, and high cognitive domain items.

TRAILS lessons are crafted to address key science and technological literacy standards and the Five Cs of 21st century skills. Through project-based engineering design pedagogy, students work in teams or in pairs to facilitate collaboration. Each design activity includes an open-ended problem, allowing for multiple solutions that require creative **c**ritical thinking. Rubrics have been modified and mapped to Common Core and NGSS Standards to be applied to evaluate students' work in TRAILS lessons. These rubrics are for evaluating critical thinking, collaboration, creativity and innovation, and communication, based upon the work of Boss (2013) for assessing student's success in 21st Century Skills. TRAILS teachers are trained in how to use these rubrics during the professional development institute.

Other data collection methods include classroom observations of teachers implementing TRAILS' lessons which are guided by Merriam's (2001) procedures in a modified format as various elements are considered such as the physical setting, participants, activities and interactions, conversations, and other**.** Formal and informal teacher interviews are also being used to collect additional data on teachers' thoughts, ideas, experiences, and recommendations. To assess students' knowledge transfer in STEM content covered in TRAILS lessons, selected students are given problems to apply knowledge in different contexts. Students are selected partly on their ability to express themselves verbally, since these transfer problem sessions are video recorded and analyzed using Concurrent Think-Aloud (CTA) Protocol to better understand student inquiry and design thinking (Kelley, Capobianco, & Kelley, 2015).

Data Analysis

This study seeks to address the research questions which assess the effectiveness of an integrated STEM education model. Teacher professional development and ongoing professional support for teachers in a community of practice is provided for the experimental group. Quantitative data includes the Likert scores from the T-STEM survey measuring teacher attitudes on teaching self-efficacy, outcome expectancy, 21st century learning, and STEM career awareness. The Likert scores are being statistically analyzed by ordinal regression modeling using cumulative link models (CLM) to detect significant differences in survey pretest, posttest, and delayed posttest scores. Independent variables used in ordinal regression analysis include group (comparison or experimental) and subject (science or ETE teacher). Preliminary data analysis indicates significant differences in the experimental group teacher pretest and posttest survey data for teaching self-efficacy and STEM career awareness, with p-values of 0.001 detected (n=12). When only science teachers were analyzed in the experimental group, significant differences were found in teaching self-efficacy, teaching outcome expectancy, and STEM career awareness. However, no significant differences were found in the ETE teacher experimental group data. Interestingly, it appears the professional development had a greater impact on science teachers on these constructs when groups are analyzed separately by subject area, though samples sizes are small. Scores on the STEM content knowledge portion of the assessment for the pretest and posttest are being collected and analyzed for significant differences using paired t-tests. Data from classroom observations, teacher interviews, and 21st century learning rubrics will also be analyzed to triangulate conclusions and inferences drawn from the data analysis.

Summary

This study examines the effectiveness of an integrated STEM model by researching teacher confidence, challenges to implementing integrated STEM lessons, student learning and attitudes, and student interest in STEM careers. High school science and ETE teachers participating in the TRAILS project experimental group attended a ten-day 70-hour summer professional development institute. The professional development is designed to educate teachers in using an integrated STEM education model developed for the TRAILS project to implement integrated STEM lessons as partners in their respective high schools. Teachers can have significant influence on student interest in and understanding of STEM educational pathways and careers.

In this study, the research design employs a quasi-experimental nonequivalent comparison group design. One group of teachers participated in the experimental group which included attendance at the TRAILS professional development institute in June 2016 (teacher cohort 1). The comparison group did not attend the professional development. The study is designed to assess the effectiveness of the integrated STEM education model taught in the professional development workshop and ongoing professional support for teachers in a community of practice who are in the experimental group. The measures used to analyze the impact of the teacher professional development included the Likert scores from surveys and test scores from STEM content knowledge tests. Data is also being collected with students using the S-STEM survey and knowledge tests. In addition to these assessments, classroom observations, teacher interviews, rubrics for 21st century learning skills, and student knowledge transfer problems are being utilized to obtain further data on student learning. At the date of this submission, preliminary results indicate significant differences in some pretest and posttest data in the experimental group, keeping in mind this is a relatively small sample size (n=12). However, data collection is on-going and more analysis needs to be completed.

Conclusion

Ultimately an increase in teacher and student, efficacy, learning and interest as measured by the surveys, STEM knowledge tests, knowledge transfer problems, observations, interviews, and rubrics after teachers implement the TRAILS lessons would provide valuable insight into the effectiveness of this integrated STEM model and professional development approach. For a more accurate assessment of teacher and student learning and interest, the various methods of data collection, as illustrated in Figure 1, provide varied sources of information and perspective to inform and validate conclusions.

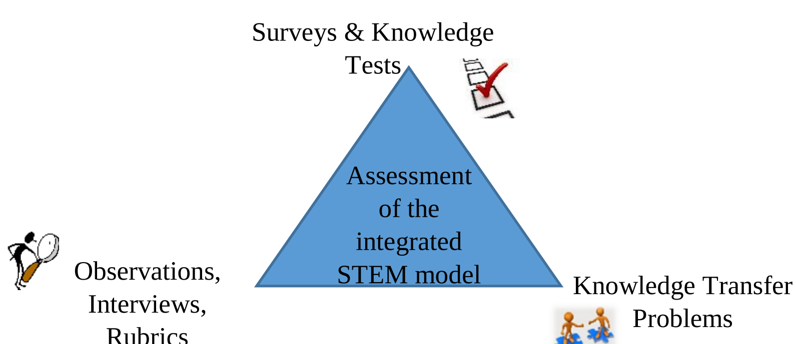

Figure 1

References

Abell, S., & Lederman, N. (2007). *Handbook on research in science education*. Thousand Oaks: Sage.

Arredondo, D., & & Rucinski, T. (1996). Integrated curriculum: Its use, initiation and support in Midwestern schools. *Mid-Western Educational Researcher, 9*(2), 37-44.

Ary, D., Jacobs, L., Sorensen, C., & Walker, D. (2014). *Introduction to research in education* (9th ed.). Belmont, CA: Wadsworth.

Avery, Z. (2013). Developing effective STEM professional development programs. *Journal of Technology Education, 25*(1), 55-69.

Boss, S. (2013). *Project based learning toolkit series: PBL for the 21st century success*. Novato, CA: Buck Institute for Education.

Breiner, J., Harkness, M., Johnson, C. C., & Koehler, C. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics, 112*(1), 3-11.

Creswell, J. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (3rd ed.). Los Angeles, CA: Sage.

Czerniak, C. (2007). Interdisciplinary science teaching. In S. Abell & N. Lederman. *Handbook on research in science education* (pp. 537-559). Thousand Oaks: Sage.

Fortus, D., Dershimer,C., Krajcik, J., Marx, R., & Mamlok-Naaman, R. (2004). Design-based science and student learning. *Journal of Research in Science Teaching, 41*(10), 1081-1110.

Friday Institute for Educational Innovation. (2012a). *Middle and High School STEM-Student Survey*. Raleigh, NC: North Carolina State University. Retrieved from: http://miso.ncsu.edu/articles/s-stem-survey

Friday Institute for Educational Innovation. (2012b). *Teacher Efficacy and Attitudes toward STEM Survey (T-STEM)*. Raleigh, NC: North Carolina State University. Retrieved from: http://miso.ncsu.edu/articles/t-stem-survey-2

Kelley, T., Capobianco, B. & Kaluf, K. (2015). Concurrent think-aloud protocols to assess elementary design students. *International Journal of Technology and Design Education, 25*(4), 521-540. doi:10.1007/s10798-014-9291-y

Kelley, T. & Knowles, J. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(11), 1-11. DOI 10.1186/s40594-016-0046-z

Knowles, J.G., Kelley, T. & Hurd, B. (September, 2016). Innovate the intersection of entomology and technology. *Technology & Engineering Teacher, 76*(1), 1-7.

Merriam, S. B. (2001). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass.

National Academies Press. (2010). *Rising above the gathering storm, revisited: Rapidly approaching category 5*. Washington DC: National Academies Press.

National Academies Press. (2011). *Expanding underrepresented minority participation: American's science and technology talent at the crossroads*. Washington DC: National Academies Press.

National Center on Education and the Economy. (2006). *Tough choices or tough times: The report on the new commission on the skills of the American workforce*. Hoboken, NJ: Jossey-Bass.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common core state standards for mathematics.* Washington, DC: Authors.

National Research Council (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. Washington, DC: National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press.

President's Council of Advisors on Science and Technology (PCAST). (2010). *Prepare and inspire: K–12 education in science, technology, engineering, and math (stem) for America's future*. Washington, DC: Author.

Riggs, I. & Enochs, L. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74*(6), 625-637.

Sanders, M. (2009). STEM, STEM education, STEMmania. *The Technology Teacher, 68*(4). 20-26.

Shadish, W., Cook, T., & Campbell, D. (2002). *Experimental and quasi-experimental designs for generalized causal inference.* New York: Houghton Mifflin Company.

Sipple, J. W., & Brent, B. O. (2008). Challenges and opportunities associated with rural school settings. In H. F. Ladd & E. B. Fiske (Eds.), *Handbook of research in education finance and policy* (pp. 612–629). New York: Routledge.

Tao H., Purzer, S., & Cardella M. (2011). A psychometric re-evaluation of the design, engineering and technology (DET) survey. *Journal of Engineering Education, 100*(4), 800-818.

United States Department of Education (2010). *Transforming American education: Learning powered by technology*. Washington, DC: Office of Educational Technology, United States Department of Education.

Wang, H, Moore, T.J., Roehrig, G.H., & Park, M.S. (2011). STEM integration: teacher perceptions and practice. *Journal of Pre-College Engineering Education Research, 1*(2), 1-13. doi:10.5703/1288284314636

Elements of this paper are supported by the National Science Foundation, award #DRL-1513248. Any opinions and findings expressed in this material are the authors and do not necessarily reflect the views of NSF.