Enhancing the Levels of Complex Reasoning Used by Pre-Elementary Education Majors Engaging in Technology-Enhanced Scientific Practices

Summary of Original Proposal
Gayle Buck (Curriculum & Instruction)

The purpose of this action research study is to enhance our understanding of how to improve pre-education majors’ practices associated with data interpretation, scientific explanations, and scientific argumentation through the use of current educational technologies. The context of the study is Q200: Introduction to Scientific Inquiry. This lab-based science course is a requirement for all pre-education majors. We will revise, implement, and study a series of four inquiry-based labs over the course of one semester. Each lab, occurring over 2-4 class sessions, will incorporate interfaces, computer software, and sensors. This technology will be used to support data collection and analysis during inquiry and facilitate students’ interpretations of complex data sets, while developing scientific explanations and argumentation. This study of the re-conceptualization efforts will be guided by three research questions:

1) To what extent do our course re-conceptualization efforts lead to broader and more specific understandings of and skills in data interpretation, explanation, and argumentation?
2) What categories of complex reasoning were displayed in the students’ interpretations of data collected during technology-enhanced inquiry?
3) In what ways did the strategies utilized in the re-conceptualized course foster or hinder students’ levels of complex reasoning during data interpretation, explanation, and argumentation?

As participant observers, we will collect data by being actively involved in developing the curriculum and participating in the process of teaching and learning. Data sources will include pre- and post-course questionnaires, assessments, planning meeting transcripts, course documents, pre-education majors’ group interviews, field notes from the course, complex reasoning scores, and videotaped classroom observations. An ongoing and iterative evaluation of data will occur simultaneously with research. After the data collection is complete, cumulative data will be analyzed.
This study will yield implications for revising this multi-section course, inform our elementary teacher education program, and contribute to the field of science teacher education.
Scholarship of Teaching and Learning Grants

Title: Enhancing the Levels of Complex Reasoning Used by Pre-Elementary Education Majors Engaging in Technology-Enhanced Scientific Practices

Investigator: Gayle A. Buck
Professor, Science Education

Department: Curriculum and Instruction

Email: gabuck@indiana.edu

Funding Level: Phase I, $2,000

Duration: January 1, 2015-August, 31, 2015
Abstract: The purpose of this action research study is to enhance our understanding of how to improve pre-education majors’ practices associated with data interpretation, scientific explanations and scientific argumentation through the use of current educational technologies. The context of the study is Q200: Introduction to Scientific Inquiry. This lab-based science course is a requirement for all pre-education majors. We will revise, implement and study a series of four inquiry-based labs over the course of one semester. Each lab, occurring over 2-4 class sessions, will incorporate interfaces, computer software, and sensors. This technology will be used to support data collection and analysis during inquiry and facilitate students’ interpretations of complex data sets, while developing scientific explanations and argumentation. This study of the re-conceptualization efforts will be guided by two research questions: 1) To what extent does our course re-conceptualization efforts lead to broader and more specific understandings of and skills in data interpretation, explanation and argumentation? 2) What categories of complex reasoning were displayed in the students’ interpretations of data collected during technology-enhanced inquiry? 3) In what ways did the strategies utilized in the re-conceptualized course foster or hinder students’ levels of complex reasoning during data interpretation, explanation and argumentation? As participant observers, we will collect data by being actively involved in developing the curriculum and participating in the process of teaching and learning. Data sources will include pre- and post-course questionnaires, assessments, planning meeting transcripts, course documents, pre-education majors’ group interviews, field notes from the course, complex reasoning scores, and videotaped classroom observations. An ongoing and iterative evaluation of data will occur simultaneously with research. After the data collection is complete, cumulative data will be analyzed. This study will yield implications for revising this multi-section course, inform our elementary teacher education program, and contribute to the field of science teacher education.
Scientific practices are used to establish, extend and refine our current understandings of the world. Engaging in these practices helps my students, pre-education majors, to understand scientific knowledge and how it develops, makes that knowledge more meaningful, embeds it more deeply into their worldview, and helps them understand the instructional approaches they will ultimately be expected to use. The Framework for K-12 Science Education (National Research Council, 2012), the structure guiding the development of the science standards for K-12 schools, lists seven practices that all students should have the opportunity to experience. These include (1) asking questions and defining problems, (2) developing and using models, (3) planning and carrying out investigations, (4) analyzing and interpreting data, (5) using mathematics, information and computer technology, and computational thinking, (6) constructing explanations and designing solutions, and (7) engaging in argumentation from evidence. Unfortunately, in many K-12 classrooms these practices are still not a reality (Dolan & Grady, 2010) due, in part, to the fact that implicit understandings of science and science education often engender pedagogical approaches that do not promote student ownership for science learning or the development of the necessary complex reasoning skills (Songer, Lee & Kam, 2002). In order for my students to become teachers that are able to scaffold experiences with data interpretation and analysis, constructing scientific explanations and engaging in argumentation for students, they need to experience these practices for themselves. Drawing from the idea that these practices are socially constructed, Roth, McGinn, & Bowen (1998) suggested that science teacher educators need to create opportunities for inservice and pre-service teachers to participate in the practices of science, rather than treat them as skills that are inherent human practice.

Technological tools such as interfaces (e.g., LabQuest2), computer software (e.g., Inspire & TI Navigator), and sensors (e.g., Voltage Probe, Light Sensor, Go!Motion) are becoming essential resources for creating meaningful learning experiences for pre-education majors in science. These tools allow them to examine scientific phenomena in timely, efficient and precise ways through bypassing the tedium of collecting data via outdated means (e.g., pH sensor vs. pH test strips) and manually producing diagrams and graphs from the data they collect; thereby allowing the students to focus on the concepts that are explained and supported by data. These resources tend to provide the necessary support for inquiry-based learning approaches as they afford experiences involving collecting, transforming, interpreting and analyzing data, and drawing conclusions based on that data. Over the last decade, the conditions for successful technology integration in the classroom have improved significantly yet high-level technology use is still quite low (Ertmer, 2005).

In my role as course coordinator for Q200: Introduction to Scientific Inquiry, I started to align the course curriculum with the new science education reform documents. I secured six interfaces and several probes and we (the associate instructors and myself) added activities on scientific practices. The electronic devices made it easier for us to organize components of the activity and collect authentic scientific data. However, as we tried to go back and incorporate these isolated activities into the overall structure of the Q200 classroom, we found that they ended up looking much more like the traditional approach and the complex reasoning aspects were lost. There is a mismatch between what the technology allowed us to “see”, the scientific practices asked us to “do” and the overall course structure (linear steps with emphasis on rote memorization). This alignment requires more than just adding updated lessons, it is going to take re-conceptualizing the entire structure of the course. This action research study, the first phase of this process, is designed to enhance our understanding of how to improve our students’ (pre-elementary education majors) practices associated with data interpretation, scientific explanations and scientific argumentation through the use of current educational technologies. The findings will be used to inform the restructuring process. This study will be guided by two research questions:

(1) To what extent did course re-conceptualization efforts lead to broader and more specific understandings of and skills in data interpretation, explanation and argumentation?

(2) What categories of complex reasoning were displayed in the students’ interpretations of data collected during technology-enhanced inquiry?
a. Did the categories of complex reasoning change over subsequent encounters? If so, how?

(3) In what ways did the strategies utilized in the re-conceptualized course foster or hinder students’ levels of complex reasoning during data interpretation, explanation and argumentation?

**Background**

**Scientific Practices.** This idea has emerged from attempts to develop an understanding of science as a form of inquiry that many believed was hampered by a level of ambiguity that resulted from divergent pedagogical objectives (1). Scientific practices are used to establish, extend and refine our current understandings of the world. Engaging in these practices helps students to understand how scientific knowledge develops, makes that knowledge more meaningful, and embeds it more deeply into their world view (National Research Council, 2012). The Framework for K-12 Science Education that is guiding the development of the National Common Core Science Standards (1) lists seven practices that all children should have the opportunity to experience (noted above). Research has shown that while these practices may be implicitly targeted in everyday science instruction, students often miss them. We know that it is important to explicitly draw out and direct students’ attention to the ideas and help them challenge any misconceptions (6). In this course we target the scientific practices of (a) investigation, (b) data analysis and interpretation, (c) explanation, and (d) argumentation. **Scientific investigations** involve formulating an investigable question; deciding what data are to be gathered; identifying the tools needed to gather that data and determining how measurements will be recorded; planning experimental or field-research procedures; identifying variables; **analyzing data** to look for patterns or to test whether data are consistent with an initial hypothesis, using analytical tools such as spreadsheets, databases, graphs, charts to explore relationships and display results; evaluating the strength of a conclusion using grade-level mathematics and statistical techniques; and distinguishing between causal and correlational relationships. **Scientific explanation** involves constructing explanations of phenomenon using knowledge of accepted scientific theory and linking it to models and evidence; using primary and secondary evidence to support or refute an explanation; offering causal explanations based on scientific knowledge; and identifying the gaps or weaknesses in explanatory accounts. A sound scientific explanation is used to construct scientific arguments. This involves constructing an argument that includes claims, data, and reasons; using reasoning and evidence to evaluate arguments; and strengthening arguments based on criticisms (National Research Council, 2005). In our course, pre-education majors’ understandings about and skills in these scientific practices are explicitly addressed and contextualized in sustainability science units.

**Technology-enhanced Inquiry:** Technology-enhanced inquiry has been used to help students develop fluency with emerging technological tools, promote reasoning skills and develop deeper understanding of science and math concepts. Linn (2003) described important trends with regard to the use of technology in science education in the past few decades. She found that technologies have become more tailored to specific topics, audiences, and disciplines and these technologies have become more customizable to suit particular users. Linn contended that with improvements to curricular programs that incorporate data collection technologies, students’ performance and experiences also improve exponentially. Many data collection technologies used in contemporary science and mathematics education are relatively inexpensive compared to their predecessors (Kwon, 2002). As a result, these technologies are more promising for implementation in schools. Furthermore, data collection technologies tend to be better tailored to classroom use than computers, which in turn influences the ways in which these technologies can be incorporated into instruction (Krajcik, Marx, Blumenfeld, Soloway, & Fishman, 2000). Two consistent themes have emerged from the educational research related to students’ use of technology. First, nearly all studies reveal the benefit of “real-time” data collection and analysis with regard to students’ learning. Specifically, such technologies afford rapid, efficient graphical representation of data related to the physical phenomenon under investigation. Second, owing to the usage of technology such as interfaces and probeware, some of the burden of the technical/procedural aspects of computational tasks is removed. As a result, students have more time to consider the meaning and relationship of data to the phenomenon, thus they have the capacity to develop deeper, more connected science conceptions. As Kastberg and Leatham (2005) cautioned, however, simply having access to data collection technologies does not necessarily mean those technologies are being used effectively in classroom instruction.
Despite its ubiquity and large-scale implementation in classrooms, the role of data collection technologies such as probeware on students’ learning is not well studied. Only a few studies, which have focused on pre-service and in-service teachers, have been conducted (Gado & Ferguson, 2006; Lyublinskaya & Zhou, 2008; Espinoza, 2006-2007). Overall, the results of these studies are mixed. Some have indicated increased self-efficacy and competency among teachers for implementing these technologies in classrooms, while others have not. Doerr & Zangor (2000) found as teachers became more comfortable with the technology, they became more flexible in their use of calculators, which resulted in more active student engagement during instruction. In our course, we have incorporated the use of technological tools such as interfaces (e.g., LabQuest2), computer software (e.g., Inspire & TI Navigator), and sensors (e.g., Voltage Probe, Light Sensor, Go!Motion). We plan to study how we are not fostering the pre-education students’ self-efficacy and competence as they use this technology to carry-out scientific practices.

**Data Interpretation and Complex Reasoning.** Complex reasoning is the ability to analyze and interpret empirical data and formulate explanations from evidence (Songer & Gotwals, 2004). Complex reasoning differs from declarative knowledge in that complex reasoning requires students to understand the connections of claims and evidence to underlying science concepts (Songer, 2000). Complex reasoning is most effectively developed in the context of authentic science inquiry, where students can build explanations from data as well as develop an understanding of underlying science concepts (Chinn & Malhotra, 2002). With regard to data analysis and interpretation, the majority of science education studies have focused on understanding how to better support students’ skill development in data-related science practices (Bowen & Roth, 2003; Bowen & Roth, 2005; Bencze & Bowen, 2007). Roth et al. (1998) found that students’ graphic representations became increasingly elaborate over the course of 10 weeks, with increasing inquiry-based experiences and as the data they collected cascaded. Roth (1996) sought to understand the role the open-inquiry context takes among students who did not participate in field studies. Both field study and non-field study groups were presented with similar storyed database word problems. The non-field study groups had a less difficult time completing the word problems, but the field studies group was far more capable of producing defensible arguments. Wu and Krajcik (2006) used a case study to characterize the inscriptive practices of students, particularly their use of data tables and graphs, during an 8-month instructional unit. They found teacher scaffolding was critical for students in learning how to collect data, construct graphs, and interpret data.

In sum, educational research has demonstrated that the more students engage in their own, open-ended inquiry investigations, the more capable they will become in regards to developing sophisticated data collection, inscription, and analysis skills. Also, opportunities to collaborate and discuss are critical to the development of skills related to data inscription and interpretation.

**Methodology**

**Action Research:** This proposed research study is rooted in our desire to improve our efforts at enhancing non-science majors’ understandings of scientific practices. We will complete an action research study that will focus on our efforts to re-conceptualize one science course. Action research is pragmatic social science conducted in collaboration among researchers and practitioners in efforts to enact solutions to problems deemed important by the local community (Levin & Greenwood, 1998). As pragmatic research, it involves knowledge generation through action and experimentation. Our research incorporates the necessary characteristics of pragmatic action research as described by Levin & Greenwood (1998, 2002). The process is context-bound and addresses real-life problems. It involves collaborative communicative processes in which all researchers/practitioners’ contributions will be taken seriously; the diversity of experiences and capacities within our group will be considered an opportunity for enrichment of the action research process.

**The Course and Students:** There are on average 8-10 sections of *Q200: Introduction to Scientific Inquiry* in the fall semesters and 5-6 in the spring semesters. The majority of the students in this course are freshmen. Although some of the students are from non-science majors, such as family sciences, the majority are pre-education majors. The action research team will include myself and two doctoral students with responsibilities associated with the course. In addition to coordinating the course, I am the instructor for one of the sections each semester. This exploration, however, will focus on the doctoral students’ sections during the spring
semester. I will serve as the primary researcher but not the primary instructor. As this is a pragmatic action research study, all Q200 students in two sections of the course (n=48) will also be given the opportunity to take part in the study.

**Plan of Action:** The action research team will revise, implement and study a series of four inquiry-based labs over the course of one semester. Each lab, occurring over 2-4 class sessions, will incorporate interfaces (e.g., LabQuest2), computer software (e.g., Inspire & TI Navigator), and sensors (e.g., Voltage Probe, Light Sensor, Go!Motion) and Vernier probeware sensors. This technology will be used to support data collection and analysis during inquiry and facilitate students’ interpretations of complex data sets, while developing scientific explanations and argumentation. These practices will be designed to foster greater levels of complex reasoning as the series unfolds. Formative assessment prompts (Keeley, et al., 2005, p. 103) will be used to activate students’ background knowledge and frame the scientific reasoning. In all lessons, students will be asked to tabulate their data in tables, produce graphs to appropriately represent data, and apply their understanding of related science concepts during interpretation of data trends and inference to develop written scientific explanations. Writing prompts and classroom questioning by the teachers will guide students’ written interpretations.

**Data Collection and Analysis:** As participant observers (Patton, 1990) we will collect data by being actively involved in developing the curriculum and participating in the process of teaching and learning. Data sources will include pre- and post-course questionnaires, assessments (including current rubrics for argumentation and explanation), planning meeting transcripts, course documents, pre-education majors’ group interviews, field notes form the course, complex reasoning scores, and videotaped classroom observations. An ongoing and iterative evaluation of data will occur simultaneously with research. All research team members will review cumulative data from field notes, interviews, and course documents. I, as primary researcher, will remove any necessary identification and provide only cumulative data to the course instructors as per IRB requirements. Weekly planning meetings will allow us to identify approaches that are improving education outcomes for the students. During evaluation of classroom data and interviews, team members will discuss emergent themes, similarities and differences in interpretations, and future directions for improving and enhancing the course. This continuous analysis will become part of the field notes and, as such, become additional data to be analyzed in the completion of the project. After the data collection is complete, cumulative data will be analyzed. In addition to the student assessment data gathered throughout the semester, the research team will identify overarching themes in the data. We will collaboratively and recursively complete a thematic data analysis. The data will be re-analyzed until consensus about our interpretations of the data is reached.

**Future Development or Research**

The purpose of action research is to inform action. Action research is a process of inquiry that produces practical knowledge that is useful to our everyday life (Reason & Bradbury, 2002). The aim of this type of research is to improve our practice by using professional eyes to observe our own practice (Arhar, Holly, & Kasten, 2001). This study is focused on our practical understandings and designed in a manner that findings will inform those practices. The final part of this phase is to adjust our re-conceptualizing efforts.

Our past efforts with re-conceptualizing science teacher preparation and development have been very well received. We have presented at the annual conferences of the Association for Science Teacher Educators (ASTE), National Association for Research on Science Teaching (NARST), Hossier Association of Science Teachers, Inc (HASTI), as well as at the National Science Teachers Association’s (NSTA) STEM Forum & Expo, and have a manuscript in review for an NSTA journal *The Science Teacher*. I anticipate that the same audience will be interested in this subsequent exploration. In addition, I intend to complete long-term projects on the effort and I am interested in following this work into the methods courses, and ultimately K-8 classrooms to better understand how we are/are not preparing teachers to integrate technology-enhanced scientific practices into their classrooms.
References


PROPOSED BUDGET

Principal Investigator:
Gayle A. Buck

A. Salaries:
   1. 2 Graduate Assistants, wkly 3 hrs X 8 wks X $15/hr $ 720
   2. Hourly Support, 60 hrs X $10/hr transcription $ 600
      $1,320

B. Equipment:
   Probeware $ 500
   $ 500

B. Participant Support Costs:
   1. Stipends for 2 Student Focus Groups, 9 @ 1hrsX$10/hr $ 180
      $ 180

GRAND TOTAL: $2,000.

Personnel
The primary researcher is not requesting salary.

There will be two science education associate instructors on the action research team. The associate instructors (doctoral students in science education) will meet 8 times for approximately 3 hours each time. Salary is set at $10/hr.

Support for transcription is included. A graduate student will be hired to transcribe the focus-group interviews and weekly instructor meetings. Hourly help will be sought for 60 hours of transcription over the course of the project at $10 an hour.

Equipment
The additional activities will require additional Vernier probeware. This will be used with existing interfaces.

Stipends for Student Focus Groups
The budget includes $180.00 in stipends for a total of 9 students that take part in the focus-group interviews. Focus group interviews will be conducted on a pre- and post-intervention basis. The primary researcher will conduct the interviews. Students will receive $10.00 for each interview. The interviews will last no longer than 1 hour.
## Timeline for Phase I

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<tr>
<th>Project Component</th>
<th>Dates</th>
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<tr>
<td>Submit Human Subjects Application</td>
<td>December, 2014</td>
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<tr>
<td>Revise/Schedule Course Activities</td>
<td>January, 2015</td>
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<tr>
<td>Recruit Students for Focus Groups</td>
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<td>First Student Focus Group</td>
<td>January-February, 2015</td>
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<tr>
<td>Implement Course Activities/Collect Course Documents</td>
<td>February-May, 2015</td>
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<td>Weekly Meetings of Action Research Team</td>
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<tr>
<td>Data Analysis/Write up Results</td>
<td>August, 2015</td>
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<td>Revise Course Activities</td>
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GAYLE A. BUCK  
Indiana University  
Department of Curriculum & Instruction  
W.W. Wright Hall, Room 3068  
201 N. Rose Avenue  
Bloomington, IN 47405-1005  
(812) 856-8171  
gabuck@indiana.edu

EDUCATION:
Ph.D. (1998) Curriculum and Instruction: Concentration in Middle Level Education/Science Education  
Kent State University

Master of Arts (1993) Educational Studies: Science/Environmental Education  
The Ohio State University

Bachelor of Science in Education (1989) Elementary Education  
Youngstown State University

PROFESSIONAL APPOINTMENTS:
July 2014- Tenured Professor at Indiana University Bloomington  
Science and Environmental Education Program  
School of Education  
Department of Curriculum & Instruction

2006-2014 Tenured Associate Professor at Indiana University Bloomington  
Science and Environmental Education Program  
School of Education  
Department of Curriculum & Instruction

2004 –2006 Tenured Associate Professor of Science Education at University of Nebraska-Lincoln,  
College of Education & Human Sciences  
Department of Teaching, Learning, & Teacher Education

1998 - 2004 Tenure-Track Assistant Professor of Science Education at University of Nebraska Lincoln,  
Teachers College  
Center for Curriculum & Instruction

SELECT PUBLICATIONS:
Books, Book Chapters & Contributions:
Science Education, 98(4), 740-742.

Charlotte, NC: Information Age Publishing.


10 Refereed Journal Articles/Empirical Studies:


Buck, G., & Yin, X.* (2013, January). Fostering fundamental understandings about scientific inquiry and scientists at the undergraduate level. Paper presentation at International Conference for the Association of Science Teacher Educators, Charleston, SC.


SELECT PRESENTATIONS:
5 Refereed Paper Presentations:


Buck, G., & Yin, X.* (2013, January). Fostering fundamental understandings about scientific inquiry and scientists at the undergraduate level. Paper presentation at International Conference for the Association of Science Teacher Educators, Charleston, SC.

5 Refereed Presentations:


Buck, G. & Yin, X.* (March, 2012). Enhancing undergraduate students’ beliefs about scientific inquiry and scientists. Presentation at the national conference of the National Science Teachers Association, Indianapolis, IN.

5 GRANTS/CONTRACTS:


Collaborative Research: Conferences for Undergraduate Women in Science. Funded by the National Science Foundation (Division of Physics/Physics Education & Interdisciplinary Research): $64,345.00. [09/12/12-09/11/13]. Principal Investigator
One of seven involved in multi-institutional collaborative proposal.

Collaborative Research: Conferences for Undergraduate Women in Science. Funded by the National Science Foundation (Division of Physics/Physics Education & Interdisciplinary Research): $51,402.00. [11/1/11-10/31/12]. Principal Investigator
One of seven involved in multi-institutional collaborative proposal.


Friday, October 31, 2014

I am pleased to nominate Dr. Gayle Buck’s application for a Scholarship of Teaching and Learning Grant in support of her project, *Enhancing the Levels of Complex Reasoning used by Pre-Elementary Education Majors Engaging In Technology-Enhanced Scientific Practices*.

Dr. Buck seeks funding to initiate a major re-conceptualization of a pre-requisite course, Q200 *Introduction to Scientific Inquiry*, for pre-service elementary teachers (students seeking certification as general elementary classroom educators). It will provide the opportunity for students to engage with fundamental scientific practices and therefore to understand the nature of scientific thinking that is the foundation of science education for children and youth. Moreover, her proposal identifies the use of the most up-to-date technological tools that make it possible for students to engage deeply and effectively with key concepts and problems targeted by K-12 Science Education Standards. These kinds of experiences are critical for pre-service elementary teachers for a number of reasons, not the least of which is that many who enter elementary teacher education have minimal backgrounds in science and lack confidence in their abilities to teach it. The ever-growing need to promote the scientific thinking of future generations requires these kinds of concerted efforts right now.

Dr. Buck is exceedingly qualified to carry out this ambitious project. She has long coordinated the multiple sections of Q200 and its ongoing systematic evaluation and re-design has been a key focus for her research. Moreover she has been highly successful in obtaining a large number of grants in support of projects that deal both with research and professional teacher development. I have no doubt in her ability to manage and implement her proposed plan. SOTL funding will provide Dr. Buck with the opportunity to launch an innovative and carefully thought-out study with the potential to profoundly enhance scientific experiences for novice elementary teachers. She is a strong example of a researcher who has devoted a great deal of her career to work that falls within the realm of the Scholarship of Teaching. She offers an extremely strong proposal and I hope it will be carefully considered.

Sincerely,

Lara Lackey, Ph.D.

Chair, Department of Curriculum and Instruction

[lackey@indiana.edu](mailto:lackey@indiana.edu)

812-856-8150