Pre-service Elementary Teachers' Self-Efficacy and Understanding of Scientific Inquiry

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In this study we adopt a mixed method approach to research pre-service elementary teachers' self-efficacy and understanding of scientific inquiry. A survey was developed referencing the National Science Education Standards for Inquiry and previous work in the area. Two groups of elementary education students participated in the survey in two academic semesters. A semi-structured interview was conducted with a subset of the participants. Likert-scale survey results were analyzed statistically. Open ended survey responses and interview transcripts were coded qualitatively. Our ongoing goal is to compare results with those from an earlier study at the beginning of the 21st century. We hope to capture some evolutionary patterns in pre-service elementary teachers' understandings of scientific inquiry and generate implications to elementary science education, particularly concerning the evident shift away from an emphasis on usage of the term "scientific inquiry" in the Next Generation Science Standards.

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I. INTRODUCTION

Preservice elementary teachers' understanding of scientific inquiry is critical to determining the approach they use to teach elementary science, which in turn influences the next generation's understanding and potential practice in science. Teaching scientific inquiry appropriately then becomes a central feature in preservice teacher education.

Research has been done on in-service elementary teachers' knowledge about scientific inquiry [7-10] and interventions to improve pre-service elementary teachers' knowledge of scientific inquiry [11-16] but has not sufficiently addressed how pre-service elementary teachers understand scientific inquiry [6]. All the authors of the present paper have direct experience in either teaching or taking elementary science methods courses at the university level. In those courses, we noticed that preservice teachers' understandings of "scientific inquiry" varied in multiple different ways. These experiences motivated us to conduct a research study about preservice teachers' understanding of scientific inquiry to bridge the gap in the literature, and hence provide implications for curriculum design and pedagogy in science education.

K-12 physics education, especially at the elementary level, is blended in general science education. The nature of science, which is closely related to scientific inquiry, is one of the major topics of study in physics education research. The skill sets necessary to effectively engage in scientific inquiry must first be present in our preservice teachers if we hold the expectation that they will be able to educate future generations. Thus, it's important for our preservice teachers to feel confident in their ability to perform and teach such tasks. Our overarching research question for this project is: *What are pre-service teachers' understandings of scientific inquiry in relation to teaching elementary science?*

II. BACKGROUND

A. Scientific inquiry in the standards literature

Our working definition of scientific inquiry is adopted from the National Science Education Standards [2].

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

Prior to the adoption of Next Generation Science Standards (NGSS) [1], scientific inquiry was explicitly defined in the National Science Education Standards written by the National Research Council (NRC) [2, 3]. According to Surr et al.'s analysis [4], the term "scientific inquiry" originated in the NRC standards as its own individual category. It was later absent in the NGSS standards based on the argument that scientific inquiry should be embedded in all of the content standards. This decision was also based on an observation of varying definitions of scientific inquiry, which aligns with our field observation. While the removal the term "scientific inquiry" is understandable, it does pose the question of whether changing the language actually accomplishes clarity, considering the expectation is still to successfully teach and implement scientific inquiry. One may wonder if a clear, universal definition of scientific inquiry could have provided said clarity.

There is a presumptive link between self-efficacy and understanding. While the terms are not used interchangeably, they do support each other. If pre-service teachers understand a concept, then they are more likely to demonstrate self-efficacy, and vice versa. By assessing pre-service elementary teachers' self-efficacy and understanding of the skillsets required to successfully complete the tasks related to scientific inquiry, our hope is to identify any language confusion or barriers in terms of scientific inquiry. Our Likert-scale question items were designed to directly adopt the language in the NRC standards [3] for grades k-4. It allows us to gauge preservice teachers' self-efficacy on the aspects of scientific inquiry when the term scientific inquiry is removed from the currently adopted national standards [1]. Our free response questions, on the other hand, allow us to externalize pre-service teachers' cognitive configurations (i.e., their understandings) of scientific inquiry as a coined term, when the meaning of the it is not explicitly stipulated in the standards nowadays.

B. Existing research on preservice teachers' understandings of scientific inquiry

In some related research studies, different observations and interpretations were made about preservice teachers' ideas of scientific inquiry. For example, Burgess [5] identified a lack of data sense knowledge in preservice teachers, finding that preservice teachers did not interact with sets of data in a way that the researchers had hoped. This claim leads us to wonder if the assessment of the preservice teachers would accurately align with their actual performance of these tasks. Additionally, in their research study, Varma et al. [6] highlight the role of inquiry-based classroom experiences and field experiences in preparing elementary science teachers at a university-level education program. Varma et al.'s work leads us to wonder whether preservice teachers' high levels of self-efficacy reported in the results could be a reflection of their pre-service teacher preparation program.

C. Our study

Based on existing literature and our overarching research question, we adopted mixed methods collecting quantitative and qualitative data of preservice teachers' self-efficacy and understanding of aspects of scientific inquiry as well as the terms as a totality. The data set contains Likert-scale question choices, texts, and drawings. These instruments allow us to collect data and perform analyses to generate statistical descriptions of the quantitative scores and to categorize the quality of preservice teachers' understanding of scientific inquiry.

Due to the small sample size so far, our statistical analysis is preliminary. The qualitative data is more cogent, but still at an early stage. Therefore, our focus in this paper is to answer the following sub-questions embedded in our overarching research question:

(1) How do elementary preservice teachers rate their self-efficacy with regard to performing scientific inquiry?
(2) What are some textual and visual features demonstrated when preservice teachers are prompted to describe and show their understanding of scientific inquiry?

III. METHODOLOGY

A. Research Design

Our mixed-method approach includes 11 Likert-scale survey questions, two open-ended survey questions, and a follow up semi-structured interview.

The Likert-scale questionnaire was created by adapting the national standards of science inquiry [3] for grades k-4. Each question asks the participant of their confidence level, in the context of teaching elementary science, regarding a specific aspect of scientific inquiry laid out in the national standards. The key language was designed to stick to the language used in the NRC standards.

Question 1: I am confident that I can ask questions about science and scientific ideas that would be appropriate for an elementary teacher.

□ Strongly agree □ Agree □ Neutral □ Disagree □ Strongly disagree

As shown above, Question 1 asks the participant's confidence level of "asking questions." Other aspects of scientific inquiry were asked in the Likert-scale questions 2-11, summarized below.

Q2: planning and conducting an investigation
Q3: Using equipment to gather data
Q4: Using data to construct explanation
Q5: Communicating and explaining
Q6: Comparing answers
Q7: Using different kinds of investigation
Q8: Using simple instruments
Q9: Developing explanations
Q10: Publishing
Q11: Reviewing peer's research

Question 12 asked the participant if they are willing to do a follow-up interview with us. Choices of "yes" and "no" were offered. Question 13 and 14 later were only added after Group 1 data collection.

Q13: In 140 words, describe what scientific inquiry is.
Q14: Show me what scientific inquiry is.

The textual and pictorial representation prompts were designed to elicit different aspects of pre-service teachers' thinking. These two questions were originally only included in the follow-up interview protocol (they were not part of the survey). After we conducted the survey and interview with Group 1, we found the interviewee's answers to the two open-ended questions gave us valuable and unique data addressing how the participant understood scientific inquiry. But we only had one student agreed to interview, out of the eight students who took the survey. We therefore added those two questions to the survey for future data collection so that we can collect data of this kind from more participants.

Interview protocol was designed to be semi-structural, primarily allowing the participant to elaborate their response to the survey questions.

B. Participants and Context

Participants in this study were students enrolled in the elementary science methods courses offered at a primarily undergraduate institution (PUI) on both the main campus and one satellite campus. These students were preservice teachers working towards a degree in elementary education and obtaining state certification to teach in elementary schools after graduation. In order to enroll in the elementary science methods course, students must be formally admitted to the teacher education program at the university. Particular prerequisite courses include diversity and social justice in education, psychology of human growth and development, and educational psychology and assessment.

The university is an accredited regional institution of higher education. The participants in this study include undergraduate students enrolled in either the traditional Day program or an online and evening program for non-traditional students. The course sections utilized in this study are taught using a seated format. The elementary science methods course is a three-credit hour course described as follows in the university catalog: basic principles and new trends of instruction and curriculum development in elementary school science. Unit planning, laboratory activities, evaluation strategies and science learning centers are emphasized.

C. Data Collection

We submitted our research proposal and materials to IRB and received approval. We recruited participants from students who were then taking the elementary science method class at the university. Data were collected after halfway through the semester while the students were in that

course. The instructor read the recruitment letter to the class and distributed the consent form and the printed survey questionnaire. There was also an online version of the survey for students who chose to complete it at a different time. Students signed their consent forms and filled out the survey (or they opted out). The consent form and survey copies were collected and sealed.

As of the day that this paper is prepared, we have collected survey entries from 35 participants in two consecutive academic years through four consecutive semesters. Fourteen participants were from the first year and 21 students were from the second year. Among the total 35 students, six agreed to participate in the follow-up interview. Two interviews were conducted, one over Zoom and one face-to-face.

D. Data Analysis

We performed preliminary analysis on the Likert-scale survey questions 1-11. We assigned numerical scores (1-5) to the verbiage answer choices (1 corresponds to strongly disagree and 5 corresponds to strongly agree). At this stage, we yielded average score of each question and of the total score. We also calculated other relevant quantities such as standard deviations, ranges, and percentages of the choices.

For open-ended questions, we designed two rounds of coding [17] on the answers. The first round is emergent coding to capture any initial "themes" in participants' responses [18]. For example, a participant can describe scientific inquiry as a "process." Or, they can describe it as an "ability." Later in this paper we will report preliminary results from this round of coding on the 14 participants from the first year.

The second round is a finer, structured coding applying the national standards [3], therefore also in line with our survey questions 1-11. For example, in an open-ended question response, we may identify words or drawings that demonstrate the participant's understanding of scientific inquiry as involving "asking a question" or "planning and conducting a scientific investigation." Our current paper does not include results from this round of coding, due to the limited space.

One author conducted the coding. The other two authors reviewed the codes. The three authors discussed and reached consensus after discussion. Previous results have also been presented at a conference to receive feedback. Rigorous inter-rater reliability check will be conducted when the data size is appropriate for that.

Interview recordings were transcribed and coded in a similar manner to the qualitative analysis on the open-ended question answers. Any new information the interviewee brought to the interview that had not been captured in their written answers would be noted in our analysis.

In this paper, we present analyses of the 14 students from the first year. Eight were in Group 1 taking the science methods class (ten students in total) in the fall semester. Six in Group 2 taking the class (18 students in total) in the following spring semester. The two groups were taught by different instructors on different campus. Their survey questionnaires have different items (Q13 and Q14 were not in the Group 1 survey). The first 11 questions are also worded slightly differently due to revisions based on what we learned from the interview with a student from Group 1.

IV. RESULTS

We present initial statistical results of the Likert-scale questions and the first round of coding (i.e., identifying initial emergent themes) on the two groups of students' open-ended question answers. Further analyses and results will be reported in future papers.

A. Preservice teachers' self-efficacy

Table 1. Average scores of Likert-scale questions

Participants (Number of students)	Average score overall	Lowest avg. score questions	Highest avg. score questions
Group 1 (8)	4.10	3.88 (Q3, Q7)	4.38 (Q4)
Group 2 (6)	4.20	3.83 (Q10)	4.50 (Q8)
Overall (14)	4.14	3.93 (Q10)	4.36 (Q8)

The table above shows the participants' average response for all of the Likert-scale items, in addition to the highest and lowest averages amongst the test items. Participants are broken into "Group 1" and "Group 2" in this table, representing participants that engaged in the study during the first semester and second semester respectively. The small sample size in this study is a limitation at this stage and has impacted the analysis of the data. We intend to conduct more appropriate data analyses with a larger sample size in the future.

Overall, the 14 participants gave an average score of 4.14 (out of 5) when examining all of the Likert-scale items. This high average response suggests a high level of comfortability in performing tasks necessary to teach the skills stated in the NRC standards [3].

The identification of the Likert scale test items with the highest and lowest averages is significant in that it allows us to identify areas of high and low self-efficacy amongst participants. Group 1 demonstrated their lowest average of 3.88 on questions 3 and 7, which assessed their comfortability in *using equipment to gather data* and *using different kinds of investigation*. Group 2 demonstrated their lowest average of 3.83 on question 10, which assessed their comfortability with *publishing*. Considering the average academic experiences and achievements for students at the undergraduate level can help explain the lower average on question 10.

Group 1 demonstrated their highest average of 4.38 on question 4, which assessed their comfortability *using data to*

construct an explanation. Group 2 demonstrated their highest average of 4.50 on question 8, which assessed their comfort level *using simple instruments*. Again, considering the frequency of the use of simple instruments throughout K-12 education and the undergraduate level can help explain the higher average on question 8. More data will be collected to either confirm these hypotheses or provide new information.

B. Textual and visual features

Among the 14 students, we received textual entries from seven students, one from the first group and six from the second group. Because the numbers are small, we are not focusing on the frequency of appearance of a certain textual feature. Rather, we are focusing on "what" features emerged from the data that can potentially be codified to analyze larger amount of data. From those seven textual entries, we have identified four preliminary emergent themes of two categories—what scientific inquiry is and who does it—that could be used for future coding, shown below.

What it is—a process

S2: The process of researching and answering questions in the scientific field of study through the use of experiments and data collection.

What it is—an ability

S10: Scientific inquiry is the ability to investigate a topic, ask questions, conduct an experiment, record your data, and reach a conclusion that answers the questions established at the beginning.

Who does this—a generic person (you)

S9: Scientific inquiry is when you conduct a scientific question. You then will form a scientific hypothesis for your questions. After you have your hypothesis, conduct your experiment then collect and write down your data so that you can draw a conclusion. Share your results and then repeat the "Circle".

Who do this—scientists

S11: Scientific inquiry is how scientists study and research our world and its components. It is the process in which an individual can explain their research and findings.

Among the same 14 students, we received representational entries from the same seven students for Question 14. Upon examining these representational drawings, we attempted to identify emerging themes, and were able to categorize them into the following three categories.

Data-centered–Responses falling in the data-centered category display various elements of experiments. For example, responses in this category display tables, charts, and measuring tools that are used for experimental purposes, amongst other things. Compared to the other categories, this category is unique in that the responses do not attempt to address specific steps within scientific inquiry.

Cyclic–Responses falling in the cyclic category display steps of scientific inquiry as a cyclic process. Responses in this category label elements of scientific inquiry and place them in a circle with arrows, showing each element connecting and feeding in the others. Steps of scientific inquiry as displayed in these responses included things like asking a question, research the topic, hypothesis, experiment, collect data, conclusion, etc.

Linear—Responses in the linear category are similar to those in the cyclic in that they display steps of scientific inquiry. Nonetheless, these responses are unique in that the steps are displayed in a one-direction manner that has a beginning and an end, seemingly indicating a specific order, as opposed to a cycle. These responses showed corresponding steps to the cyclic responses, however, and they appear in both drawings and words (See Figure1).

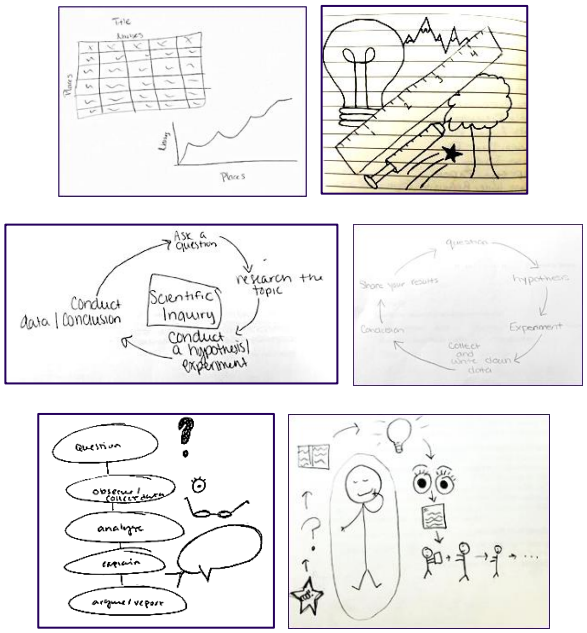

Figure 1. top: data-centered; middle: cyclic; bottom: linear

V. DISCUSSION AND FUTURE WORK

Preliminary analysis on the limited number of responses has allowed the generation of these three broad categories of representational responses. The authors hope to refine the current categories, and perhaps, increase the number of categories based upon continuing research with increasing numbers of responses.

The most promising part of this research to date has been the inclusion of textual and representational features. These features should be explored further during subsequent semi-structured interviews. The researchers plan to continue collecting quantitative and qualitative data in order to further sharpen their theory concerning preservice teachers' understanding of scientific inquiry.

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