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ABSTRACT

According to the National Science Education Standards, Standard A states that science students must have the abilities and understandings necessary to do scientific inquiry. The Standards explicitly state that small groups of students should hypothesize from prior experiences, construct explanations, evaluate explanations, design investigations, conduct experiments, gather data, analyze data, conduct peer reviews, communicate arguments, and reflect on the inquiry process. The student should be involved in at least one major investigation in which the student frames the question, designs the approach, estimates the time and cost, calibrates the instruments, conducts trial runs, writes the report, and responds to criticism. In order to successfully instruct students, the teacher also needs to be sufficient in research design. By apprenticing a preservice science teacher with a scientist, the teacher will experience doing real science. This study follows one such program and evaluated the participant's interview transcript, laboratory journal, and reflective summary to examine the participant's experience. Approximately one year after the apprenticeship experience, the researchers performed a short interview of the participants. The purpose of the study was to determine if there was transference of the apprenticeship experience into the classroom setting during the internship year. (Contains 15 references.) (MVL)

PRESERVICE SECONDARY SCIENCE TEACHER APPRENTICESHIP EXPERIENCE WITH SCIENTISTS

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Theoretical Framework

According to the *National Science Education Standards* (National Research Council, 1996), Standard A states that science students must have the abilities and understandings necessary to do scientific inquiry. The standards explicitly state that small groups of students should hypothesize from prior experiences, construct explanations, evaluate explanations, design investigations, conduct experiments, gather data, analyze data, conduct peer reviews, communicate arguments, and reflect on the inquiry process.

Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) describe inquiry in detail stating that students who participate in authentic scientific investigations have a reasonably accurate picture of inquiry in real science. The *Benchmarks* state kindergarten students should be involved in exploring phenomena. With advancement to the higher grades, students should be involved in hypothesizing, investigating, data collecting, data manipulating and presenting. The *Benchmarks* ambitiously affirm that the students should be involved in at least one major investigation, where the student frames the question, designs the approach, estimates the time and cost, calibrates the instruments, conducts trial runs, writes the report and responds to criticism. If the student participates in "progressively approximate good science, the picture they come away with will likely be reasonably accurate"(AAAS, 1993).

At the state level, states have incorporated inquiry into their teacher preparation standards. For example, Tennessee Teacher Licensure Standards state that the preservice teacher must have the knowledge and skills to accomplish the following: "demonstrate processes of science such as posing questions, observing, investigating phenomena, interpreting findings, communicating results and making judgments based on evidence and design" and "conduct inquiry-based, open-ended investigations" (p. 8-1, State of Tennessee State Board of Education, 1997). Additionally, as of September 1, 2001, Tennessee licensure guidelines dictate that all preservice science teachers will engage in an open-ended inquiry of long-term duration within their major. (p. 8-7, State of Tennessee State Board of Education, 1997).

At the national level, the National Science Teachers Association, NSTA, in association with the National Council for Accreditation of Teacher Education, NCATE, require the following standards for pre-service science teacher preparation:

- *1.1.1.C* Conducts limited but original research in science, demonstrating the ability to design and conduct open-ended investigations and report results in the context of one or more science disciplines (p. 2)
- *3.1.1.A* Plans and implements data-based activities requiring students to reflect upon their findings, make inferences, and link new ideas to preexisting knowledge (p.13)
- *3.1.1.B* Plans and implements activities with different structures for inquiry including inductive (exploratory), correlational and deductive (experimental) studies (p.13)

- *3.1.1.C* Uses questions to encourage inquiry and probe for divergent student responses, encouraging student questions and responding with questions when appropriate (p. 13) (NSTA/NCATE,1998).

Additionally, two National Science Education Teaching Standards address inquiry explicitly. Standard D states that teachers should "structure the time available so that students are able to engage in extended investigations and create a setting for student work that is flexible and supportive of science inquiry;" while, Standard E states that teachers should "model and emphasize the skills, attitudes, and values of scientific inquiry" (National Research Council, 2001).

In order for science teachers to facilitate student inquiry efforts, teachers must be able to perform investigative experiments utilizing appropriate sample size, controls, duplicates, data collection and scientific writing. To equip teachers with such an experience, teacher preparation programs are implementing various strategies for obtaining inquiry methodologies. An entire strand, Strand 4 Teacher Education, is devoted to science teacher preparation reform from the National Association for Research in Science Teaching (NARST) presentations (NARST, 2001). The strand presentation, conducted March 2001 in St. Louis, included various session titles with the following key words: inquiry-based science, authentic science, teacher preparation reform, and constructivist science. These key concepts, as defined by researchers in the field of science education, explicitly address the implementation of an authentic inquiry classroom environment required by the National Science Education Standard A. Some titles from the NARST Strand 4 presentations are:

- Teachers Learning About Nature of Science in *Authentic Science Contexts: Models of Inquiry* and Reflection (p. 53)
- Teachers' Beliefs About, Perceived Implementation of, and Demonstrated Classroom Use of *Science Reform Principles* (p. 44)
- Arizona Collaborative for Excellence in the Preparation of Teachers: The *Reform of the Professional Preparation of Science Teachers* (p. 83)
- Improving the *Connection* Between Pre-Service and In-Service Teacher Education (p. 67)
- *Inquiry in Scientific Communities* and Teachers' Perspectives on that Inquiry (p. 93)
- Narrowing the Theory-Practice Gap: First Year Science Teachers Emerging From a *Constructivist Science Education Program* (p. 67)
- Learning to *Do Research*: Struggles to Develop Causal Questions (p. 40)
- *Understanding and Teaching Scientific Inquiry*: An Evaluation Study of a Statewide Professional Development Program (p. 40)
- *Bridging Classroom Inquiry and Preservice Preparation*: Using Multiple Representations to Teach Mathematics and Science (p. 40)
- The *Use of Open Inquiry Projects in Science Methods Courses*: Implications for Subsequent Classroom Practice (p. 40)
- Toward *Inquiry-Centered Science Teaching and Learning*: Classroom Research Into an Elementary Science Methods Course (p. 75) (NARST, 2001).

The previous titles are based on educational reform of science teacher preparation; the researchers presented the reform method implemented at their particular university or institution. Some research is the implemented idea only; while, some research includes statistical data on the effectiveness of a particular methodological approach. The science teacher preparation methods varied from implementations in the methods courses, to the science courses, to the K-12 schools. The goal of the varied reform implementations is to provide preservice teachers the skills and experiences to effectively utilize a constructivist inquiry–based approach in a K-12 setting.

The Science for All Americans (1990) text, coinciding with the Project 2061 Benchmarks, explicitly defines the scientific world view, scientific methods of inquiry and the nature of the scientific enterprise. The authors state that

> scientists share certain basic beliefs and attitudes about what they do and how they view their work. These have to do with the nature of the world and what can be learned about it . . . Scientific inquiry is not easily described apart from the context of particular investigations. There is simply no fixed set of steps that scientists always follow, no one path that leads them unerringly to scientific knowledge...Although features are especially characteristic of the work of professional scientists, everyone can exercise them in thinking scientifically about many matters of interest in everyday life. (p. 2 & 4)

Since tacit knowledge of the scientific discipline is inherent in the context of that particular space and time, science teacher preparation institutions can utilize the science research facilities at their particular institution to introduce preservice teachers to the realm of the scientific enterprise and environment. This particular approach is used at a large southern Research I institution in the Spring of 2000. The goal of the apprenticeship opportunity is to teach preservice teachers about true authentic science by pairing them individually with a "real" scientist doing "real" science. Therefore, the preservice science teacher's research experience is grounded in the field; the preservice teachers do scientific research at the bench alongside the elbows of a "real" scientist. By using the apprenticeship model, science teacher educators provide a "real" science laboratory experience, where the knowledge is transferred from the expert scientist to the novice preservice.

Apprenticeship Models

Schwartz, Lederman, & Crawford (2000) conducted and analyzed an apprenticeship model at a mid-sized Western university. Their study measured Nature of Science (NOS) beliefs –not inquiry abilities–by analyzing interviews, reflective journals, data journals, participant observations and pre- and post-questionnaires. The overall finding of their study "suggested [that] the perspective held by the intern is perhaps the most critical factor in determining the learning outcomes in regard to NOS." The participants needed a philosophical perspective combining NOS and inquiry; the researches believed that "doing science is insufficient for one to adequately understand the NOS." This particular model was utilized at a different college site with slight variations in the research experience; however, the results depicted the same NOS conceptions (Westerlund, Schwartz, Lederman, & Koke, 2001). As stated earlier, these particular studies were not measuring inquiry capabilities; however, they were examples of apprenticeship models incorporating an authentic science experience into their teacher preparation programs.

A northeast land-grant institution and the National Radio Astronomy Observatory at Green Bank, West Virginia were the sites for another apprenticeship model experience (Pyle, Obenauf, Heatherly, DiBiase, Hemler, Govett, Evans, Gansneder, 1997). This model placed preservice and inservice teachers in a one to two-week summer research experience at the astronomy laboratory in Green Bank. Teachers conducted inquiry experiments with available science mentors and observatory equipment. From a generalized research problem, the teachers formulated research questions, collected and analyzed data and finally presented such data to the group. After the apprenticeship experience at the institute, the teachers planned, developed, implemented and evaluated a student-centered inquiry-orientated scientific investigation for their school. To reinforce the apprentice research inquiry experience, teacher educators utilized inquiry methods in their method's courses. Lastly, to increase the research transference into the classroom, all attempts were used to place the preservice science teacher with a mentoring teacher who was a previous Green Bank institute attendee.

Hemler (1997) researched the Green Bank program by examining the effectiveness of the preservice apprenticeship component at the astronomy laboratory. From her classroom observations, Hemler (1997) cited "five projects of the seven implemented by participants [as] successful research experiences for students." Hemler's study contended that the astronomy laboratory apprenticeship remains a "viable constructivist model for exposing preservice teachers to science research and transferring that experience to the classroom."

The program Science For Early Adolescence Teachers (Science FEAT) utilized the apprenticeship model for practicing middle school science teachers in North Florida and South Georgia (Spiegel, Collins, & Gilmer, 1995). As reported, these particular middle school science teachers had never "engaged in the practice of science nor fully understood what scientists do." Their apprenticeship involved 15 research facilities and provided 25 research opportunities, supporting a possible 81 placements. The FEAT science teachers "spent 75-100 hours during five weeks engaged in some aspect of research at a level beyond that of a technician. Also, each group produced a publishable quality abstract and presented a poster of their research." In regards to the poster quality, one participating scientist responded that he "could have taken any of those posters to a regional American Chemical Society meeting."

University of Tennessee Apprenticeship Model

This research study addresses the apprenticeship science course offered at the University of Tennessee. This science course was designed to meet the state mandated licensure component that all preservice science teachers conduct or be involved with a long-term scientific investigation within their major. The course was first offered in the Spring of 2000 in response to preservice teachers' scheduling conflicts. Some science preservice teachers were unable to sign up for the Fall 1999 graduate science course "Learning and Teaching Science – Just Do It" (Melear, Goodlaxson, Warne, & Hickok, 2000).

In order to meet Tennessee licensure guidelines, the course requirements included nine weekly hours with the scientist, six seminar meetings with the science educator, and one final research symposium. Three graduate science credit hours were awarded for the completion of these requirements. The preservice teachers scheduled nine or more hours in the scientist's laboratory to work on a particular aspect of research. All seven preservice teachers gathered for a round-table discussion to reveal their research progress to the science educator, who volunteered her time, support, and guidance. A final symposium was held at the end of the year upon which preservice teachers presented their research results to all of the participating scientists and preservice teachers. The preservice teachers logged raw data, transformed data, and explained results in their scientific logbooks. Additionally, the preservice teachers reflected on the apprenticeship experience by writing in a personal journal the details of their frustrations, elations, set-backs and accomplishments. The preservice teachers submitted a final summary paper of their reflective journal.

Apprenticeship Model Theory

The apprenticeship novice/expert model was grounded within current science education research. Duit and Treagust (1998) stated "in the apprenticeship model, [that] the novice learner gets to be an expert through the mechanism of acculturation into the world of the expert." When the novice preservice teacher entered the scientific laboratory of the expert scientist, the research experience was authenticated in a manner that educational methods or traditional science courses cannot replicate. The term *authentic,* as defined by Roth (1995), was "the activity in which [the] learner engages has a large degree of resemblance with the activity in which core members of the community actually engage." The apprenticeship model included the theories of social constructivism (Vygotsky, 1978) along with situated and distributed learning (Roth, 1995). The novice tacitly acquired methodological and procedural knowledge from the interpersonal or social interaction with the scientist. The novice then intrapersonalized, or individualized, this information.

Methods

Three primary researchers triangulated the interview transcript, laboratory journal, and reflective summary data to examine the apprenticeship program participants' experience. During the apprenticeship, the preservice teachers wrote in a bound laboratory notebook and personal reflective journal. At the end of the laboratory study, the student/novice wrote a short paper about their experience. Approximately one year after the apprenticeship experience, the researchers performed a short interview of the participants. The transcribed interview data was the participant's disclosure of their "real experience" of the science laboratory apprenticeship. The purpose of this study is to determine if there was transference of the apprenticeship experience into the classroom setting during the internship year.

Research Questions

The central question of this study is:

What is the value of a novice/expert apprenticeship between a scientist and preservice teacher at the University of Tennessee?

The primary and secondary interview questions are:

Describe the experience.

How involved were you in the design of the study?

Design an experiment.

What does a scientist do?

How did the course prepare you for teaching?

How could you use this experience in the classroom?

Participants

Three of the seven pre-service science teachers involved in the apprenticeship program participated in this study. At the time of the interview in Spring 2000, all three were completing course requirement for teacher certification. Two of the three participants had conferred biology degrees, while one had a biology minor. All three female participants were teaching two science courses at a local high school in order to complete certification requirements to obtain biology certification at the secondary level. The three novice teachers, their corresponding expert scientists, and their research topics are listed in Table 1.

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Table 1

Three Novice/Expert Participants and Research Topics

Preservice teacher[a]	Scientist[b]	Research topic
Lynne	Dr. M Dr. C	Effects of shade treatment on rhizome growth of Helianthus eggertii (Asteraceae)
Michelle	Dr. S	Distance test for catilipsis of Agelenopsis aperta
Val	Dr. G	Echolocation call of the Mexican free tailed bat (Tadarida brasiliensis) at high altitudes

Note. Pseudonyms are used for actual names of the [a]preservice teachers and [b]scientists.

Data Analysis

The three researchers compiled the participant's summary paper, laboratory journal, and interview transcript as a detailed portfolio of their experience. The first two principal researchers then coded and analyzed the portfolios for themes. To reduce investigator bias, the two researchers coded and analyzed each portfolio individually before collaborating to reach a consensus on common emergent themes. The common themes that emerged from the three different experiences are presented in this study. This study is specifically based upon these three participants and their experiences at the University of Tennessee; no attempts are made to generalize the findings beyond these participants.

Results

Lynne

Lynne graduated from a small religious college before arriving at the University of Tennessee. During Lynne's apprenticeship, she worked with Dr. M and Dr. C from the Botany department. Lynne arrived at the laboratory after the experiment began and spent her laboratory time doing measurements of rhizomes. From Lynne's interview transcript and journal entries, four themes emerged. The four themes included: data collecting attitude, vocabulary restrictions, project ownership, and experimental understanding.

The first theme was Lynne's dislike or disdain for the collection of data, which involved measuring the length, number, biomass and root tips of plant rhizomes. Lynne performed the data collection for approximately seven hours a week. Lynne described this collection task as "monotonous, boring and very, very old." Negative tones, expressions, and feelings about the data collection pervaded the interview from Lynne's statements such as, "my job was to count," "I got stuck in the collecting of data," "I was doing the same thing the whole semester, "and "I was just the data collector." Lynne stated that she does "the same thing so it didn't make [her] like it a whole lot." Additionally, her comments in her journal expressed her exasperation on the seemingly infinitesimal amount of data to collect from statements such as "there are tons of roots still left to measure," "[excavating roots from boxes] takes a long time" and "I worked the whole time and did not finish one box." Overall, from her collection experience and from watching the experiences of others in the lab, Lynne felt scientists basically "came in everyday and did your experiment; worked on it all day long; went home and came back and tried something different."

The second emerging theme was that the scientists use technical oral and written vocabulary foreign to Lynne. During the weekly meetings of the laboratory scientists, the scientists discussed their research. Lynne stated that she "wasn't familiar with the terms and vocabulary they were using and the ideas and theories that they were working with because [she] hadn't been exposed to any of that." Lynne repeatedly stated that the papers and discussions "were way over [her] head." When reading scientific papers, she would "read a paragraph or a sentence, and would…have no clue what [the] sentence just said." The scientists did however "try to break it down on [her] level and explain [the papers]." However, during seminar meetings, Lynne felt that she "had no clue … [she] felt out of place." The lack of a common discourse between Lynne and the scientific cohort possibly caused isolation, thereby undermining Lynne's confidence.

The third theme was an additional lack of understanding from the fact that Lynne's experiment was "already set up and planned." When Lynne arrived at the lab, Dr. C gave her "a basic understanding of the experiment and how it [was] set up." Therefore, Lynne felt "basically the project that [she] was working on … was [Dr. C's] project." Due to the omission of Lynne devising the research question and lack of involvement with the experimental design, Lynne acquired very little ownership of the rhizome research.

The last theme emerging from Lynne's data was the lack of understanding in designing an experiment. Although, Lynn stated that she had "a better understanding of how to help people set up and come up with an idea that they want to [do a] project on," her explicit explanations of how to perform this goal lacked canonical scientific knowledge and protocol. When asked to design an experiment determining how much water a plant would need to survive, Lynne displayed a lack, or limited, understanding of sample size, data collection, and dependent variables. Lynne "said six, [but] I am not sure" for the sample size, and then proceeded to explain "[how] ever many variables you want, that is how many plants you need." The following excerpt of Lynne's response to a hypothetical experiment supported the previous claim of her lack in experimental knowledge after the apprenticeship:

> I think you record every time you water the [plants]. You could take measurements every week, every other week of the plant. You

> could … hum, write down the color of the leaves, if is dying, if it is falling over, if it is wilting. Hum, just those kinds of measurements to see if it is surviving or … take your results, the [plants] that survived and the [plants] that didn't or the [plants] that some might have been watered too much and also died and find the [plants] that seem to do the best and say that based on my experiment, these plants, this amount of watering, ever so often, was good amount for this particular plant to survive and this much was too much and this much was too little and somewhere between, lie whatever you have between.

From the previous statement, Lynne demonstrated zero understanding or need for quantitative, numerical data, even though her actual experience was exactly that. Her entire semester experience (12 x 7 hrs = 84 hrs) was spent measuring rhizome roots. Most of her data explanation of her hypothetical experiment was qualitative and observational, not quantitative.

Michelle

Michelle's degree included a Biology minor. During Michelle's apprenticeship, she worked with Dr. S, a professor in the Ecology and Evolutionary Biology department. Dr. S has done extensive research on arachnids and had already chosen an experiment for Michelle's apprenticeship. Michelle conducted experiments on the distance for catilipses (cationic state) for funnel web spiders. Michelle used three different apparati to test the distance at which the male could release a pheromone that would knock out the female so he could safely mate with her. Data analysis of Michelle's experience showed four emerging themes. The four themes included: lab environment, project ownership, classroom confidence, and experiential value.

Michelle spoke positively about the lab environment in which she completed her apprenticeship. She expressed comfort in the lab in that Dr. S was "very receptive to what [she] had to say" about the experiments. Michelle didn't have the same background as some of the other people working in the lab, but she stated that Dr. S "didn't treat [her] any different than any of the other people coming and doing research in her lab." Michelle "felt like [she] knew what was expected of [her] and what [they] were doing and why [they] were doing it," and from that understanding, Michelle exhibited a sense of ownership of the project. When discussing the research, Michelle often used the pronoun *we*, referring to herself and Dr. S, as from the following statements of "we were testing" and "we would design." Overall, Michelle "felt like [she] was really part of something."

The third theme was an increase in confidence in the secondary science classroom. Michelle felt this apprenticeship "gave [her] more confidence" as she began her internship in the classroom. "It got [her] ready to be in the classroom". The apprenticeship "helped [her] feel like [she] was a little bit more prepared in helping [her] students going into the lab". She felt more confident explaining experiments to the students and "qualified to talk about science because [she] didn't just read it out of a book."

To Michelle, scientific experience was invaluable in the classroom. "If you can relate [science] to [the students] or give an example in your life, they tend to listen more." During Michelle's internship experience, she found that "unless you have some good experience to relate to [the students], they don't care." Michelle felt prepared for the classroom by seeing the "other things in [Dr. S's] lab and [seeing] the stuff that was going on, and [to be] around the [lab] setting." Michelle felt "this experience will be helpful to [her] in the classroom because [she is] better prepared to guide students in asking their own questions." She felt if she could "help [her] students learn to ask questions about things they are interested in, then [she had] accomplished something." "By asking questions and discovering what one wants to know, they have begun a scientific investigation."

The final theme was that Michelle thought this was a valuable experience. She "gained a better appreciation of performing a scientific investigation. ... and it taught [her] about more than doing a literature search and compiling data." She "learned how to write up a protocol and … scientific paper." She found it very helpful to write her own scientific paper about her study. Even though she didn't believe "the inquiry design for most high school classes would work," she did believe that this apprenticeship was "a very valuable learning experience."

Val

Val had a degree in Biology and had worked at a scientific laboratory before deciding to become a science teacher. During Val's apprenticeship, she worked with Dr. G from the Evolutionary biology department. She worked independently alongside biology graduate students analyzing prerecorded audiotapes of bat echolocations. Triangulation of the data sources revealed four emergent themes: attitudinal change, authentic experience, project ownership, and technique transference.

The first them of attitudinal change began as "[Val] first heard about it [in that she] was very irate," and she "was not so thrilled about having to participate." The apprenticeship started "out [as] a very negative experience for [her]. [She] thought, you know, this is ridiculous." The initial resentment was due, in part, to economic factors, because Val had to terminate her employment in order to fulfill the research requirement. However, as Val became increasingly involved with the project, she "got into it and … loved it." She viewed her work as personally relevant and "would go over to the [bat] lab … even when [she] wasn't supposed to; [she spent] extra time…in the evenings and stuff." As her attitude increased positively of the apprenticeship, so did her attitude of bats. After research bats, she referred to them as "cute little bats," and actually became a "bat buff." At the time of the interview, a year after the apprenticeship, Val still remembered the lab experience fondly. She still thought "wow, being in a lab, I just love the lab environment," and "when I was over in the lab, I felt so at home. I loved finding out new things. I loved presenting findings and talking about what I found."

The second theme of the apprenticeship experience was identified as authentic scientific practice. She had been "exposed to the reality of 'doing' science." She stated that she had never done a laboratory experiment in which the outcome was not already known. Some components of her authentic scientific practice included making procedural adjustments ("tinkering"), conferring or consulting with experts, and sharing/defending findings within the community of scientists. Val's tinkering consisted of "figuring out ... what would be the best way to list data, so that [she] can keep track of what's going on." From her tinkering, she also found "that it would be more efficient to [download] sounds to the program Bat Calls, then go back and analyze them." Val then discovered "it would be more efficient to save several calls/file."

The third theme of project ownership was apparent during the laboratory training and data presentation. Although Val was not involved in the initial formulation of the research question, she clearly had a vested interest or ownership in the inquiry analysis and outcome. Through her involvement from beginning to the end of the project, she felt that "when you have that finished product...it gives you a tremendous ego boost...[that] you have accomplished something." Dr. G oriented Val to the laboratory by training her to use specific laboratory bat-call analysis tools. Val examined copies of Dr. G's work and viewed a PBS broadcasted videotape of the bat project. Val stated that Dr. G "was always available for assistance"; he "was really helpful to [her] in the analysis part and in getting [her] going." Val felt during the final analysis, "[they] worked the closest" because Dr. G assisted her in summarizing her findings before the symposium presentation. Val "loved [presenting]; she "got so excited" that she "did not want a time constraint." The presentation experience appeared to be the highlight of the apprenticeship for Val. In addition, Dr. G conferred with Val that "if this gets published, [your] name will be on it." The possibility of "getting published [and] having your name out there [was] an ego boost" to Val.

Val expressed the final theme of technique transference by discussing her inability to incorporate the process of authentic scientific inquiry into her teaching practices. During the internship, Val believed that her enthusiasm and increased appreciation for science and bats would "rub off" on her students. However, what she discovered was that "in the classroom, things are very different. It's not that [she] wouldn't want to, it's just that it is very difficult to take students and get them involved in long-term research projects." Val believed "it's very difficult [and] I can, of course, do the cookbook labs…[there isn't] a time where I could get them involved in any long-term project." Most shocking was that Val believed that she "couldn't do research in public schools [or specifically] do research with [a] 10th grade class. It's just not done, as far as scientific research." Val viewed teaching science and doing scientific research as mutually exclusive at the secondary level. Val stated that one "can do qualitative research…for education, but … it's just not there to do actual research, laboratory research." Val attributed this lack of transferability to end-of-course competency exams, which required certain amounts of content coverage. Val stated "the time is not there," as there are "certain things [one] has to teach" Secondly, she refered to lack of student interest. Val "felt [the students] find the answer, and they were happy with that one answer and they didn't want to move on."

Discussion

From the apprenticeship experience, all three preservice teachers, the novices, learned a scientific skill from their mentoring scientists, the experts. During the semester, the three participants worked alongside a scientist in a university laboratory, as they learned various procedures modeled by the scientists while situated in the context of the ongoing experiment. No single participant learned a scientific skill from reading a procedural manual only. Each preservice teacher actively observed and participated in learning the scientific procedures by close proximity with the mentoring scientist. Specifically, Lynne demonstrated appropriate protocol for laboratory procedures in rhizome measurement, Val for bat call interpretations and Michelle for pheromone distancing in spider mating. From these various apprenticeship experiences, the researchers assumed that content, procedural, and tacit knowledge are distributed to the preservice teachers.

A discrepancy appeared in how the preservice teachers viewed the data collection phase of the experimental. The overall experimental process should have involved devising a question, designing an experiment, collecting data, and interpreting the results, and these experimental steps should not necessarily be linear as written. These teachers entered the apprenticeship experience at various intervals of this process. Lynne expressed repeatedly her dislike for data collection; she was "bored" and saw the data collection as "tedious and monotonous." However, Michelle did not view the data collection negatively. Even though Michelle stated that data collection was "repetitive," she took a positive stance and tried to learn something new from the experience every day. Also, Michelle utilized this time as an attempt to overcome her slight case of arachnophobia. Val did not personally collect the bat call data; however, she expressed a "love" of listening to and coding the various calls. Val even spent additional hours in the lab to listen to the bat call recordings.

To explain this discrepant attitude in data collection, the researchers surmised that the key element was the involvement of the preservice teacher in the overall experimental process. Once Michelle was shown research articles and spider-mating laboratory set-up procedures, she worked in designing the next experiment. Michelle collaborated with her mentoring scientist, and after viewing the data, she and the professor decided collectively what the next experimental design should be. Michelle was involved in most facets of experimental research – reading literature, collecting data, modifying experiments, analyzing modification, evaluating data, collaborating with colleagues, and writing research. Val was involved in the bat research in the same manner – interpreting calls, writing research, critiquing definitions, and collaborating with scientists. Valued above all, Val was offered a stipend to continue the research over the summer; her name was to appear on future related published materials. In her view, Lynne did not experience many of the research elements; she saw herself as "just the data collector." Lynne's experiment was already designed upon her arrival into the laboratory. She also had limited experience in evaluating the data and writing results.

Therefore, the proposed link to an improved apprenticeship attitude was to increase involvement in the overall experiential process. This involvement related directly to feelings of ownership of the learning. The two participants having a vested interest in the overall scientific process had an increased positive experience than the one who did not. The increased involvement coincided with the increased overall ownership.

An area of concern among the researchers occurred with one of the overall goals of the apprenticeship experience–the transference of the short-term laboratory experience to the science classroom setting by the use of inquiry investigations. When asked directly how the apprenticeship experience had affected their current teaching practice, the participants stated many reasons why they felt they could not implement that type of classroom methodology. Arguments such as time limitation, content coverage, and end-of-course tests prohibited their use of long-term or short-term investigative approaches.

Specifically, Val was concerned with lack of student interest in anything longer than a one class period experiment; she stated the experiments would not keep student interest. Val also stated that scientific research could not be done in a 10th grade science class; the research environment and science classroom are just "two different worlds." Michelle was more optimistic about using her research experience in the classroom, as she wanted to relate the content to the students by discussing how she had "done science." Michelle saw value in taking a question through to a final research paper. However, Michelle struggled with experimental implementation in the classroom. Michelle wanted to do other things than those listed in the textbooks, but she didn't know how. Michelle wanted references that would give her additional resources in how to implement research methodology into the classroom. Lynne displayed a lack of experimental design and understanding, and without this comfort, she did not implement long-term investigative experiments.

Future Implications

Implications for future studies could involve following the participants during their first years in teaching to determine if they use or if their attitude changes toward their ability to do inquiry. Modifications in the scientific apprenticeship, such as training mentoring scientists and extending the allotted research semester, could be implemented and measured. Extending the research experience to two or more semesters could allow more time for the preservice teacher/novice to become acclimated within the laboratory culture. This extended time could also alleviate the difficulty of completing an entire research problem from beginning question to ending results during one semester. By training all mentoring scientists to include certain inquiry research attributes, the preservice teachers would have an increased comparable research experience. Comparison of the apprenticeship program to the other inquiry teacher preparation courses could be evaluated from the teacher's chosen methodologies for instruction in their secondary classroom. In conclusion, in order for preservice teachers to comply with the inquiry research state and national standards, teacher preparation institutions must consider more avenues in giving teachers opportunities to perform some kind of authentic research experience. The best approach in offering this experience remains under debate.

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