# Exploratory Study of the Teaching Practices of Novice Science Teachers Who Participated in Undergraduate Science Education Research

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## Abstract

Research experiences for teachers have been shown to improve their knowledge and teaching practice. One type of research experience not as well studied is undergraduate science education research. Using qualitative research methodologies, the teaching practices and tools of seven novice teachers who participated in undergraduate science education research along with three novice teachers who did not participate in research were compared. Novice teachers with research experience included some similar practices and tools in their teaching—collecting student data, regularly using formative assessments, and employing questioning as a teaching tool—which novice teachers without the research experience did not. The results of this exploratory study suggest a positive impact of undergraduate science education research on teachers' practices likely because it changes the preservice teachers' learning community; however, more exploration is needed to understand the characteristics of the research experience which might have made it valuable to the preservice teachers' learning.

Key words: Undergraduate Research; Preservice Teacher Education; Science Education Research; Novice Teachers

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## Introduction

Research experiences for inservice or preservice teachers positively impact the science teacher's knowledge and teaching practice (e.g. Cullen, Akerson, & Hanson, 2010; Roth, 2007; Yezierski & Herrington, 2011). One type of research experience makes teachers researchers in their class settings. This type of research saw a resurgence in the late 1980s and 1990s as part of teacher education and professional development (Cochran-Smith & Lytle, 1999), and is typically called action research (Efron & Ravid, 2013). A second kind of research experience allows teachers to conduct research in science laboratories and other scientific settings as part of research groups, often referred to as Research Experiences for Teachers (RETs; Herrington, Luxford, & Yezierski, 2012). Inservice teachers typically complete RETs, but preservice teachers may also have similar opportunities to participate in science research at their institutions through undergraduate research. Both of these research experiences have been explored for their impact on teachers' practice (e.g. Cullen et al., 2010; Lebak & Tinsley, 2010; Silverstein, Dubner, Miller, Glied, & Loike, 2009; Yezierski & Herrington, 2011), but there is another form of research experiences some preservice science teachers have participated in as part of their education—undergraduate science education research.

Undergraduate science education research experiences are not action research experiences because the preservice teachers are not part of an educational setting being studied. They are not science content-related research experiences either because even though they are often part of an inquiry team similar to science research experiences, the focus of the research is an educational topic. Action research and science research experiences have been shown to have different impacts on teachers' learning and teaching practices (e.g. Mamlok-Naaman & Eilks, 2012; Roth, 2007; Yezierski, & Herrington, 2011). More research is needed on the impact of research experiences on teachers (Roth, 2007), specifically in the areas of undergraduate science education research experiences (e.g. Del Carlo, Hinkhouse, & Isbell, 2010; Hohleoch, Grove, & Lowery Bretz, 2007). Since the undergraduate science education research experience is rarely required and occurs during preservice education when the focus is on developing knowledge or skills to use as novice teachers, its impact may be different than other types of research experiences. This exploratory study attempts to begin to understand the benefits of undergraduate science education research on novice teachers' knowledge and practice by comparing the practices of novice science teachers from two teacher education programs with and without undergraduate science education research experiences.

## Literature Review

### Research Experiences for Teachers (RETs) and Action Research

Most programs for teachers in which they act as researchers can be categorized one of two ways: (1) Research Experiences for Teachers (RETs) or (2) Action Research. These programs are often designed for inservice teachers; however there have been some programs within each of the categories for preservice teachers. What follows is a definition of each type of program and a brief review of the current literature available on these types of programs.

RET programs, also called authentic scientific research experiences for teachers, allow teachers to conduct science-content based research as part of a scientific research team in an academic or industrial setting. Recently a number of professional development programs have used this basic model as part of their program (e.g. Miranda & Damico, 2013; Schwartz, Westerlund, Garcia, & Taylor, 2010; Silverstein et al., 2009; Yezierski & Herrington, 2011). Teachers in RET programs improve their understanding of the intricacies of scientific work, and with explicit instruction on the Nature of Science (NOS), improved their understanding of NOS and their technical skills (Sadler & McKinney, 2010; Schwartz et al., 2010). In addition to improving NOS understanding, the research experiences fostered collaboration between teachers and scientists, and, in some cases affected the teachers' practices resulting in the teachers modifying laboratory activities (Schwartz et al., 2009). RETs have also been shown to impact teachers' practices in terms of their choice of types of or use of laboratory activities (Herrington et al., 2012; Miranda & Damico, 2013). Finally, one RET program demonstrated impact on student achievement. Silverstein et al. (2009) reported improved student performance on Regents exams (New York's required content tests for high school students) after teachers participated in a summer RET program. While currently not as common as RET programs for inservice teachers, science research experiences for preservice science teachers have similar outcomes with improved understanding of the practice of science, improved critical thinking skills, and positive attitude towards science and scientific research reported (Langford & Huntley, 1999; Melear, Goodlaxson, Warne, & Hickok, 2000; Raphael, Tobias, & Greenberg, 1999).

Action research is "usually defined as an inquiry conducted by educators in their own settings in order to advance their practice and improve their student learning" (Efron & Ravid, 2013, p. 2). Because of the reflective nature of action research and the analysis of their teaching practice, much of the literature about the effects of action research on teachers have focused on inservice teachers' use of action research projects as part of advanced degree programs (e.g. Lebak & Tinsley, 2010) or professional development programs (e.g. Cullen et al., 2010; Eilks & Markic, 2011). Action research experiences encourage reflective practices and tend to lead to use of more student-centered teaching practices (Cullen et al., 2010; Lebak & Tinsley, 2010; Mitchener & Jackson, 2012; Roth, 2007). In addition, studies have found action research as a part of professional development encourages the use of new curricular materials (Gerard, Spitulnik, & Linn, 2010; Mamlok-Naaman & Eilks, 2012).

While much of the literature has focused on inservice teachers' use of action research as part of professional growth, the inclusion of action research projects within preservice teacher education has also been documented by researchers (e.g. Clift, Lou, Johnson, & Holland, 1990; Liston & Zeicher, 1990; Rudduck, 1992; van Zee, 1998). These action research projects tend to be semester-long projects during capstone courses, final methods courses, or student teaching done in small groups or with a cooperating inservice teacher. Recently some have focused on the use of action research with preservice teachers to improve students' attitudes towards educational research and communication skills (Kotsopoulos, Mueller, & Buzza, 2012; Everett, Luera, & Otto, 2007; Otto, Luera, & Everett, 2009). These studies, as with previous studies, focused on immediate outcomes of the action research projects; they did not follow the preservice teachers as they began their teaching practice.

**Undergraduate Science Education Research**

Research experiences for undergraduate preservice teachers in science education have not been well studied. Two small case study research studies have been reported. Del Carlo et al. (2010) used two case studies to provide evidence for undergraduate science education research as a mechanism for modeling and teaching reflective practices to preservice teachers. Del Carlo et al. argued this reflection may move beyond the gains inservice teachers get through action research projects to a general attitude of reflective practice. Hohleoch et al. (2007) provided a reflection from a single teacher who did undergraduate chemistry education research involving the redesign of a chemistry course for elementary education majors. The reflection focused on her content learning (using what they did in the class), her confidence in her skills and goals, and the value she found in the experience as helping her develop as a science teacher.

The literature provides support in general for research experiences for preservice teachers, but the possible impact of undergraduate science education research on preservice teachers' development and teaching practice is not clear. Action research tends to be situated, focusing on changing and improving the teacher's practices in the specific context of the class or school in which they are teaching (Roth, 2007); while valuable, this has a different implication than other science education research. RETs for inservice or preservice teachers have been criticized as being too short for the teachers to gain more than a technician's understanding of the research process (Feldman, Divoll, & Rogan- Klyve, 2013; Brown & Melear, 2007). However, undergraduate science education research, specifically those that are the focus of this study, can be in-depth or long term research work covering semesters or entire summers. There is a possibility that undergraduate science education research experiences therefore could have different impacts on preservice teachers than action research or authentic science research

## Theoretical Framework

Since undergraduate science education research occurs while preservice teachers are in school fulltime, an immediate impact on their novice teaching practice must occur while they are learning to teach. Hammerness et al. (2005) developed a framework to understand how teachers learn to teach in which the preservice teachers are part of a *learning community* that helps them develop their *vision* for teaching (See Figure 1). The learning community provides the preservice teachers with opportunities to continually develop their *understandings*, knowledge about teaching; *practices* for teaching; *tool* kit of resources; and *dispositions* towards teaching and learning which all support their vision for teaching.

**Figure 1**

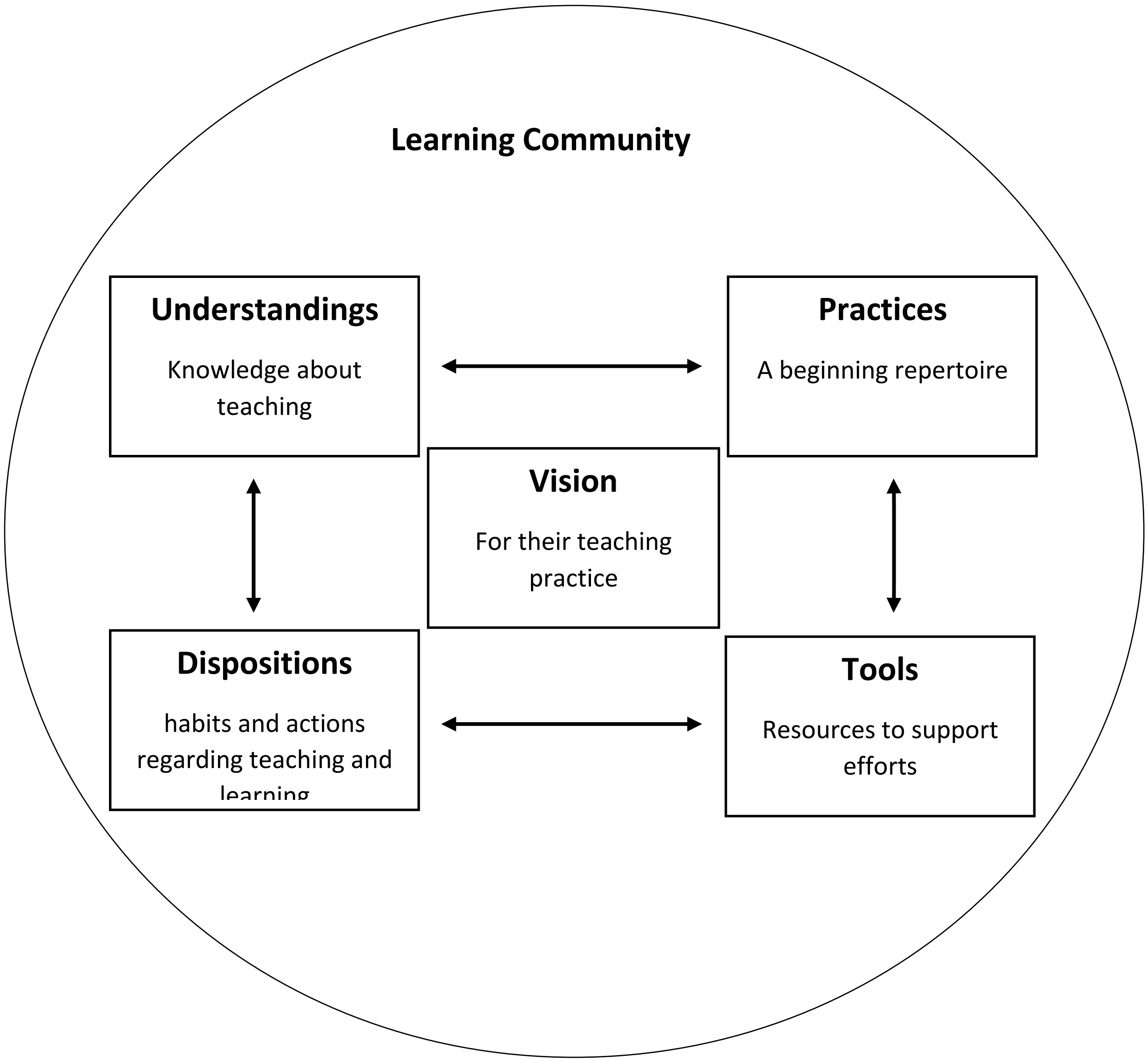


Figure 1. Framework for Teacher Learning. Modified from Hammerness et al., 2005, p 386.

Accordingly, all preservice teachers in the same teacher education program would have similar learning communities due to requirements for their degrees and licensure, but preservice teachers with undergraduate science education research would alter their learning community with the research experience. The topic of their research would likely directly affect specific understandings, practices, or tools the preservice teachers learned and incorporated. In addition, it is possible that the research experience generally would impact their dispositions or visions for teaching, which then according to the framework would impact their learning in all the other areas in their learning communities (their teacher education programs). If the change in their learning community can influence just one area of the teachers' learning, then it potentially affects how they learn and interact with the other areas.

With the gap in the research literature as it relates to undergraduate science education research and this understanding of teacher learning, we sought to begin to understand how the altered learning community created by an experience in undergraduate science education research might affect the understandings, tools, dispositions, and/or practices preservice teachers develop and ultimately enact as novice teachers. Understandings and dispositions are difficult to observe and/or identify, but as the framework suggests, impact the practices and tools a teacher learns and uses; these practices and tools are more readily identified. To begin to understand the possible impact of undergraduate science education research on the preservice teachers' development as science teachers in their learning communities, the guiding question for this qualitative study was: Are there any differences in the reported teaching practices of or tools of novice science teachers who participated in undergraduate science education research and novice teachers who did not participate in undergraduate science education research? If so, what are the differences?

**Definition of Undergraduate Science Education Research**

For the purpose of this study, an experience in undergraduate science education research required that the teachers worked on a research project with three characteristics. (1) The topic of the research project had to relate to science education (e.g. science-inquiry use by teachers, beliefs about teaching science/chemistry, or student learning of a science topic), not a general educational research topic (e.g. classroom assessment practices). (2) The project had to be carried out under the direction of a tenured or tenure-track university faculty member. And (3) the student had to participate in the project for at least one semester or full summer session (8-10 weeks). The students might have received "Undergraduate Research" course credit for the experiences, but these experiences were not required for another course. In addition, payment for their work as research assistants may have occurred, but it was not part of the definition.

## Methods

Due to its exploratory nature and the nature of the research question, this study used qualitative research methodology (Berg, 2009; Merriam, 1998). Novice teachers with and without undergraduate science education research experiences completed a questionnaire, were interviewed, and provided classroom documents. Data was coded, themes identified, and similarities or differences in the novice science teachers' reported practices were identified.

A convenience sample of practicing teachers who had participated in science education research projects as undergraduates at two different Midwestern Universities (MU1 and MU2) was used for this study along with graduates who had not participated in research from the same institutions. To allow for multiple sources of data and a stronger study (Maxwell, 2013; Merriam, 1998), three sources of data were collected from each participating teacher: a questionnaire, a phone interview, and classroom documents. The questionnaire (See Appendix A) included questions on the teachers' backgrounds, their experience with research, and their experiences teaching. Once the teachers had returned their questionnaire, a semi-structured phone interview with the first author, which lasted between 35 and 55 minutes, was conducted with each participant at a time of their choosing. The interview protocol (See Appendix A) included questions about the teachers' general beliefs about teaching science, current teaching practice, use of data, and other professional activities. Some of the questions were based on Luft and Roehrig's (2007) *Teacher Beliefs Interview Protocol*. In addition, just prior to the phone interview, participants were asked to email the interviewer all "electronic copies of handouts, labs, worksheets, etc." (exact wording used) which they used during the previous week. The electronic documents were used to confirm and clarify participants' comments about classroom activities during the interview. Interviews occurred during the Spring 2013 and Spring 2014 semesters. All were audio-recorded and transcribed.

Transcripts, background surveys, and class documents were read and initial coding (Lofland & Lofland, 1995) of the data was carried out by both study authors. Codes from both researchers were then compared and discussed (Berg, 2009; Lofland & Lofland, 1995). The qualitative software NVivo was used for the coding process. Word counts were taken as well as other queries. After coding of each participant's documents through NVivo, each participant's data was reread and used to create an approximately one-page summary of their background experiences and teaching practice by the second author. This summary document provided another manner of comparison outside of the NVivo program. Both researchers compared summaries and codes for each research participant, looking for similarities and/or differences between the teachers or groups of the teachers in the study. Constant comparative analysis was used throughout (Maykut & Morehouse, 1994) to find themes from all participants. Data with its codes/themes were explored and grouped, and then examined for commonalities between the teachers providing the data. More details on the methods used in this study, including participant recruitment, interview techniques, and coding can be found in Appendix B.

**Participants**

Table 1 below provides a description of the teachers, using pseudonyms, who participated. All the participants attended one of two primarily undergraduate Midwestern universities as undergraduate preservice teachers (MU1 and MU2); all graduated with a teaching license.

*Table 1*
*Participants*

| **Name** | **Degree, *University*** | **Teaching Experience** | **Courses Taught** | **Classification** |
|---|---|---|---|---|
| Adam | Chemistry, *MU2* | 2 years | Chemistry | Nonresearcher |
| Gail | Middle/Junior High Science Teaching, *MU1* | 2 years | 7th Grade Life Science, 8th Grade Earth Science, Advanced Physical Science, Chemistry | Nonresearcher |

| | | | | |
|---|---|---|---|---|
| Rita | Physics Teaching and Chemistry Teaching, *MU1* | 1.5 years | Physics, Chemistry | Nonresearcher |
| Abe | Chemistry, *MU2* | 1 years | Chemistry, Environmental Science | Researcher |
| Bill | Chemistry Teaching, *MU1* | 1.5 years | Chemistry, Chemistry in the Community | Researcher |
| Chelsey | Chemistry, *MU1* | 3.5 years | Chemistry<br>AP Chemistry | Researcher |
| Greg | Chemistry and Chemistry Teaching, *MU1* | 1 year | Honors Chemistry, College-Prep Chemistry | Researcher |
| Kate | Middle/Junior High Science Teaching, *MU1* | 4 years | 8th Grade Science, 8th Grade Physical Science | Researcher |
| Kim | Biology, *MU2* | 4 years | Biology, Chemistry | Researcher |
| Wanda | All Science Teaching, *MU1* | 3 years | Earth Science, Chemistry | Researcher |

Note: Half years of experience denote teachers who started their teaching careers in January as long term substitutes or new hires filling in mid-year openings.

At the time of the study all the participants were teaching science in a secondary school in four different states. None were teaching in the same school nor were the demographics of the schools similar. The schools the participants taught in ranged from smaller rural schools to larger suburban and urban schools; one teacher was in a charter school. The schools were all distinct in terms of location and demographics. All of the participants were considered novice teachers since they had less than five years of teaching experiences. The participants who had not participated in an undergraduate science education research experience are termed *nonresearchers*. Teachers in the *researcher* group had, as an undergraduate, participated in an experience which met the definition of undergraduate science education research described earlier.

## Findings

Data analysis identified usage of two teaching tools and two teaching practices which differed between novice teachers who had participated in undergraduate science education research (researchers) and those who had not (nonresearchers): 1) collection of student data, 2) regular formative assessments, 3) application of knowledge, and 4) questioning. Each of these is discussed below. In addition, beyond just a difference between the researchers and nonreseachers in their use of these tools/practices, it was also found that there were differences among these practices *within* the researchers group; these findings are reported in the final part of this section.

### Practice: Collection of Student Data

After having been asked numerous questions about what they had done in their classes for the last week (and not during any conversation about research), the teachers were asked directly if they "collected any data" on their students; since these were all science teachers it was expected that they would be familiar with the term data. The nonresearchers had difficulty with this question; they seemed to stumble as the question was asked. For example, Rita responded: "(Pause) Ummm I mean, as far as like grades? Or like background information? Or (drawn out)" Interviewer: "I'll take anything you would consider data." Rita: Well (pause)… not really. I mean grades." Gail responded to the same question "(Pause) Umm, most of the data is just related to grading but also like attendance. But other than that I don't necessarily track any other data on them." Both Rita and Gail considered grades the data they collected on students; and this was the only form of data they could think they collected besides attendance. They were asked if they did anything else with the grades besides assigning grades, but they did not say they did anything else with it. Gail responded "(Pause) Ummm (Pause) Are you talking like how I divide things?" She did not seem to understand that the grades could be anything other than grades. When Adam was asked about collecting data, he said "this [that day] is actually the second time I've collected data." His principal was requiring that teachers pretest and post test their students regularly and he had just given a post-test and pre-test for the next unit that day. This required data collection was the only form of data he was collecting and he had only just started it. While he did not stumble with the question as much as Rita and Gail did, he was not collecting data on his students until it was being required of him and this was the only data he was collecting.

Teachers with undergraduate science education research experience did not struggle with this interview question like the nonresearchers did. Again, the question was asked near the end of the interview after the teachers had been discussing their practice and not near any questions about their research experience. Abe immediately answered "We do pre and post test data collection. … The same style of data collection we do for lab reports." Kim immediately replied "We have been trying to do more often" and then went on to describe breaking tests and assignments down by question, not just pre- and post-test scores. Bill responded "Well just, just every day formative assessment I guess." During the interviews, the novice teachers who had participated in undergraduate science education research did not pause or ask for clarification when asked about collecting data, and they were all collecting data on their students in some format. Like nonresearcher Adam, some of the data collection they described was required. Chelsey, Abe, and Greg were required by their schools to collect pre-test and post-test scores from their students. Kate and Kim were required to collect quiz and test scores from their students to compare with other teachers in their schools/districts. However, unlike Adam, even those required to collect data were also collecting data they were not being required to collect. Abe, for example, in addition to test scores collected students' scores from the rubric they used for lab reports. He had even broken the rubric into sections so he could see what skills, i.e. writing the conclusions, data analysis etc., the students needed to improve. Kim described collecting student feedback forms that asked students for their opinions on specific class activities to better understand how they perceived the activities and then her department, if the students found the activity useful, would "keep it in the curriculum for next year and see if we can do something similar in the next unit." Kate said she gave students "like a learning style inventory" so that she could "get to know them." There was at least one non-required data collecting activity described by all the teachers who had participated in undergraduate science education research. Data collection, some required and some not, was a part of these teachers' teaching practice in some format.

There is some evidence to suggest that these data skills resulted from the teachers' research experiences. The teachers in nonresearcher and researcher groups came from the same two preservice programs, so while data analysis might have been part of their preservice programs, the nonresearchers from the same programs did not demonstrate these skills. At least 1 novice teacher from both researcher and nonresearcher groups mentioned pre- and post-testing data required by their school; so while it was not controlled for, it is likely that the data collection the participants mentioned was not completely prompted by the schools where they taught. In addition, when asked near the beginning of the interview about the impact of their research experiences on their teaching without any discussion of data prior in the interview, several of the novice teachers specifically connect their data skills to their research experiences.

> Kim: I think for me analyzing data really helped, so now when I look at test scores I feel I can prepare it better"
>
> Bill: I've really developed a lot of data interpretation skills. And that's like, being a data driven teacher right now is the hot thing. So I'm able to do that and I feel like I'm able to do that ethically.
>
> Abe: There's endless possibilities that you could be looking at data and just tweaking things that YOU do and being able to notice differences or being able to look at test scores and notice that there IS change happening based on what you did, I think that's pretty cool to understand and if you haven't done undergraduate research you might not even think to look at that.

While not all the researchers connected their data collection to their research experience, the fact that they all used data in their practice and had an answer for the data collection question while the nonresearchers had very different responses. The evidence is not conclusive enough to suggest the research experience developed the data skills in the novice teachers but it is a similarity which the teachers who participated in undergraduate science education research share.

**Tool: Regular Formative Assessments**

The novice teachers who participated in undergraduate science education research also differed from the novice teachers without research experience in their use of formative assessments as a tool in their teaching practices. Formative assessments are tools designed to inform instruction, providing feedback to the students and the teachers about learning (Keeley, 2008). While much of the types of data collected described above could be used as formative assessments if instructional decisions are made based on the data collected, we are defining formative assessments here, similar to Keeley (2008), to indicate techniques which "allow teachers to continuously gather information on student thinking and learning" (p. 4). The results of the formative assessments could be recorded (data collected).

All of the novice teachers who had participated in undergraduate science education research used the term formative assessment during the interview, used the name of a specific type of formative assessment (e.g. exit slips), and/or described a formative assessment when they talked about making instructional decisions in their classroom. For example, Kate said "One of the things we do every day is we do a bell ringer, which reviews the day, the big objectives that we covered the day before. Basically starts off our class discussion for that day. If no one raises their hand to answer the question, 'hey I don't think we got that.'" Bill described thinking about his almost daily "formative assessments."

> ….every day formative assessments. I'll have an exit survey about the objectives we were covering for the day. Ok what does that mean, I have 7 numbers, these 5 people get it, 3 people don't get it, 2 people kind of get it, ok what does that mean?

As part of his teaching practice, Greg described a formative assessment tool he used called Active Engage.

> They all have laptops so I can say 'alright now do this problem and then type your answer' and so they will type in the answer and within seconds when everyone's done I have a bar graph of everyone that answered and then it categorizes them and in this particular one it shows 58% of the class had this answer. So that allows me to look at the, to say 'hey you got this answer, here's what you did wrong.'

As examples of some of the things the other researchers described, Abe described using exit slips, Chelsey and Wanda described the use of whiteboards, and Kim described, among other things, "warm-ups" similar to Kate's bell ringers. These teachers described these formative assessment parts of their practice in response to either the question about data use or in response to the question "How do you know learning is occurring in your classroom?" When asked the same questions about their teaching practices, teaching beliefs, and use of data in their classrooms, none of the nonresearchers discussed formative assessments in their teaching practice, nor did they provide any clear examples of it in the classroom documents they provided. It might have been present in their teaching practice, but since they did not discuss it despite multiple opportunities, it must not be a tool they valued in their teaching.

**Practice: Application of Knowledge and/or Student Use of Data**

Student data use and the application of knowledge was a part of the teaching practice of some of the novice teachers who had participated in research. While she did not have a project for every unit in her class, several of the units Kim described had a project which framed the unit, and in which the students were expected to apply the knowledge they gained during the unit to complete. Her description did not quite meet the typical definition of project-based learning in which a project is presented to students at the start of a "unit" to solve and learn content as well (Eberlein et al., 2008), but it was similar. In addition, Kim said part of her role as the teacher was "helping students to get to that point where they can analyze data and come up with conclusions on their own." Kim appeared to value data use and application of knowledge by the students. Others also mentioned student data use or application of knowledge. Greg gave students their own formative assessment data to help them study for their final exam; he "collect(s) data personally on that so then they can see at the end of the time where we're ready to review for the Standards of Learning test I can say alright, here's your personalized form." Wanda described knowing that learning was occurring by saying "when they (students) are able to go into a lab and they can apply what they've done. I do labs that have that application of what we just learned." Wanda provided an example of this type of application experiment in her classroom documents that seemed to match her verbal description. In a conversation about student learning Bill said, "they (students) also need to apply that skill to something." While not all of the novice teachers who participated in undergraduate science education research described students' use of data or application of knowledge, it was not part of the conversation with any of the nonresearchers using the interview protocol questions nor was it a part of the classroom documents they provided given the same email request for classroom documents the researchers received.

**Tool: Questioning**

Several of the researchers discussed using questions as tools, which they used to help students learn. In these examples, described below, the questions are not designed to assess student understanding directly but rather they are used as a tool to help the students extend in their understandings. Questions were used by some of the researchers for teaching not just assessing. For example from Kim:

> We learned about the structure of DNA. We built a model using like paper cut outs and color-coded it and then for DNA replication they (the students) would take that structure and some prompting question like "how well did DNA replicate" because there's so many bases, if it can't make a copy, what does it need to do? And through that talking they came up with the conclusion.

A few moments later Kim said "I was just prompting them with questions." She was using questions not to assess but rather to teach. Chelsey had a similar comment. While describing what she does during laboratory experiments she said she walked around asking students questions like "'Ok now did you run this data? Ok, what can you see with this? Well what can you see with the data? Ok what should we have done differently? What could we have done differently? How could you test this differently?' So I try and ask questions like that as much as possible." Greg, when describing his role as a teacher, said "in class it's a lot of 'now what's next? What's next?' And I keep asking leading questions in order to get them to where I want them to go. I'm the questioner in class. I want to make them think." Wanda, when talking about leading class discussions, said

> I start by questioning them "alright so, where do we need to start at?" And so they'll give me an answer of where they need to start and I say "alright, so write that down" and then it's like 'What's the next thing we need to do?" so I kind of facilitate it in a way of letting them rethink and have them think out wow. Just trying to guide them to what they need to be doing.

These comments indicate that they see questions as a tool to help them teach, to improve student learning, and not just as a way to assess students. However, not all the researchers had these types of comments. Some only used questions as tools in terms of practice problems or forms of assessment like Abe: "I like to ask the class a lot of questions, just to keep them on their toes." He was using questions to gauge understanding and as a classroom management technique; the questions were not used to increase student understandings.

Even though not all the novice teachers who were researchers used questions as teaching tools, all of the nonresearchers described the use of questions similar to Abe—as assessment or classroom management tools. Gail said, "I'll do a section review question" or Adam, when describing how he knew if students learn, said "I throw some problems out there or I throw some questions up on the board"

**Two types of undergraduate science education research experience**

The teachers who had participated in research were asked to describe their research experience, including the activities they did, groups they worked with, and time they participated. Several of the participants described a research experience in which they had designed much of or large portions of the research project themselves (See Table 2 for a description of each teacher's research experience). Research methodologies, instrument design, or data analysis with faculty guidance was a large part of their research experiences. For example, Kim talked about an instrument she designed to analyze teacher lesson plans: "they (her faculty advisors) gave me a lot of guidance and kind of let me go do it." Bill said "It was just a question in my head and [Faculty Advisor's Name], my supervisor, said 'Why don't you do it? Why don't you research it?'" In addition, they were often co-authors on professional presentations or articles published in scholarly journals, or both. Thinking of these teachers as co-authors of the research projects they did as undergraduate describes their experience nicely because of their level of involvement and influence on the research projects they did. Participants with this type of experience were categorized as *initiative takers* (term developed by authors to succinctly describe their actions during their research experience); this term was used because it conveys the idea that these teachers helped develop at least part of the research projects they were working on independently.

*Table 2*
*Research Experience for Participants*

| Name | Classification | Research Work Summary |
|---|---|---|
| Bill | Initiative Taker | Conducted a pre/post survey of preservice teachers' self-efficacy after taking an inquiry course. Self-initiated question in which he found/modified the instrument and collected and analyzed his data. |
| Greg | Initiative Taker | Investigated his questions about group dynamics in a science class. Conducted interviews and analyzed data. |
| Kim | Initiative Taker | Researched instruments to measure the level of inquiry in teachers' lesson plans, developed a new instrument, and then used the instrument to assess lesson plans, and analyzed results. |
| Abe | Worker Bee | Developed online tutorials using Camtasia for different chemistry topics. |
| Chelsey | Worker Bee | Transcribed interviews conducted by others and was one of several coders of the transcripts for "inter-rater reliability" |

| | | |
|---|---|---|
| Kate | Worker Bee | Transcribed videos of students, and then coded them using a coding system developed by another. |
| Wanda | Worker Bee | Observed a class and tracked the questions being asked. Consolidated her data into graphs/tables |

Contrastingly, the four other teachers who participated in undergraduate research described doing tasks asked of them by university faculty as part of a larger research study with no little or no input on any part of research project design. They were merely workers on the project with no input into its design or execution. For example, for Kate "most of it was watching [observation] videos and transcribing videos" while for Abe "it was just developing those [online tutorials for a website]." These teachers were not coauthors on presentations or articles. These participants have been labeled *worker bees* (term developed by authors to succinctly describe their actions during their research experience). This term, while a colloquialism, quickly conveys the difference in their research experience as compared to the other researchers. [Note: It was not evident in the data whether each group chose their path in the project or if it was chosen for them by their faculty mentors, thus the categories are meant only to represent the experience *not* the participants' attitudes or choices.]

Table 3 summarizes the skills and characteristics described above and the teachers whose data provided evidence of them. The table does not show level of development, rather, just that the skills or characteristics of the teaching practice were present. As can be seen in the table, the initiative takers as a group had more of the observed characteristics than the worker bees, but the both groups of researchers had numerous characteristics which the non-researchers did not have.

*Table 3*
*Summary of Findings*

| **Teacher** | **Category** | **Non-required student data collection** | **Use of Formative Assessments** | **Student Use of Data or Applying Knowledge** | **Questions used as teaching tool** |
|---|---|---|---|---|---|
| Adam | Nonresearcher | | | | |
| Gail | Nonresearcher | | | | |
| Rita | Nonresearcher | | | | |
| Abe | Worker Bee | X | X | | |
| Chelsey | Worker Bee | X | X | | X |
| Kate | Worker Bee | X | X | | |
| Wanda | Worker Bee | X | X | X | X |
| Bill | Initiative Taker | X | X | X | |
| Greg | Initiative Taker | X | X | X | X |
| Kim | Initiative Taker | X | X | X | X |

In the initiative takers group, Bill is the only one who does not show some development of all the skills and teaching characteristics described. This might be because Bill felt confined by his teaching situation. Note: Bill is an exception to this likely because of his situation at the time.

> They push at our school and I'm noticing at other schools what's called common unit design. Where teachers are coming so the small school teachers teaching this high school chemistry class, they're all using the same tests, they're all using the same homework assignments, they're teaching the same thing on the same day. So that's the way I know this school's moving towards. I know other districts are moving that way as well. Just to hold teachers accountable, to make sure all students are receiving the same material and things like that. …
> I feel like it's a disseminator of knowledge. I don't, as of right now I don't feel like I'm a facilitator. I'm really the way the common unit design has been framed here is that I'm the teacher up front and the kids learn from me.

Even though he felt confined by his situation he still displayed many of the same characteristics as the other initiative taker.

Wanda was the only worker bee whose skills and teaching characteristics had all four characteristics described above. Her use of questions was only mentioned in terms of experiments (quote is above), not necessarily as a teaching tool she used in other situations as Kim and Greg described; her use of it may not even be as developed as Greg's practice, who only has one year of teaching experience. Worker bees Kate and Abe used the data but had not developed the other characteristics in their teaching practice enough.

**Limitations**

As with any study, but particularly exploratory studies, there are limitations to the data collected and described above. The sample and sample size is the main limitation for this study. It was a small convenience sample, so it is possible that there are other factors not explored by the data collected in this research which could link or group the teachers other than research experience. Complete details of the research experience and personalities of participants were not collected to understand this possible link-something a future study should explore. For example, the initiative takers, based on personality, might have sought out this opportunity for greater involvement in the projects, and thus personality traits might account for their similar characteristics grouping rather than the research experience. School culture for the teachers was also not well explored by the data. There were some questions about teacher leadership and individual professional development, but not about school culture, so it is possible that all the researchers were teaching at schools that emphasized data collection with significant professional development to support it. In terms of the data collected, though, since the novice teachers were teaching at different schools, coming from the same teaching programs, with varying levels of experience even within the less the five years, when grouped by the themes noted above, their research experience was the similar characteristic within the groups.

Another difficulty in this study is that the teachers self-reported information about their classroom teaching and classroom practices. The teachers were spread out by more than 1000 miles so observations by the researchers were impractical. There is also the chance since the participants knew the study involved the impact of the research on their teaching that they answered the questions differently than they would have if this context were removed. However, interviewing techniques to ask for specific examples and explanations of their classroom practices along with the collection of classroom documents was used to help improve the validity of this self-reported data.

One final limitation to this study which may also impact its generalizability is all the teachers in the study were science teachers with science or science education degrees. None of the teachers were certified in or taught a subject other than a secondary science. It is unclear then how these findings would transfer to secondary teachers in other subject areas or even to elementary teachers.

## Discussion and Conclusions

"Data-driven instruction" has become a more integral part of the teaching landscape since the implementation of the *No Child Left Behind* requirements (Kronholz, 2012). Data interpretation is part of many inservice teachers' jobs as they participate in Professional Learning Communities (PLC's) in which they are often asked to collect and compare data about their students (Darling-Hammond & Richardson, 2009). Data use and interpretation skills have been identified as important for novice teachers and should be a part of preservice teacher education programs (Shepard et al., 2005). In addition, the regular use of formative assessments in the class, especially quick ones with less formal data collection (i.e. exit slips, bellringers instead of pre and post-tests), has been shown to improve student learning (Keeley, 2008) and using it to make instructional decisions is an important skill for novice teachers to have (Shepard et al., 2005). The practice of the novice teachers who participated in undergraduate science education research included these desired data collecting skills more fully than the novice teachers who did not participate in research. Regular formative assessments were the tools they used more often as part of this practice. The researchers appeared more prepared for the data analyses aspect of their teaching careers, and better preparation in pedagogical skills means they are more likely to continue in the profession (Ingersoll, Merrill, & May, 2012). While this study cannot claim the use of data by the teachers is a direct result of their research experience, all the novice teachers who had participated in research possessed these skills, while those from the same programs who had not conducted research did not. From the Framework for Teacher Learning (Hammerness et al., 2005) discussed earlier, perhaps the research experience affected their learning community or maybe their dispositions towards teaching which then would influence the practices they learn or the tools they gather from the same teacher education courses as the nonresearchers. As discussed in the limitations section, it might have also been dispositions initially which impacted their choice of participation in research, the initial findings of this study suggest there might be a link been research experience and these data skills which is worth exploring more closely in future research.

Undergraduate science education research experiences may also give students an advantage when compared to students who go through the same teaching program but do not conduct research. The researchers had other teaching practices which were not present for the nonresearchers, like the use of questioning as a teaching tools and the practice of data use by students. These are desired characteristics of reform-based science teaching (Llewellyn, 2013; Treagust & Tsui, 2014); while they may have been part of their teacher education programs, the research experience affected the learning community or their dispositions and thus made them more willing to accept and or try these practices in their first years of teaching. This may provide these novice teachers with a career advantage. They can work on improving and refining these skills to become even better teachers, whereas the nonresearchers may need to first learn the skill, and then improve and refine it; the nonresearchers might need to find the community which will affect their dispositions so that they can continue to learn them.

Undergraduate science education research experiences, however, are not created equal. The initiative takers, those who took part in the design or creation of the research projects or portions of the research projects, reported more of these desired characteristics as a group than the worker bees, who simply helped with the projects but did not design them. Both groups appear to have benefited from participating in undergraduate science education research, but in different ways. These findings are similar to Mamlok-Naaman and Eilks's (2012) findings in which they compared professional development programs involving teachers in different forms of action research. The professional development which used a longer- term action research project had a greater impact on the teachers' practice than a professional development program which used a more traditional action research, but benefits were received by the teachers participating in both professional development programs. The commitment needed for all preservice teachers to be initiative takers may be too extensive (faculty mentors, time in their program, availability of research topics and subjects, etc.), but there are benefits from a smaller level of commitment as well. As with Mamlok-Naaman and Eilks findings, situations and goals may need to dictate the type of undergraduate science education research experiences offered preservice teachers.

Finally, the evidence from this study suggests undergraduate science education research may influence novice science teachers' teaching practices and teaching skills in ways not currently reported for other types of research experiences. While action research has been reported to increase preservice teachers' use of and knowledge of educational research (e.g. Kotsopoulos et al., 2012; Everett et al., 2007), it has not been shown to increase their use of data as they begin teaching. With inservice teachers, action research has been shown to help them make changes to their teaching practices after collecting data (Cullen et al., 2010; Lebak & Tinsley, 2010; Gerard et al., 2010), but these seem like larger pedagogical changes in their approach to a topic and not daily or regular instructional decisions in the context of formative assessment data. It is not clear from the research literature if action research projects help teachers use data for regular instructional choices, yet this study suggests that undergraduate science education research may teach novice teachers to use this data regularly along with making larger changes. As Del Carlo et al. (2010) argued, the undergraduate science education research experience, because it is long-term, more developed, and typically mentored by a faculty member, might provide a more sustained, in-depth experience for preservice teachers that capstone action research projects do not provide. The focus of the undergraduate science education research experience is also typically seeking a greater understanding and conclusion to influence a wider audience, rather than, as action research is often critiqued (Roth, 2007), an individualized understanding about specific environment. These differences might allow for a richer experience and better understanding of the use of data to draw conclusions and make changes.

## Implications

The results of this study demonstrate that novice science teachers with undergraduate science education research experience have similar, desirable, teaching practices when compared with novice science teachers without the experience. Preservice science teacher education programs are typically full of coursework for degrees and certification with little room or time for additional requirements, but it may be worth adding time or changing requirements so the students have the opportunity to participate in research. The results of this study suggest that if preservice teachers find the time to incorporate it into their learning community as undergraduates, undergraduate science education research impacts their future teaching practice. However, the necessary components of the research experience that create the impact are not clear. The initiative takers and worker bees had different experiences and appear to have had different levels of outcomes. What was it about the research experience, e.g. faculty mentor, longer time period, experimental design, etc., that was important to the difference in the preservice teachers' development or might it have to do with the personalities of the initiative takers and the worker bee? As mentioned previously, undergraduate science education research experiences take a lot of faculty time and effort along with time in the preservice teachers' packed curriculums, so an answer to this question is needed.

While this study cannot directly connect the teaching practices and the research experience due to the limitations of the study, the results do suggest the need for more research into the undergraduate science education research experience; they also suggest we might want to encourage preservice teachers to explore these options and for teacher educators to look at incorporating them into their preservice programs. Learning experiences that improve novice teachers' skills even before they reach the classroom only help to improve their retention rates and improve their students' learning (Ingersoll et al., 2012).

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## Appendix A: Background Questionnaire and Interview Protocol

### Background Questionnaire

1. Name:
2. Age:
3. How many years (counting the current year) have you been teaching?
4. What degree(s) have you earned and what was your major?
5. Do you hold any other special certifications or recognitions (i.e. National Board certified teacher or mentor teacher etc.)
6. What course(s) are you currently teaching?
7. If you had to pick, which class is your favorite to teach this year? Why? (For simplicity, this class will be used as the focus of interview questions about your classroom practice.)
8. What courses have you taught in the past that you are not currently teaching?
9. Do you belong to any professional organizations? If so, what?
10. Do you or have you ever held any leadership positions within any organizations? Please explain.
11. Have you served on any committees or groups within your school or school district (e.g. curriculum committee, discipline committee, school improvement, etc.)? If yes, could you please list what you have done.
12. Do you have or have you ever had a student teacher? If yes, how many or how often?
13. Do you have or have you ever had preservice teachers' observing (field experiences in your classroom)? If yes, how many or how often?
14. Have you ever conducted any research? If so, could you explain the research or the project you did. (For those with Undergrad research, question was written as "What did you do during your undergraduate research? Title of the project if you remember it?
15. Have you done any professional presentations or written any articles? If so, please list the title and dates of any (approximate is close enough).

### Interview Protocol

*Request Permission to Record:*

I would like to audio-record this interview to transcribe and analyze later. Is it ok if I record our conversation?

*Questions:*

1. Clarifying question(s) from background questionnaire. [For example, what did you do when you served on the curriculum committee? Or how long have you had student teachers?] Researchers- specifically ask about what they did for the research and for how long

2. Can you tell me a little about your experiences teaching science?*

3. How would you describe your role as a teacher?*

4. How do your students learn science best?*

5. How do you know when learning is occurring in your classroom?*

6. Tell me what you did last week in (class identified as favorite from background questionnaire). Is this typical?

7. What general topics do you cover in this course? Where do these topics come from?

8. Do you have any projects or larger assignments in course? What's their purpose?

9. Do you collect any data about your students in a formal manner? How do you use that data?

10. Do you read in professional research like *The Science Teacher* or *Journal of Science Education* etc.? If yes, what do you read? Why?

11. (Skip if nonresearcher) How do you think your research experience has affected your teaching?

12. Do you continue to conduct research? In what way? (Or if nonresearcher, Do you conduct research? In what way?)

13. Is there anything else you would like to tell me or add?

* Questions adapted for Luft and Roehrig (2007).

## Appendix B: Methodology Extended Discussion

More details about the methods used in this study are found below in order to provide the reader with more information if desired but keep the article to a manageable length.

### *Participant Recruitment*

Six science education faculty members within science departments from two different, largely undergraduate Midwestern universities with reputations for educating teachers (MU1 and MU2) were used to identify potential participants for this study. The Midwestern universities are both primarily undergraduate institutions, though they do both have some graduate programs including masters' degrees in education and/or science education. Both universities also have a reputation for educating teachers, and there are faculty members within the science departments whose interests include science teacher education. In addition, undergraduate research within the science departments is supported monetarily by both universities, but is not required for students to graduate with a teaching degree from either university. After a brief description of the study, the faculty members were asked for names of former students who as undergraduates "participated in science education research with you", along with names of other recent graduates from their program or teaching courses. The faculty identified sixteen former students who had conducted research with them and eighteen former teacher education students who had not. The researchers used information provided by faculty member along with search engines and department of education listings to find contact information for possible participants. All possible participants in which contact information could be found (34 possible) were sent an email and asked to participate in the study. By using graduates from only two different preservice education programs, the researchers were attempting to create a larger sample, but also control for their preservice educational experiences.

### *Interviewing*

The initial questionnaire also asked the teachers to identify their "favorite course" which they were currently teaching; it would be used as the focus of the interview. The reason to focus the interview on the teacher's favorite course was so the teachers would/could speak in specifics about their teaching practice rather than general statements. Asking for specifics rather than generalizations is considered good interviewing technique since it preempts the interviewee from the task of analysis or interpretation and provides clarity to interviewees' definitions of words and ideas (Weiss, 1994). The purpose of including a variety of questions in the interview was to prompt the teachers to think about many different aspects of their teaching. Since the teachers knew the study involved research experiences, and there were questions about those experiences on the questionnaire and interview, question variation was also an attempt to take the focus off their research experience in their minds so they would discuss their teaching practice, not just as it related to their research experience. Throughout the interviews, the interviewer asked the teachers to provide examples from their teaching experiences, specifically their favorite course, to explain and confirm ideas they described (Berg, 2009; Weiss, 1994).

*Documents*

The number of documents provided by the teachers ranged from three documents to thirteen documents; one teacher provided the link to her class website which had documents for the entire year. The participants included experiment/activity handouts, worksheets, notes, project descriptions/explanations, and assessments. It varied based on what they had done the prior week.

*Coding*

Final codes, which included demographics, data collection methods, analyzing data, attitude toward teaching practice, attitude toward student learning, belief about teaching, beliefs about student learning, curriculum, teaching routine, and research were created from the initial round of coding, and the transcripts and background surveys were recoded based on the new categories until consensus was reached. The course documents were used to substantiate comments made both during the interview and during the analysis. They were used as a check for the comments in the interview; if a document contradicted statements from the interview, it would not be marked. For example, if the teacher were to call something open inquiry but then gave a handout which would be classified as a "cookbook" experiment, then this section of the interview would have been challenged by the researchers. However, the participants' descriptions of their classes and their supporting documents matched, thus the interview data became the main data source.