Preservice Teachers' Consideration of Life Science Concepts and Elementary Students' Ideas within Structured Formative Assessment Assignments

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Author Note

This work is funded by the Spencer Foundation. However, any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors.

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Abstract

Preservice teachers often have limited science subject matter knowledge. In order to effectively engage students in scientific practices and connect students' ideas about science to appropriate instructional strategies, teachers should learn disciplinary concepts and how to apply their content knowledge to elementary classroom environments with proven instructional practices, such as formative assessment. However, the use of formative assessment practices is not widespread in part because teachers may not understand formative assessment or have enough science content knowledge to effectively engage in the practice. To address this concern, we developed an innovative course for elementary preservice teachers built upon two pillars—life science content and formative assessment. As a part of the course, preservice teachers engaged in formative assessment assignments that provided structure to engage them in each step of the formative assessment process and to support them in considering their own and elementary students' life science understanding. Here, we will present results of a mixed methods study designed to evaluate how engaging in these assignments provided opportunities for preservice teachers to gain content knowledge and the ability to productively engage in formative assessment for science.

Descriptors: preservice teacher education, formative assessment, life science

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Preservice elementary teachers often have limited science subject matter knowledge and the content they encounter in college science courses is typically not well translated to elementary science learning environments (Rice, 2005; Haefner & Zembal-Saul, 2004). Further, they often have difficulty understanding some of the biological concepts found in elementary science curricula and may have some of the same alternative conceptions about life science concepts as their students (Krall, Lott, & Wymer, 2009; Rice, 2005). Effective engagement in practices that allows teachers to engage with their students' ideas requires teachers to have an understanding of the disciplinary concepts they are teaching, the knowledge of how to apply their content knowledge to elementary classroom environments, and the ability to integrate their content knowledge with instructional practices (Ball & Forzani, 2009).

Formative assessment is one type of instructional practice that provides connection between disciplinary content knowledge and instruction and allows teachers to elicit, evaluate, and respond to students' ideas (Bell & Cowie, 2001; Coffey, Hammer, Levin, & Grant, 2011). Past work has shown that preservice teachers with more life science content knowledge are able to engage more productively in formative assessment practices (Sabel, Forbes, & Zangori, 2015) and that formative assessment practices lead to significant gains in students' science learning (Ruiz-Primo & Furtak, 2006). However, the use of formative assessment is still not widespread in elementary classrooms; possibly because teachers do not understand formative assessment or have the necessary content knowledge to effectively engage in the practice (Coffey et al., 2011; Otero & Nathan, 2008).

To build elementary teacher content knowledge, novel approaches are needed to provide preservice teachers with opportunities to learn life science concepts within their undergraduate teacher preparation programs so that they can effectively teach those concepts to elementary students (Ball, Thames, & Phelps, 2008; Forbes, Sabel, & Zangori, in press; Haefner & Zembal-Saul, 2004; Nowicki, Sullivan-Watts, Shim, Young, & Pockalny, 2013). To address these needs, we developed a new course for undergraduate, preservice elementary teachers that combined instruction on life science content and instructional practices appropriate for elementary science classrooms (Forbes, Sabel, & Zangori, in press). Structured formative assessment assignments that prompted preservice teachers to engage in each step of formative assessment were used as scaffolds to support them as they engaged in the practices. Although some past work has examined how preservice teachers engage in formative assessment (e.g., Buck, Trauth-Nare, & Kaftan, 2010; Graham, 2005; Otero, 2006; Otero & Nathan, 2008; Sabel et al., 2015), this study has addressed key gaps in the existing literature by focusing on how particular classroom artifacts can service as scaffolds to support preservice teachers' in learning life science content knowledge as they engage with elementary students' ideas in formative assessment practices. This study is informed by the following research questions:

1. How does engaging in structured formative assessment assignments influence preservice teachers' understanding of biological concepts?
2. How does engaging in structured formative assessment assignments influence preservice teachers' understanding of the process of evaluating students' ideas about biological concepts?
3. In what ways did the formative assessment assignments allow students to engage in reflection and metacognition about their ideas and the formative assessment process?

Background and Theoretical Framework

Formative Assessment

Formative assessment is a high-leverage instructional practice that allows engagement with students' ideas by crafting responsive instruction with a diverse set of practices that are based on students' ideas (Ball & Forzani, 2009; Bell & Cowie, 2001; Black & Wiliam, 2009; Coffey et al., 2011). It involves taking individual student progress into account and centrally involving students who are active in their own learning (Harlen & James, 1997). The practice allows both teachers and students to recognize learning, respond to it, and determine ways to enhance understanding and can provide students with opportunities to demonstrate their knowledge to the instructor (Bell & Cowie, 2001; Ruiz-Primo, 2011). While assessment has long focused on examining what students have learned, formative assessment aims to use assessment to *enhance* students' learning. Students learn more when instruction includes formative assessment because ongoing assessment allows teachers to fine-tune their instruction and allows students to focus on their progress (Cauley & McMillan, 2010). By eliciting and responding to students' ideas, teachers can assess students' understanding in a way that allows them to more effectively adjust instruction and engage students in sense-making and scientific practices and also support them in their progression toward scientific knowledge (Hammer, Goldberg, & Fargason, 2012). This is particularly important because the accuracy of teachers' analysis of their students' understanding is directly related to the extent of their students' learning and past research has shown that the use of formative assessment in classrooms has led to significant student learning gains (Herman & Choi, 2008; Ruiz-Primo & Furtak, 2006; Wiliam, 2011).

Preservice Teachers' Engagement with Formative Assessment

Preservice teachers often have difficulty with formative assessment for science due to a number of factors. First, they frequently have limited understanding of elementary students' prior knowledge (Buck et al., 2010; Otero & Nathan, 2008). Second, they tend to consider student understanding simply in terms of "get it or don't" ideas and this limits their response to students' ideas (Otero, 2006). In particular, they may not identify the particular gap in understanding students have and so are unable to provide the type of feedback students need in order to build upon their ideas (Buck et al., 2010). Third, they tend to only describe students' responses or look for particular vocabulary words as indicators of understanding rather than focusing on whether or not students' have made sense of the concept (Talanquer, Bolger, & Tomanek, 2015). Finally, teachers may not be able to effectively engage in formative assessment practices is because they do have enough disciplinary content knowledge (Buck et al., 2010; Coffey et al., 2011; Falk, 2011; Heritage, Kim, Vendlinski, & Herman 2009; Morrison, 2013; Otero & Nathan, 2008; Sabel, Forbes, & Flynn, in review). In order for preservice teachers to begin to better understand formative assessment, teacher preparation programs need to include opportunities for preservice teachers to engage and reflect on learning strategies, to learn about the ways and the context in which students learn science, and to gain the science content knowledge they will need to engage in these practices and effectively respond to students' ideas and support knowledge building (Kohler, Henning, & Usma-Wilches 2008; Levin, Hammer, & Coffey, 2009).

Past work has shown that preservice teachers are able to expand their understanding of classroom assessment if they are provided opportunities to engage with students' ideas, have support to consider appropriate actions to take to address students' ideas, and implement formative assessment practices that support students in building upon their ideas (Buck et al., 2010; Graham, 2005; Otero & Nathan, 2008; Talanquer, Tomanek, & Novodvorsky, 2013). For

example, Buck et al. (2010) explored the use of explicit instruction on formative assessment within a preservice course and found that preservice teachers had a substantial gain in their understanding of formative assessment, but considered the formative assessment model presented as the only "correct" model as opposed to an option among many models. Graham (2005) showed that professional dialogue about assessment methods helped preservice teachers to consider alternative assessments as ways to evaluate student understanding. Otero and Nathan (2008) documented prior knowledge preservice teachers had about formative assessment when they began a science methods course and found that some of those ideas changed over the semester, but others did not. Finally, Talanquer et al. (2013) examined the classroom elements that preservice teachers tend to notice during assessment and suggested providing more support to help guide preservice teachers toward the particular pieces that would be most useful for them to notice regarding their students' ideas.

Teachers' Disciplinary Content Knowledge

Preservice teachers need opportunities to learn life science concepts that they will need to understand to effectively teach elementary life science lessons (Haefner & Zembal-Saul, 2004; Nowicki et al., 2013). This is important because teachers who have more robust disciplinary knowledge have been shown to be able to more effectively implement teaching strategies that support student learning; in particular, content knowledge is an important factor in teachers being able to effectively elicit and evaluate students' ideas and understanding (Gottheiner & Siegel, 2012; Morrison & Lederman, 2003; Sabel et al., in review). However, some teachers tend to see disciplinary content as simply a body of information with particular vocabulary words selected as a focus for lesson objectives (Coffey et al., 2011). This leads them to then present science subject matter as a collection of facts or procedures that students need to simply accept and

remember (Kennedy, 1998). Further, past work has shown that inservice elementary teachers often have similar alternative conceptions about life science concepts as their elementary and middle school students (Krall et al., 2009) and that teachers have difficulty with understanding some of the basic biological concepts that are present in elementary science curricula (Kikas, 2004; Rice, 2005). As a result, teachers tend to rely heavily on the information provided in the curriculum and often misinterpret students' ideas as correct if they simply contain the correct scientific terms; this limits the types of decisions they make about their students' understanding of disciplinary concepts (Forbes, Sabel, & Biggers, 2015; Sabel et al., 2015; Kikas, 2004). Teachers must understand the biological content and its importance themselves in order to help their students do the same (Kennedy, 1998).

Self-Reflection and Metacognition

Self-regulated learning consists of forethought, which takes place before a task begins, performance, which involves self-monitoring during a task, and self-reflection, which takes place after a task. Self-reflection involves students evaluating and reflecting on their performance on a task (Zimmerman, 2000). Reflection typically involves "a conscious exploration of one's own experiences" (Silver, 2013, p. 1). The focus within this study is on self-reflection because students were asked reflective questions following the assignments, but were not asked specifically to engage in the forethought or performance stages.

Metacognition is also considered a part of self-regulated learning and involves students' awareness of their own learning process (Sinatra & Taasoobshirazi, 2011; Wood, 2009). Reflection and metacognition are often used interchangeably but have distinct differences in that reflection focuses on exploring experiences more generally and metacognition focuses on students' thinking about their own thinking. Students who engage in metacognition have better

performance and learning gains, and the process of considering the plausibility or intelligibility of their ideas may help them to change alternative conceptions to scientifically-accurate conceptions (e.g., Anderson & Nashon, 2006; Baird, 1986; Tanner & Allen, 2005). Metacognition is made up of three dimensions and related questions: (1) "Intelligibility: Does the explanation make sense to me?", (2) "Plausibility: Do I think that the explanation is a possible explanation?", and (3) "Wide-applicability: Can I apply the explanation beyond the contexts in which I have learned it?" (Grotzer & Mittlefehldt, 2012, p. 82). These three dimensions are the foundation for examining the extent to which preservice teachers engaged in metacognition as they used formative assessment assignments within this study.

Very few studies have examined preservice teachers engaging in metacognition within science learning environments. Preservice teachers' metacognitive knowledge has been found to be better when they engaged with content knowledge than when they considered instructional methods (Yerdelen-Damar, Özdemir, & Ünal, 2015). Further, preservice teachers gained greater understanding of the nature of science (NOS) when instruction on NOS was combined with instruction and practice using metacognitive strategies (Abd-El-Khalick & Akerson, 2009). While the research on metacognition has shown performance and learning gains for students, in general, more work is needed on how instruction and practice with both reflection and metacognition could help preservice teachers learn to integrate content and practices.

Study Design and Methods

Context and Participants

Research approach and context. This convergent parallel mixed methods design consists of both quantitative and qualitative data collected and analyzed in parallel and then merged to reach greater understanding of how preservice teachers engaged in formative

assessment assignments to learn both content and instructional practices (Cresswell & Plano Clark, 2011. Quantitative analysis of assignment and exam scores and survey responses were used in combination with a multiple case study with cross case analysis (Miles et al., 2014; Yin, 2014) of five students interviewed after each of three formative assessment assignments. The case studies will allow in-depth investigation into the phenomenon while cross case analysis will allow the study to have enhanced generalizability as well as deepen the understanding and explanation of the students' experiences (Miles et al., 2014; Yin, 2014).

This study was conducted during the implementation of a newly designed undergraduate course that integrated science content with elementary science instructional methods. The course was one of three that were developed in response to changing state requirements for elementary teacher licensure that required an increased number of course credit hours in science subject areas. The three courses each focused on one of three disciplinary domains: life, earth, and physical science. This study focuses only on the life science course which was the first of the three to be implemented. The purpose of this course was to provide preservice elementary teachers with the tools they would need to understand life science concepts emphasized in the Next Generation Science Standards (NGSS Lead States, 2013), to implement elementary science curriculum focused on these concepts, and to implement instructional practices that are responsive to students' ideas (Forbes et al., in press). Formative assessment was a key focus throughout the course and preservice teachers were provided opportunities to practice implementing strategies that allowed them to evaluate elementary students' ideas and develop next instructional steps that addressed those ideas, all in the context of the life science content they were learning. The course consisted of two meetings per week: one in which the entire class (49 students) engaged with life science content and relevant elementary standards, and a second

in which small groups of 12-20 students met for methods labs that focused on the instructional strategies teachers could use to engage elementary students in those life science concepts.

Throughout the semester, the preservice teachers engaged in Curriculum Topic Study (CTS; Keeley, 2005) that integrated life science content with relevant elementary standards and common alternative conceptions that elementary students might have about the content. CTS allowed the preservice teachers to learn about and use resources that support them in learning content knowledge that is relevant to the elementary science lessons they will need to teach. CTS also provided them with resources to find information on how particular concepts are considered in the standards, common student ideas they might encounter regarding those concepts, and how they might address alternative conceptions. The preservice teachers completed one CTS per week and this served as critical source of life science content throughout the course.

Participants. All undergraduate students in a new elementary life science instructional methods course were recruited to participate in the study (n=49). These students were preservice elementary teachers and were juniors and seniors enrolled in a three-year elementary education program at The University of Iowa. The preservice teachers were at various points in the elementary education program, though all took the class prior to student teaching, and had various areas of specialization including science (1), social studies (4), math (11), and language arts/reading (42). All were from Midwestern states, 45 were female, and four were male. All students in the course completed pre- and post-tests, three formative assessment assignments, and a demographic and science-interest survey as a normal part of the course. Among these participants, some preservice teachers were purposefully selected (Merriam, 2009) to take part in interviews. Ten students were interviewed after each of the formative assessment assignments. Five students remained constant across all three assignments while another five varied for each

of the assignments (n=10 interviews per assignment, n=30 interviews total). Each student who agreed to participate was assigned a non-identifying, randomly generated number that was used in place of their names on all documents collected for research.

Data Collection

Preservice teachers completed a content assessment at the beginning and the end of the semester that focused on life science concepts that aligned with the course topics. These assessments consisted of 48 multiple-choice questions that were selected from the AAAS assessment item bank (AAAS Project 2016, 2013). These test bank items were developed to align with CTS topics and we selected the questions that aligned specifically with the CTS topics covered in the course.

All 49 students enrolled in the class completed a survey during the first week of the course. This survey consisted of primarily closed-response questions with two open-response questions. These questions were used to identify demographic information about the students as well as their past experience with science classes and their comfort, interest, and perceived ability to be able to teach science and biology, in particular. For the purpose of this study, we focused only on the closed-response items in which students indicated comfort, interest, and ability in science and biology on a Likert scale (Gall et al., 2007).

Preservice teachers also completed three formative assessment (FA) assignments that consisted of examining elementary student work, evaluating trends in students' ideas, and proposing next instructional steps to address those ideas. These assignments were completed in an online format during the small-group methods labs and were accompanied by class discussion to further emphasize formative assessment practices. Components of the assignment consisted of a lesson plan provided by the instructors that we chose to align with the CTS topic the class had

completed that week and actual elementary student work that teachers who had enacted the lesson plan had provided to us as a part of another research project.

Assignment 1 focused on seed dispersal which aligned with the CTS topic on Plant Life. The key concept of the lesson was that "Seeds can be dispersed in many different ways based on their physical characteristics." The student prompt asked students to answer "How does this seed [picture included] called a cocklebur travel? How do you think it travels this way?" Assignment 2 focused on the skeletal system which aligned with the CTS topic on Human Body Systems. The key concept for Assignment 2 was "Bones have three major functions in the human body: support, protection, and locomotion." The student prompt asked students: (a) What are the three main functions of a skeleton? (b) The skull is a hollow case made of bony plates. Which of the functions listed above is the primary function of the skull?" Assignment 3 focused on habitats which aligned with the CTS topic on Habitats and Local Environments. The key concept or Assignment 3 was: "Crayfish habitats must include clean, cool water; food; and shelter. These are what the animals requires to live in its habitat." The student work asked students: (a) Draw a habitat that would be suitable for several crayfish and label the objects you draw. (b) What basic needs are supplied by the objects in your drawing? (c) What basic need(s) does the crayfish have that you could not draw?"

Preservice teachers answered questions related to the content of the elementary science lesson and then reviewed the lesson plan. Based on the lesson plan, preservice teachers were asked to anticipate ideas elementary students might have about the key concept. The preservice teachers then reviewed the elementary student work and evaluated students' ideas to identify trends in elementary students' understanding of the key concept. Finally, based on their

evaluation of students' ideas, they were asked to outline the next instructional steps they would take to address the problems they saw in how students considered the key concept.

A subset of preservice teachers participated in semi-structured interviews (Merriam, 2009) following each of the three FA assignments. Five students were interviewed after all three assignments and an additional five varied for each of the assignments so that each assignment had ten interviewed students for a total of 30 interviews. These interviews were approximately 15-20 minutes in length and were used to explore preservice teachers' ideas about their processes for engaging in formative assessment practices and, in particular, to further understand their ideas behind their answers on the FA assignments. The interviews were audio-recorded and transcribed for analysis.

Data Analysis

The pre- and post-tests were scored using a pre-developed answer key. The three FA assignments were scored using a rubric developed for the project that aligned with the questions on the assignment (Sabel et al, 2015). The rubric consisted of a five point scale (0-4) and allowed a score to be assigned to the degree of detail and accuracy in which the preservice teachers described their (a) anticipation of elementary students' ideas, (b) evaluation of students' responses, and (c) proposed next instructional steps. The rubric was developed and revised concurrently with two scorers testing the scoring. The rubric was considered complete when the two scorers were able to obtain consist scores. A round of scoring was completed by both scorers on a 10% subset of the assignments (n=15) after the final revision to establish rubric reliability and consistency. Coefficient alpha for the interrater reliability was 0.982. Based on this high level of interrater reliability, the first author scored all remaining assignments alone.

Closed-response survey responses were quantitized (Miles et al., 2014) on a scale from 1 to 5 so that responses that indicated the least amount of interest or comfort were given a score of 1 and those with the highest amount of interest or comfort were given a score of 5 (e.g., Very uncomfortable = 1, Somewhat uncomfortable = 2, Neutral = 3, Somewhat comfortable = 4, Very comfortable = 5). The pre- and post-test scores, FA assignment scores, and survey results will be imported into SPSS for analysis. We used correlation analysis to test relationships between survey responses, exam scores, and assignments scores; used bivariate regression analysis to examine the relationship between the pretest scores and the assignment scores; and used repeated measures ANOVA to test the difference in how preservice teachers performed on the content questions embedded within the three assignments.

We purposely selected (Merriam, 2009) the five students who had participated in the interviews after all three assignments in order to examine their growth over the semester (n=15 interviews). The interview transcripts were analyzed for patterns within and across the assignment interviews. The interview transcripts and assignment responses from each of the five cases were imported into qualitative analysis software (QDA Miner 4). We coded these interviews first to identify where preservice teachers discussed life science content and then where they engaged in reflection as well as the intelligibility, plausibility, and wide-applicability of their own ideas and the elementary students' ideas (Grotzer & Mittlefehldt, 2012). We then used open coding (Merriam, 2009) to identify themes in how the preservice teachers considered the content, particularly in terms of their previous knowledge of the concepts and how reading students' responses influenced the way they thought about the content themselves. These data were used to develop cases for the five students and cross-case analysis (Yin, 2014) were used to determine similarities and differences with the five students in how their ideas and engagement

changed over the semester as they learned more content and had more experience with evaluating students' ideas. Preservice teachers' interviews, assignment scores, and survey responses were used to triangulate the data sources to ensure the findings were corroborated across sources (Gall et al. 2007; Miles et al., 2014).

Results

In research question 1, we asked, "How does engaging in structured formative assessment assignments influence preservice teachers' understanding of biological concepts?" First, using correlation analysis of the surveys, assignment scores, and pretest scores, we found that preservice teachers' self-reported comfort with biology was positively correlated with their performance on the pretest and with their scores on Assignment 1 (Table 1). However, this significant correlation did not extend to their performance on Assignment 2 or Assignment 3 (Table 1). Second, using bivariate regression analysis, we found that preservice teachers' performance on the pretest predicted their performance on Assignment 1, but not on Assignments 2 or Assignment 3 (Table 2). These results suggest that the prior experiences the preservice teachers had with life science content significantly influenced their early performance in the course – specifically on the pretest and the first assignment. However, their prior knowledge and experience with science was less of an influence as they progressed through the semester. This suggests the assignments helped to structure their progression from relying on prior experiences and knowledge to incorporating new information as they completed the tasks.

Table 1

Correlations With Self-reported Comfort With Biology

	r	*p*
pretest	0.564	0.000*
Assignment 1	0.564	0.000*
Assignment 2	0.286	0.051

Assignment 3	0.256	0.082

*significant at $p \leq 0.05$

Table 2

Regression Analysis of Pretest Performance Predicting Assignment Performance

	b	*p*
Assignment 1	0.649	0.038*
Assignment 2	0.397	0.148
Assignment 3	0.274	0.359

*significant at $p \leq 0.05$

Second, analysis of the life science content questions on each of the three assignments using repeated measures ANOVA showed a significant difference over time ($F(1, 46) = 31.35$, $p = 0.000$) from the mean scores on Assignment 1 to Assignment 2 to Assignment 3 (see Table 3 for descriptive statistics). These content questions were not simply a measure of the preservice teachers' content knowledge, but rather, their ability to synthesize information in the lesson plans that were provided to them as a part of the assignment. Therefore, this increase indicates that the formative assessment assignments supported preservice teachers both in learning more life science content, and also in learning how to seek out and consider the relevant content from within the resources provided to them.

Table 3

Descriptive Statistics of Assignment Scores

	Mean	SD
Assignment 1	77%	21.3
Assignment 2	86%	8.5
Assignment 3	95.5%	8.0

Qualitative analysis of the interviews following each of the assignments supported this quantitative finding as preservice teachers mentioned primarily their own prior knowledge in the

first assignment but increasingly mentioned the lesson plan and other resources from the course in Assignments 2 and 3. On the first assignment, preservice teachers discussed life science content they had learned in high school or mentioned not knowing a lot of science content when they began the assignment. Students who indicated less comfort with science concepts on the surveys were more likely to discuss not knowing content on the first assignment. On Assignment 1, Audrey said "Science has never been one of my very strong suits" (Audrey, Assignment 1). Similarly, Miranda said "[Seed dispersal] is probably not something I knew very much about. I would say sadly science, I know very little about overall" (Miranda, Assignment 1). However, even those students who indicated higher comfort with science mentioned not knowing the specific information required for the assignment. Julia said, "I thought I was comfortable with [the topic of seed dispersal] and then I did the assessment and I realized I don't know a lot of things" (Julia, Assignment 1).

For all preservice teachers, this mention of life science content knowledge they had prior to the course diminished through Assignments 2 and 3. By the second assignment, Audrey had moved away from talking about science not being one of her "very strong suits" (Audrey, Assignment 1) to mentioning that "As with all of my science stuff, I just want to brush up on it beforehand, but I think I would feel a lot more comfortable teaching it with having a lot of other resources…" (Audrey, Assignment 2). By Assignment 3, she said, "That was really simple… I was able to find that fairly quickly within the lesson plan. I wasn't really sure, I had a good idea [crayfish] were probably carnivores, for sure, I didn't realize they were omnivores" (Audrey, Assignment 3). These results suggest that the way in which the preservice teachers engaged in the formative assessment assignments affected how they considered life science content over the semester and that they began to feel more comfortable with finding the relevant information they

needed to understand the concepts. In the first assignment, preservice teachers also connected the ideas they thought students would have about the topics to their own prior knowledge whereas by Assignments 2 and 3, they began to mention feeling comfortable with the topic and connected their ideas about what students would understand more to the ideas they had learned as a part of the assignments or reading prior to class.

In research question 2, we asked, "How does engaging in structured formative assessment assignments influence preservice teachers' understanding of the process of evaluating students' ideas about biological concepts?" First, using qualitative analysis of the interviews following the assignments, we found that the preservice teachers progressed from being unsure about how to interpret students' ideas on the first assignment, to feeling more confident by the second assignment. On the first assignment, when asked about how hard it was to determine whether or not students understood the topic of seed dispersal, Miranda said,

> Yeah, I think it was hard. I switched it around a few times. The first time, I put down more students understood than did not understand. Then, I felt I got a bit more critical about their answers, so then I put it half and half, and then they got more critical, I think it was about three times, so I put more didn't understand than they did. (Miranda, Assignment 1)

Similarly, Isabel said, "I guess I didn't know how picky I should be, because there are obviously the ones who said it got attached to the fur, and I thought that they would understand, that they got it." In both of these examples, the preservice teachers mentioned not knowing how to decide whether or not students understood because they weren't sure of the criteria they should use or how strict they should be in their evaluation of students' ideas. Some students took this a step further and also connected not being sure how strict to be in their interpretation of student

understanding based on the consequences it would cause for classroom instruction. For example, Audrey said,

> Thinking back on it, it made it so that I had a very low amount of students that I thought understood it. I guess my question would be, "At what point do you?" If you always hold, I mean you want to have high standards, but at what point, you don't have time in the year to reteach everything, to that extent. I think you have to pick and choose your battles. (Audrey, Assignment 1)

By the second assignment, the preservice teachers had progressed and thought the task was easier because they had a better idea of what they were looking for in the students' responses or what they needed to accomplish. For example, Julia said,

> I think I was way more confident on this assignment than the seeds assignment [because] I knew more about what I was looking for.… Because I did an assignment before and this one seems more direct, the key concepts, or I had a more direct feel for it, I guess. I understood more about what the students were supposed to get out of the lesson in this one than in the previous one… The instruction of the assignment, I think [helped with that]. (Julia, Assignment 2)

By the third assignment, the preservice teachers were again more confident in their abilities to engage in formative assessment. Kate said,

> I think I understood this one more than the other two…Which is weird for me because I didn't have any knowledge on crayfish. I've never done anything with crayfish within my education. I just think that after the two that we've had, it was easier for me to go through and know what's expected of me. The first one it was kind of you didn't know what was

> going on at all. Then the second one you're getting used to it more, but I feel like this one ran smoother for me. (Kate, Assignment 3)

In both of these examples, Julia and Kate showed that they had gained confidence in their ability to assess students' ideas and engage in the process of formative assessment and they attributed that increased ability to the previous assignments. Therefore, having had the structured experience of the formative assessment process helped the preservice teachers to be more confident in engaging in that process in the subsequent assignments.

However, the preservice teachers did have difficulties on the third assignment that were different from those on the previous assignments due to the fact that the elementary students were asked to draw, rather than write, their response. This difference in format than they had previously experienced on the first two assignments was difficult for the preservice teachers. For example Miranda said,

> It was a little tricky to determine whether they got it or not, because I feel when it comes to drawing, a lot of it can be from interpretation, and if you don't talk to the student about what their drawing includes, or what they're trying to say, we might not know what their drawing is saying, (Miranda, Assignment 3)

This shows that, even while they are increasing their overall confidence and ability in engaging in formative assessment, the preservice teachers do still need additional experience and exposure to a wide variety of student prompts.

Second, the structure within the assignment helped the preservice teachers to consider the effectiveness of the prompt the elementary students were given and the preservice teachers were able to progress in their suggestions for modifications to the student prompt in order to receive better feedback on students' understanding. On the first assignment, the preservice teachers

considered how the prompt allowed them to interpret students' ideas primarily in terms of changes to get the students to answer in a particular way. The key concept in Assignment 1 was "Seeds can be dispersed in many different ways based on their physical characteristics" while the student prompt was "How does this seed [picture included] called a cocklebur travel? How do you think it travels this way?" The preservice teachers tended to want to get the students to answer in ways that they thought would elicit a more correct answer, however they struggled with how to do that. For example, Kate said the question should be changed to "Why do you think that basically or how do you think the seeds travel?" and then commented "I don't know if that would be getting too much information by actually stating in the question like "What physical characteristics make you think that?...But then if you're also trying to see, I mean if that's your goal you don't really want to give it away. You want them to get at that themselves and pay attention to those physical characteristics" (Kate, Assignment 1).

In a second example, Audrey said,

> If you showed them a picture of a seed, and then said, "How does this seed travel?" Or, another, like, more of a process of elimination question, given them, giving them one of the ways of dispersal, saying, "Why could this seed not travel by wind?" Or why, I was wondering if that would maybe, elicit a better answer from the students, instead of just a broad one. This is a new seed, how is it dispersed and what makes it disperse that way? (Audrey, Assignment 1)

In both cases, the preservice teachers concentrated on how they could get the students to answer the question in a particular way rather than on whether or not the students understood the underlying concept.

By the third assignment, even though they had more difficulty with interpreting students' ideas with the drawing prompt, the preservice teachers were also beginning to consider different types of learners and the idea that some prompts may work better for some students or that they may have to be flexible in their interpretation if the answers do not match the preservice teachers' preconceptions of a good answer. In some cases, the difficulty with interpreting the student work in the third assignment prompted this, such as when Kate said,

> At first I thought that it was a good idea because that's just something new. It's something different. But then I looked at the student work. I kept thinking about how I would feel if I were asked to draw a habitat and that might freak me out at the beginning, especially for those learners that aren't as visual and they don't feel that they have any artistic capabilities. I know what I looked for within that prompt was just I didn't so much look at the pictures at all, really. I just looked at the words that they put around it. I feel that since I did that, that kind of took away from the whole drawing aspects, so maybe they didn't need to do that. (Kate, Assignment 3)

In a second example, Audrey said

> I think I've become more, I don't want to say lenient, but I've become a lot more open to students interpretation of the information that is provided. Such as, some of them, when they weren't able to give a written explanation and they didn't include water…I'm assuming that they didn't include it in there because it was kind of one of those things, if you asked them, "Why didn't you include water?" They'd say, "well, duh. Why wouldn't they have water?" It's not something that processes. (Audrey, Assignment 3)

Therefore, the assignments helped the preservice teachers to learn more about what makes a good prompt, but also to be able to move forward with interpreting students' ideas even if the prompt does not give them exactly the information they anticipated.

In research question 3, we asked "In what ways did the formative assessment assignments allow students to engage in reflection and metacognition about their ideas and the formative assessment process?" Using qualitative analysis of the interviews following the assignments we found that, first, the formative assessment assignments allowed the preservice teachers to reflect on their own content knowledge and learn new information. For example, in each of three assignments, Julia mentioned something new she had learned in the process of engaging with the concepts. In Assignment 1, she said "Now we realized corn kernels are seeds, and I was confused. I thought corn was a grain…Then grains can be seeds…So, yeah, I found that out today" (Julia, Assignment 1). In Assignment 2, she said, "I was not too sure about the marrow, and I didn't know that they produce the blood cells. I had no idea about that." (Julia, Assignment 2). And, in Assignment 3, she said, "I didn't realize that crayfish eat everything basically dead plants and living and just everything." (Julia, Assignment 3). Further, as they progressed through the assignments, this reflection of their ideas helped them to realize the need to carefully read the lesson plan and learn relevant content through the reading. In Assignment 1, Hannah said, "Because I didn't read about seeds…and I didn't know about the four dispersals. Was that in the reading?" (Hannah, Assignment 1). By Assignment 2, she said, "I was able to refer to the text, the teacher knowledge part…If I had to introduce without that I wouldn't got them all wrong" (Hannah, Assignment 2). These examples show how the assignments helped the preservice teachers reflect on the content knowledge they did not know which allowed them to identify where to find necessary content knowledge to teach new concepts.

Second, while reflection regarding content knowledge was common, reflection on the process of learning formative assessment was less common. All of the preservice teachers reflected on their content knowledge in the interviews following all of the assignments. In contrast, the preservice teachers did not always include reflection on their process of engaging in formative assessment for all of the assignments. However, all five did include at least one reflection statement on the third assignment even if not on the previous two assignments (see Table 4). This suggests that, by the third assignment, they were more comfortable with the basic process and were able to start reflecting on their engagement with that process. When they did reflect on their process of engaging in formative assessment, the preservice teachers primarily kept the discussion to their difficulty with knowing what to look for and the process of deciding which students understood, as described earlier.

Table 4

Number of Interview Reflections on Formative Assessment Practices

Preservice Teacher	Assignment 1	Assignment 2	Assignment 3
Julia	0	2	1
Miranda	4	0	3
Kate	1	2	3
Audrey	2	2	2
Isabel	2	0	1

Finally, the preservice teachers also engaged in limited metacognition but primarily for the content questions rather than for the FA questions. In particular, preservice teachers talked about their consideration of whether or not an idea made sense or was a plausible answer when they discussed determining the correct content answers, but they did not discuss thinking about how the ideas were widely applicable. For example, in response to an interview question about

how she selected the answers to an assignment question asking what items were seeds, Miranda said,

> Because the other ones I know grapes, raspberry are fruits and I know they have seeds but they're not necessarily a seed. I didn't know what a peach pit is. A corn kernel didn't seem like a seed. I know that it pops into popcorn but it's doesn't reproduce, unless that's reproducing it–I don't think so. A peanut, it didn't make sense for it to be a seed. A rose is a flower. That's how I [about it]. (Miranda, Assignment 1)

Here Miranda is referring both to what made sense to her ("A peanut, it didn't make sense for it to be a seed") and what was not plausible to her to be a seed ("a corn kernel didn't seem like a seed" and "a rose is a flower" so it can't be a seed).

Although some preservice teachers engaged in some reflection regarding formative assessment, most did not show evidence of engaging in metacognition when they discussed the formative assessment process. In a few instances, they did discuss if the ideas of formative assessment made sense. For example, when considering how she decided whether or not students understood, Isabel said,

> If they looked at the picture and then they thought about a way that it gets dispersed and if they mentioned a way that it would get dispersed, that was close enough to one of the four ways that made sense for the spikes, I thought. (Isabel, Assignment 1)

However, the preservice teachers did not discuss if the ideas were plausible or were widely applicable. Importantly, though, the assignments did not include prompts to specifically ask them to do this which suggests adding such prompts may help the preservice teachers to engage in metacognition and improve their process further.

Summary of Findings

Overall, these findings indicate that the structured formative assessment assignments supported the preservice teachers to increase both their content knowledge and their understanding and engagement in formative assessment practices. Although the preservice teachers relied primarily on their own prior knowledge when they completed Assignment 1, by Assignments 2 and 3 they were using information provided as a part of the assignment. In this way, the assignments helps the preservice teachers both to increase their own content knowledge and to learn how to incorporate information provided to them through artifacts like lesson plans. The assignments also helped the preservice teachers to become more confident in their ability to evaluate students understanding and supported them to evaluate characteristics of an effective prompt to get the most out of their evaluation of students' responses. Finally, the assignments provided structure for the preservice teachers to begin to engage in reflection regarding their own ideas and thought processes and as they engaged in the process. While preservice teachers exhibited some reflection for both content knowledge and formative assessment practices, this reflection was more prevalent for content knowledge. Further, the preservice teachers engaged in metacognition to only a limited amount, but tended to do so more for content knowledge than for formative assessment practices and primarily focused on whether ideas made sense or were plausible, rather than on the extent to which they were widely applicable.

Synthesis and Discussion

In this study, we examined how engaging preservice elementary teachers in structured formative assessment assignments supported them in learning life science content, learning to engage in formative assessment, and in reflecting on their experiences. Preservice elementary teachers often have some of the same alternative conceptions about life science topics as their students and need support to learn both science subject matter and how to translate that content

into elementary science learning environments (Haefner & Zembal-Saul, 2004; Krall et al., 2009; Rice, 2005). Understanding life science content relevant to the lesson is an important piece of teachers learning to engage in high-leverage instructional practices, such as formative assessment, to evaluate students' ideas of life science topics, and to create instruction that is responsive to those ideas (Ball & Forzani, 2009; Bell & Cowie, 2001; Coffey et al., 2011). Teachers benefit from engaging in formative assessment because they are able to more effectively adjust their instruction in response to students' ideas and engage students (Cauley & McMillan, 2010; Black & Wiliam, 2009). Students also benefit in that they are active in their own learning and are more likely to learn more if their teachers have accurate information about their current understanding (Harlen & James, 1997; Herman & Choi, 2008).

Here we have shown how assignments intended to support preservice teachers led to improvements in how they engaged with life science content and learned to integrate resources to enhance their own content knowledge and their formative assessment practices. This builds on previous work that has focused on how preservice teachers engage in formative assessment (e.g., Buck et al., 2010; Forbes et al., in press; Graham, 2005; Otero, 2006; Otero & Nathan, 2008; Sabel et al., 2015), how preservice teachers make decisions about student understanding of disciplinary concepts (Forbes et al., 2015; Kikas, 2004; Sabel et al., 2015), and how preservice teachers engage in reflection and metacognition in science learning environments (Yerdelen-Damar et al., 2015; Abd-El-Khalick & Akerson, 2009). These structured formative assessment assignments within a course that combined life science content instruction with elementary pedagogical methods is one type of novel approach that has been called for to provide preservice teachers with opportunities to learn disciplinary content and how to teach that content to students (Ball et al., 2008; Haefner & Zembal-Saul, 2004; Nowicki et al., 2013). As such, the results from

this study help to provide an example of a type of effective scaffold that can be used to support preservice teachers to engage in both content and instructional practices appropriate for elementary students.

First, these results suggest the assignments supported preservice teachers to move beyond relying on their prior knowledge and their past experiences to incorporating information from the lesson plans and course resources to guide their consideration of the content. The preservice teachers discussed learning new content and their increased performance on the content questions showed their improved ability to apply the concepts. In this way, the assignments supported the preservice teachers to move beyond considering the content as simply a collection of facts to remember or particular vocabulary words to identify as indicators of understanding (Kennedy, 1998; Talanquer et al., 2015). This increased disciplinary knowledge may in turn help them to more effectively elicit and evaluate students' understanding (Gottheiner & Siegel, 2012; Morrison & Lederman, 2003; Sabel et al., in review). This finding that preservice teachers' content knowledge can be increased through the use of structured formative assessment assignments is noteworthy since past work has shown lack of disciplinary content knowledge to be a factor in the extent to which teachers are able effectively engage in formative assessment practices (Buck et al., 2010; Coffey et al., 2011; Falk, 2011; Heritage et al., 2009; Morrison, 2013; Otero & Nathan, 2008; Sabel et al., in review). Thus, by engaging in these assignments, the preservice teachers gained important knowledge about content, but also about how to consider the content in the particular context of students' ideas which may help them to better support students' knowledge building in the future (Kohler et al., 2008; Levin et al., 2009).

Second, the assignments supported preservice teachers in learning how to evaluate elementary students' ideas of biological concepts. In particular, the preservice teachers were able

to learn to engage in the process of formative assessment through evaluation of actual student answers. This is in line with past work that has shown that preservice teachers gain classroom assessment understanding when they have opportunities to consider students' ideas and practice taking actions to address those ideas (Buck et al., 2010; Graham, 2005, Otero & Nathan, 2008; Talanquer et al., 2013). However, these results extend beyond those previous findings in that preservice teachers were able to simultaneously gain formative assessment experience and content knowledge as they engaged with the ideas and student work within the assignments. This is particularly important because accurate identification of, and responsiveness to, student ideas has the potential to lead to student learning gains and to enhance understanding and progression toward scientific knowledge (Hammer et al., 2012; Ruiz-Primo, 2011; Ruiz-Primo & Furtak, 2006; Wiliam, 2011).

Finally, the assignments gave preservice teachers the opportunity to reflect on their knowledge of biological content and the formative assessment process and to begin to engage in metacognition. The preservice teachers were able to engage in reflection to evaluate their performance and their experiences (Zimmerman, 2000; Silver, 2013). However, we did not see evidence of preservice teachers engaging in all of the dimensions of metacognition: intelligibility, plausibility, and wide-applicability (Grotzer & Middlefehldt, 2012). While we did not see evidence of preservice teachers considering the wide-applicability of ideas, we did see some examples of intelligibility and plausibility. Because metacognition involves students being aware of their own learning process (Sinatra & Taasoobshirazi, 2011; Wood, 2009), the preservice teachers' infrequent use of metacognition may be due to the fact that they are still at the beginning stages of that learning process for formative assessment practices. To that end, additional exposure to the process as well as questions to expand their metacognitive reflection

may help to expand the ideas they consider in relation to the assignments. Improving this component will be important moving forward because engaging in metacognition may help the preservice teachers to achieve even greater learning gains and change alternative conceptions to scientifically-accurate conceptions (e.g., Anderson & Nashon, 2006; Baird, 1986; Tanner & Allen, 2005).

Implications and Conclusion

Preservice teachers need opportunities to learn disciplinary content knowledge, how to apply that knowledge at the elementary classroom level, and how to integrate that knowledge with instructional practices that forefront students' ideas (Ball & Forzani, 2009). In particular, preservice teachers should learn to engage in effective formative assessment practices because formative assessment is a proven, high-leverage instructional practice known to increase student learning gains in science (Ball & Forzani, 2009; Ruiz-Primo & Furtak, 2006; Wiliam, 2011). As this study focuses both on disciplinary content knowledge and formative assessment, it has important implications for preservice teacher education.

First, in order to learn the practice formative assessment and then to improve the effectiveness of that practice, preservice teachers need experience in engaging with the steps of formative assessment. Assignments like the ones used in this study are one way to support students in this process. Findings from this study have shown that preservice teachers gained more confidence in their ability to engage in the practice and were also able to more effectively evaluate students' answers and understand the disciplinary content knowledge necessary to evaluate understanding. Second, to be able to accurately identify student understanding and appropriate prompts to use to elicit that understanding, preservice teachers need to have exposure to examples of actual student responses. This study has shown that preservice teachers began to

understand that not all prompts gave them the information that would be most useful to interpret students' understanding. Further, by examining actual student answers, the preservice teachers were able to see the kinds of answers students provide as well as the wide range of understanding among students in a single class. Third, while formative assessment is discipline-independent, evaluating students' ideas about a particular content-specific idea requires knowledge of that discipline. Therefore, preservice teachers need support to not only learn biological content, but also to connect that content to the ways in which they will encounter it in elementary classrooms.

While the structured formative assessment assignments used as a part of this study support preservice teachers in all of these ways, more work is needed to further examine how these types of assignments can support preservice teachers and how to extend that support beyond the course. This work is limited in that it examines preservice teachers over the course of a single semester. In addition, while preservice teachers were able to examine actual student work, the three assignments provided only limited exposure to the different types of prompts and student answers they might encounter. Therefore, extended exposure both to practice using formative assessment and additional types of student work examples will be necessary for these preservice teachers to continue to enhance their abilities to engage in this instructional practice. Further, additions to the assignments to help the preservice teachers reflect and use metacognition throughout the process will help to enhance their ability to effectively engage in the practice. Finally, studies that expand beyond a single semester and follow preservice teachers as they participate in practicum experiences, student teaching, and begin their teaching careers will be an important extension to this work to examine the extent to which preservice teachers continue to engage in these practices and how they improve in their abilities to elicit and evaluate students' ideas.

Formative assessment assignments provided structure to help preservice teachers consider life science topics, integrate resources, and expand their life science content knowledge which allowed them to begin to learn to engage in formative assessment. Overall, this type of support has potential to lead to gains in preservice teachers' ability to effectively elicit and evaluate student ideas which, in turn, has potential to lead to increased student learning gains. As such, this study will be of interest to science teacher educators who may consider implementing similarly structured assignments that combine both life science content knowledge and formative assessment practices.

References

AAAS Project 2061. (2013). AAAS Project 2061 Science Assessment Website. Retrieved from assessment.aaas.org.

Abd-El-Khalick, F., & Akerson, V. (2009). The influence of metacognitive training on preservice elementary teachers' conceptions of nature of science. *International Journal of Science Education*, 31(16), 2161-2184.

Anderson, D., & Nashon, S. (2006). Predators of knowledge construction: Interpreting students' metacognition in an amusement park physics program. *Science Education*, 10, 298-319.

Baird, J. R. (1986). Improving learning through enhanced metacognition: A classroom study. *European Journal of Science Education*, 8(3), 263-282.

Ball, D. L., & Forzani, F. M. (2009). The work of teaching and the challenge for teacher education. *Journal of Teacher Education*, 60(5), 497-511.

Ball, D.L., Thames, M.H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59(5), 389-407.

Bell, B., & Cowie, B. (2001). The characteristic of formative assessment in science education. *Science Education*, 85(5), 536–553.

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation, and Accountability*, 21, 5–31.

Buck, G. A., Trauth-Nare, A., & Kaftan, J. (2010). Making formative assessment discernable to pre-service teachers of science. *Journal of Research in Science Teaching, 47*(4), 402-421.

Cauley, K.M., & McMillan, J.H. (2010). Formative assessment techniques to support student motivation and achievement. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 83(1), 1–6.

Coffey, J. E., Hammer, D., Levin, D. M., & Grant, T. (2011). The missing disciplinary substance of formative assessment. *Journal of Research in Science Teaching,* 48, 1109- 1136.

Cresswell, J. W., & Plano Clark, V. L. (2011). *Designing and Conducting Mixed Methods Research*. Los Angeles, CA: SAGE.

Falk, A. (2011). Teachers learning from professional development in elementary science: Reciprocal relations between formative assessment and pedagogical content knowledge. *Science Education, 96*(2), 265-290.

Forbes, C.T., Sabel, J.L., & Biggers, M. (2015). Elementary teachers' use of formative assessment to support students' learning about water-earth materials interactions. *Journal of Geoscience Education,* 63(3), 210-221. doi: 10.5408/14-063.1

Forbes, C.T., Sabel, J.L., & Zangori, L. (In press). An integrated life science and instructional methods course to support prospective elementary teachers' subject matter knowledge for teaching. *American Biology Teacher*.

Gall, M. D., Gall, J. P., & Borg, W. R. (2007). *Educational research: An introduction* (8th ed.). Boston, MA: Pearson Education, Inc.

Gottheiner, D.M., & Siegel, M.A. (2012). Experienced middle school science teachers' assessment literacy: Investigating knowledge of students' conceptions in genetics and ways to shape instruction. *Journal of Science Teacher Education, 23,* 531–557.

Graham, P. (2005). Classroom-based assessment: Changing knowledge and practice through preservice teacher education. *Teacher and Teacher Education, 21*, 607-621.

Grotzer, T. & Mittlefehldt, S. (2012). The role of metacognition in students' understanding and transfer of explanatory structures in science. In A. Zohar and Y.J. Dori (Eds.)

Metacognition in science education: Trends in current research. (pp. 79-99). New York, NY: Springer Science+Business Media B.V.

Haefner, L. A. & Zembal-Saul, C. (2004). Learning by doing? Prospective elementary teachers' developing understandings of scientific inquiry and science teaching and learning. *International Journal of Science Education*, *26*(13), 1653-1674.

Hammer, D., Goldberg, F., & Fargason, S. (2012). Responsive teaching and the beginnings of energy in a third grade classroom. *Review of Science, Mathematics, and ICT Education, 6*(1), 51-72.

Harlen, W., & James, M. (1997). Assessment and Learning: differences and relationships between formative and summative assessment. *Assessment in Education,* 4(3), 365–379.

Heritage, M., Kim, J., Vendlinski, T., & Herman, J. (2009). From evidence to action: A seamless process in formative assessment? *Educational Measurement: Issues and Practice*, 28(3), 24–31.

Herman, J.L., & Choi, K. (2008). Formative assessment and the improvement of middle school science learning: the role of teacher accuracy. (CRESST Report 740).

Keeley, P. (2005). *Science curriculum topic study.* Thousand Oaks, California: Corwin Press.

Kennedy, M. M. (1998). Education reform and subject matter knowledge. *Journal of Research in Science Teaching*, *35*(3), 249-263.

Kikas, E. (2004). Teachers' conceptions and misconceptions concerning three natural phenomena. *Journal of Research in Science Teaching*, *41*(5), 432-448.

Kohler, F., Henning, J.E., Usma-Wilches, J. (2008). Preparing preservice teachers to make instructional decisions: An examination of data from the teacher work sample. *Teaching and Teacher Education*, *24*, 2108-2117.

Krall, R. M., Lott, K. H., & Wymer, C. L. (2009). Inservice elementary and middle school teachers' conceptions of photosynthesis and respiration. *Journal of Science Teacher Education*, *20*(1), 41-55.

Levin, D. M., Hammer, D., & Coffey, J. E. (2009). Novice teachers' attention to student thinking. *Journal of Teacher Education*, *60*(2), 142-154.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco, CA: Jossey-Bass.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook.* (3rd ed.). Thousand Oaks,, CA: SAGE Publications, Inc.

Morrison, J. A. (2013). Exploring exemplary elementary teachers' conceptions and implementation of inquiry science. *Journal of Science Teacher Education, 24*(3), 573-588.

Morrison, J. A., & Lederman, N. G. (2003). Science teachers' diagnosis and understanding of students' preconceptions. *Science Education, 87*, 849–867.

NGSS Lead States. (2013). *Next generation science standards. For states, by states*. Washington, DC: The National Academies Press.

Nowicki, B. L., Sullivan-Watts, B., Shim, M. K., Young, B., & Pockalny, R. (2013). Factors influencing science content accuracy in elementary inquiry science lessons. *Research in Science Education, 43*(3), 1135-1154.

Otero, V. K. (2006). Moving beyond the "get it or don't" concept of formative assessment. *Journal of Teacher Education, 57*(3), 247-255.

Otero, V. K., & Nathan, M. J. (2008). Preservice elementary teachers' views of their students' prior knowledge of science. *Journal of Research in Science Teaching*, *45*(4), 497-523.

Rice, D. C. (2005). I didn't know oxygen could boil! What preservice and inservice elementary teachers' answers to 'simple' science questions reveals about their subject matter knowledge. *International Journal of Science Education, 27*(9), 1059-1082.

Ruiz-Primo, M. A., (2011). Informal formative assessment: The role of instructional dialogues in assessing students' learning. *Studies in Educational Evaluation*, 37, 15-24.

Ruiz-Primo, M.A., & Furtak, E.M. (2006). Informal formative assessment and scientific inquiry: exploring teacher' practices and student learning. *Educational Assessment,* 11(3 & 4), 205–235.

Sabel, J.L., Forbes, C. T., & Flynn, L. (in review). Elementary teachers' use of content knowledge to evaluate students' thinking in the life sciences.

Sabel, J. L., Forbes, C. T., & Zangori, L. (2015). Promoting prospective elementary teachers' learning to use formative assessment for life science instruction. In *Journal of Science Teacher Education,* 26(4), 419-445. doi: 10.1007/s10972-015-9431-6

Silver, N. (2013). Reflective pedagogies and the metacognitive turn in college teaching. In M. Kaplan, N. Silver, D. LaVaque-Manty, & D. Meizlish (Eds.) *Using reflection and metacognition to improve student learning: Across the disciplines, across the academy* (pp. 1-17). Sterling, VA: Stylus.

Sinatra, G. M., & Taasoobshirazi, G. (2011). Intentional conceptual change. In B. J. Zimmerman & D. H. Schunk, *Handbook of self-regulation of learning and performance*. (pp. 203-216). New York, NY: Routledge.

Talanquer, V., Bolger, M., & Tomanek, D. (2015). Exploring prospective teachers' assessment practices: Noticing and interpreting student understanding in the assessment of written work. *Journal of Research in Science Teaching*, 52(5), 585-609.

Talanquer, V., Tomanek, D., & Novodvorsky, I. (2013). Assessing students' understanding of inquiry: What do prospective science teachers notice? *Journal of Research in Science Teaching, 50*(2), 189-208.

Tanner, K., & Allen, D. (2005). Approaches to biology teaching and learning: Understanding the wrong answers—teaching toward conceptual change. *Cell Biology Education*, 4, 112-117.

Wiliam, D. (2011). *Embedded Formative Assessment.* Bloomington, IN: Solution Tree Press.

Wood, W. B. (2009). Innovations in teaching undergraduate biology and why we need them. *Annual Review of Cell Developmental Biology*, 25, 93-112.

Yerdelen-Damar, S., Özdemir, Ö. F., & Ünal, C. (2015). Pre-service physics teachers' metacognitive knowledge about their instructional practices. *Eurasia Journal of Mathematics, Science & Technology Education*, 11(5), 1009-1026.

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.).Thousand Oaks,, CA: SAGE Publications, Inc.

Zimmerman, B. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13-41). New York, NY: Academic.