SURFACING STUDENTS' PRIOR KNOWLEDGE IN MIDDLE SCHOOL SCIENCE CLASSROOMS
Exception or the Rule?

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Middle school is a critical time for students to develop a strong understanding of and appreciation for science, yet science education in the middle grades in the United States is in crisis. This research focuses on the practices of 18 predominately alternatively certified teachers in an intensive professional development program in a southeastern state as they accessed their students' prior ideas. The program engaged participants in specially designed, job-embedded graduate coursework in science education and science content, and other complementary experiences to support their enactment of a reform-based middle school science curriculum. The design of the program and the curriculum emphasized the importance of eliciting student preconceptions for meaningful science learning. Specifically, we asked, "How do middle school science teachers in an intensive professional development program surface students' prior knowledge?" The analysis of 61 classroom observations revealed that the teachers have begun to incorporate strategies to highlight the students' prior ideas in their instruction. In addition, they utilized a number of strategies, many of which were suggested in the reform-oriented curriculum the teachers were enacting. Despite ongoing professional development support, there was a great deal of variability in teachers' enactments of this practice with some important features of the practice not well observed in the classroom observations, such as probing and documenting student prior ideas.

As young adolescents, middle school students undergo rapid developmental changes that have unique implications for their educational needs. This special population also requires crucial guidance to achieve their potential in a dynamic world where social pressures are ubiquitous and the need to "fit in" is a high priority. Historically, middle schools have focused on easing the transition from elementary to high school in addition to improving preparation for college and future careers (Juvonen, 2004). The Exemplary Middle School was a concept envisioned by Alexander and George (1981) to address the developmental needs of young teenagers: lack of motivation, poor attitudes about school, academic achievement in core subjects (language arts, math, science, social studies), and perceptions

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of their ability in these areas. The Association for Middle Level Education (AMLE) (2010) describes a vision to guide the development of middle level schools that promotes and supports the healthy development of young adolescents into self-sufficient young adults. Schools that are equitable and empowering, as well as offer academically challenging and developmentally appropriate curricula are essential features of successful middle schools.

Middle school is a critical time for students to develop a strong understanding of and appreciation for science, yet science education in the middle grades (6-8) in the United States is in crisis. Results from the most recent National Assessment of Education Progress indicated that only 32% of eighth-grade students performed at or above the "proficient" level in science (National Center for Education Statistics, 2010). Similarly, recent results from the Trends in Mathematics and Science Study indicated that American eighth grade students scored below the international average and only above students from five other participating nations (Martin, Mullis, Foy, & Stanco, 2012). These results stand in contrast to the performance of American fourth grade students who scored close to the international average. Such results also indicate that eighth grade American students' attitudes toward science are less positive compared to their fourth grade counterparts (Martin et al., 2012).

Students who do not have positive learning experiences in middle school become disengaged in STEM across the transitions to high school and college (Gallagher, 1994; Tai, Liu, Maltese, & Fan, 2006). Yet middle school science instruction is often dominated by lecture and bookwork, which contrasts with contemporary views of effective science teaching (Darby, 2005; Logan & Skamp, 2008; Marshall, Horton, Igo, & Switzer, 2009; Speering & Rennie, 1996). Research suggests that science achievement is higher for students who have participated in inquiry-based lessons in their science classrooms (Martin et al., 2012). In addition, the achievement of middle school students on measures such as the National Assessment of Education Progress has been shown to be greater with inquiry-based science curriculum (Schneider, Krajcik, Marx, & Holloway, 2002). Inquiry-based approaches to science instruction acknowledge students as active participants in the learning process as recommended by current K–12 science education reform documents (Duschl, Schweingruber, & Shouse, 2007; National Research Council, 2012).

The current vision for K–12 science education is for students to build on their prior knowledge as they progressively deepen their understanding of the disciplinary core ideas, crosscutting concepts, and scientific and engineering practices (National Research Council, 2012; NGSS Lead States, 2013). We believe that teachers play an essential role in helping students become aware of their own prior knowledge and build connections between their initial ideas and thinking, and the disciplinary core ideas, crosscutting concepts, and scientific and engineering practices. Accordingly, we focus on middle school science teachers' actions in surfacing students' prior knowledge in this research, as this practice is an important component of effective science instruction (Banilower, Cohen, Pasley, & Weiss, 2010).

THEORETICAL PERSPECTIVE

This research is guided by constructivist perspectives on science learning and teaching. Shapiro (1994) posits that the role of the learner is to actively construct new meaning rather than to passively receive information (p. 8). Similarly, Tobin (1993) states, "A learner has to make sense of science through an existing conceptual structure. Whatever science knowledge is constructed will be an interpretation of experience in terms of *extant* knowledge" (p. 9). Furthermore, the science knowledge that is constructed by the learner will fit with their prior experience (Tobin, 1993), thus fostering meaningful learning. Both Tobin (1993) and Shapiro (1994) hold that the role of the teacher is to facilitate and guide the process of knowledge construction. Teacher facilitation goes beyond simply correcting student misconceptions and presenting the current scientific understandings of phenomena. Instead, teachers should encourage the process of knowledge construction by providing students with experiences to allow them to test the "viability of knowledge claims" (Tobin, 1993, p. 10), and generate "new ways of thinking about phenomena" (Shapiro, 1994, p. 8). Both Tobin (1993) and Shapiro (1994) emphasize that teachers must be aware of students' prior knowledge in order to plan appropriate learning opportunities to promote conceptual change.

Posner, Strike, Hewson, and Gertzog (1982) describe conceptual change in science as any change in knowledge structures involving the modification to or reorganization of the network of science ideas children bring with them to school. This understanding of conceptual change is mirrored in current reform documents in science education (Duschl et al., 2007; National Research Council, 2012). Such documents promote the idea that students' conceptual frameworks undergo both evolutionary as well as revolutionary changes as they gain proficiency in science.

Research has documented common children's preconceptions related to many concepts and theories within the physical, earth, and biological sciences (Harlen, 2001; Driver, Squires, Rushworth, & Wood-Robinson, 1994). Children's preconceptions are the result of their observations and interpretations of everyday experiences in the natural world (Mintzes, Wandersee, & Novak, 1998; Vosniadou, 1994). However, such ideas are understood to be resistant to change as they are often based on a multitude of everyday experiences. In other words, children are not apt to let go of ideas that are well supported by their many experiences on the playground, at home, or in the community. Research suggests what children experience and ultimately learn in the classroom is influenced by their knowledge base (Duschl, 1990). Hanson (1958) explains how individuals can observe the same source of information yet perceive it differently. He differentiated between two types of seeing: "Seeing as" observations, which focuses on the literal description of patterns, and "seeing that" observations, which uses prior knowledge to attach specific meanings to what is being observed. Therefore, teachers need to be aware of children's knowledge base in order to effectively plan instruction and facilitate the conceptual change process.

Gunstone and Mitchell (1998) highlight the importance of metacognition in the process of conceptual change. They define metacognition as a complex construct that involves knowledge of the learning process as well as awareness and control of one's own learning. For learners to evaluate and change their conceptions, they must first be aware of their prior knowledge. However, the development of metacognition is an incremental process that spans childhood into adulthood for some individuals (Georgiades, 2004). Given this, Gunstone and Mitchell (1998) suggest that the teacher has a key role in eliciting students' ideas and promoting reflection. Furthermore, they suggest that teachers use specific teaching strategies including Predict-Observe-Explain, concept maps, and Venn diagrams to both elicit student ideas and thinking, and encourage reflection.

In addition to metacognition, scholars investigating effective pedagogical strategies to promote conceptual change have pointed out the importance of helping students connect new ideas to their prior knowledge and experiences (Barnett & Moran, 2002; Driver, Asoko, Leach, Scott, & Mortimer, 1994; Krajcik & Sutherland, 2010; Trundle, Atwood, Christopher, & Sackes, 2010). Teachers should enable students to become aware of their prior ideas and guide them in forging connections between their prior knowledge and classroom experiences. However, research indicates that teachers may struggle in adopting new practices emphasizing students as active learners and regard students as "blank slates," ignoring their prior knowledge in the classroom (Anderson, 2007). Accordingly, this research focuses on the practices of teachers as they access their students' prior ideas, which has relevance for their effectiveness in promoting conceptual change and meaningful science learning. Specifically, we ask, "How do middle school science teachers in an intensive professional development program surface students' prior knowledge?"

METHODS

Participants and Context

This study was conducted in a state in the southeastern United States. The participants were 18 middle school science teachers (1 male, 17 females) involved in a 2-year professional development program arising from a National Science Foundation funded partnership between a large, public university and eleven low-achieving school districts (1 small suburban, 1 medium suburban, 9 small rural). The program engaged participants in specially designed, job-embedded graduate coursework in science education and science content, and other complementary experiences (e.g., monthly meetings, field trips) to support their enactment of a reform-based middle school science curriculum. Upon the satisfactory completion of their coursework and teacher inquiry capstone project, the teachers earned a master's degree in science and environmental education.

Participants were recommended for the program by their district administration on the basis of positive teaching evaluations and past leadership roles (e.g., science department chair, science fair coordinator). Just over two thirds of the teachers had taught science in Grades 6-8 for more than 5 years when they entered the program. Interestingly, only five of the teachers majored in science or science education in college. These teachers were certified in middle grades science (Grades 5-9) or biology (Grades 6-12). In contrast, the majority of our teachers earned their undergraduate degrees in nonscience majors such as business administration, German, music therapy, elementary education, physical education, and psychology. These individuals entered into teaching middle school science by alternative routes, and held certificates in middle grades integrated curriculum (Grades 5-8) or middle grades science (Grades 5-9) when they were admitted to the program.

The reform-based middle school science curriculum was designed to specifically incorporate students' prior knowledge and to promote the progressive development of sophisticated student understandings in science (Krajcik, McNeill, & Reiser, 2008). In this inquiry-based curriculum, students documented their experiences and evolving understanding of science ideas in interactive student books. Students were ultimately able to develop a scientific explanation for a "driving question" for each unit. In this curriculum, teachers were provided with elaborate educative materials describing both the science content and instructional strategies. The teachers were directed to surface students' prior knowledge at multiple points during each unit using a variety of instructional strategies including class discussions, student writing, and student-generated models. The curriculum materials provided teachers with sample prompts to surface students' prior knowledge in "brainstorming" discussions and written responses in the interactive student books.

This study took place during the first year of the teachers' involvement in the professional development program, during which the coursework for their first three (of five) science education courses focused on how children learn science, effective science instruction, inquiry-based science teaching, science curriculum development, and formative and summative assessment practices. The importance of using strategies for surfacing students' prior knowledge was embedded within each of these courses. Examples of course assignments related to surfacing students' prior knowledge are described in Table 1.

TABLE 1
Examples of Course Assignments Related to Surfacing Students' Prior Knowledge

Course Title	*Examples*
Inquiry-based science teaching	Analyze how a teacher surfaced and responded to students' prior knowledge in a vignette describing a sixth-grade science lesson, and the implications for conceptual change
Science curriculum development	Identify how learning progressions can be used to build on students' initial science ideas in sample middle school science curriculum units
Data-driven instruction in science	Use a formative assessment probe to preassess middle school students' ideas related to a specific science concept, and use this data to plan instruction

Data Collection

Classroom observations were conducted between October 2012 and May 2013. Each teacher (n = 18) was observed at least once by one of the four trained classroom observers. Seven teachers were randomly selected to be observed multiple times (2 to 4 days in fall 2012 and 2 to 4 days in spring 2013). Sixty-one total observations were completed.

For each class observed, the observers wrote detailed field notes, paying particular attention to teacher-student interactions. Field notes captured teacher talk and questions, student responses and questions, and teacher reactions to student ideas and questions. Audio-recordings were also made during each class observation. Following each observation, the observers completed the Annotated Classroom Observation Protocol (Horizon Research, 2012). Observers were trained to complete this protocol by staff from Horizon Research, Inc. When observers rated teacher practices during subsequent training observations using the protocol, the interrater agreement was high (88%–92%), providing support for reliability.

In the protocol, the observers rated the instructional opportunities related to elements of effective science instruction: surfacing prior knowledge, engaging with relevant phenomena, using evidence to critique claims, and sense making (Banilower et al., 2010). Given the research questions in this study, only the section on surfacing prior knowledge will be discussed further. This section focused on teacher practices that strategically elicited and probed students' prior ideas and thinking towards identifying relevant student preconceptions. The following six practices related to surfacing students' prior science knowledge were indicators on the observation protocol:

1. Opportunities were structured/implemented so that students would be aware of their own prior knowledge.
2. Opportunities surfaced students' reasons for how they were thinking.
3. Opportunities had students record aspects of their prior knowledge.
4. Opportunities had students make public aspects of their prior knowledge.
5. Opportunities allowed students' ideas to be surfaced without judgment.
6. Opportunities were aligned with student learning goals.

Observers provided ratings (1 = *not at all*, 2 = *to a limited extent*, 3 = *somewhat*, 4 = *to a great extent*) with supporting descriptions of the ensuing teaching and learning activities.

Data Analysis

A convergent parallel mixed methods design was used in this study (Creswell, 2014). Protocol ratings from all 61 classroom observations were entered into SPSS, and Cronbach's alpha values were calculated to assess internal reliability of individual scales on the protocol. For this study, descriptive statistics including means and standard deviations were calculated for the six features of surfacing prior knowledge. In addition, the supporting descriptions and field notes were read and analyzed using a constant comparison method looking for emerging themes and patterns (Creswell, 2012). Specific descriptive codes that emerged from this analysis were identified to characterize the instructional opportunities related to surfacing prior knowledge. Example codes included "teacher-led whole class discussion," "discussion between student pairs," "teacher recording on overhead projector/whiteboard," "individual recording in student books," "individual recording on sticky note/index card," and "individual drawing/model." The individual codes were reviewed and discussed to identify consensus codes. In further analysis, these codes were organized into general categories and themes identifying the instructional opportunities and strategies related to surfacing prior knowledge.

RESULTS

The purpose of this study was to investigate how middle school science teachers in an intensive professional development program elicited students' prior knowledge. The classroom observation data in this study were analyzed to identify teacher practices concerning surfacing students' prior knowledge in the middle school classroom. Teachers' use of specific features in the curriculum for eliciting and probing students' prior knowledge was identified as well.

Opportunities to surface prior knowledge were identified in nearly 40% (24 out of 61) of the classes observed. However, the representation of teacher practices concerning surfacing students' prior knowledge varied greatly as shown in Table 2, with some features represented more strongly than others. A high Cronbach's alpha (0.86) indicated a strong internal consistency for this scale with this set of observations.

Of the six features of surfacing prior knowledge, the highest rated feature was "Opportunities allowed students' ideas to be surfaced without judgment." This indicates that teachers largely did not communicate to the students that their ideas were valid or invalid. Teachers in most observations simply accepted student responses or offered neutral or mildly positive responses to students such as "That's possible," "Good," and "OK." Teachers were rarely observed providing evaluative feedback or correcting student ideas. For example, one sixth-grade teacher during a sixth-grade lesson on the structure and function of the eye point-

TABLE 2
Teacher Practices for Surfacing Students' Prior Knowledge as Indicated by the ACOP ($n = 24$)

Key Features	*Minimum*	*Maximum*	*M*	*SD*
1. Opportunities were structured/implemented so that students would be aware of their own prior knowledge.	2	4	3.33	.08
2. Opportunities surfaced students' reasons for how they were thinking.	1	4	2.50	1.18
3. Opportunities had students record aspects of their prior knowledge.	1	4	2.33	1.27
4. Opportunities had students make public aspects of their prior knowledge	1	4	3.00	0.93
5. Opportunities allowed students' ideas to be surfaced without judgment.	2	4	3.71	0.55
6. Opportunities were aligned with student learning goals.	2	4	3.13	0.85

edly stated while conducting a whole class discussion that such "brainstorming sessions are judgment-free." She also recorded and displayed all the students' ideas during this discussion sending a powerful message that all ideas were accepted.

Of the six features, "Opportunities surfaced students' reasons for how they were thinking" was rated the lowest. This indicates that teachers did not routinely ask follow-up or probing questions when eliciting the prior knowledge of their students. For instance, in another classroom observation, the teacher was observed asking, "What causes a deer population to change?" during a sixth-grade lesson on interactions in ecosystems. Although her students provided short verbal responses such as "What eats a deer," no attempt was made for students to further explain their ideas. Alternatively, teachers did not probe the thinking of the majority of their students, opting instead to probe the thinking of select students. For example, after several of her students verbally shared "what they know about how the eye works," the 6th grade teacher only asked one student to "tell me more," challenging her to explain her thinking. During this interaction, others students were required to provide just their short responses as no follow-up occurred.

Notably, the feature "Opportunities had students record aspects of their prior knowledge" was rated lower than "Opportunities had students make public aspects of their prior knowledge." This suggests that teachers relied more heavily on discussions rather than written or drawn records to elicit student prior knowledge. Discussions included whole class discussion, small group discussion, and pair discussions. For example, one sixth-grade teacher organized her students into small groups to share their initial ideas about how the molecules of a substance behave when heated. Following the group discussion, she asked a representative from each group to share aloud the ideas that were discussed in their group. By allowing students to discuss first in small groups and then in the large group, this teacher ensured that all students were involved in sharing their prior ideas.

Student recording also took many forms with students writing down their thoughts on sticky notes and index cards, responding to teacher prompts in their notebooks, and drawing models to document their ideas and thinking. For instance, a sixth-grade teacher asked her students to draw a model of the inside of a beach ball when it was inflated, deflated, and again when inflated. She also asked students to provide written labels explaining different aspects of their models. In some classrooms, recording tasks were followed by discussions, providing students with multiple opportunities to surface their prior ideas and thinking. For example, two teachers gave their sixth-grade students the same modeling task as the previous teacher but then asked their students to share and discuss their models with a partner.

Some teachers also assumed the role of recorder during opportunities to surface prior knowledge but had different strategies about their usage in developing the lesson. For example, during an eighth-grade lesson on heredity, the teacher recorded her students' ideas on the whiteboard. She, however, erased these ideas later in the lesson when she needed the space to record some emerging vocabulary terms. In contrast, another teacher recorded her students' ideas on an overhead transparency during a sixth-grade lesson on the behavior of light. She placed this transparency in a folder and told the class they would revisit their ideas during a later lesson.

Although the opportunities to surface prior knowledge were generally aligned with the student learning goals as indicated by the ratings, there were some differences in the specificity of the elicitations. Teachers were observed relying on generic rather than more specific prompts to surface students' prior knowledge. For example, in a sixth-grade lesson where the learning goal was "Describe how water moves between reservoirs," the teacher asked her students to share their ideas about water in a class discussion. In contrast, another teacher started the class discussion for the same sixth-grade lesson, she asked, “How does water move?” and even more specifically “How does water get into the Colorado River?”

Use of Curricular Features to Surface Prior Knowledge

Teachers were observed using four features of the reform-based curriculum to provide opportunities to surface prior knowledge. These features included (a) brainstorming discussions, (b) the Driving Question Board (DQB), (c) student modeling, and d) literacy practices. The curriculum materials provided teachers with specific guidance in enacting these features.

Brainstorming Discussions. Teachers used the discussion prompts provided in the teacher educative materials to initiate brainstorming discussions. Some teachers incorporated additional strategies such as “What do you know? What do you want to know? What did you learn?” (KWL) graphic organizers and think-pair-share peer discussions in these discussions. These additional strategies allowed more students to share their prior ideas than in many whole class discussions. Furthermore, in some whole class discussions, the teacher simply introduced the discussion prompt provided by the curriculum, allowed students to share a few responses, and then moved on to the next activity without probing any student ideas. For example, a sixth-grade teacher used a think-pair-share with the brainstorming prompt, “What do you know about the eye and how we see?” She required each student to think for a minute, write their response on a sticky note, and share their ideas with their partner.

DQB. Teachers introduced the driving question board at the beginning of each unit and used driving questions to initiate brainstorming discussions. During such a discussion, students were requested to share their initial responses and any additional related questions. Questions were typically recorded on sticky notes and placed on the driving question board, which was a bulletin board or wall display. For example, a teacher asked her 6th grade students to share their ideas for the driving question for the chemistry unit, “How can I smell things at a distance?” in a whole class discussion before asking them to generate their own questions related to the phenomena of smelling odors. Students recorded their questions on sticky notes and placed them on the DQB.

Student Modeling. Teachers directed students to draw pictures to represent their initial understanding of a phenomenon. Teachers often requested that student models be labeled. In some cases, teachers also requested that students develop a key or written explanation of important features. For example, during a lesson on changes in matter, a sixth-grade teacher asked her students to draw a model of how matter can change phases. She reminded students to include a key identifying the major features of their models. Students then shared their models with their group mates.

Literacy Practices. Teachers directed students to document their initial ideas in writing in the interactive student books. For instance, during a lesson on reflection and transmission of light, a sixth-grade teacher asked her students to write down their ideas about “why the moon is bright at night and why it is hard to see during the day” in their student books before discussing their ideas as a class. In instances where the student books did not provide space to do so, teachers provided students with sticky notes for the purpose of documentation of prior ideas. Students placed sticky notes in their books or on the class DQB or KWL.

Integration of Strategies and Curricular Features. Although teachers relied on discussions to surface students’ prior knowledge, they did incorporate and integrate other strategies and curricular features to elicit students’ prior knowledge. Specifically, teachers were observed creatively incorporating familiar cooperative learning strategies (e.g., think-pair-share) and graphic organizers (e.g., KWL, concept maps) in their discussions about the driving question or student models.

The following segment of a field note shows the integration of multiple strategies and curricular features in a sixth-grade lesson on sight.

> The teacher asked students to write about what they know about the eye and how we see at the beginning of the lesson. In the class discussion, nearly all students shared their responses: "There are four steps for us to see, the eye helps you to see, the eye is a sphere, the eye is sensitive, the eye sends a message to the brain to help you see, the pupil helps you to see and gets bigger when lights are off and smaller when the lights are on, the brain flips the image you see the right way." They put their written responses on sticky notes in a KWL graphic organizer for the class. The teacher moved the questions from the KWL to the Driving Question Board after the discussion.

The results provide evidence that the teachers in our professional development program have incorporated the reform-oriented practice of surfacing students' prior knowledge during instruction. The results also indicate that the specific features of the curriculum played a significant role in scaffolding how teachers surfaced students' prior knowledge. However, there was a great deal of variability in teachers' enactments of this practice with some important features of the practice not well observed in the classroom observations, including probing and documenting student prior ideas and thinking more thoroughly.

DISCUSSION

In this study, we examined the practices of middle school science teachers as they accessed their students' prior ideas. Current research and reform documents give much credence to surfacing prior ideas noting the potential to impact children's science learning (Duschl et al., 2007; National Research Council, 2012). Constructivism purports that learners make sense of new experiences against the background of the knowledge they have previously constructed (Shapiro, 1994; Tobin, 1993). It is important, therefore, for teachers to be cognizant of the importance of this aspect/phase during the enactment of science learning activities.

Middle school is a critical time for building and maintaining students' expertise and interest in science. Previous research has indicated that reformed teaching practices have not permeated the middle school science classroom (Darby, 2005; Logan & Skamp, 2008; Marshall et al., 2009; Speering & Rennie, 1996). Our professional development program aimed to shift middle school science teaching practices and, specifically, develop classrooms where middle school learners' initial ideas were appropriately accessed as the foundation for science instruction. Given this specific goal, this research examined how participating teachers elicited students' prior ideas in the middle school science classroom.

We were encouraged that our teachers did elicit students' prior ideas in a significant portion of the classes observed during their first year of involvement in the professional development program. Although the curriculum does provide guidance in how to identify the prior knowledge of students, the teachers could have ignored this portion of the instructional sequence. By enacting the curriculum with fidelity, teachers implemented instructional strategies to allow students to become aware of their own prior knowledge, which is an essential component of teaching science for conceptual change (Duschl et al., 2007). Furthermore, teachers resourcefully incorporated additional strategies to enable students to become aware of their prior knowledge, suggesting that they are deliberately integrating the practice of surfacing students' prior knowledge and making it their own.

However, it appears that some aspects of surfacing students' prior knowledge may be challenging for our teachers to put into practice in their first year of involvement in the professional development program. Specifically, teachers did not routinely probe student ideas or require students to record their ideas.

The lack of consistency in the use of these two practices might have negatively impacted the meaningful science learning of the young adolescents in these classrooms. Metacognition and reflection are necessary for cognitive change (Gunstone & Mitchell, 1998). Given that young adolescents are still developing their metacognitive abilities (Georgiades, 2004), the students may not be able to unpack their reasoning for initial ideas without teacher support. In addition, these young adolescents may not be able to adequately reflect on and evaluate their initial ideas during instruction without a record of such ideas for later reference. Based on research on effective professional development for science teachers (Loucks-Horsley, Hewson, Love, & Stiles, 2009), additional professional development including opportunities for practice and feedback related to the use of these two practices are currently being planned for this group of teachers.

Implications for Practice

Most of the middle school science teachers in this study entered the classroom by alternative certification routes. Alternatively certified middle school science teachers are no doubt capable of becoming skilled practitioners as we have seen in our program. However, science teacher educators may need to be strategic in how they design and deliver professional development activities for teachers who have limited formal preparation to teach middle school science. Specifically, alternatively certified middle school science teachers may need additional support, in terms of the science content and pedagogies needed to teach their subject matter to young adolescents. For example, alternatively certified science teachers may benefit from professional development concerning common student ideas in science and strategies for uncovering and responding to these ideas in ways that promote conceptual change and meaningful science learning. Science teacher educators should be mindful that the translation of knowledge to practice may not be direct or immediate even with significant support, and should be prepared to provide ongoing development and support based on the documented needs of their teachers.

Implications for Future Research

Similar to other areas of learning, the learning of our middle school science teachers appears to be progressive with individual teachers demonstrating a range of practices concerning surfacing prior knowledge, which has implications for their ability to facilitate students' learning. This aspect of instruction warrants further study to examine the trajectories of teachers as they master the practice of surfacing their students' prior knowledge and the impact on student learning. Furthermore, prior research indicated that teachers' beliefs influenced how they implemented reformed practices such as inquiry-based science teaching (Crawford, 2007). Research is needed to identify if teacher beliefs influence teachers' actions concerning surfacing students' prior knowledge and their enactment of curriculum features designed to elicit relevant student preconceptions. For a better understanding about teachers' perspectives on STEM curriculum, please consider the manuscripts "STEM Integration in Mathematics Standards" and "Factors underlying middle school mathematics teachers' perceptions about the CCSSM and the instructional environment" in this issue.

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REFERENCES

Alexander, W. M., & George, P. S. (1981). *The exemplary middle school*. New York: Holt, Rinehart and Winston.

Anderson, R. (2007). *Inquiry as an organizing theme for science curricula.* In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 807–830). Mahwah, NJ: Erlbaum.

Association for Middle Level Education. (2010). *This we believe: keys to educating young adolescents*. Westerville, OH: National Middle School Association.

Banilower, E., Cohen, K., Pasley, J., & Weiss, I. (2010). *Effective science instruction: What does research tell us?* Chapel Hill, NC: Center on Instruction.

Barnett, M., & Moran, J. D. (2002). Addressing children's alternative frameworks of the moon's phases and eclipses. *International Journal of Science Education, 24*(8), 859–879.

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching, 44*(4), 613–642.

Creswell, J. (2012). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Thousand Oaks, CA: SAGE.

Creswell, J. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Thousand Oaks, CA: SAGE.

Darby, L. (2005). Science students' perceptions of engaging pedagogy. *Research in Science Education, 35*, 425–445.

Driver, R., Asoko, H., Leach, J., Scott, P., & Mortimer, E. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5–12.

Driver, R., Rushworth, P., Squires, A., & Wood-Robinson, V. (Eds.). (1994). *Making sense of secondary science: Research into children's ideas*. London, England: Routledge Press.

Duschl, R. A. (1990). *Restructuring science education: the importance of theories and their development*. New York, NY: Teachers College Press.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (2007). *Taking science to school*: *Learning and teaching science in grades K–8.* Washington, DC: National Research Council.

Gallagher, S. A. (1994). Middle school classroom predictors of science persistence. *Journal of Research in Science Teaching*, *31*, 721–734.

Georgiades, P. (2004). From the general to the situated: Three decades of metacognition. *International Journal of Science Education, 26*(3), 365–383.

Gunstone, R., & Mitchell, I. (1998). Metacognition and conceptual change. In J. Mintzes, J. Wandersee, & J. Novak (Eds.), *Teaching science for understanding: A human constructivist approach* (pp. 133–163). San Diego, CA: Academic Press.

Hanson, N. R. (1958). *Patterns of discovery; an inquiry into the conceptual foundations of science.* Cambridge, England: Univ. Press.

Harlen, W. (2001). *Primary science: Taking the plunge.* Portsmouth, NH: Heinemann.

Horizon Research, Inc. (2012). *Annotated Classroom Observation Protocol*. Chapel Hill, NC: Author.

Juvonen, J. (2004). *Focus on the wonder years: Challenges facing the American middle school*. Santa Monica, CA: Rand.

Krajcik, J., McNeill, K. L., & Reiser, B. J. (2008). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education, 92*(1), 1–32.

Krajcik, J. S., & Sutherland, L. M. (2010). Supporting students in developing literacy in science. *Science, 328*(5977), 456–459.

Logan, M., & Skamp, K. (2008). Engaging students in science across the primary secondary interface: Listening to the students' voice. *Research in Science Education*, *38*(4), 501–527.

Loucks-Horsley, S., Hewson, P., Love, N., & Stiles, K. (2009). *Designing professional development for teachers of mathematics and science.* Thousand Oaks, CA: Corwin.

Marshall, J. C., Horton, R., Igo, B. L., & Switzer, D. M. (2009). K–12 science and mathematics teachers' beliefs about and use of inquiry in the classroom. *International Journal of Science and Mathematics Education*, *7*(3), 575–596.

Martin, M. O., Mullis, I. V. S., Foy, P., & Stanco, G. M. (2012). *TIMSS & PIRLS International Study Center.* Chestnut Hill, MA: Boston College.

Mintzes, J., Wandersee, J., & Novak, J. (Eds.). (1998). *Teaching science for understanding: A human constructivist approach* (pp. 133–163). San Diego, CA: Academic Press.

National Center for Education Statistics. (2010). *An introduction to NAEP National Assessment of Educational Progress.* Washington, DC: Institute of Education Sciences.

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: The National Academies Press.

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

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211–227.

Schneider, R. M., Krajcik, J., Marx, R. W., & Soloway, E. (2002). Performance of students in project-based science classrooms on a national measure of science achievement. *Journal of Research in Science Teaching, 39*(5), 410–422.

Shapiro, B. (1994). *What children bring to light: A constructivist perspective on children's learning in science.* New York, NY: Teachers College Press.

Speering, W., & Rennie, L. (1996). Students' perceptions about science: The impact of transition from primary to secondary school. *Research in Science Education*, *26*(3), 283–298.

Tai, R., Liu, C., Maltese, A., & Fan, X. (2006). Planning early for careers in science. *Science, 312*(5777), 1143–1144.

Tobin, K. (Ed.) (1993). *The practice of constructivism in science education.* Hillsdale, NJ: Erlbaum.

Trundle, K. C., Atwood, R. K., Christopher, J. E., & Sackes, M. (2010). The effect of guided inquiry-based instruction on middle school students' understanding of lunar concepts. *Research in Science Education, 40*(3), 451–478.

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction, 4*(1), 45–69.