A Veteran Science Teacher's Transitions to NGSS

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Abstract

Curricular reforms in science education represent an opportunity for changes in instructional approaches with the intent of making learning and teaching more meaningful and effective. While beginning teachers may receive instruction on pedagogy aligned with adopted reforms, veteran teachers need support and development to implement instruction aligned with reforms. This qualitative case study focused on the transitions of a veteran, Grade 6 science teacher to implement instruction consistent with three-dimensional instruction outlined in the Next Generation Science Standards (NGSS Lead States, 2013). Themes that emerged through analyses of data included the desire and methods for developing pedagogical knowledge, collaborative supports for changing pedagogy, and resulting changes in pedagogy. Suggestions for further study include exploration of types of professional development that support changing pedagogy and a long-term study of teacher efficacy in three-dimensional instructional approaches outlined in NGSS (NGSS Lead States, 2013).

Key words: Changing pedagogy, Curricular reforms, Instruction, Middle School, Next Generation Science Standards (NGSS), Science and Engineering Practices, Veteran Science Teachers

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Introduction

Implicit in the development and adoption of standards is the expectation of uniform outcomes throughout a district, region, state, or country as measured by standardized assessments (Deboer, 2002; Eisner, 2005; Qureshi et al., 2016). While a focus on standardization frames opportunities for accountability measures, the consequence is a narrowing of curricula to focus instruction and learning on what is tested (Eisner, 2005). As curricula narrow, Deboer (2002) identified a tension between standards-based instruction focused on specific content learning associated with accountability through high-stakes testing and student-centered instruction focused on inquiry and constructivist methods for developing content understanding, thus creating what Eisner (2005) described as an over-emphasis on technical aspects of teaching. This neglects the "organic' and "humanistic" (Eisner, 2005, p. 16) components of teaching. Without experience or development, veteran science teachers may persist with their views that the Next Generation Science Standards (NGSS) conflict with student-centered instruction (Herrington & Daubenmire, 2016; NGSS Lead States, 2013; Penuel, Harris, & DeBarger, 2015).

In contrast to what may be a perceived tension between standards and student-centered instruction, transition to instruction aligned with NGSS represents opportunities to transform teaching and learning through a three-dimensional instructional approach and requires education of science teachers (NGSS Lead States, 2013; Penuel et al., 2015). The development of content knowledge and pedagogy relevant to NGSS can foster instruction that improves teacher effectiveness and increases student voice in the teaching and learning process (Marshall, Smart, & Alston, 2017; Qureshi et al., 2016; Shulman, 1986; 1987). To facilitate changes in instruction, teachers require support, often in the form of professional development and accompanying institutional systems (Herrington & Daubenmire, 2016; Shulman, 1986; 1987; 2015). Through teacher development and subsequent practice, science instruction that incorporates the three-dimensions outlined in NGSS can transform the teacher mindset that views instruction as either standards-based or student-centered (Deboer, 2002; NGSS Lead States, 2013; Penuel et al., 2015; Qureshi et al., 2016).

This study explores pedagogical content knowledge (PCK) and actions of a veteran teacher related to changes in science instruction in a Grade 6 classroom in response to the adoption of NGSS by a school district (NGSS Lead States, 2013; Shulman, 1986, 1987). The study addresses the need for teacher understanding and practice in implementing NGSS-aligned instruction and explored the research question, "How does a veteran science teacher transition to three-dimensional science instruction to address adopted content standards?" Data for this study were collected as part of a larger study on instruction in middle school science classrooms.

Literature Review

Classroom instruction can range along a continuum of practices based on educator attitudes and preparation (Herrington & Daubenmire, 2016; Penuel et al., 2015; Lund & Stains, 2015). The attitudes and practices of educators can be addressed through professional development experiences that aid in overcoming gaps between research and practice (Herrington & Daubenmire, 2016; Penuel et al., 2015). These attitudes and practices are relevant as teachers move toward three-dimensional instruction aligned with NGSS. As educators embrace and implement instruction that is increasingly student-centered, student interest and achievement can be positively impacted (Connell, Donovan, & Chambers, 2016; Freeman et al., 2014; Kang & Keinonen, 2018). The positive impacts of changing instruction may be related to the use of three-dimensional instruction (NGSS Lead States, 2013) and the growth of teachers' PCK (Shulman, 1986, 1987) that occurs during professional development.

Three-dimensional Science Instruction

Berland et al. (2016) identified reforms in science education as moving from teachers telling about science to students engaged in doing science. This is exemplified in the inclusion of science and engineering practices with the disciplinary core ideas and crosscutting concepts in NGSS (NGSS Lead States, 2013). Science and engineering practices and crosscutting concepts allow students to engage in constructing, explaining, and applying science core ideas to varied phenomena (Berland et al., 2016; Krist, Schwarz, & Reiser, 2018; NGSS Lead States, 2013; Reiser et al., 2017). By scaffolding opportunities for the use of practices, teachers can bring students into the process of doing science (Berland et al., 2016).

To ensure opportunities for students to engage in doing science, teachers must understand pedagogy for three-dimensional instruction (Reiser et al., 2017). Furthermore, teachers must support students in both learning and using processes to do science (Berland et al., 2016). As reported by Berland et al. (2016), "Introducing disciplinary practices into a school culture faces challenges" (p. 1085). Approaches to three-dimensional instruction cannot simply be fit into instruction based largely on teachers telling students about science. Instruction of students to do science requires teacher development to support experiences that are meaningful in both classroom and scientific communities (Berland et al., 2016; Reiser et al., 2017).

Professional Development

Teachers benefit from development opportunities, instructional resources, and continuing support to transform science instruction (Harris et al., 2012; Herrington & Daubenmire, 2016; Marshall et al., 2017; Penuel et al., 2015; Reiser et al., 2017; Yager et al., 2013). Through the development and use of PCK, teachers can make connections between content and pedagogical resources, which are important to delivery of instruction at appropriate levels for student understanding (Park, Jang, Chen, & Jung, 2011; Shulman, 1986, 1987). Development experiences aligned with teacher need are reported to positively impact teacher PCK (Haag & Megowan, 2015; Park et al., 2011; Roseler & Dentzau, 2013; Shulman, 1986, 1987; Zhang, Parker, Koehler, & Eberhardt, 2015). Roseler and Dentzau (2013) reported that effective development should include contextual factors and empowerment of teachers in identifying and addressing an issue, such as science instruction. In contrast to the ideas suggested by Roseler and Dentzau (2013), many approaches to development have focused on dissemination of knowledge (Herrington & Daubenmire, 2016). To close the gap between effective instructional approaches identified in research and teacher practice in the classroom, Herrington and Daubenmire (2016) suggested an approach centered on teachers developing best practices.

Professional development can change teacher beliefs, resulting in changes in teachers' instructional practices (Herrington & Daubenmire, 2016; Marshall et al., 2017). Marshall et al. (2017) reported that professional development focused on inquiry improved student achievement through the growth of teacher knowledge and pedagogy. Professional development centered on teachers as professionals can be an effective aid for teachers to apply research to practice (Herrington & Dabuenmire, 2016). This centering of teachers as professionals is consistent with developing learning that is relevant to teachers' practice (Herrington & Daubenmire, 2016; Roseler & Dentzau, 2013). When presented with opportunities to direct their professional development, teachers' instructional practices can change, resulting in positive impacts on student learning (Haag & Megowan, 2015; Park et al., 2011; Roseler & Dentzau, 2013; Yager et al., 2013; Zhang et al., 2015).

In contrast to beginning teachers educated after adopted reforms, professional development is especially important for veteran teachers that did not participate in pre-service coursework aligned with current reforms. Collaborative relationships encompass opportunities for teachers to interact and direct their development to address understanding, beliefs, and implementation of instruction aligned with NGSS (Haag & Megowan, 2015; Herrington & Daubenmire, 2016; Park et al., 2011; Roseler & Dentzau, 2013; Yager et al., 2013; Zhang et al., 2015). Developing veteran teachers' PCK that leads to implementation of instruction consistent with the three-dimensions of

NGSS instruction requires systems that provide support for changing instruction (Herrington & Daubenmire, 2016; Park et al., 2011; Roseler & Dentzau, 2013).

Theoretical Framework of Pedagogical Content Knowledge

The confluence of content and pedagogical knowledge required for science teachers to engage in three-dimensional instruction can be considered through the application of Shulman’s (1986, 1987) theory of PCK. While teacher preparation and evaluation have traditionally treated content and pedagogy as a dichotomy, content knowledge and pedagogical knowledge both play a role in teaching. Shulman (1986, 1987) proposed that successful educators possess a balance in the interaction of content knowledge and pedagogical knowledge that enhance the teaching and learning process. This balance within PCK can foster instructional approaches that incorporate student learning of science content and practices. Shulman (1987) outlined categories of teacher knowledge that include disciplinary content, general pedagogy, pedagogical content and curricular. The structure of knowledge presented by Shulman (1986, 1987) is significant in the assertion that educator preparation and evaluation should be based on a synthesis of content and pedagogy termed PCK (Shulman, 1986). In PCK, general pedagogy is re-interpreted to meet the needs of specific content instruction, which is true in the considerations of science instruction based on standards and student-centered instruction (Deboer, 2002; Shulman, 1987).

Science classroom instruction relies on a balance of educator knowledge of content, context, and pedagogy that creates an environment where students can understand and engage in experiences that provide opportunities for learning (Shulman, 1986, 1987). In the case of student-centered science instruction, educators must have knowledge in pedagogy and content for science, science practices, and the interactions of students with science content and practices. Shulman's (1986) theory of PCK can be applied to explain the overlap of content and pedagogical knowledge in student-centered science instruction, helping to balance the content of standards with student-centered approaches (Deboer, 2002; Park et al., 2011). Kind (2015) presented PCK in science as a continuum that ranges between integrative and transformative. As science educators consider the different demands of science curricula, including content matter, practices, and engagement, they must integrate and transform the pieces of science curricula into cohesive learning experiences and opportunities. This process relies on each educator’s PCK (Kind, 2015; Park et al., 2011; Shulman, 1986, 1987).

Methods

The implementation of three-dimensional instruction outlined in NGSS (NGSS Lead States, 2013) in science classrooms requires an understanding of the knowledge and actions of science teachers. For this study, one teacher’s actions to establish instruction aligned with NGSS in her Grade 6 science classroom represents the contemporary phenomenon for this qualitative case study. Data were gathered on teacher practices of planning for, implementing, assessing, and reflecting on instruction as a means for describing teacher actions related to instruction in the science classroom (Stake, 1995; Yin, 2014).

Multiple and varied data sources were used to support the case study as recommended by Stake (1995) and Yin (2014). Data sources in the study included interviews, observations, and document reviews. Each data source represented perspectives that informed the researcher about the planning for, implementation of, and reflection on the participant's approaches to science instruction. Semi-structured interviews were guided by an interview question protocol developed from literature on PCK in science instruction (Park et al., 2011). Fifteen observations of classroom instruction consisting of 57-minutes each were completed over a nine-week unit of study. Information from observations was recorded using a researcher-developed protocol that included space for recording instructional approaches including science and engineering practices and literacy, classroom set-up, and notes. Interview questions were organized into three categories. Teaching experience and background questions consisted of four questions (i.e. How would you define science teaching?). Four General pedagogy questions (i.e. How would you describe your approach to teaching science?) were asked. Interviews paired with observations consisted of four questions before (i.e. How did you consider science skill development in your lesson planning?).and five questions after the observation (i.e. How did you incorporate science practices in the lesson?). A document review protocol was used to facilitate the review of documents, including lesson plans and materials used by the teacher with students. The document review protocol provided structure for recording learning expectations, planned instructional strategies, and evidence of activities to meet objectives. All protocols were reviewed by experts for content and construct validity. Data were coded by the researcher through iterative cycles of analysis. Initial codes were developed from literature on PCK and science instruction (Kind, 2015; Park et al., 2011).

Site Selection

The selected site, Bell Middle School (BMS, a pseudonym), is an urban, Grades 6-8 public middle school located in the northeastern United States. The school was recently impacted by the adoption of NGSS and aligned curricula. Of the 760 students served by BMS, 65% identified as Caucasian, 22% as Hispanic, 8% as African-American, 2.5% as Asian, and 2.5% as multiple race. BMS qualifies for Title I funding with over 47% of the student population receiving free or reduced-price breakfast and lunch. BMS reported a proficiency rate on 2017 state literacy assessments, as measured by the state mandated standardized testing, of 51%, which is lower than the district and state rate of 55% of students scoring proficient or better.

Participant

Kaitlyn, a 44-year-old Caucasian female with a state teacher certification in Grades K-6 instruction, attained a master's degree in elementary education in 2002. Due to levels of teacher certification determined by the state department of education, elementary (Grades K-6) certification is necessary for teaching Grade 6, even in a middle school with separate courses focused on content. Specialized content certifications are typically at the Grades 7-12 level. Therefore, Kaitlyn is considered highly qualified in science due to experience and district documentation of competency in science instruction. Kaitlyn was in her 20th year of teaching, which included seven years of elementary teaching and 13 years in her current position teaching Grade 6 science. The district science curriculum has been largely unchanged until the recent adoption of the NGSS by the state and district. During the time of this study, Kaitlyn was preparing for the implementation of the newly adopted NGSS standards, revised curriculum, and related pedagogy. Kaitlyn was familiar with the lead researcher as both had worked at the same school prior to the researcher's departure.

As a veteran educator, Kaitlyn was successful in implementing instruction aligned with adopted standards and curricula. The adoption of NGSS by the state and district resulted in curricular changes that included pedagogical changes associated with three-dimensional instruction of NGSS (NGSS Lead States, 2013). Kaitlyn expressed a goal to move toward instruction that aligned with these three-dimensions and increased student-centered instruction in her classroom. However, she was concerned about compromising the integrity of what she viewed as effective, current practice. Overall, Kaitlyn stressed her goal for implementing NGSS-aligned instruction that moved beyond asking questions in which she would respond, "That's right! You got it!" Even though Kaitlyn desired a change in her instruction, she acknowledged that this change would not necessarily come easy as she stated, "I have to change what I have learned and practiced for the last 20 years."

Kaitlyn's in-service professional development experiences prior to the year of this study focused on teacher-led strategies and familiarity with NGSS. The adoption of NGSS presented a rationale for Kaitlyn's desire to change pedagogical approaches. The school district provided science teachers with a professional development experience to aid in transitions to curricula that incorporate NGSS and the identified three-dimensions of science instruction, including content, practices, and crosscutting concepts (NGSS Lead States, 2013). Kaitlyn only summarily referenced the NGSS preparation provided by the district and spoke more frequently of collaboration with a colleague that had received a separate preparation at a local university. She referred to the collaborative planning time and suggestions of her colleague as "greatly influencing and contributing to [Kaitlyn's] instruction."

Through sharing of different perspectives, strategies, and the efficacy of these strategies in the science classroom, Kaitlyn and her colleagues planned instructional approaches that deviated from past practice by focusing on a phenomenon and related student-generated questions to drive instruction. This collaboration represented what Kaitlyn described as "meaningful development" that motivated and supported her desire to change her practice. She was prompted by these interactions to explore and implement varied ways for teaching literacy, science skills and practices, and science content to meet her personal goal of student-centered instruction aligned with NGSS.

Findings

Kaitlyn expressed a goal to move toward instruction aligned with the three-dimensions of NGSS with a focus on engaging students in doing science, not just looking for the teacher-directed correct answer. Prior to the adoption of NGSS, Kaitlyn focused her instruction on meeting the state mandated science content standards as well as meeting literacy and math goals established at the school level. Her instruction often focused on implementing teacher-directed strategies focused on improving student scores on standardized assessment items. This led to the use of literacy strategies focused on discrete actions and often resulted in Kaitlyn telling students about science either through lecture or reading activities. She expressed an ongoing struggle between meeting school-based goals for standardized assessments and the lack of opportunity for students to be engaged in doing science practices. In response to the adoption of NGSS and Kaitlyn's expressed desire to change her instruction to align with three-dimensional instruction, the findings are organized by the themes that emerged through analyses of data and included Kaitlyn's desire and methods for developing pedagogical knowledge, supports for changing pedagogy, and resulting changes in Kaitlyn's pedagogy.

Desire to Develop Pedagogical Knowledge

Kaitlyn described that initial district-provided preparation related to NGSS was primarily focused on developing understanding of the disciplinary core ideas, science and engineering practices, and crosscutting concepts. While all three dimensions were overviewed, the focus was on science and engineering practices. In particular, the focus reported by Kaitlyn was primarily teacher strategies for using practices. These experiences centered on teacher understanding of instructional methods and subsequent classroom implementation of discrete strategies that were not presented as holistic approaches in a progression of learning. Throughout interviews, Kaitlyn recognized learning and use of isolated strategies as a continuation of past practice and expressed a personal goal to move beyond pedagogy that "had been engrained for over 20 years." She wanted students to participate through "deeper questions and thought" that moved beyond teacher-directed questions and expected student responses, thus transitioning to NGSS-aligned instruction.

Kaitlyn established a personal goal to change her approach in the classroom that focused on disconnected science, math, and literacy strategies to improve test scores and acknowledged that she needed to move toward holistic approaches to science instruction that incorporated content, practices, and crosscutting concepts. For example, Kaitlyn had participated in district provided professional development focused on literacy instruction in the content areas. This district provided professional development that had historically been focused on generalized strategies to be applied across curricular areas as evidenced in the mandatory instruction tied to graphic organizers and other general strategies for reading and writing instruction. Teachers were encouraged to choose and implement strategies or organizers to lead students through reading and writing instruction, representing teacher-initiated choice and classroom instruction. As she learned about NGSS, Kaitlyn sought to engage in learning in addition to what had been provided through district facilitated development to allow her to provide experiences that engage students in doing science.

Supports for Changing Pedagogy

The professional development provided by Kaitlyn's district focused on introducing teachers to NGSS and related strategies for using science and engineering practices. However, this preparation was limited to three days. The limitation of the instruction did not include formalized on-going support or learning opportunities. Kaitlyn contrasts the district-provided preparation with preparation experienced by her colleague.

Kaitlyn explained that she desired to meet the expectations of NGSS-aligned instruction and that her primary source of support was a colleague that was involved in an ongoing professional development experience offered by a local university. Through collaborative planning, Kaitlyn's colleague was able to share ongoing learning and influence Kaitlyn's practice. Kaitlyn attributed her willingness to integrate instruction based on student engagement with science and engineering practices with the ongoing support she knew was available through her colleague and through the colleague's interactions in the university program. The learning and supports provided by the university sponsored professional development were present throughout implementation to aid in addressing classroom challenges and to share successful approaches.

Changes in Kaitlyn's Pedagogy

As part of Kaitlyn's goal for implementing NGSS-aligned instruction, she wanted students to become active participants in asking questions, investigating ideas, and constructing scientific explanations and knowledge. Even though Kaitlyn desired a change in her instruction, she acknowledged that this change would not necessarily come easy as she said, "I have to change what I have learned and practiced for the last 20 years." The school structures focused on improving literacy and math scores coupled with development focused on strategies to meet these goals influenced Kaitlyn's prior instruction. As Kaitlyn collaborated with her colleague, considered NGSS and related curricula, she was motivated change her practice as evidenced in two areas that included her focus on use of authentic experiences integrated in science and engineering practices and changing assessments.

Authentic experiences in science and engineering practices. As Kaitlyn implemented instruction, she said she wanted to focus on engaging students with content and practices. While Kaitlyn felt the process of planning and teaching students in ways consistent with NGSS was "very overwhelming," she kept returning to content knowledge, stating, "I look at the DCIs [disciplinary core ideas] and try to figure out the best way for my students to experience the information." In planning for experiencing information, Kaitlyn began with a phenomenon that allowed students to ask questions and investigate to construct knowledge and did not rely on teacher-directed investigations. Kaitlyn's emphasis on "student experiences" allowed for uses of science and engineering practices that were intentionally structured to feel authentic rather than contrived or forced into classroom instruction. As students explored ideas, Kaitlyn structured scaffolds that included the use of reading traditional texts as background and obtaining information from charts and graphs and writing through documenting procedures and data through summaries, charts, and graphs. The varied forms of text were selected based on student questions and were viewed by Kaitlyn as authentic to the practices of scientists.

The integration of science practices as authentic experiences was evident in one observed unit that focused on the phenomenon of declining barn owl populations. During the course of the unit, students questioned food sources of barn owls. In response to student inquiries, Kaitlyn presented students with owl pellets and opportunities to explore the pellets as a source of data for answering their questions. Students read about owl pellets to understand what they are and how the pellets could provide relevant information. Students led the dissection of the pellets, gathering, identifying, and recording quantities of bones using a guide with diagrams and captions provided by Kaitlyn. Data were used by students to construct ideas about and explanations of energy flow within the ecosystem in which the barn owl resides. This use of the owl pellet dissection differed from Kaitlyn's approach in prior years when she directed the process of dissection, identification, and relation to food webs. In the observed use of owl pellets, students assisted each other in the dissection and explanation of energy flow on a student-created graphic organizer with a brief written conclusion rather than being directed by the teacher.

Kaitlyn provided opportunities for students to produce, communicate, and support or defend their own ideas, thus aligning instruction with core science ideas, science and engineering practices, and crosscutting concepts. Students constructed ideas based on their current level of understanding science content and the phenomenon. These ideas were then communicated through discourse, models, and summaries. Through each method of communication, Kaitlyn probed students for evidence to support their ideas. The science and engineering practices were used as the foundation for supporting student engagement in doing science and communicating ideas.

The transition of instruction to include student engagement through science practices occurred in Kaitlyn's classroom through two key areas that included types of questioning and think-alouds, when Kaitlyn narrated her thinking process for students. First, Kaitlyn began asking questions that were open-ended and did not necessarily have one correct answer. These questions required students to interpret information and apply their thinking to answer the question. Kaitlyn stated that she was working on "moving away from, 'You've got it!' or "That's right!' to, 'What makes you think that? What evidence can you provide to support that answer?'" She continued:

> It's hard changing my response to my students to build confident science learners who can be willing to take a risk, answer a question, and not get the quote, unquote, teacher answer that they have been looking for and I have been giving for all these years. It's huge to change that classroom culture that I've been engrained in for 20 years and I continually work on that.

Kaitlyn explored students' questions and scaffolded supports to build student confidence and facilitate discourse focused on science ideas and supporting evidence.

Think-alouds were also used by Kaitlyn to scaffold the use of graphs and diagrams as data sources related to an anchoring phenomenon. Initially, Kaitlyn used think-alouds to model and scaffold the science and engineering practice of gathering and evaluating information (NGSS Lead States, 2013). As the school year and unit of instruction progressed, Kaitlyn expected students to develop and use the skills modeled during class. In Kaitlyn's planning and reflection, she identified think-alouds as a key pedagogical tool for engaging students, saying, "they [the students] also begin to understand the processes." Think-alouds were used both in direct instruction of content area strategies and in the release and support of students applying science practices in learning science content.

Assessments. Kaitlyn structured varied opportunities for students to document their construction of knowledge and developing understanding of science. As described by Kaitlyn, she was shifting her pedagogy toward "more student-centered demonstration of the concepts with open-ended type assessments." This emphasis was visible in Kaitlyn's instruction as she modeled and later allowed students to choose different types of "outputs" as formative assessments within their science notebooks, each of which incorporated writing in some form. Short-term and long-term writing activities provided additional formative assessments and included brief summaries, sketches or diagrams with labels and captions, and models with explanations. Reports and presentations were used as forms of summative assessments. Additionally, discourse was used by Kaitlyn to assess students' understanding of science content and supporting evidence. The classroom environment created by Kaitlyn facilitated sharing ideas and constructing knowledge in what she called a "comfortable zone of expectations that we are all here as learners, we're all here to make mistakes, to grow" and allowed her to formatively assess students throughout the unit of instruction.

Having an environment that was comfortable for students to express ideas without being judged based on an expected answer was important to Kaitlyn. Students engaged in speaking and listening to aid each other in gathering and analyzing data, sharing ideas, and constructing knowledge, using evidence, and integrating feedback. Kaitlyn facilitated student discourse through using prompts such as, “Can anyone build on what was just shared?” or “Does anyone have any other evidence that supports or disagrees with that idea?” The techniques used by Kaitlyn made the actions of students personal and therefore relevant to students. Kaitlyn was then able to structure opportunities that did not require her to provide affirmation of student thinking, but allowed students to build on ideas to clarify understanding or offer a different perspective. As the school year progressed, students engaged in discourse with fewer scaffolds from Kaitlyn as they constructed and demonstrated knowledge about science concepts and asked questions to drive learning.

Discussion

The adoption of NGSS impacted Kaitlyn’s instruction in science (Hannant & Jetnikoff, 2015; NGACBP & CCSSO, 2010; NGSS Lead States, 2013). Standards influenced curricula, evidenced in Kaitlyn’s desire to engage students in doing science. Kaitlyn identified professional development centered on collaboration as key in navigating the implementation of instruction that incorporated the three-dimensions of instruction outlined in NGSS (NGSS Lead States, 2013). Through this study the integration of science and engineering practices and ongoing professional support were identified in aiding Kaitlyn’s instructional reforms to engage students in NGSS and overall science learning.

Integration of Science and Engineering Practices

Kaitlyn used science practices to build opportunities for student engagement in instruction. Throughout science processes, Kaitlyn facilitated lessons that built on and strengthened skills relevant to broader applications that were student-centered and paralleled uses by science experts. This was evidenced in Kaitlyn’s revision in her approach to an owl pellet dissection lab that moved from a prescriptive activity to an exploration that required student thinking to construct a diagram of energy flow in the ecosystem. Kaitlyn planned for the use of critical thinking and analysis in conjunction with science practices by encouraging discourse that related classroom activities to content (Michaels & O’Connor, 2015). The use of literacy skills relied on science practices in instruction and structured lessons that utilized science practices leading to skill development to promote student choice in representations of learning in their science notebooks (NGACBP & CCSSO, 2010; NGSS Lead States, 2013).

Kaitlyn integrated literacy approaches within science and engineering practices by incorporating information that required student interpretation and communication. This created authentic contexts for learning as students practiced skills used by scientists (Michaels & O’Connor, 2015; NGSS Lead States, 2013). These contexts aided Kaitlyn in moving her instruction away from discrete strategies to authentic experiences that were student-centered and paralleled the activities of expert scientists (Granger et al., 2012). Ranging from student-driven questions about the anchoring phenomenon through formative and summative assessments using science and engineering practices, Kaitlyn provided opportunities for students to engage in learning. The transition of Kaitlyn’s pedagogy from direct, general instruction to application of literacy skills and science and engineering practices demonstrated a change in her PCK. This change was a realization of Kaitlyn's initial goal to engage students in doing science and building science content knowledge (Fisher & Ivey, 2005; Granger et al., 2012).

The integration of science and engineering practices represented a shift in Kaitlyn's approach to science instruction based on her understanding of NGSS and her desire to engage students in doing science (NGSS Lead States, 2013). This change is consistent with recommendations by the National Research Council (NRC) that instruction and assessment must be consistent with the vision of three-dimensional science instruction (NRC, 2012). To further transitions to activities that engage students in science and engineering practices, teachers, including veteran teachers such as Kaitlyn, and professional development facilitators may utilize tools for identifying cognitive demand of tasks, such as the Task Analysis Guide in Science (TAGS) presented by Tekkumru-Kisa, Stein, and Shunn (2015). Tools such as TAGS can aid in teacher identification of tasks aligned with the desired outcomes consistent with NGSS (NRC, 2012; NGSS Lead States, 2013; Tekkumru-Kisa et al., 2015).

Ongoing Professional Support

Kaitlyn was influenced by professional learning experiences inclusive of NGSS learning offered by faculty at a local university. While not directly participating in the University provided professional learning experience, she benefited by collaborating with a grade level colleague who had participated in the professional development (Reiser et al., 2017). As previously described, Kaitlyn was initially skeptical of and resistant to approaches she thought detracted from literacy and content learning. However, after her collaborative planning efforts, she voluntarily implemented instruction aligned with her colleague's learning from the professional learning experience. Consistent with research, collaboration and practice of pedagogical changes resulted from professional learning and a willingness to embrace changes, at least as an initial trial of new learning with ongoing supports (Harris et al., 2012; Herrington & Daubenmire, 2016; Reiser et al., 2017; Yager et al., 2013). Kaitlyn implemented instruction that was co-planned with her grade-level colleague based on the colleague's NGSS preparation. The co-planned lessons and resulting instruction represented new learning for Kaitlyn that influenced her pedagogical knowledge. Consistent with Shulman's (1986, 1987) findings that revealed experience influenced PCK; Kaitlyn's authentic use of science and engineering practice instruction provided experiences that, over time, shaped her evolving PCK, resulting in increased uses of practices and literacy integrated within science instruction.

The professional learning experience encompassed in Kaitlyn's collaboration served the purpose of aiding PCK development, both in addressing pedagogical need and in overcoming limitations of prior experiences. This experience helped Kaitlyn move toward her goal of student-centered instruction (Haag & Megowan, 2015; Herrington & Daubenmire, 2016; Park et al., 2011; Roseler & Dentzau, 2013; Shulman, 1986, 1987; Zhang et al., 2015). Kaitlyn learned from her colleague and engaged in planning and implementing lessons and units aligned with NGSS and inclusive of science and engineering practices. She became comfortable in utilizing approaches that provided opportunities for student-centered lessons consistent with three-dimensional instruction outlined in NGSS (Herrington & Daubenmire, 2016; NGSS Lead States, 2013; Reiser et al., 2017; Yager et al., 2013).

Conclusion

Veteran science teachers experience both opportunities and challenges when confronted with educational reforms like incorporating three-dimensional instruction as stipulated in NGSS (Haag & Megowan, 2015; NGSS Lead States, 2013; Penuel et al., 2015; Qureshi et al., 2016). Opportunities include approaching content through inquiry and skills that allow students to assume an active role in the teaching and learning process (Freeman et al., 2014; Granger et al., 2012). An example is anchoring phenomenon to drive questioning and instruction and integrating science and engineering practices to create learning environments that maintain a focus on engaging students in doing science to learn and apply science content (Freeman et al., 2014; Granger et al., 2012; Qureshi et al., 2016; Yager et al., 2013).

Student interest fostered through participation in and direction of activities using practices outlined in NGSS provided the basis for experiences and questions that furthered instruction (Freeman et al., 2014; Granger et al., 2012; Kang & Keinonen, 2018; Marshall et al., 2017; NGSS Lead States, 2013; Olsen & Rule, 2017). The use of science and engineering practices can encompass a range of skills that include authentic application of literacy, discourse, questioning, and thinking skills to construct and communicate learning about content (Kang & Keinonen, 2018; Lee & Hannafin, 2016; Michaels & O'Connor, 2015). With scaffolds and development, teachers and students can become comfortable co-constructing environments that engage students in science processes and maintain the teaching and learning of content (Connell et al., 2016; Freeman et al., 2014; Haag & Megowan, 2015; Harris et al, 2012; Lund & Stains, 2015).

This study highlights the importance of peer collaboration when implementing educational reform that supports for developing appropriate PCK. Teacher knowledge of the content is an essential component of instruction and may represent a starting point for developing learning opportunities prior to advancing pedagogy (Park et al., 2011; Shulman, 1986, 1987). Direct and indirect learning experiences can facilitate the development of student-centered pedagogy. As illustrated in this study, collaboration between colleagues allowed the formal preparation of one individual to impact the instruction of a grade-level teammate. The use of collaboration to address new content standards and shifts in pedagogy can inform the structure of professional development systems that meet the range of needs of teacher professional development and offer ongoing support throughout implementation of learning (Harris et al., 2012; Herrington & Daubenmire, 2016; Roseler & Dentzau, 2013; Zhang et al., 2015).

The impacts of teacher goals, aligned professional development, and collaborative experiences emerged from the study. Teachers supportive of educational reform but provided limited professional development may better implement instruction aligned with reforms when provided opportunities for collaboration with teachers who attended extensive professional development. Pairing teachers with different depth of understanding and development can facilitate implementation of instruction aligned with shifts such as the three-dimensional instruction of NGSS (NGSS Lead States, 2013). Collaborative planning allows for sharing of knowledge and the ongoing support to sustain instructional shifts.

While this study is focused on a single case, the case investigates the shifts in instruction implemented by a veteran science teacher in response to NGSS. The understanding of the case provides insight not only for this case but also the possible transfer of ideas to other, similar cases (Yin, 2014). Further exploration of types of professional development and structures for collaboration could improve ongoing supports that aid teachers in setting and reaching goals (Reiser et al., 2017). A long-term study of teacher efficacy can aid in understanding of instruction that aligns with three-dimensional approaches outlined in NGSS (NGSS Lead States, 2013).

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