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To cite this article: Allison Antink-Meyer & Ryan A. Brown (2017): Second-career science teachers’ classroom conceptions of science and engineering practices examined through the lens of their professional histories, International Journal of Science Education, DOI: 10.1080/09500693.2017.1338787

To link to this article: http://dx.doi.org/10.1080/09500693.2017.1338787

Published online: 20 Jun 2017.

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Second-career science teachers’ classroom conceptions of science and engineering practices examined through the lens of their professional histories

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ABSTRACT
Science standards in the U.S. have shifted to emphasise science and engineering process skills (i.e. specific practices within inquiry) to a greater extent than previous standards’ emphases on broad representations of inquiry. This study examined the alignment between second-career science teachers’ personal histories with the latter and examined the extent to which they viewed that history as a factor in their teaching. Four, second-career science teachers with professional backgrounds in engineering, environmental, industrial, and research and development careers participated. Through the examination of participants’ methodological and contextual histories in science and engineering, little evidence of conflict with teaching was found. They generally exemplified the agency and motivation of a second-career teacher–scientist that has been found elsewhere [Gilbert, A. (2011). There and back again: Exploring teacher attrition and mobility with two transitioning science teachers. Journal of Science Teacher Education, 22(5), 393–415; Grier, J. M., & Johnston, C. C. (2009). An inquiry into the development of teacher identities in STEM career changers. Journal of Science Teacher Education, 20(1), 57–75]. The methodological and pedagogical perspectives of participants are explored and a discussion of the implications of findings for science teacher education are presented.

Science education reform documents, research, and teacher education programs in the U.S. have prioritised inquiry-based, student-centred teaching for many decades. Despite this emphasis in both teacher education and science curricula, the actual implementation of inquiry in classrooms remains limited (Capps & Crawford, 2013; Roth et al., 2006; Weiss, Pasley, Smith, Banilower, & Heck, 2003). Capps and Crawford (2013) describe a persistent lack of inquiry-based teaching in U.S. classrooms, and in cases where students are involved in inquiry, it remains skills-specific and teacher guided. One explanation for the resistance to reforms-based teaching is teachers’ lack of experience with scientific inquiry (Melville, Fazio, Bartley, & Jones, 2008). This study explored the perceptions about inquiry skills and teaching practices reflective of U.S. reforms among teachers who contradict this explanation; teachers who changed careers from science and engineering fields.
Science teachers who enter the profession as a second career bring a unique set of experiences and perspectives to the science classroom. Although research has shown that scientists do not necessarily possess more sophisticated epistemological knowledge (Brown & Melear, 2007; Raphael, Tobias, & Greenberg, 1999; Sadler, Burgin, McKinney, & Ponjuan, 2010; Schwartz & Lederman, 2008; Schwartz, Lederman, & Crawford, 2004), their greater ontological awareness is a source of content knowledge and context knowledge (Greenwood, 2003; Grier & Johnston, 2009). Powell (1997) has described the potential for science teachers, whose classrooms closely relate to the fields in which they have expertise, to be well equipped to enrich their instruction through supportive analogies and practical examples.

The application of that potential to the teaching of, and about, scientific inquiry and engineering design is perhaps the most relevant aspect of science teaching to the scientist and/or engineer career changer’s repertoire. International reform efforts (American Association for the Advancement of Science, 1993; Abd-El-Khalick et al., 2004; National Research Council [NRC], 1996, 2000) have emphasised scientific inquiry since the late twentieth century. In the U.S., those emphases did not provide teachers, many of whom do not have experiences doing scientific inquiry, with guidance about specific practices implicit in inquiry. Present U.S. standards, the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013), attempt to make the skills of both scientific inquiry and engineering design explicit for teachers. Specific skills, which are important pieces of scientific inquiry and engineering design, are referred to as Science and Engineering Practices in the NGSS.

The Practices are integrated with science concepts (i.e. Disciplinary Core Ideas) in U.S. standards in an effort to shift K-12 classrooms towards the more inquiry-based teaching long sought after in reforms. Teachers that have previously been scientists or engineers can potentially provide examples and connections between concepts and practices based on their experiences, making them well positioned to be effective relative to the goals of reforms. However, career changers have also been found to regress to more teacher-centred practices when they begin their careers as teachers (Powell, 1997). In other words, despite their first-hand experiences and knowledge about the emphases of reforms, second-career science teachers are not likely to create classroom environments that reflect those reforms. The purpose of the present study was to investigate the alignment between second-career science teachers’ beliefs embedded in their professional histories in engineering and science education fields.

Literature review

**Subject matter knowledge of career changers**

The practices of scientific inquiry and engineering design constitute subject matter that science teachers can have difficulty contextualising for students (Roehrig & Luft, 2004). Although inquiry experiences in teachers’ backgrounds does not guarantee reform-oriented classroom practices (Blanchard, Southerland, & Granger, 2009), it can be supportive of their conceptions, perceptions, and student learning (Herrington, Bancroft, Edwards, & Schairer, 2016; Houseal, Abd-El-Khalick, & Destefano, 2014). In the case of career changers, their subject matter knowledge in this regard can be significant in their particular areas of expertise. However, research has suggested for some time that the explanatory ability of teachers with more subject matter knowledge than their
counterparts teaching the same classes is not necessarily superior (Kennedy, 1991). In addition, subject matter knowledge has not been shown to relate proportionally to pedagogical content knowledge (PCK) (Gess-Newsome, 1999). Instead, research suggests that the act of teaching itself supports the development of knowledge about subject matter relevant to specific teaching instances (Jong, Van Driel, & Verloop, 2005).

**Classroom practices of career changers**

Assumptions about the ability of science teachers who possess greater understanding of nature of science and the enterprise of science to provide more meaningful science experiences are longstanding. However, research suggests inconsistency in this assertion (Abd-El-Khalick, Bell, & Lederman, 1998; Lederman, 2007; McComas, Clough, & Almazroa, 1998). Some studies have shown that teachers who are career changers from science and engineering fields are similar to the majority of new teachers in their transition to textbook and teacher-centred classrooms (Powell, 1997). Greenwood (2003) found that the conceptions of science held by career changers, defined as science as experienced, influenced the development of PCK among third-year teachers and their approach to instruction more so than their conceptions of science teaching. In other words, their instructional decisions were found to more closely relate to how they understood science as an enterprise rather than how they understood pedagogy. Koballa, Nichols, and Lyon (2002), as well as Greenwood (2003), also found variety in careers changers’ conceptualisations of science, science teaching beliefs, and classroom practice potentially attributable to their professional experiences as teachers.

The label, STEM career changer, is itself such a broad label that it likely cannot inform generalisable understandings of a distinct category of teachers. The disciplines from which teachers’ STEM-related professional experience arises are varied, as are the practices and nature of work in those disciplines. This underpinned the need for the present study to describe teachers’ former professional practices related to science and engineering, and their conceptions of the practices in the NGSS. These descriptions can inform future research, teacher training, and induction programmes by illuminating the needs and strengths of these teachers.

**Theoretical framework**

**Teacher knowledge and beliefs**

Beliefs have been conceptualised in a variety of ways and have been of consistent interest to researchers despite the methodological challenges their examination presents. Kagan (1992) understood beliefs as personal knowledge and much of teacher knowledge as beliefs. More recent conceptualisations characterise beliefs as inter-related with knowledge as well as socio-culturally embedded. The nature of a teacher’s beliefs about teaching then, should not be assumed to relate only to their classroom experiences. Beliefs about content and pedagogy can also relate to teachers’ sociocultural contexts outside the classroom including contexts prior to entry into the teaching profession.

Although teachers’ beliefs can be inconsistent with their practice (Jones & Carter, 2007), they are nevertheless a matter of importance to the adoption of science education reforms. Belief systems underlie teachers’ decision-making processes because beliefs
influence attitudes and are related to teachers’ ‘content knowledge, confidence, self-efficacy, experience, and social context’ (Jones & Carter, 2007, p. 1094). Beliefs do not have a causal relationship to their actions in the classroom, but their influence is of paramount importance. Understandings about teacher beliefs can inform teacher preparation, professional development, and adoption of reforms.

Mansour (2009) described beliefs and knowledge as inter-related whereby ‘teachers’ beliefs act as an information organizer and priority categoriser’ (p. 28). The beliefs of second-career teachers, therefore, potentially organise their knowledge and experiences from their previous careers in their work with students (Greenwood, 2003; Grier & Johnston, 2009; Tigchelaar, Vermunt, & Brouwer, 2012). Unlike attitudes, which are affective in nature, beliefs are generally conceived to be cognitive (Fishbein, 1967) and are ‘part of belief systems [where] attitudes are components of this larger system’ (Jones & Carter, 2007, p. 1070). Previous personal, educational, and work experiences all contribute to complex, and sometimes conflicting, beliefs (Mansour, 2009; Tigchelaar et al., 2012).

A high level of agency exists when a professional makes the decision to ‘construct’ a new career (Gilbert, 2011) but evidence also suggests that the beliefs that career changers develop are not always congruent with their previous professional identities and can be a source of internal conflict (Snyder, Oliveira, & Paska, 2013). We used this potential point of tension, or intersection between two contexts, as our methodological focal point for this study. In order to explore between participants’ socioculturally embedded beliefs about the science and engineering practices (1) as they experienced and understood them from their previous careers and (2) as they experienced and understood them as manifest in their science classrooms.

**Methodology**

This qualitative study utilised a descriptive case study approach (Creswell, 2002; Merriam, 2002; Stake, 1995) in order to explore the experiences and beliefs of four, second career, high school science teachers. The following two research questions served to guide the study’s design:

(1) What do second-career science teachers perceive as best practice in science teaching?
(2) How do second-career science teachers perceive professional science and engineering and how do they perceive the relationship between their former STEM-related work practices and the science and engineering practices in their classrooms?

**Participants**

Participant selection for this study began with recruitment emails that were sent to science department chairpersons of regional high school and regional science teacher listervs. The selection criteria for participation in the study included the following four conditions: (1) a bachelors or terminal degree in a science or engineering discipline, (2) post-baccalaureate teacher certification programme, (3) at least two years of full-time professional experience in a science or engineering field, and (4) at least three years of full-time classroom teaching. Of those that responded, four completed all phases of data collection and they are described in Table 1.
**Data collection**

Two interviews and one classroom observation were conducted with each participant. The first interview was based on a semi-structured interview protocol (Merriam, 2002) developed for this study (Figure 1) that focused on their experiences and perspectives as scientists or engineers as well as on their pathways to teaching.

The second interview (Figure 2) was also based on a semi-structured protocol but focused on topics such as how their teaching was aligned with the NGSS practices, the importance that they place on the practices, and how their teaching is reflective of the science or engineering that they practiced in their professional histories. This also served as a member-checking opportunity in order to support validity and generally took place between one and two weeks after the observations discussed next.

In an effort to examine their beliefs from another angle, observations of a lesson in each participant’s classroom were also conducted by both researchers at the conclusion of the initial interview. The purpose of these observations was not to derive representations of the nature of their classroom practice generally. Instead, the purpose was to examine their beliefs about what constitutes good teaching relative to the science and/or

1. How do you define your discipline/What is your scientific discipline?
2. What is your education and professional history? (programs/schools; academic and research positions)
3. What classes and grades do you teach?
4. Please describe your work experiences in the science and engineering fields of which you are a part?
5. Can you describe a project that you worked on including the purposes/questions you addressed?
6. The methodologies you used in your investigations?
7. Related research agendas?
8. Collaborators and the disciplines of those collaborators?

**Figure 1.** Initial interview protocol.
engineering practices through an example that they have selected. They were asked to
choose a lesson that they felt was a reflection of how they believe the practices can be
manifest in classroom science. Observation data was organised using an observation pro-
tocol that was designed for the current study based on the learning progression for the 9–
12 grade band of the science and engineering practices in the U.S. NGSS (NGSS Lead
States, 2013). Researchers used a protocol for observations in order to provide a consistent
lens relevant to research question two. In order to develop a valid protocol, the NGSS
Appendix F (NGSS Lead States, 2013) was used as a basis for construct validity
(Krathwohl, 2009) and two science education experts also reviewed the protocol to
further establish face validity. Prior to using this tool in the study, a pilot with two high
school science teachers was conducted in order to establish intra- and inter-scorer consist-
ency. Based on several areas of inconsistency in the original version, revisions were made
and the refined protocol was used in two additional classrooms. Inter-rater reliability was
above 92% in both cases. The protocol is 11 pages in length and has a separate page for
each practice and includes additional space for field notes, descriptions and demographic
information. Figure 3 provides a snapshot of one page of this protocol, referred to as the

Data analysis

Initial and final interviews analysis

All interviews and observations were audio recorded and transcribed. Structural coding
(Saldaña, 2013) was used as a first-cycle coding method with the first and second interview
transcripts. Statements were uncovered using this strategy that indicated participants' beliefs about: (1) science teaching, (2) the practices of science and engineering in professional settings, and (3) the practices of science and engineering in classroom settings. In this process, transcript statements were categorised according to any of these three categories which were derived from the research questions. Both researchers applied the structural coding method independently in an approximately one month, iterative cycle until their individual codes were generally in agreement with their previous iteration. They then met and compared their results in order to refine the few areas of inconsistency through discussion until they were in agreement.

Next, a thematic analysis framework (Boyatzis, 1998; Braun & Clarke, 2006) was applied to the structural codes and this analysis was used to create descriptions of each of the four participants in the three belief areas just identified in order to inform both research questions. This process consisted of both researchers repeated readings prior
to coding efforts, the generation of initial codes independently in a manner similar to the structural coding method, the interpretive analysis or search for themes within the overarching structural codes established previously, the review and refinement of themes between both researchers where differences were discussed until 100% agreement reached, the definition of themes, and finally narrative development.

**Classroom observations and protocol analysis**

The transcripts from the classroom observations were analysed alongside the Design and Inquiry Practices Observation Protocol. First, both researchers compared their field notes and indicators from their use of the protocols for each participant. Any differences were discussed until resolution was reached and in some instances, the transcripts of the observations were used to resolve disagreement. The transcripts and protocols from the observations were also compared to the first interviews prior to the final interviews being conducted. Question 3 on the final interview protocol (Figure 2) was developed using these comparisons and additional clarifying questions were as well as a means of member checking.

**Findings**

The four participants are described and discussed in the following section. This section is organised by participant and each participant case is arranged to address the research questions in order. To remind the reader, the two research questions that guided the study’s design were:

1. What do second-career science teachers perceive as best practice in science teaching?
2. How do second-career science teachers perceive science and engineering and how do they perceive the relationship between their former STEM-related work practices and the science and engineering practices in their classrooms?

Given these questions, and the structural codes previously identified (i.e. science teaching, etc.), each case first describes the beliefs expressed by each participant and then followed by the beliefs they expressed about professional versus classroom science related to the practices. Those beliefs were expressed in response to the interview questions (see Figure 1 and Figure 2) in which they were explicitly asked about the practices of their previous work experiences and the extent to which those practices related to their classrooms. Thus, research question one is predominantly addressed in the section subtitled, Beliefs about Science Teaching, and research question two is predominantly addressed in the section of each case subtitled, Beliefs about the Practices of Science and/or Engineering in Research and Classroom Settings.

In addition to the participant information presented in Table 1, Table 2 describes the methodological perspectives and work environments from each of their professional histories. The methodological base was a set of codes derived from their interviews that describe the nature of their work in science and/or engineering. Design-based indicates problem driven design (i.e. designing a product given constraints that meets pre-determined needs), experimental indicates research grounded in hypothesis testing, and technician indicates work that involved the implementation of protocols and protocol design. The environment column in Table 2 was another set of codes also derived from their interviews.
that describe the setting in which their former work experiences took place. All participants worked for at least some period of time in laboratory settings and two participants’ work also consisted of computer-based design and inquiry research.

**Benjamin**

**Beliefs about science teaching**

Benjamin was a former chemical and computer engineer who transitioned to teaching after his spouse had decided to enter the profession. At the time of the study, he had been teaching chemistry for 14 years and was the science department chair. As chair, he was leading a department initiative to transition to model-based pedagogy in all science classrooms and he viewed the NGSS science and engineering practices as relevant to the work already being done in his department.

> [T]here used to be 30 desks in there and now those desks are all gone and kids sit at the lab tables every single day and then 3 years ago, you know, we’ve been messing around with this idea of the modeling methodology of instruction in chemistry and we’ve expanded it to all of our science classes. (Benjamin, Interview 1)

Compared to the other three participants, Benjamin’s classroom emphasised students’ critical thinking more prominently and the observation included more indicators of aspects of science and engineering practices than other participants.

> [W]e feel like we are asking kids questions, we are developing models, we are planning and carrying out investigations, we’re analyzing and interpreting data. Kids have to get up in front of the classroom and defend what they found and present their solutions to problems so when I look at these eight things from NGSS, I see the things that we should be doing, and that we are doing here. (Benjamin, Interview 2)

Model-based pedagogy, or inquiry (Windschitl, Thompson, & Braaten, 2008) where students are engaged in inquiry and engineering design, was considered best practice in science teaching by Benjamin. It is teaching practice that emphasises conceptual knowledge and epistemic understanding about science and for Benjamin it was clearly connected to the eight practices from the NGSS. More importantly to him, it was connected to professional science and engineering as he understood it.

**Beliefs about the practices of science and/or engineering in professional and classroom settings**

Benjamin expressed views about science and engineering that drew both on his experiences as a graduate student in chemical engineering and on his postgraduate, professional work experiences, which were more design-based and driven by computer modelling work.
rather than traditional laboratory work. More so than any of the other participants, Benjamin stated the importance of student engagement in thinking and reasoning through science in similar ways as practicing scientists do. ‘I’m looking at this NGSS summary and asking questions, and analyzing and constructing and engaging in arguments. I mean that’s what we did as grad students and that’s what we do with our students now’ (Benjamin, Interview 2).

He was the only participant whose students were observed engaging in the Development and Use of Models practice (NRC, 2012) and all five of the indicators for this practice on the protocol were observed. These were (1) evaluating the limitations of a specific model or comparing the merits and limitations of two different models, (2) using their evaluation of a model or set of models to make model revisions, (3) designing a test of a model, (4) developing and/or using different types of models to describe and predict phenomena and/or to generate data to support explanations, and (5) developing models that allow for manipulation and testing of a process or system. This emphasis reflected his own background, where computer modelling of systems was his primary postgraduate focus and where systems engineering, not science, was the nature of his work. He acknowledged the personal importance of having an engineering background in his work as a science teacher.

I wouldn’t trade my engineering background for anything. I don’t think I feel like I learned much in my education classes. I feel like that my time spent in undergrad in engineering, even though it was kind of nightmarish, really helped me more than anything else. (Benjamin, Interview 1)

The lesson he selected that represented students’ engagement in science or engineering was the first day of a student-driven inquiry project where only the question was provided to students: what is the pressure inside a soda can? The methodological base of his previous work experience included both experimental, hypothesis-driven work as well as design-based projects reflective of engineering practice. This project reflected the latter where students had to apply their knowledge of chemical phenomena to design apparatus and protocols in order to address the question. They selected glassware, drew on techniques they had used in previous, more traditional protocol-based labs in order to design a testing model that could be used to measure the pressure inside a soda can. He also put constraints on their use of materials to further an underlying lesson about engineering design itself. Students were provided with one can of soda, but were charged one dollar for any additional sodas they might want as a result of a failed test or system. Although unusual pedagogically, this experience of design constraints, ambiguity, and peer collaboration reflected his own experiences in his previous career.

Annika

Beliefs about science teaching

Annika holds a bachelors’ degree in biology and began her career as a chemist in an environmental lab at a county health department conducting water quality tests and serving as a lab director. She transitioned to teaching for family reasons, to have a more predictable summer schedule and to be able to spend more time with her children. She began her teaching career as an adjunct instructor in biology at a local university and...
completed her teaching certification in order to have greater job security. At the time of the study, she was in her third year at a large, public high school that was divided into career academies where she taught Biology and AP Environmental Science. Due to the emphasis in the school on career and technical education (CTE), teachers were engaged in designing curricula and classroom activities intended to be hands-on and to emphasise critical thinking skills.

I think we’re using models much more often so instead of lecture we’re building molecules and things like that instead of showing pictures of them so we’re actually developing those models which I think helps students understand much, much more. Or we’re doing more like computer simulations and uses of models than we had in the past. (Annika, Interview 1)

Unlike Benjamin’s emphasis on model-based pedagogy, Annika’s use of models was as teaching tools rather than as a means of designing a system in order to understand. The only example she provided of her use of models was ball and stick representations of molecules. While they provide a means for students to develop conceptual understanding of bond angles, lengths, and chemical structure, they are not models that students generate in the scientific sense. Instead, she seemed to place great importance on attention to detail in students’ hands-on experiences in her classroom. Best practice in science teaching seemed related to hands-on experiences that required great student care in data collection and analysis. Unlike the other participants, Annika emphasised analytical practice and saw the NGSS as necessitating more hands-on, inquiry experiences that required the collection and analysis of data in great depth and with greater reliability.

**Beliefs about the practices of science and/or engineering in professional and classroom settings**

Annika’s work experiences emphasised protocol development and adherence.

She was a technician and laboratory manager and elements of these experiences seemed evident in her reflection on the science practices that she viewed as most important in her classroom such as the analytical skills just discussed. In her interviews, she described the influence of her previous career most prominently in relation to the importance of quality control and she similarly emphasised the importance of students’ data analysis experiences in her classroom.

I was doing quality control to make sure that the integrity of my samples was within, you know, the ranges that I needed it to be for the EPA, so I didn’t do experiments per se but I had to focus on having very accurate data that could stand up to scrutiny because we were closing down restaurants, and people couldn’t see their houses based on it. So it had to be reputable. I focus on quality control of the data that I used to use when the students come and they need to analyze their own data in different ways. Like when they look at it one way and are confused and we decide something like, oh, why don’t we make a standard curve? (Annika, Interview 1)

As she states in the above quote, Annika’s professional experiences in the sciences were not those of research scientists in the sense that she was not advancing understanding of the natural world. Instead her work involved utilising scientific understanding to analyse and describe water and soil samples with the potential to affect public health. Therefore, her work was not driven by questions crafted to build new knowledge. Within her classroom, she viewed that science practice, *asking questions*, as the most challenging to incorporate in her teaching.
Asking questions seems the simplest, but I think that’s what students struggle with the most. But on paper it looks really simple – ask a question. But just having a question, like is this a testable question, can scientists answer this question? Can you develop an experiment to investigate this? Oh and by the way, what are you going to measure? That is such a high skill that’s so difficult. To have them ask very good scientific questions is something we struggle with and that we’re getting better at. (Annika, Interview 1)

The lesson that she selected as reflective of her best effort at students’ engagement in science or engineering was a presentations day. Her AP Environmental Science students had just completed a self-designed inquiry project. Although asking scientific questions was a practice that she regarded as particularly challenging, her students were observed during peer presentations to question one another about how they developed their original project question. The observation of her classroom was the only one in which data analysis was prominent among the four participants. Each student presenter was able to articulate ‘the limitations of data analysis including sample selection and measurement error’ (NGSS Lead States, 2013, p. 391), and this was the only classroom in which this was observed. A more nuanced understanding of data analysis was important to Annika because ‘there’s not a recipe to follow on how you should analyze this data’ (Interview 2), which reflects both her professional experiences and the emphases of her CTE-focused school.

**Liam**

**Beliefs about science teaching**

Liam holds a Ph.D. in chemistry and transitioned to teaching after spending over 25 years as an industrial chemist. Most of his career was spent in product design in the cosmetics, industrial water treatments, and lubricants industries in which he held a number of patents. His entry into teaching began after he turned 55 and was ‘pushed out the door’ (Liam, Interview 1) of the company he was working for. While looking for another job as a chemist, a friend that taught at a private Catholic school recommended that he look into teaching. He was hired by an all-boys, private, Catholic high school and completed no formal teacher education training. As with new teachers and those who transitioned into teaching without formal sustained mentorship, Liam grappled to some extent with classroom management.

I used to give movie days regularly. This year I decided I was gonna make it dependent upon class behavior. So that’s what that is there [referring to a chart on the wall]. You hit twenty-one you get a video day. So no acting up, no detention, no disturbances, no off- task, no playing on your computer, and that kinda stuff. (Interview 1)

At the time of the study, Liam was in his 10th year of teaching which was to be his final year before retirement. Unlike the other participants, he was not familiar with the NGSS science and engineering practices prior to his participation in the study and viewed them as skills that were involved to some extent in the labs that he routinely completed with the main exception of the first practice, asking scientific questions and defining problems. He acknowledged that the question or purpose underlying lab experiences in his class were often not explicit, and that students conducted investigations using prescribed procedures. Liam seemed to view best practice in chemistry through the aspects of science practice generally characterised as technician skills. He provided instruction prior to, and during, labs explicitly focused on the necessity of precision in bench work. For example, rinsing a
stirring rod and dabbing the excess deionised water off between use with different solutions, recognising the role of heat control in the separation of substances, and the use of balances to precisely weigh products (the school did not have electronic balances). These types of techniques are typical in chemistry lab instruction, but Liam’s classroom made these types of routines a prominent focus of the instruction itself in a way that was not observed in any other participants’ classrooms.

Beliefs about the practices of science and/or engineering in professional and classroom settings

Liam described his own experiences during his second interview as a student in an era when chemistry sets, with materials that are today considered hazardous, were given as toys to children. He described this, and his professional work experiences developing products for industry, as invaluable for developing scientific ingenuity but also for developing awareness of the importance of safety.

The materials in labs could be dangerous if you were slightly careless. I have a lot of, you know thirty years of working with chemicals, I know how they behave. You know I’ve put something together and I know what to expect will happen and what dangers there are and if you don’t do that kind of work you don’t have that kind of experience. And that pretty well sums up the issue. The other science teachers don’t have similar backgrounds and you see them maybe struggle a little bit because they can’t pull those things in. (Liam, Interview 1)

He emphasised the value of his previous work experience in his interviews and its importance in giving him ‘an awful lot of real world stuff I can talk to them about that other people wouldn’t have any knowledge at all’ (Liam, Interview 1).

I got involved a lot of different areas of chemistry and industry, it was a lot of fun. I also had a lot of experience developing presentations for safety and stuff like that. I’m a very good safety trainer and I’m a real big stickler on that factor which sometimes my students don’t appreciate but that’s life. (Interview 1)

Unlike the other participants, Liam’s curriculum and classroom practices weren’t reflective of a school or department-wide initiative or identity. The lesson that he selected for researchers to observe as representative of his views about student engagement in science was a demo and lab in which they performed a double replacement reaction and identified the precipitates that formed. He began the class with a careful description of the logistics of the lab and focus on and the lab in which they performed a double replacement reaction and identified the precipitates that formed. He began the class with a careful description of the logistics of the lab and focus on the skills needed to perform the lab with attention throughout the class period on technical skills such as measurement, precision, and performing accurate calculations. Like Annika, he emphasised attention to detail and accuracy in student lab work but unlike her his focus was on laboratory techniques and not on data analysis procedures. This possibly reflected his work in his previous career but the views he expressed were more focused on how that previous career influenced his abilities as a teacher, instead of his content emphases.

The other time [his previous work] it comes into play is a something I only realized just recently, I do a lot of demo’s. I mean I got a bunch of seventeen years old kids and they
want to see me blow stuff up. It’s hard to do demo’s but over the years I’ve gotten quite a few where I blow stuff up for them. (Interview 1)

Unlike the other participants, Liam’s confidence in his pedagogy seemed more underpinned by his former career. However, unlike the other participants, he did not have any formal pedagogical training.

**Sam**

**Beliefs about science teaching**

Sam was a former mechanical and materials engineer who transitioned to teaching after 2 years designing products primarily for commercial, medical, and military-related purposes. As an engineer, his work had been contract-based where companies and agencies would present contracts for the development of specific products meeting specific constraints. At the time of the study, he had been teaching physics for 3 years in a traditional public high school in a suburban community. Although he viewed science and engineering practices as important, he also raised the issue of limits to student engagement in the practices. He was the only participant to do so.

Many students ask great questions, but sometimes they are just unreasonable to test. For example, a student recently asked me if we could test the strength of the strongest spider web while we were testing the strength of springs. Unfortunately, we don’t have these spiders and testing the web would be very difficult. Other times, we just don’t have time or the questions are outside the scope of the class. Genuine questions that are testable within a science classroom do occur, though. (Interview 2)

Here he acknowledges the tension between the curricular goal, to include students’ questions, and pedagogical constraints, such as time. The lesson he selected for the researchers’ observation was a teacher-directed lab that included very few indicators on the Design and Inquiry Practices Observation Protocol, but which reflected an emphasis on student thinking.

I think this is one of the main challenges of a science teacher. Finding ways for students to really think and solve problems while doing science should be a major goal of all science teachers. I feel, when done properly, it can provide students with a lot of satisfaction in a science class. Some of my major goals as a science teacher are to increase critical thinking skills and to have students gain an appreciation for science. (Interview 1)

Sam was a younger teacher who had spent less time working in the engineering field before transitioning to teaching. His classroom, and the views he expressed about best practice in teaching, seemed similar to that of many new teachers who are forming their identities as educators. He expresses his belief that critical thinking was important to his work similar to the other participants, but he did not articulate beliefs about the context for their thinking. This was unlike Benjamin, Annika, and Liam, who each described connections between the ways in which their students’ engagement in science and engineering practice linked to their work experiences.

**Beliefs about the practices of science and/or engineering in professional and classroom settings**

Unlike the other three participants who each identified aspects of their former work lives, their beliefs about science and engineering, and their teaching. Sam was constructing his
conceptions of these connections and each of these three areas. Although his prior experiences were relevant to his classroom, he did not express the same degree of association between the two.

Having an authentic experience doing science is important but I think it’s tough. It’s tough to assess some of the engineering stuff for example. In terms of, if you’re doing an engineering project like building, I feel like there’s a lot of up front work, even teaching freshman would be really tough because it’s more hands-on building stuff. (Interview 1)

His interviews and classroom observation provided evidence of a new teacher grappling with the balance between pedagogical and curricular demands, while his own beliefs about what that balance should be were still emergent.

I don’t feel like the stuff I teach, well, the kids aren’t going to be using physics equations in their jobs, like very, very few of them will if at all, you know what I mean? But I feel like as an engineer, like, someone who worked prior to teaching I understand how like it’s not, nobody just gives you a goal and just says go do it and have it done. I feel like you’ve got to be able to show your work. You’ve got to explain what you’re doing. You’ve got to be able to communicate with other people because they’re not just going to trust you. (Interview 1)

The elastic collisions lab observed was an example of this view. Presented to students in a teacher-directed form with specific directions provided.

[Pop]ush a car at the edge of the track until it collides with another car located at the center of the track. The two cars will collide elastically. You will record the motion on the cars with logger pro and motion detectors. (Student handout, observation)

Students were given three data tables identifying the data to be collected in each trial and prompts to complete calculations. Although the lab was not student driven, students’ critical thinking was observable in the problem solving necessary to work with the digital tools provided and to translate the data in the form provided (graphical) into a form that could be used in calculations. In this example, Sam’s curricular choice may not have been informed by his former work experiences or the NGSS, but the value with he claimed to place on student thinking was evident.

**Discussion and conclusions**

The four participant cases discussed were informed by explorations of their experiences and beliefs in their STEM-related careers and their science education careers. Some literature acknowledges the potential for conflict within an individual because their beliefs (in this case their beliefs about scientific inquiry and the practices) are socio-culturally grounded in their work as scientists or as teachers. However, the four participants who participated in this study demonstrated little evidence of conflict. Instead, they seemed primarily to exemplify the agency and motivation of a second-career teacher–scientist that has been found in other research (Gilbert, 2011; Greenwood, 2003; Grier & Johnston, 2009; Tigchelaar et al., 2012). This may be due in part to an alignment between the skills and ways of thinking inherent in the science and engineering practices with their professional histories. As discussed in the theoretical framework section, an individual’s beliefs can organise and prioritize information (Mansour, 2009). In the case of the participants in
the present study, their knowledge and experiences as former scientists and engineers aligned with the classroom reforms of their schools and the practices in the NGSS.

These cases served to highlight the importance of two main factors related to the relationship between the perspectives developed through former career experiences and those developed as teachers. First, the balance between the extent of experiences in their former and present careers potentially matters. Koballa et al. (2002) have demonstrated that teaching itself can influence career changers science conceptions but these participant cases suggest that it is possible that the number of years of experience in both teaching and in a STEM-related field might be mediating factors. For example, Sam had the shortest career in both engineering and teaching and his reflections were somewhat emergent in comparison to the other three participants. Conversely, Liam became a teacher after a thirty-year career as a chemist. His perspectives on teaching chemistry were heavily coloured by his experiences engaged in the work of chemistry and his identity as a teacher-scientist was much more pronounced than any other participant despite his ten years in the classroom.

The second factor related to the relationship between perspectives engendered by both their former careers and their teaching experiences relates to the value of the technical skills implicit within the science and engineering practices. Technical skills that are both fine motor, tactile skills such as pipetting, and which fit within practices such as carrying out investigations, as well as technical skills that are conceptual such as data reduction techniques and which fit within practices such as analysing and interpreting data were emphasised by three of the participants. These types of technical skills are less explicit in the NGSS. However, for teachers with extensive experiences, they emerged as areas given considerable consideration. Greenwood (2003) found that career changers’ conceptions of science as they have experienced it can influence their approach to instruction more so than their conceptions of teaching. This is demonstrated in this case, where their professional histories with the practices prioritise more specific skills than those emphasised in the standards themselves.

Science education reform documents in the U.S. have articulated goals for K-12 science to be more reflective of the practices and structures of science ever since inquiry emerged as a primary narrative of the field in the later twentieth century. The incorporation of voices from STEM-related fields makes sense given this goal, but the extent to which scientist perspectives, the developmental needs of learners, and pedagogical constraints coalesce is an area of some ambiguity that this study has informed. What is also needed is large-scale inquiry into how teachers’ professional backgrounds relate to their conceptions of science, science teaching, and teaching practices. Identifying in-service teachers who are career changers is challenging but informing post-baccalaureate teacher licensure curricula could leverage the skills and support the weaknesses of these teachers as they transition into a new career.

Disclosure statement

No potential conflict of interest was reported by the authors.

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