J Sci Teacher Educ (2015) 26:619–645
DOI 10.1007/s10972-015-9441-4

Secondary Science Teachers' Beliefs and Persistence: A Longitudinal Mixed-Methods Study

Sissy S. Wong[1] · **Julie A. Luft**[2]

Published online: 14 December 2015

Abstract While many studies focus on why teachers leave the classroom, there remains a need to study why teachers persist in teaching. One area to study is the beliefs of teachers, which may impact persistence in the field. This 5-year mixed-methods study explored whether 35 beginning secondary science teachers' beliefs were related to their persistence in teaching. Quantitative analysis of the teachers' responses to annual semi-structured interviews revealed that teachers with more student-centered beliefs were more likely to persist at the end of the third year of teaching. Additionally, the teaching beliefs of teachers were more teacher-centered, while the learning beliefs of teachers were more student-centered. A case study of one persisting teacher and one non-persisting teacher revealed that personal experiences and knowledge impacted beliefs about teaching and learning. Bruce, who had extensive inquiry-based school experiences, believed in teaching via student-centered methods. Oscar, who underwent mostly direct instruction during his school experiences, believed in teacher-centered instruction and focused on classroom management. This longitudinal study contributes to the field of science education by examining beginning secondary science teacher persistence over time. Implications from this study call for challenging teacher beliefs during the induction period, proper placement of new teachers into their first teaching positions, and understanding the impact of prior experiences on teachers' beliefs.

Keywords Persistence · Beliefs · Induction · Secondary science teachers

✉ Sissy S. Wong
sissywong@uh.edu

[1] Department of Curriculum and Instruction, College of Education, University of Houston, Houston, TX 77204, USA

[2] Department of Mathematics and Science Education, College of Education, University of Georgia, Athens, GA, USA

Introduction

Globally, there is a concern about the attrition of science teachers (Darling-Hammond & Sykes, 2003; Dolton & van der Klaauw, 1999). In the USA, approximately 50 % of secondary science teachers leave teaching within the first 5 years in the classroom (Ingersoll, 2012). In Australia, 40 % of teachers leave teaching within the first 5 years (Paris, 2013). Retention of qualified teachers is also an ongoing issue in the UK creating challenges for increasing standards and providing high-quality educational experiences (Rhodes, Nevill, & Allan, 2004). Worldwide, finding ways to retain effective teachers is imperative.

The high attrition rate in science teaching is alarming because new science teachers can improve significantly upon their instruction during their first few years (Henry, Fortner, & Bastian, 2012). Science teachers who leave the profession just as they are developing their teaching skills leave students with inconsistent instruction that hinders science learning and achievement (Goodpaster, Adedokun, & Weaver, 2012). Science teacher attrition is troublesome since students with experienced subject-matter specialists achieve scores higher than students with beginning, underprepared, or out-of-field teachers (Darling-Hammond, 2000). "Students with teachers who were experienced, prepared, and fully credentialed (i.e., not entering teaching through one of a state's several alternative route programs) were more likely to produce higher student achievement gains on end-of-course tests in subjects like biology" (Coble, Smith, & Berry, 2009, p. 2).

Research findings support the importance of experienced and prepared in-field teachers for student achievement, yet this population is most at-risk for leaving the classroom during the beginning years. In the USA, secondary teachers are more likely to leave the field than elementary teachers, especially in the science and mathematics fields (Guarino, Santibanez, & Daley, 2006). In addition, teachers with advanced college degrees are more likely to leave teaching than are teachers with less content knowledge and pedagogical experience (Borman & Dowling, 2008). This is problematic since teachers with advanced degrees have more experiences in science and science education, which can translate into effective science teaching practices as advocated by the *Next Generation Science Standards* (*NGSS*) (NGSS Lead States, 2013) and *A Framework for K-12 Science Education* (National Research Council, 2011).

The high attrition rate for science teachers has resulted in science being taught by out-of-field teachers, or teachers without a major, minor, or teaching certificate in science. The National Center for Education Statistics (2010) found that out-of-field teachers instructed between 60 and 70 % of earth science, chemistry, physics, and physical science classes (as cited by Pirkle, 2011). In addition, science teacher attrition has also contributed to school staffing problems. Ingersoll and Perda (2009) revealed that in the USA, 44 % of schools had vacancies in life science and 38 % had vacancies in the physical sciences. These vacancies were often the result of teachers leaving the profession or moving to another school.

Science teacher attrition disrupts coherence of curriculum and instruction (Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2009; Coble et al., 2009; Shen, 1997). Over

time, teachers learn about how to implement and build curriculum. When there is a constant revolving door of teachers in a school, learning the curricular progression begins anew with each new teacher. This results in students receiving fragmented curriculum that can hinder their learning since each new cycle of beginning teachers may repeat instructional missteps instead of learning and improving upon their instruction over time (Boyd et al., 2009). Science teacher attrition also results in increased expenses in school districts for teacher recruitment and hiring (Barnes, Crowe, & Schaefer, 2008; Watlington, Shockley, Gugielmino, & Felsher, 2010). For instance, the cost of teacher turnover in Chicago Public Schools is approximately $86 million per year for the recruitment, hiring, and support of new teachers (Barnes et al., 2008).

Findings from several research studies have revealed many reasons why teachers leave the teaching profession (Guarino et al., 2006; Ingersoll & Perda, 2009; Marvel, Lyter, Peltola, Strizek, & Morton, 2006). A link between science teacher attrition and dissatisfaction with the teaching career stems from inadequate preparation time, deficient faculty influence, class size, and lack of autonomy (Guarino et al., 2006; Ingersoll & Perda, 2009; Macdonald, 1999; Marvel et al., 2006). Additional reasons for teacher attrition included issues with student behavior, poor student motivation, inadequate administrative support, low appreciation for teachers' intrinsic merits, little opportunity for advancement, and few rewards for experienced and inexperienced teachers (Guarino et al., 2006; Ingersoll & Perda, 2009; Macdonald, 1999; Marvel et al., 2006; Schlechty & Vance, 1983; Shen, 1997). Additionally, low salary and the attractiveness of other professions were motivating reasons for teachers to leave the profession (Guarino et al., 2006; Macdonald, 1999; Marvel et al., 2006; Murnane, Singer, Willett, Kemple, & Olsen, 1991).

Research findings have revealed various reasons why teachers leave; however, the reasons teachers continue in the profession are unclear. Most study findings regarding teacher retention suggested that teachers stay in teaching because of job satisfaction, good relationships with students, and commitment to the profession (Certo & Fox, 2002; Marso & Pigge, 1997; Nieto, 2003). Limited research about why teachers continue in the profession makes this a critical topic for further investigation. One aspect that may be important in the decision regarding teacher persistence may be teachers' beliefs about teaching and learning in the classroom. This information is especially appropriate among beginning teachers with malleable beliefs that are continuously influenced by personal experiences, school experiences, and formal knowledge (Apostolou & Koulaidis, 2010; Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Jones & Leagon, 2014; Pajares, 1992; Richardson, 1996; Yerrick, Parke, & Nugent, 1997). While researchers often investigate teacher beliefs and the way they impact teacher decisions (Brickhouse, 1990; Luft & Roehrig, 2007; Simmons et al., 1999), it is unclear how teacher beliefs may influence one's decision to stay or leave teaching at the secondary level. Therefore, exploring the impact of personal experiences, classroom experiences, and other factors regarding teacher's beliefs is important in order to understand how they influence a teacher's decision to persist in or leave the teaching profession.

Since science teacher attrition is a critical issue plaguing the education system, there is an urgency to investigate the factors involved in secondary science teacher persistence. Teacher persistence in this study was defined as a teacher's commitment to, and continuation in, classroom teaching despite experienced challenges or difficulties at the school or district level. Thus, the focus of this study was:

1. How do the beliefs of science teachers who persist and do not persist in teaching change over 5 years?
2. What factors may impact the beliefs of the persisting and non-persisting science teachers over time?

Relevant Literature

Teacher Retention and Persistence

Educational researchers have a long-standing interest for increasing teacher retention, or discovering ways to increase the number of teachers who continue teaching in the classroom. Studying teacher retention is important for understanding why some teachers remain in the classroom while other teachers leave the profession. Studies that focused on strategies to retain teachers revealed positive effects of various factors correlated with teacher retention. Increasing teacher salaries, providing a supportive environment during the first teaching experience, and scheduling adequate planning time increased teacher retention (Certo & Fox, 2002; Ingersoll, 2012; Ingersoll & Perda, 2009; Kirby & Grissmer, 1993; Murnane et al., 1991). Teacher retention also increased when there was a prioritization of student learning over administrative tasks, sample opportunities for professional growth, and teacher autonomy (Macdonald, 1999; Shen, 1997). Even with these findings on how to increase teacher retention—secondary science teacher attrition continues to be an issue (Guarino et al., 2006; Ingersoll, 2012; Watlington et al., 2010).

Another means to increase teacher retention is through teacher induction and mentoring programs. In 2008, approximately 91 % of beginning teachers participated in induction programs, which increased dramatically from 50 % of beginning teachers having participated in induction programs during 1990 (Ingersoll, 2012). Induction programs have been shown to positively impact teacher retention, but the increase in retention depends upon the configuration and duration of the support provided to the new teachers. The more comprehensive the induction program (different forms of support), the more likely the teacher remained in teaching. Having a same subject mentor and collaborative time with same subject colleagues were the most powerful factors pertaining to teacher retention (Ingersoll, 2012). In addition, when induction and mentoring were subject-specific there was an increase in teacher retention (Fletcher & Luft, 2011; Pirkle, 2011). Studies by Luft et al. (2011) and Wong, Firestone, Luft, & Weeks (2013) revealed that subject-specific induction and mentoring support was critical to fostering beginning secondary science teachers' implementation of inquiry-based instruction and development of more student-centered beliefs.

There are findings from numerous studies regarding teacher attrition and recommendations about how to lower the attrition rate, but only limited research studies exist about why teachers remain in teaching. Yee (1990), in an early study of staying, interviewed 59 experienced teachers and determined they remained in the field because of their perceived supportive work conditions. Certo and Fox (2002) also found job satisfaction was important to teacher retention. Specifically, teachers who received administrative support, leadership opportunities, encouragement, and interaction with mentors and colleagues cited a higher level of job satisfaction. The teacher–student relationship also plays an important factor in teacher satisfaction and contributes to teacher persistence. Nieto (2003) interviewed eight persisting elementary teachers from diverse urban schools to examine why some teachers persevere through teaching challenges. She discovered the teachers reported several personal, relational, and emotional factors, such as their love for students, which contributed to their persistence in the teaching profession. The teachers also held high expectations for their students and viewed teaching and education as a way to impact students' lives in positive ways (Nieto, 2003).

Studies on teacher persistence include Marso and Pigge's (1997) work that revealed a link between teachers' intentions and persistence. Teachers who had intentions of becoming teachers early in their career were more likely to persist than were teachers that selected the teaching profession later in their careers. In addition, teachers whose spouses were also educators remained in teaching, or within the educational profession, as compared to those without spouses in the educational field (Chapman, 1983). There is literature available about teacher persistence, but studies on this topic are limited. In addition, there is a need for research focusing specifically on science teacher persistence.

More recent research within teacher retention and persistence indicates an interesting trend: More effective teachers tend to remain in teaching, while less effective teachers leave the profession or transfer to another school (Boyd et al., 2009; Goldhaber, Gross, & Player, 2007; Hanushek, Kain, O'Brien, & Rivkin, 2005). Hanushek et al. (2005) found teachers who remained in teaching had higher gains in student achievement scores when compared with teachers who left the profession. The findings from the study conducted by Boyd et al. (2009), in New York City schools, discovered that less effective first-year teachers in low-scoring schools were most likely to leave teaching, while less effective first-year teachers in high-scoring schools transferred to other schools. Teachers who transferred remained less effective than did their peers. The more effective first-year teachers remained in high-performing schools or transferred to other high-performing schools. Boyd et al. (2009) concluded that the transferring of teachers might contribute to the persistent student achievement gap in the USA.

Importance of Science Teacher Beliefs on Classroom Decisions

Examining teacher beliefs is important because the beliefs of teachers are a strong influence on decisions and actions (e.g., Apostolou & Koulaidis, 2010; Brickhouse, 1990; Cronin-Jones, 1991; Jones & Leagon, 2014). This importance is emphasized by Goodenough (1963) who asserted that beliefs should be "accepted as

guides for assessing the future, are cited in support of decisions, or are referred to in passing judgment on the behavior of others" (p. 151). Nespor (1987) also reinforced the role of beliefs by stating beliefs "are important influences on the ways they conceptualize tasks and learn from experiences" (p. 317) and "organizing the knowledge and information relevant to those tasks" (p. 324).

Studies on teacher beliefs also reveal the importance of beliefs on teacher decisions. For instance, Brickhouse (1990) conducted a case study of three science teachers and determined that each held different beliefs about science, which influenced decisions on how they adapted science curriculum. Cronin-Jones (1991) studied two middle-grade science teachers and found both teachers' beliefs about how students learn, their role in the classroom, and the abilities of the students influenced their implementation of curriculum. More recently, Apostolou and Koulaidis (2010) discovered that a teacher's view regarding the scientific method impacted the teacher's decisions about the design and instruction of science lessons.

Many factors influence teacher beliefs, including their personal experiences. Pajares (1992) explained that teachers, unlike other professionals, are not strangers in a strange land. Unlike lawyers or doctors who usually have limited prior experiences in a courtroom or operating room, teachers have had extensive personal experiences in the classroom as students (Pajares, 1992). These personal school experiences, and experiences with formal knowledge, influence the formed beliefs of teacher candidates (Forbes & Davis, 2010; Luft & Roehrig, 2007; Otero & Nathan, 2008; Richardson, 1996; Tsai, 2002). Eick (2002) analyzed autobiographical papers written by secondary science education graduates and established that life experiences formed a core belief system that promoted continuing career choices. While core beliefs are resistant to change (Kagan, 1992; Rokeach, 1968), Luft and Roehrig (2007) found that beginning teachers are more likely to change beliefs than are their more experienced peers.

Teachers' beliefs about teaching are influenced by experiences as students in science classrooms (Brownlee, Boulton-Lewis, & Purdie, 2002; Crawford, 2007; Luft & Roehrig, 2007; Pajares, 1992; Tsai, 2002). Years of experiences as students impact teachers' beliefs about how to teach, which can influence curricular and instructional decisions. Teachers that experienced teacher-centered instruction as students were more likely to implement teacher-centered practices (Tsai, 2002). Crawford (2007) found evidence that prospective teachers' beliefs about pedagogy, nature of science, student learning, and schools were powerful factors in decisions regarding teaching science as inquiry. It was also ascertained that beliefs were impacted by teaching experience in the classroom, which influenced the implementation of inquiry-based practices (Crawford, 2007).

Teachers' beliefs about student learning are critical to decisions regarding curriculum and instruction (Crawford, 2007). When a teacher focuses on the learning of concepts and how students make sense of science content and the nature of science, the teacher's instructional goals may emphasize students' conceptual knowledge over memorizing facts and information (Crawford, 2007). Otero and Nathan (2008) found that preservice teachers' beliefs about student prior-knowledge favored the use of formative assessments. In another study, Holt, Hargrove, and Harris (2011) discovered that teachers who believed in the importance of

establishing and maintaining caring relationships with students exhibited more effective classroom management and procedures.

Teachers' beliefs are also impacted by their interactions with peers and the school culture (Jones & Leagon, 2014; Nieto, 2003). Chester and Beaudin (1996) found increased self-efficacy beliefs of new teachers in urban schools when there was a perceived positive collegial school culture with high degrees of collaboration among teachers and administrators. This positive school culture may lead to perceived job satisfaction. Weiss (1999) analyzed data from the Schools and Staffing Survey and found that first-year teachers in the USA were highly affected by their perceptions of the workplace and teacher experiences.

An important point to note is that beliefs are particularly difficult to study. Thompson (1992) described belief systems as "dynamic in nature, undergoing change and restructuring as individuals evaluate their beliefs against their experiences" (p. 130). In addition, Crawford (2007) stated teachers hold conflicting beliefs, such as personal beliefs and beliefs influenced by school expectations. While beliefs are difficult to assess, and are malleable, there is consensus among researchers that beliefs are important to study (Crawford, 2007; Jones & Leagon, 2014; Luft & Roehrig, 2007; Vedder, Horenczyk, Liebkind, & Nickmans, 2006) because belief systems shape the way an individual views the world and makes decisions (Kagan, 1992; Pajares, 1992; Richardson, 1996; Simmons et al., 1999). Although beliefs are difficult to assess, their impact on teacher decisions is undeniable among educational researchers.

Beliefs help frame a person's decisions, actions, and overall view of the world, which is especially relevant when considering that teacher beliefs are influenced by personal observations and experiences (Lortie, 1975; Pajares, 1992). Understanding teacher beliefs may provide insight into decisions made in the classroom, about views of the teaching profession, and what guides persistence in the profession. For beginning science teachers, the decision to remain or leave the teaching profession may occur during the induction years (the first 3 years in practice) when beliefs and experiences influence the choices teachers make.

Study Methods

The approach implemented for this study was a longitudinal complimentary mixed-methods design, which was selected to reveal "an enriched, elaborated understanding of the phenomenon" (Greene, Caracelli, & Graham, 1989, p. 258). Instead of convergence of findings, as with triangulation, a complimentary mixed-methods design provides clarification, explanation, and/or illustration of results from one method with results from another method (Bryman, 2006; Greene et al., 1989). According to Bryman (2006), using quantitative and qualitative approaches allows, "the researcher to offset their weaknesses to draw on the strengths of both" (p. 106). In this study, the implementation of quantitative methods was helpful to study belief trends longitudinally for persisting and non-persisting teachers. Qualitative methods were useful for exploring the intricacies and complexities of the quantitative results (Stake, 1995).

Research Participants

A total of 35 teachers were included in this study. All teachers were involved in induction programs offered by their school or district. The induction programs focused on general teaching topics, such as time and classroom management, with little emphasis on content-specific support. The teachers selected were representative of the average secondary science teacher in the USA. All teachers held certification to teach science prior to the start of the study. Of the participants, 27 were persisting teachers that remained full-time public school teachers during the 5 years of this study. There was mobility within the persisting teacher population. Seven teachers moved to new schools during the study; six teachers moved to different schools after the first year of teaching, and one teacher moved to a new school after the second year of teaching.

There were eight non-persisting teachers in this study. Of the eight non-persisting teachers, four teachers left teaching after 1 year in the classroom, one teacher left after 18 months to teach at the community college level, and three teachers taught for 3 years before leaving the teaching profession (Table 1).

Data Collection

The collection of data in this study was via semi-structured annual interviews conducted by different members in a research team. Different researchers conducted the annual interviews for each teacher to limit potential subjectivity or bias of a primary researcher (Mertens, 1998). The researchers took notes and digitally audio-recorded the interviews, which were later transcribed for further analysis of data. There were up to six annual interviews conducted with each teacher during the study.

Table 1 Demographics of science teachers at the start of the study ($N = 35$)

	Persisting teachers: $N = 27$	Non-persisting teachers: $N = 8$
Location	Midwest = 12	Midwest = 3
	Southwest = 15	Southwest = 5
Gender	M = 10	M = 4
	F = 17	F = 4
Grade level	Elementary (K-5) = 2	Elementary (K-5) = 1
	Middle school (6–8) = 7	Middle school (6–8) = 3
	High school (9–12) = 18	High school (9–12) = 4
Degree area	Life science = 11	Life science = 6
	Chemistry = 5	Chemistry = 0
	Earth science = 4	Earth science = 0
	Other science = 1	Other science = 0
	No science background = 6	No background in science = 2
School free or reduced lunch	0–29 % = 17	0–29 % = 4
	30 % or more = 9	30 % or more = 4
	No data available = 1	No data available = 0

The first annual interview occurred before the teachers' first year and named T1 for Time 1. This process continued until the last year of the study concluding with T6.

There were two parts to the semi-structured interview (Seidman, 2013). The first part of the interview included general questions such as inquiries into the teachers' preparation programs, teaching experiences, and levels of support for teaching. The responses to these questions helped the researchers to understand the preparation of the teachers, the context in which the teachers were working, and the perceptions of the teachers about the support they received. This portion of the interview took approximately 30 min.

The second part of the interview included in this study involved the Teacher Beliefs Interview (TBI) developed by Luft and Roehrig (2007). The TBI was based on beliefs research and utilized a semi-structured interview format, which allowed for adaptability during the interview process (Fylan, 2005). Development and refinement of the protocol resulted in seven prompts and corresponding rubrics for each prompt. Each rubric contains five categories arranged in a continuum from teacher-centered to student-centered. Table 2 represents the general trends of the five categories for the TBI rubrics. Validity for the TBI occurred when depictions

Table 2 Categories and example responses for TBI questions

Category	Orientation	Description	Examples
Traditional	Teacher-centered	Focus is on teacher providing information and resources in a structured manner and environment	I decide what students need to know when planning my lessons Arranging all desks to face the instructor
Instructive	Teacher-centered	Teacher decides experiences and reacts based on subjective evaluation of student actions and performance	I will look at student responses I will observe students as they complete the activity
Transitional	Teacher considers students	Emphasis on teacher–student relationship that includes subjective and affective components that does not necessarily focus on teaching or learning of science	By using different types of activities for different learning styles By building a relationship with my students and getting to know them
Responsive	Student-centered	Centers on opportunities and value of collaboration between students and teacher, as well as between students as peers. Focus is on development of science learning and content knowledge	Small group activities that provide opportunities to generate questions, create, collaborate, and question Student have opportunities to engage in discussion with the teacher and peers
Reform-based	Student-centered	Focus on individualized and student-centered methods of learning that considers student responses, interests, and abilities. Promotes a collaborative environment in which students apply skills and knowledge to novel situations	Students learn in different ways and have different interests. I consider the various ways to support content learning so that students can utilize existing skills and develop new skills Students to choose their own vehicles to learn the content by

Table 3 TBI questions separated by beliefs on teaching and beliefs on learning

Beliefs about teaching	Beliefs about learning
1. How do you maximize student learning in your classroom?	3. How do you know when your students understand?
2. How do you describe your role as a teacher?	6. How do your students learn science best?
4. In the public school setting, how do you decide what to teach or what not to teach?	7. How do you know when learning is occurring in your classroom?
5. How do you decide when to move on to a new topic in your class?	

were consistent through, "multiple reviews of the interview" (Luft et al., 2011, p. 1207). Reliability was determined through a Cronbach α coefficient calculated at 0.77 (Luft & Roehrig, 2007; Luft et al., 2011). Please see Luft and Roehrig (2007) for a complete discussion of the development and use of the TBI. This portion of the interview took approximately 30 minutes to complete.

For this study, the seven questions of the TBI were separated into beliefs about teaching and beliefs about learning (Fletcher & Luft, 2011). Research findings supported the notion that beliefs impact teacher decisions in practice, or how to teach (e.g., Brickhouse, 1990; Cronin-Jones, 1991). Beliefs also impact how teachers view science learning (e.g., Cronin-Jones, 1991). Table 3 provides a description of the two categories: Beliefs about teaching and beliefs about learning. Please see Fletcher and Luft (2011) for additional information about the division of TBI questions.

Data Analysis

The selection of complimentary mixed-methods design for this study was to help understand the phenomenon of teacher persistence (Greene et al., 1989). Quantitative data were analyzed to depict the change in teaching and learning beliefs among the teachers over time. This analysis provided an overall representation of differences between persisting and non-persisting teachers. Follow-up descriptive analyses also represented the beliefs about teaching and beliefs about learning among persisting and non-persisting teachers. The low number of non-persisting teachers required a descriptive examination of these data, or by *t* tests when possible. To elaborate on the insights from the quantitative analysis, qualitative analyses of two cases were completed to provide an in-depth look at the factors potentially associated with a teacher's decision to persist or leave the teaching profession.

Quantitative Analysis

Two randomly assigned researchers first independently scored completed TBI interviews. Scores were established by comparing participant responses to each of the seven TBI prompts to the corresponding TBI rubric. Each response to the TBI prompts was scored as one of the five categories identified on the corresponding

rubric. After the two individual researchers scored an interview, the two researchers cross-coded the data to reach consensus on the final categorization of the responses for the seven TBI prompts. The consensus model was followed, and the final categorization was then quantized for a numerical score (Miles, Huberman, & Saldana, 2014; Teddlie & Tashakkori, 2006). For details on coding of interviews, please see Table 4 and Luft et al. (2011).

The scores from the TBI were analyzed descriptively to depict the changes in beliefs between persisting and non-persisting teachers over time. The descriptive analysis used means and nonparametric analyses to represent the differences between the two groups of teachers. Descriptive and nonparametric analyses were appropriate for this analysis because of the low number of non-persisting teachers. All time points were used to analyze the data for persisting and non-persisting teachers, as well as contrasts between teaching and learning beliefs.

Qualitative Analysis

The qualitative portion of this study involved one purposefully selected persisting teacher (Bruce) and one non-persisting teacher (Oscar) for beliefs case study. Bruce

Table 4 Example coding for Bruce on TBI Question 5: How do you decide when to move on to a new topic in your class?

Response	Category	Explanation for categorization
A lot of times that's dictated by a list of topics you're given and how long you think you have to dedicate to each one. There's currently a practical aspect to what—I need to teach you guys this many things and we have this much time to do it	Traditional	This response was categorized as traditional because the response indicated the teacher would rely on a schedule to decide when to move on. The teacher is the sole decision maker
If you're in a biology class, and have to get through all the standards you could probably make a calendar. That's not set in stone. You could tell—in the verbal explanation I think was the easiest way to tell whether a student got it or not. Based on how they explained the concept. They didn't know what they're going to be asked when they came up, so this was sort of off the top of their head. You know, "Explain to me why this happened in the lab." The level of sophistication that they had in their explanation, and whether they were able to apply the basic science concept to what happened in the lab, that gave out a lot in their verbal explanations	Responsive	This response was categorized as responsive because the teacher is aware of teaching the state standards, but focuses on student learning to decide when to move on to a new topic in the class. This response indicates the teacher emphasizes the consideration of student responses and explanations to decide whether students understood the concept. This teacher also included opportunities for students to discuss with him, and others, their understanding of concepts
A lot of times after one round of these check-ins with students, we'd go back, and discuss the concept one more time. Say, "I don't think most of you got this. Let's talk about it again"		

(pseudonym) was selected as an instrumental case study (Creswell, 2005; Stake, 1995) to understand teacher persistence because of his reflective and thorough responses during all six points of data collection. His responses provided rich and detailed information that was critical in this study. He was also selected because he exhibited similar characteristics to the selected non-persisting teacher. Oscar (pseudonym) was selected because he was the only non-persisting teacher who completed more than one interview during the study (Miles & Huberman, 1994).

The general and the TBI portions of the interviews were transcribed for data analysis purposes. The transcriptions and digital audio recordings were compared to each other in order to ensure there were no errors in the transcriptions. Coding followed Bogdan and Biklen (2006), in which salient ideas that pertained to the beliefs of the teachers were coded using coding software.

After the individual cases were constructed for the persisting (Bruce) and non-persisting (Oscar) teachers, a cross-case analysis was conducted to intensify understanding of the participants' beliefs (Miles & Huberman, 1994). This was completed through a time-ordered display, which visually illustrated data by sequence and time to show the chronological order of events and to facilitate analysis of events (Onwuegbuzie & Dickinson, 2008). In this study, the time-ordered display also allowed the researchers to create critical incidence charts to identify points in the participants' teaching experience that were noteworthy during their recollection of events (Onwuegbuzie & Dickinson, 2008).

To create accurate, robust, and valid cases, the following verification strategies (Stake, 1995) were used in this study:

1. Longitudinal data collection over a 5-year period resulting in six interview points,
2. Random assignment of different researchers to conduct interviews and data analysis,
3. Coding of interview data by two independent researchers before obtaining consensus,
4. Use of multiple sources of evidence by including the general portions, as well as responses to the TBI of six interviews, and
5. Re-examination of the corpus of data over time by the researcher to determine whether interpretations held the same meaning under different circumstances.

Results

Quantitative Results

The quantitative analysis revealed some similarities and differences between the beliefs of the persisting and non-persisting science teachers. Table 5 shows the means and standard deviations of these groups of teachers. The most notable difference resides in T4, when non-persisting teachers held more transitional beliefs. Specifically, the T4 time revealed a significant difference at 0.05 between the

Table 5 Means and SDs of persisting ($N = 27$) and non-persisting teachers (T1: $N = 8$; T2: $N = 6$; T3: $N = 3$; T4: $N = 3$)

Group	T1	T2	T3	T4	T5	T6
Overall score: persisting	16.7 (2.5)	17.2 (3.3)	16.3 (2.2)	17.2 (5.8)	18.3 (2.5)	17.8 (1.4)
Overall score: non-persisting	17.3 (3.9)	17.3 (5.8)	19.0 (2.6)	14.3 (1.5)		
Learning beliefs: persisting teachers	2.7 (0.6)	2.7 (0.7)	2.6 (0.6)	2.9 (0.6)	3.0 (0.6)	2.8 (0.5)
Teaching beliefs: persisting teachers	2.1 (0.8)	2.2 (0.8)	2.0 (0.7)	2.0 (0.7)	2.3 (0.8)	2.3 (0.6)
Learning beliefs: non-persisting	2.5 (0.8)*	3.0 (1.0)*	3.0 (0.7)	2.6 (0.5)*		
Teaching beliefs: non-persisting	2.2 (0.8)*	2.0 (0.9)*	2.5 (1.0)	1.5 (0.6)*		

* Significantly different at 0.05

persisting and non-persisting teachers. This statistical finding revealed that teachers with more student-centered beliefs overall were more likely to persist at the end of the third year of teaching than did the teachers who held more teacher-centered beliefs.

The second analysis examined the difference between teaching and learning beliefs of the persisting and non-persisting teachers. A t test was used to examine the differences between teaching and learning beliefs, as it is a conservative test. In this analysis, the teaching and learning beliefs within persisting teachers were significantly different at 0.05 for each year. The teaching and learning beliefs within the non-persisting teachers were also significantly different at 0.05, except at the end of year 2. However, the T3 and T4 points of both analyses should be viewed with caution, as they comprise low number samples. This finding aside, the averages from these groups represent different types of beliefs.

Overall, the quantitative results indicated that the beliefs of persisting and non-persisting teachers were similar, but the teaching beliefs and the learning beliefs of teachers were different. Statistical analysis of beliefs revealed that the teaching beliefs tended to be instructional (teacher-centered), while the learning beliefs of teachers tended to be responsive (student-centered). This statistical result implies that the teachers held more teacher-centered teaching beliefs, but held more student-centered learning beliefs. This indicates a misalignment between how teachers believed they should teach science versus how they believed students learn science.

Qualitative Results

Bruce and Oscar were selected as individual cases to illuminate the complexities of teacher persistence. Bruce was selected as the persisting case, while Oscar was selected as the non-persisting case. Pseudonyms have been used to protect the participants' identities and to follow IRB regulations.

Bruce

Bruce began his college career with the goal of becoming a biologist. He received his Bachelor of Science degree in a life science content area and attended graduate school to pursue a Ph.D. in a biology-related field. During his both undergraduate and graduate experience, Bruce engaged in many research experiences that included inquiry-based investigations of tide pools and coastal areas, which were of personal interest to him.

Although he enjoyed his research experiences, Bruce realized he did not want to pursue a career in scientific research during his Ph.D. program. Bruce had, "really fell in love with teaching" (Personal communication, August 13, 2005) during his graduate program and decided to change direction in terms of his career. With the support of his kindergarten teacher spouse, Bruce pursued secondary science teaching instead of completing his doctoral program in science.

Reflecting back upon his years as a teaching assistant during his PhD program, Bruce stated that he had realized some of his undergraduate students held incomplete or inaccurate scientific knowledge. "The reason they're in [a top university] is because they're good at school. That doesn't really mean they've learned anything. It just means they're good at school" (Personal communication, August 13, 2005). Bruce explained his teaching goal was to help students gain a general understanding of science instead of reinforcing their ability to become good at school.

Bruce's Teaching Context

Bruce taught biology, earth science, and environmental science courses at the high school level during the data collection period. He initially taught at an urban public school with a predominantly White, upper-middle-class demographic. After his third year, Bruce moved to a different high school to be closer to his home. The second school in which he taught was an urban public school with a predominantly White, middle-class demographic.

During the induction years, Bruce stated his assigned mentor was helpful. "He gave me anything I wanted as far as lessons go. I went in there a bunch of times during the year to talk about classroom management stuff" (Personal communication, June 19, 2006). Bruce also actively pursued opportunities to collaborate with other colleagues. Of these colleagues, Bruce said, "they were always responsive when I had questions. They're usually available whenever I need to spend a little time talking about something" (Personal communication, June 18, 2007). Bruce repeatedly expressed throughout the study that he felt supported by colleagues and administration.

Bruce's Beliefs About Teaching

Bruce believed that students could easily access information from sources, such as the Internet; therefore, he believed his responsibility was to identify what was most important, organize it, make it relevant, and implement engaging activities for

students to apply the information to new situations. He affirmed that it was important to teach in a way so that students understand science is a dynamic process versus a collection of concrete facts or a set method. Bruce believed science class should focus on students understanding the big picture of science with opportunities for observation, questioning, and exploration.

Bruce followed the state standards in terms of what to teach in his classes but emphasized the ones he felt were most important by spending additional time on them, or integrating concepts to visit those standards again. He decided what to emphasize based on his own personal experiences. Bruce stated, "If it's something that I forgot that I learned, then I don't think it's important that they know it and I always tell that they don't have to memorize something that I forgot" (Personal communication, June 18, 2007). Bruce's belief that he should decide the topics to teach remained stable throughout the study period. During his last interview, Bruce said, "I probably spend more time on evolution—just because I think it's such a unifying—it explains everything in Biology. If the kids have an understanding of evolution they can understand why everything else is the way it is" (Personal communication, July 6, 2010).

Bruce believed it was important to teach engaging lessons that were relevant to the students. Throughout the years, he emphasized the importance of making science interesting and interactive. For example, Bruce said, "I think that's number one as far as—the kids aren't going to learn anything if they're not engaged at all no matter what your lesson is like" (Personal communication, July 20, 2008). He also stated,

> The more I teach, the more I think I have that awareness for [students] rather than just delivering a lesson. I think about how much the kids are actually paying attention and how I can keep them more engaged. This has become more important to me. (Personal communication, July 20, 2008)

He believed that hands-on activities were better teaching strategies because they incorporated interaction. He also believed strategies limiting interactions, such as reading the textbook, were less desirable.

Bruce's Beliefs About Learning

Bruce believed that students learn through engaging in inquiry-based activities. He believed that he would need to provide guidance initially to introduce the concept, but then provide, "a bunch of materials and say, 'design an experiment to test some ideas that you've thought of'" (Personal communication, August 13, 2005). At the end of the study, Bruce still believed in the importance of activities.

> I think it probably goes back to what we were talking about with inquiries. The kids learn best by doing science. Those are the things that they remember. I think in addition, one of the things I'm noticing over the last couple years is instead of just giving them a bunch of details, just making things relevant for them. Not just them doing labs, but giving them examples of a lot of the

> concepts that we're talking about that they would encounter in their daily lives. (Personal communication, July 6, 2010)

Bruce believed that students learn through engaging in relevant science activities that integrated student thoughts and ideas.

Bruce insisted the questions students asked were a good indicator of student learning. He expressed that he assessed learning by "both the questions they ask each other and the questions that they ask me" (Personal communication, June 19, 2006). If students asked questions about something they should have known, but did not know, then perhaps they were not where he wanted them to be conceptually. Conversely, if students asked questions about how to apply information, or asked questions that went beyond course discussions, this indicated that students understood the concept and were thinking about the concept beyond what was included in class.

Bruce also believed in assessing learning by giving students opportunities to explain and apply knowledge in new situations. "Any time I can allow the students to explain things for themselves either in words that they write down, or something that they've talked to me about, I think that shows a lot of understanding" (Personal communication, June 19, 2006). During interview T4 Bruce explained,

> The biggest thing is when you ask them to apply or somehow analyze the information that you've given to them. If they can effectively apply that information and use it to analyze a situation or come up to a solution to a problem, then that's when you know they've really learned it (Personal communication, July 20, 2008).

During his last interview, he stated, "If I'm asking them questions that requires them to explain or apply or synthesize or evaluate–all of those higher level thinking skills. You really get to know what they know and don't know" (Personal communication, July 6, 2010).

Oscar

Oscar, a non-persisting teacher, attended college with the career goal to become a dentist. He earned a Bachelor's degree in a science discipline with a minor in mathematics before enrolling in dental school. After approximately a year and half of dental school, Oscar reported that he could not handle the course load, and did not achieve the grades required to remain enrolled by the school. Reflecting on his undergraduate experience, Oscar shared that his assignments consisted mainly of bookwork and lecture. Oscar felt his school experiences were very structured. The few laboratories he completed were "focused on things" (Personal communication, June 27, 2006) and emphasized repeating known results.

Oscar became a science teacher because he was looking for an occupation that included a decent wage and gave him an opportunity to make a difference. He also wanted a job that was stable and provided benefits. Upon prompting, Oscar further explained that he actually wanted to teach mathematics. He stated, "I think math is going to be easier than science. I want to get an easier job" (Personal

communication, September 4, 2005), but could not be hired for a job teaching math because he did not hold the appropriate certification to teach that subject area.

Oscar's Teaching Context

Oscar taught earth science for 1 year in a middle school in an urban public school with a predominantly White middle-class demographic. Oscar noted during the two interviews he completed that he felt unprepared to teach earth science at the middle school level. He tried to prepare by taking additional earth science classes prior to beginning his first year in the classroom. Oscar also noted he felt unprepared to work with the student population at his school. He would have preferred a student population similar to the ones during his student teaching experience, which were, "a lot of much more wealthier kids. You know, it's just a different situation" (Personal communication, September 4, 2005).

Oscar found his assigned mentor approachable, but not helpful. Oscar explained during his second interview that occurred after his one year of teaching,

> She was very different than the way I would do it, and the way that the other teachers would do it, because I would watch and see how things were done by other teachers, and they were much more efficient in, for example, classroom discipline. (Personal communication, June 27, 2006).

Oscar could not find other colleagues to work with and shared "the other teachers on my team didn't like me. When the teachers don't like you, and the students don't like you, well, who likes you?" (Personal communication, June 27, 2006).

Oscar experienced issues with establishing classroom management during his year as a teacher. During both interviews, Oscar stated his students were difficult to motivate, and was not prepared for how challenging it was to motivate students to engage in class and complete tasks. In addition, he was frustrated with the lack of support regarding discipline at his school. Oscar explained the administration was helpful, but did not help solve the problems he experienced in the classroom. He illustrated this position when he shared, "my attitude was we needed an after school detention and he [the principal] said, 'That's not going to solve our problem'" (Personal communication, June 27, 2006). Oscar felt establishing classroom management would have made a difference and believed the lack of discipline at the school level was a hindrance to his ability to teach.

Oscar's Beliefs About Teaching

Oscar viewed standards as the ultimate source on what to teach in his class,

> The greatest thing in education is to be able to just turn to some standard at any time and just be like, 'What do I teach next?' Now they've got these state standards and it makes it very clear to what the kids need to know. (Personal communication, June 27, 2006)

Oscar did not believe he needed autonomy in what to teach, how to teach it, nor did he believe he needed to modify the provided curriculum when he taught in his classes.

Oscar affirmed his role was to interest students in science, but had difficulty achieving this goal. When he assigned class work to engage students in learning, he felt the students were resistant. "I tried to have them write a 10-sentence paragraph telling what they knew about hurricanes, but then they still fight me. They're like, we don't want to" (Personal communication, September 4, 2005). When asked at the end of the year about his role as a teacher, Oscar explained that he was there to lecture, explain, and answer questions.

Oscar's beliefs about teaching increasingly focused on classroom management during his teaching year. Initially, Oscar commented he used teaching strategies that would minimize student interactions. At the end of the year, Oscar stated he could teach by, "controlling them and having the class under control" (Personal communication, June 27, 2006). Although Oscar wanted to incorporate hands-on activities, he believed he could not do so because classroom management and discipline had not been established in his classroom.

Profile of Oscar's Beliefs About Learning

Oscar believed students learned through, "lecture and book work, that's student learning. Then hands-on. You know. They read it, they see it" (Personal communication, June 27, 2006). In regard to student learning, he also shared,

> They learn it best when there is classroom management in the classroom, and when [the Teacher's Assistant] is there, they learn best. They learn best when we lecture, discuss, and then we read together as a class. Then they answer questions based on what we just read. (Personal communication, June 27, 2006)

Oscar believed in establishing classroom management and discipline before he could teach science through lecture, discussions, and reading texts.

Oscar assessed student learning through completed work or a correct response. When asked to elaborate, Oscar stated:

> Well, if they have intelligent questions or comments. If I'm lecturing, and they ask a good question, or they have a good comment, you know, when I ask a question. That's when I know they're learning. My last question, they're going to know the answer already, most likely, because we've already discussed it. I frequently ask questions based on things that we've already discussed in class, but it's hard to discuss things when [the Teacher's Assistant] is not there. It's got to be MTV, or running around the classroom, airplanes, balls made out of paper. (Personal communication, June 27, 2006).

Oscar believed that if a student could reiterate information he had previously provided, that indicated the student understood the concept.

When asked for additional information on assessment of student learning, Oscar discussed an examination he had given to students in his classes. The examination included short response questions, which he found time-consuming to grade.

> I've learned the wrong, the hard way. You don't write exams like this. I wrote it because I wanted them to, you know, give them a good exam. I need to write exams that are multiple choice. In my student teaching we had books where there were multiple-choice exams in the book, and then I just, I photocopied the book, like the teacher told me to. It would just be an A, B, C, D, or you know? (Personal communication, September 4, 2005)

Oscar focused on the time it would take to assess learning. Although he found most of the advice he received from colleagues unhelpful, he asserted that the suggestion of using pre-made exams helped him with time management.

Discussion

The focus of this study was to investigate whether secondary science teacher beliefs related to persistence and to determine whether the results have implications for areas of science education, teacher preparation, and teacher induction. The research questions in the context of the literature review and the collected and analyzed data are discussed in the following paragraphs.

Question 1: How Do the Beliefs of Teachers Who Persist and Do Not Persist in Teaching Change Over 5 Years?

Overall, the results of the quantitative analysis revealed that the new teachers' beliefs were individualistic and stable. What is interesting to note is that the finding of stable beliefs over the 5-year period contradicts the literature that states beginning teachers' beliefs are malleable (Luft, 2001; Luft & Patterson, 2002; Luft, Roehrig, & Patterson, 2003; Simmons et al., 1999). Although the quantitative analysis findings revealed the teachers' beliefs were generally stable, this could have resulted from analysis of data from a group of teachers whose beliefs may have fluctuated at the individual level. While the teachers' beliefs overall remained relatively consistent, the findings from this study did not reveal changes in beliefs of individual participants. For example, some teachers may have developed more student-centered beliefs over time, while others moved toward more teacher-centered beliefs over time. Again, the data did not show fluctuations that may have occurred with individual teachers. This finding suggests the need to examine beliefs at a more distinctive level in order to reveal the nuances of individual teacher's beliefs and belief systems.

Another consideration relevant to these results is that the teachers in this study were not involved in an induction, mentoring, or professional development program designed to challenge beliefs about teaching and student learning. They participated in induction programs provided by their school or district, and the programs did not specifically focus on science teaching. The beliefs of teachers in this study were seldom challenged during their induction experience, which could have resulted in

seemingly stable beliefs during this period. In alignment with work by Fletcher and Luft (2011) and Wong et al. (2013), findings from this study highlight the importance of content-specific support in helping beginning secondary science teachers develop more student-centered beliefs and approaches in the classroom.

In this study, overall teachers' beliefs remained stable over time. However, one interesting discovery was the statistical finding that teachers with more student-centered beliefs were more likely to persist at the end of the third year of teaching than did teachers who held more teacher-centered beliefs. This finding is interesting because student-centered beliefs often align with student-centered instruction, which is emphasized by national science education reform documents, such as the *NGSS* (NGSS Lead States, 2013) and *A Framework for K-12 Science Education* (National Research Council, 2011).

Question 2: What Factors May Impact the Beliefs of the Persisting and Non-persisting Teachers Over Time?

Influence of Prior School Experiences

The manner in which Bruce and Oscar learned throughout their previous educational experiences impacted their beliefs about teaching and student learning. Bruce's experiences conducting scientific field experiments during his college years influenced his beliefs, while Oscar's personal school experiences focusing on bookwork and completing laboratories influenced his beliefs. These personal experiences influenced the formation of Bruce's student-centered beliefs and Oscar's teacher-centered beliefs.

Several educational researchers (e.g., Brownlee et al., 2002; Crawford, 2007; Holt et al., 2011; Lortie, 1975; Luft & Roehrig, 2007; Pajares, 1992; Richardson, 1996; Tsai, 2002) noted the influence of prior school experiences on beliefs. In terms of science teaching, research findings show how personal school experiences and science course work can impact the teaching and learning beliefs of teachers (Holt et al., 2011; Otero & Nathan, 2008). The findings for this study revealed that personal experiences influenced the beliefs about teaching and student learning of both Bruce and Oscar. Bruce explained how his field experiences influenced his beliefs about the importance of inquiry-based instruction. Oscar's more linear school experiences led to his focus on memorization and learning of discrete facts. These findings support work by Crawford (2007) and Forbes and Davis (2010) that found beliefs about teaching impacts curricular and instructional choices.

The findings from this study also support work by Crawford (2007), Otero and Nathan (2008), and Holt et al. (2011) which revealed beliefs regarding the ways students learn impacts instruction. Bruce's experiences as a teaching assistant influenced his beliefs about the importance of deep conceptual understanding over being "good at school" (Personal communication, August 13, 2005). In contrast, Oscar's school experiences in teacher-centered environments guided his beliefs on emphasizing facts and recall of information he had previously provided to his students. Bruce and Oscar also held beliefs about student learning that influenced the way they assessed students. Bruce believed class discussions, open-ended responses on

examinations, and the question students asked provided views into student understanding of concepts. Conversely, Oscar implemented student assessments that were already available, easy to grade, and emphasized student recall of information.

Perceived Support from Mentors and Colleagues

Bruce believed his mentor and fellow teachers supported him, and were available when he needed advice. He also found the advice he received from his mentor and colleagues useful to his teaching and classroom management, and often integrated the activities his mentor provided in his classroom. Conversely, Oscar did not believe he was supported by his assigned mentor, colleagues, or administration. Oscar's beliefs about teaching and learning contradicted the beliefs of the people he worked with and he discarded the ideas he was provided by his mentor. At the root of these perceptions of support was the alignment between the ideas provided to Bruce and Oscar by their mentors and colleagues. Bruce's beliefs were aligned with those that he felt supported him, while Oscar's beliefs were misaligned with those that he worked with.

The disparity between Bruce's perceived support and Oscar's perceived lack of support is in agreement with the work of Crawford (2007) and Yee (1990). Crawford (2007) explained that beliefs are a complex phenomenon that can lead to "tension between having a vision of teaching science as inquiry, and holding contradictory beliefs about schools, the role of the teacher, and the role of the student" (p. 636). From the interviews, Bruce stated his beliefs about teaching and student learning aligned with the beliefs of his mentor and others from whom he sought advice. This alignment of beliefs supports work by Chester and Beaudin (1996) who revealed that perceived collegial school culture with high levels of collaboration related to higher self-efficacy in new teachers.

Conversely, Oscar's beliefs about teaching and student learning clashed with his mentor, other teachers, and administrators at his school. Oscar held more teacher-centered beliefs and felt unsupported in his attempts to establish classroom management at his school. Oscar's beliefs also did not align with the ideas and advice he received from his mentor, colleagues, and administration causing him to resist and discard the new ideas from his colleagues. This finding supports work by Kagan (1992) and Rokeach (1968) that new ideas and beliefs that do not align with an individual's existing core beliefs are resistant to change.

Other Factors that May Impact Persistence

Investigation into Bruce and Oscar's personal experiences revealed other factors that may have influenced their beliefs and persistence in teaching. Nieto's (2003) work discovered that teachers invested in developing the teacher–student relationship were more likely to persist in teaching. In Bruce's case, he believed in the importance of providing opportunities for students to explain their thinking, and made it a priority to speak with them individually to assess their learning. He believed in giving students voice in his classroom and wanted them to learn science instead of recite scientific facts. Oscar, on the other hand, did not develop relationships with his students as he continuously struggled with classroom

management. This finding supports Nieto's (2003) work that discovered teachers who believed in the importance of teacher–student relationships were more likely to persist in the teaching profession.

Findings from this study also supported research conducted by Marso and Pigge (1997), and Johnson and Birkeland (2003) that found teachers who left the teaching profession during the early years either viewed teaching as a temporary position, experienced dissatisfaction, or experienced failure. Bruce was committed to teaching as his lifelong profession and viewed challenges he faced in his classroom as learning opportunities. In contrast, Oscar viewed teaching as something he could do since he did not reach his original goal of becoming a dentist. Oscar was frustrated with his teaching experience. Oscar's reason for becoming a teacher, his dissatisfaction with his teaching experience, and conflicts with colleagues, supported the finding from Johnson and Birkeland's (2003) study that teachers who viewed teaching as a temporary position and experienced dissatisfaction were more likely to leave the teaching profession.

In addition, the findings from this study support work by Chapman (1983) that revealed teachers with spouses also in the teaching profession were more likely to remain in teaching. Bruce's wife was a kindergarten teacher during the study period and supported his decision to transition to teaching while he was in graduate school. Oscar was not in a relationship in which the other person was in a teaching profession during the study period.

Conclusion and Implications

Teacher persistence is important because teachers that remain in the classroom accrue the experience correlated with increased student achievement (Coble et al., 2009; Darling-Hammond, 2000; Henry et al., 2012; Ingersoll, 2002). The need to increase the retention of effective science teachers was the impetus for this study, which examined whether teacher beliefs influenced beginning secondary science teacher persistence. Several findings from this study illuminate why some teachers persist in the field past the induction period. From these findings, there are implications for secondary science teacher preparation and support programs.

First, the study findings elaborated upon the impact of personal school experiences on teacher beliefs. Pajares (1992) explained that teachers enter the teaching professional with vast experiences as students, and these experiences impact beliefs and belief systems. In this study, both case studies revealed the extent in which personal school experiences impacted teachers' beliefs about how to teach science and how students learn science. In Bruce's case, personal school experiences steered his beliefs about the importance of inquiry-based instruction, while Oscar's case highlighted how personal school experiences led to his beliefs that emphasized structured teaching methods. To address prior school experiences that may impact teacher beliefs, it is imperative that teacher preparation programs include content-rich opportunities that foster student-centered beliefs and student-centered instruction. Feiman-Nemser (2001) shared that effective teacher preparation programs must bring "deliberate efforts by teacher educators to model the kind

of interactive, content-rich teaching they are trying to promote and to create opportunities for preservice students to experience that teaching as learners" (p. 1025). In addition to providing content-rich, student-centered experiences, the implications from this study also advocate for instructors in teacher preparation programs to prompt preservice teachers to compare their personal teaching beliefs to the models of teaching exemplified in science education. Recognizing and understanding how individual beliefs impact teaching may assist preservice science teachers in resolving any conflicts between how they have learned science and the best practices advocated by national documents, such as the *NGSS* (NGSS Lead States, 2013) and *A Framework for K-12 Science Education* (National Research Council, 2011).

Second, the results from this study supports the importance of content-specific induction and mentoring programs as advocated by Luft et al. (2011) and Wong et al. (2013), but also calls for teacher induction programs to challenge the beliefs of beginning secondary science teachers. As teachers gain experience in the classroom, they need the content-specific support for effective science teaching (Luft et al., 2011). Teachers also need opportunities to reflect upon their beliefs about teaching and learning, and compare their personal beliefs with colleagues. Engagement in opportunities to reflect upon personal teaching beliefs may reveal alignment or misalignment of beliefs with other faculty and administration within the school context.

Content-specific induction and mentoring programs also should guide teachers toward the student-centered beliefs correlated with persistence. Beginning science teachers' instructional needs range from general to science-specific (Britton, 2009). Beginning teachers typically begin with more teacher-centered views, and with support, move toward more student-centered views (Hall & Hord, 2001). Bruce held more student-centered beliefs, which aligned with the beliefs of this mentor and colleagues. Oscar, on the other hand, maintained teacher-centered beliefs, which misaligned with his mentor and other individuals at his school. In Oscar's case, it is important to ponder whether a different mentor who was prepared to guide Oscar toward more student-centered beliefs could have impacted Oscar's job satisfaction and decision to leave the profession. Regardless, individuals who work with beginning secondary science teachers, including mentors and administrators, must elicit beginning teacher beliefs and foster the student-centered beliefs that are important for teacher persistence and student-centered instruction.

Third, findings from this study highlighted the importance of proper placement of new teachers into their first teaching positions. Bruce's student teaching experience mirrored his teaching position in terms of grade level, content area, and student population, which led him to feeling prepared for the profession. Conversely, Oscar's student teaching experience differed with his only year of teaching in terms of grade level, content area, and student population. This may have resulted in his dissatisfaction and frustration in teaching science. Oscar's negative experiences during his first year as a teacher may have been a factor in his decision to leave the teaching field.

Findings from this study indicate that teacher beliefs alone may not determine whether a teacher persists in the profession, but teacher beliefs are a factor among

many that impact teacher persistence. The finding that persisting teachers tend to hold more student-centered beliefs is important and relevant, but there remains a need to further study the persistence of secondary science teachers. As Cochran-Smith (2004) expressed, "teacher retention is a multidimensional problem, requiring both macro- and micro-level analyses and policy initiatives" (p. 390). Many considerations for improving teacher retention include teacher preparation, professional development, school cultures, teacher autonomy, and opportunities for collaboration (Cochran-Smith, 2004). In addition, the findings of this study also advocates for additional exploration into the factors that increase teacher persistence, particularly how current teacher preparation programs and teacher support systems can evolve to maximize the effectiveness and persistence of beginning secondary science teachers.

Acknowledgments The authors of this study would like to recognize these faculty members and research assistants who helped with various parts of this study: Sandra K. Abell, Krista Adams, EunJin Bang, Jonah B. Firestone, Derek Fay, Jennifer Neakrase, Irasema Ortega, Steve Semken, Mary Lee Smith, and Gillian Roehrig. This study was made possible by National Science Foundation Grants 0550847, 0918697, and 1247096. The findings, conclusions, and opinions herein represent the views of the authors and do not necessarily represent the view of personnel affiliated with the National Science Foundation.

References

Apostolou, A., & Koulaidis, V. (2010). Epistemology and science education. A study of epistemological views of teachers. *Research in Science and Technological Education, 28*, 149–166. doi:10.1080/02635141003750396

Barnes, G., Crowe, E., & Schaefer, B. (2008). *The cost of teacher turnover in five school districts: A pilot study*. National Commission on Teaching and America's Future.

Bogdan, R., & Biklen, S. K. (2006). *Qualitative research for education: An introduction to theories and methods*. Boston, MA: Pearson.

Borman, G. D., & Dowling, N. M. (2008). Teaching attrition and retention: A meta-analytic and narrative review of the research. *Review of Educational Research, 78*, 367–409. doi:10.3102/0034654308321455

Boyd, D., Grossman, P., Lankford, H., Loeb, S., & Wyckoff, J. (2009). *Who leaves? Teacher attrition and student achievement*. CALDER working paper no. 23. Washington, DC: National Center for Analysis of Longitudinal Data in Education Research. doi:10.3386/w14022

Brickhouse, N. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41*(3), 53–62. doi:10.1177/002248719004100307

Britton, E. D. (2009). Induction programs and beginning science teachers. In A. Collins & N. Gillespie (Eds.), *The continuum of secondary science teacher preparation: Knowledge, questions, and research recommendations* (pp. 159–170). Rotterdam, The Netherlands: Sense Publishers.

Brownlee, J., Boulton-Lewis, G., & Purdie, N. (2002). Core beliefs about knowing and peripheral beliefs about learning: Developing an holistic conceptualization of epistemological beliefs. *Australian Journal of Educational and Developmental Psychology, 2*, 1–16.

Bryman, A. (2006). Integrating quantitative and qualitative research: How is it done? *Qualitative Research, 6*, 97–113. doi:10.1177/1468794106058877

Certo, J. L., & Fox, J. E. (2002). Retaining quality teachers. *High School Journal, 86*(1), 57–75. doi:10.1353/hsj.2002.0015

Chapman, D. W. (1983). A model of the influences on teacher retention. *Journal of Teacher Education, 34*(5), 43–49. doi:10.1177/002248718303400512

Chester, M., & Beaudin, B. (1996). Efficacy beliefs of newly hired teachers in urban schools. *American Educational Research Journal, 33*, 233–257. doi:10.3102/00028312033001233

Coble, C. R., Smith, T. M., & Berry, B. (2009). The recruitment and retention of science teachers. In A. Collins & N. Gillespie (Eds.), *The continuum of secondary science teacher preparation: Knowledge, questions, and research recommendations* (pp. 1–21). Rotterdam, The Netherlands: Sense Publishers.

Cochran-Smith, M. (2004). Stayers, leavers, lovers, and dreamers: Insights about teacher retention. *Journal of Teacher Education, 55*, 387–392. doi:10.1177/0022487104270188

Crawford, B. (2007). Learning to reach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Education, 44*, 613–642. doi:10.1002/tea.20157

Creswell, J. W. (2005). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Upper Saddle River, NJ: Pearson.

Cronin-Jones, L. L. (1991). Science teacher beliefs and their influence on curriculum implementation: Two case studies. *Journal of Research in Science Teaching, 28*, 235–250. doi:10.1002/tea.3660280305

Darling-Hammond, L. (2000). *Solving the dilemmas of teacher supply, demand, and standards: How we can ensure a competent, caring, and qualified teacher for every child*. New York, NY: National Commission on Teaching and America's Future, Teachers College, Columbia University.

Darling-Hammond, L., & Sykes, G. (2003). Wanted: A national teacher supply policy for education: The right way to meet the "highly qualified teacher" challenge. *Education Policy Analysis Archives,*. doi:10.14507/epaa.v11n33.2003

Dolton, P., & van der Klaauw, W. (1999). The turnover of teachers: A competing risks explanation. *Review of Economics and Statistics, 81*, 543–552. doi:10.1162/003465399558292

Eick, C. (2002). Studying career science teachers' personal histories: A methodology for understanding intrinsic reasons for career choice and retention. *Research in Science Education, 32*, 353–372. doi:10.1023/a:1020866111670

Feiman-Nemser, S. (2001). From preparation to practice: Designing a continuum to strengthen and sustain teaching. *Teachers College Record, 103*(6), 1013–1055. doi:10.1111/0161-4681.00141

Fletcher, S. S., & Luft, J. A. (2011). Early career secondary science teachers: A longitudinal study of beliefs in relation to field experiences. *Science Education, 95*, 1124–1146. doi:10.1002/sce.20450

Forbes, C. T., & Davis, E. A. (2010). Beginning elementary teachers' beliefs about the use of anchoring questions in science: A longitudinal study. *Science Education, 94*, 365–387. doi:10.1002/sce.20370

Fylan, F. (2005). Semi structured interviewing. In J. Miles & P. Gilbert (Eds.), *A handbook of research methods for clinical and health psychology* (pp. 65–78). Oxford: Oxford University Press.

Goldhaber, D., Gross, B., & Player, D. (2007). *Are public schools really losing their best? Assessing the career transitions of teachers and their implications for the quality of the teacher workforce*. Washington, DC: National Center for Analysis of Longitudinal Data in Education Research. doi:10.1037/e722632011-001

Goodenough, W. (1963). *Cooperation in change*. New York, NY: Russell Sage Foundation.

Goodpaster, K. S., Adedokun, O. A., & Weaver, G. C. (2012). Teachers' perceptions of rural STEM teaching: Implications for rural teacher retention. *Rural Educator, 33*(3), 9–22.

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a conceptual framework for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis, 11*, 255–274. doi:10.3102/01623737011003255

Guarino, C., Santibanez, L., & Daley, G. (2006). Teacher recruitment and retention: A review of the recent empirical literature. *Review of Educational Research, 76*, 173–208. doi:10.3102/00346543076002173

Hall, G., & Hord, S. (2001). *Implementing change: Principles, patterns, and potholes*. Boston, MA: Allen and Bacon.

Hanushek, E. A., Kain, J. F., O'Brien, D. M., & Rivkin, S. G. (2005). *The market for teacher quality*. NBER working paper no. 11154. Cambridge, MA: National Bureau of Economic Research, Inc. doi:10.3386/w11154

Henry, G. T., Fortner, C. K., & Bastian, K. C. (2012). The effects of experience and attrition for novice high-school science and mathematics teachers. *Science, 335*, 1118–1121. doi:10.1126/science.1215343

Holt, C., Hargrove, P., & Harris, S. (2011). An investigation into the life experiences and beliefs of teachers exhibiting highly effective classroom management behaviors. *Teacher Education and Practice, 4*(1), 96–113.

Ingersoll, R. M. (2002). The teacher shortage: A case of wrong diagnosis and wrong prescription. *The NASSP Bulletin, 86*, 16–31. doi:10.1177/019263650208663103

Ingersoll, R. M. (2012). Beginning teacher induction: What the data tells us. *Phi Delta Kappan, 93*(8), 47–51. doi:10.1177/003172171209300811

Ingersoll, R. M., & Perda, D. (2009). The mathematics of science teacher shortage: Fact and Myth. *The Consortium for Policy Research in Education*. doi:10.12698/cpre.2009.rr62

Johnson, S., & Birkeland, S. (2003). Pursuing a "sense of success": New teachers explain their career decisions. *American Educational Research Journal, 40*, 581–617. doi:10.3102/00028312040003581

Jones, M. G., & Leagon, M. (2014). Science teacher attitudes and beliefs. In N. Lederman & S. Abell (Eds.), *Handbook of research on science education* (Vol. 2, pp. 830–843). New York, NY: Routledge.

Kagan, D. M. (1992). Implication of research on teacher belief. *Educational Psychologist, 27*, 65–90. doi:10.1207/s15326985ep2701_6

Kirby, S. N., & Grissmer, D. W. (1993). *Teacher attrition: Theory, evidence, and suggested policy options*. Paper presented at the meeting of Seminar of the World Bank/Harvard Institute for International Development on Policies Affecting Learning Outcomes through Impacts on Teachers, Cambridge, MA.

Lortie, D. C. (1975). *Schoolteacher: A sociological study*. Chicago, IL: University of Chicago Press.

Luft, J. A. (2001). Changing inquiry practices and beliefs: The impact of inquiry-based professional development programme on beginning and experienced secondary science. *International Journal of Science Education, 23*, 517–534. doi:10.1080/09500690121307

Luft, J. A., Firestone, J., Wong, S. S., Ortega, I., Adams, K., & Bang, E. J. (2011). Beginning secondary science teacher induction: A two-year mixed methods study. *Journal of Research in Science Teaching, 49*, 1199–1224. doi:10.1002/tea.20444

Luft, J. A., & Patterson, N. C. (2002). Bridging the gap: Supporting beginning science teachers. *Journal of Science Teacher Education, 13*, 267–282. doi:10.1023/a:1022518815872

Luft, J. A., & Roehrig, G. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education, 11*(2). Retrieved from http://ejse.southwestern.edu/volumes/v11n2/articles/art03_luft.pdf

Luft, J. A., Roehrig, G., & Patterson, N. C. (2003). Contrasting landscapes: A comparison of the impact of different induction programs on beginning secondary science teachers' practices, beliefs, and experiences. *Journal of Research in Science Teaching, 40*, 77–97. doi:10.1002/tea.10061

Macdonald, D. (1999). Teacher attrition: A review of literature. *Teaching and Teacher Education, 15*, 835–848. doi:10.1016/s0742-051x(99)00031-1

Marso, R., & Pigge, F. (1997). A longitudinal study of persisting and nonpersisting teachers' academic and personal characteristics. *The Journal of Experimental Education, 65*, 243–254. doi:10.1080/00220973.1997.9943457

Marvel, J., Lyter, D. M., Peltola, P., Strizek, G. A., & Morton, B.A. (2006). *Teacher attrition and mobility: Results from the 2004–05 teacher follow-up survey* (NCES 2007–307). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

Mertens, D. M. (1998). *Research methods in education and psychology. Integrating diversity with quantitative and qualitative approaches*. Thousand Oaks, CA: Sage.

Miles, M. B., & Huberman, A. M. (1994). *An expanded sourcebook: Qualitative data analysis*. Thousand Oaks, CA: Sage.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook*. Los Angeles, CA: Sage.

Murnane, R. J., Singer, J. D., Willett, J. B., Kemple, J. J., & Olsen, R. J. (1991). *Who will teach? Policies that matter*. Cambridge, MA: Harvard University Press.

National Research Council. (2011). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*, 317–328. doi:10.1080/0022027870190403

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press.

Nieto, S. (2003). *What keeps teachers going?* New York, NY: Teachers College Press.

Onwuegbuzie, A. J., & Dickinson, W. B. (2008). Mixed methods analysis and information visualization: Graphical display for effective communication of research results. *The Qualitative Report, 13*, 204–225.

Otero, V. K., & Nathan, M. J. (2008). Preservice elementary teachers' views of their students' prior knowledge of science. *Journal of Research in Science Teaching, 45*, 497–523. doi:10.1002/tea.20229

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*, 307–332. doi:10.3102/00346543062003307

Paris, L. F. (2013). Reciprocal mentoring: Can it help prevent attrition for beginning teachers? *Australian Journal of Teacher Education, 38*, 136–158. doi:10.14221/ajte.2013v38n6.5

Pirkle, S. F. (2011). Stemming the tide: Retaining and supporting science teachers. *Science Educator, 20*, 42–46.

Rhodes, C., Nevill, A., & Allan, J. (2004). Valuing and supporting teachers: A survey of teacher satisfaction, dissatisfaction, morale and retention in an English local educational authority. *Research in Education, 71*, 67–80. doi:10.7227/rie.71.7

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), *Handbook of research on teacher education* (pp. 102–119). New York, NY: Macmillan.

Rokeach, M. (1968). *Beliefs, attitudes, and values: A theory of organization and change*. San Francisco, CA: Jossey-Bass.

Schlechty, P. C., & Vance, V. S. (1983). Recruitment, selection, and retention: The shape of the teaching force. *The Elementary School Journal, 83*, 469–487. doi:10.1086/461327

Seidman, I. (2013). *Interviewing as qualitative research: A guide for researchers in education in education and the social sciences*. New York, NY: Teachers College Press.

Shen, J. (1997). Teacher retention and attrition in public schools: Evidence from SASS91. *Journal of Educational Research, 91*, 81–88. doi:10.1080/00220679709597525

Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D., & Labuda, K. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching, 36*, 930–954. doi:10.1002/(sici)1098-2736(199910)36:8<930:aid-tea?3.0.co;2-n

Stake, R. (1995). *The art of case study research*. Thousand Oaks, CA: Sage.

Teddlie, C., & Tashakkori, A. (2006). A general typology of research designs featuring mixed methods. *Research in the Schools, 13*, 12–28.

Thompson, A. G. (1992). Teachers' beliefs and conceptions: A synthesis of research. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 127–146). New York, NY: Macmillan.

Tsai, C. C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education, 24*, 771–783. doi:10.1080/09500690110049132

Vedder, P., Horenczyk, G., Liebkind, K., & Nickmans, G. (2006). Problems in ethno-culturally diverse education settings: Problems, challenges and solutions. *Educational Research Review, 1*, 157–168. doi:10.1016/j.edurev.2006.08.007

Watlington, E., Shockley, R., Gugielmino, P., & Felsher, R. (2010). The high cost of leaving: An analysis of the cost of teacher turnover. *Journal of Education Finance, 36*, 22–37. doi:10.1353/jef.0.0028

Weiss, E. (1999). Perceived workplace conditions and first-year teachers' moral, work choice commitment, and planned retention: A secondary analysis. *Teaching and Teacher Education, 15*, 861–879. doi:10.1016/s0742-051x(99)00040-2

Wong, S. S., Firestone, J. B., Luft, J. A., & Weeks, C. B. (2013). Laboratory practices of beginning secondary science: A five-year study. *Science Educator, 22*(1), 1–9.

Yee, S. M. (1990). *Careers in the classroom: When teaching is more than a job*. New York, NY: Teachers College Press.

Yerrick, R., Parke, H., & Nugent, J. (1997). Struggling to promote deeply rooted change: The "filtering effect" of teachers' beliefs on understanding transformational views of teaching science. *Science Education, 81*, 137–159. doi:10.1002/(sici)1098-237x(199704)81:2<137:aid-sce2>3.0.co;2-g