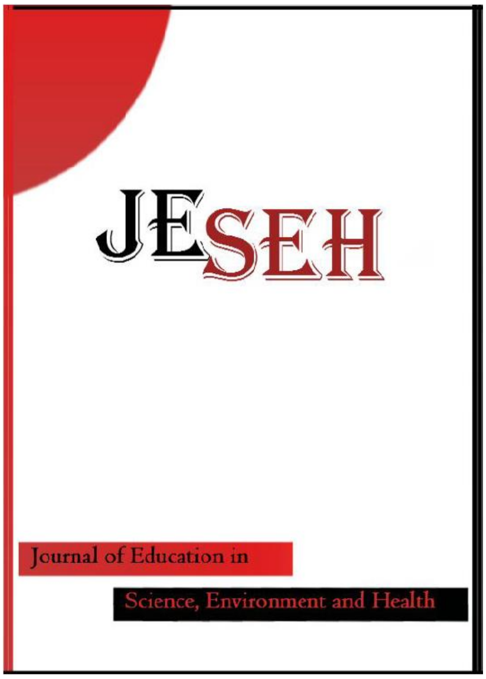

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Development of Teacher Beliefs through Online Instruction: A One-Year Study of Middle School Science and Mathematics Teachers' Beliefs About Teaching and Learning

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Abstract

Understanding teachers' beliefs is important because beliefs influence teacher decisions. In science, teacher beliefs have an impact on how science curriculum is interpreted and implemented in the classroom. With the push for science, technology, engineering, and mathematics (STEM) education in the United States, it is also critical to examine the beliefs of teachers who integrate science in the classroom. This study of 21 U.S. middle school science and mathematics teachers found that teachers' participation in the first year of a two-year graduate online program that emphasised inquiry-based instruction and student-centred frames of mind influenced participants' beliefs. Overall, participants moved toward holding more student-centred beliefs. When types of beliefs were disaggregated, participants' beliefs about teaching and about learning both moved toward a more student-centred position. Further, teachers' beliefs significantly changed regardless of their years of teaching experience. One surprising finding was that science teachers' beliefs changed significantly, while those of mathematics teachers did not. The findings from this study support the notion that formal knowledge has an impact on teacher beliefs.

Key words: Mathematics teacher beliefs, Middle school, Online instruction, Science teacher beliefs

Introduction

In the United States, certain national documents advocate for science teachers to engage students in inquiry-based lessons to foster students' scientific literacy (National Research Council [NRC], 1996; NGSS Lead States, 2013). Inquiry-based instruction has been found to foster student learning of concepts (Lott, 1983; NRC, 1996) and is a more accurate and authentic representation of how scientists do science (NRC, 1996). Even though inquiry is well supported for elevating K–12 students' learning of science, teachers have consistently struggled with implementing inquiry in their classrooms (Crawford, 2007; Luft, Wong, Ortega, Adams, & Bang, 2011). Further, inquiry instruction is hampered by a lack of time, limits set by district curricula, and teachers' perceived lack of classroom control (Costenson & Lawson, 1986) as well as teachers' beliefs about teaching and learning.

Considerable research has shown that teacher beliefs have an impact on their decisions (Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Haney, Czerniak, & Lumpe, 1996; Nespor, 1987; Simmons et al., 1999), including what to teach and how to teach. For example, Brickhouse found that teachers' beliefs affected how they interpreted the nature of science curriculum and how they implemented it in the classroom. Cronin-Jones' study of two middle-grade science teachers showed how teachers' beliefs about how students learn, the teacher's role in the classroom, and the ability level of the students influenced the ways that teachers modified packaged curriculum. Overall, teachers' beliefs about how students learn have an impact on what teachers do in the classroom.

Beliefs are influenced by both personal and school experiences as well as by formal knowledge (Apostolou & Koulaidis, 2010; Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Jones & Leagon, 2014; Pajares, 1992; Richardson, 1996). Luft and Patterson (2002) developed a one-year science-specific induction program to connect theory with practice for beginning science teachers. They found that "75% of the participating teachers [felt that] the program [had] significantly challenged their ideologies about teaching science" (p. 278). Luft et al. (2011), in a two-year study, found that science-specific induction and mentoring that emphasised student-centred frames of mind, which is important for inquiry-based instruction, led to teachers' developing more student-centred beliefs about teaching and learning. In contrast, teachers who did not receive science-specific induction and mentoring did not experience change in their beliefs.

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Studies on teacher professional development have examined the changes in beliefs of beginning and practicing teachers. Luft (2001) found that beginning science teachers were more likely to change their beliefs about teaching science as compared to their more experienced peers, whose beliefs were found to be more static over time. Luft's findings are in keeping with those of Simmons et al. (1999), who, in a study of 114 science teachers, found that novice teachers' beliefs were more malleable when compared to those of more experienced teachers. Teachers in the beginning phase of their career are still negotiating, within the school context, their role as a science or mathematics teacher (Henry, Bastian, & Fortner, 2012; Luft, 2001).

Studying science teachers' beliefs is critical because teachers are the negotiator of content and curriculum in the classroom (Ramsey & Howe, 1969). This content and curriculum, however, also are influenced by the current push for science, technology, engineering, and mathematics (STEM) education. The call to increase those in the STEM workforce is in response to the desire to keep the United States competitive in the evolving global market (Bybee, 2010; Gerlach, 2012). Thus, educators and certain U.S. agencies have advocated for the integration of STEM classes in K–12 classrooms. For example, the *National Science and Education Standards* (NRC, 1996) support the integration of science and mathematics because they increase students' understanding and applications of both subjects. The *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000) also advocates for the integration of science and mathematics because "process and content of science can inspire an approach to solving problems that applies to the study of mathematics" (p. 66). The *Next Generation Science Standards* (NGSS) promotes practices that integrate science and engineering applications (NGSS Lead States, 2013). With the call for integration of science and mathematics subject areas, it is important for science teachers and teachers who integrate science into their curriculums to hold beliefs that foster the implementation of student-centred inquiry-based instruction.

Research Questions

This study examined middle school science and mathematics teachers' beliefs over a one-year period. The questions that guided this study are:

1. To what extent do middle school science and mathematics teachers' beliefs change based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?
2. To what extent do middle school science and mathematics teachers' beliefs about teaching and learning change based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?
3. To what extent are there differences between middle school science teachers' and middle school mathematics teachers' beliefs based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?
4. To what extent are there differences between beginning (0-5 years) middle school science and mathematics teachers' beliefs and experienced (6 or more years) middle school science and mathematics teachers' beliefs based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?

The above distinction, in regard to years of teaching experience, between beginning and experienced teachers is drawn from the research of Luft et al. (2011).

Relevant Literature

Belief Systems

Belief systems encompass such areas as self-efficacy, epistemologies, and expectations (Jones & Carter, 2007). Nespor (1987) defined belief systems as "loosely-bound systems with highly variable and uncertain linkages to events, situations, and knowledge systems" (p. 321). Thompson (1992) stated that beliefs systems are an organization of a person's beliefs, with central beliefs' being difficult to change and peripheral beliefs' being more susceptible to change. In an essence, belief systems are like hubs in which core or central beliefs are more static and less apt to change, while exterior beliefs that radiate from the hubs are more susceptible to change, particularly as related to environmental factors (Jones & Carter, 2007).

Beliefs influence how individuals view the world and the decisions that they make. Nespor (1987) stated that beliefs "are important influences on the ways [individuals] conceptualize tasks and learn from experiences" (p. 317), and "play a major role in defining teaching tasks and organizing the knowledge and information relevant to those tasks" (p. 324). Specific to the teaching field, Kagan (1992) stated that beliefs are "a particularly provocative form of personal knowledge that is generally defined as pre- or in-service teachers' implicit assumptions about students" (p. 65). Crawford (2007) noted that a teacher's beliefs about learning and content knowledge are interwoven, which supports the notion that a teacher's beliefs about inquiry influence curricular and instructional decisions.

Challenges in Changing Beliefs

Scholars have called for teacher education and professional development to purposefully elicit and challenge teacher beliefs as a means to influence decisions and practice (Brousseau & Freeman, 1998; Horak & Lunetta, 1979; Kagan, 1992). This may be difficult to do with teachers who already have extensive personal experiences in the classroom as both students and teachers (Pajares, 1992). These personal experiences have a large impact on teachers' beliefs and actions (Richardson, 1996; Tsai, 2002). Tsai found such effects amongst beginning teachers; those who experienced teacher-centred practices as students tended to implement teacher-centred practices as teachers. As related to our understanding of belief systems, it becomes clear that beliefs formed through years of personal experiences in the classroom may be difficult to change.

There are other challenges to changing beliefs, including accessing and assessing them. According to Rokeach (as cited by Pajares, 1992), beliefs are difficult to understand because "beliefs cannot be directly observed or measured but must be inferred from what people say, intend, and do—fundamental prerequisites that educational researchers have seldom followed" (p. 314). Further, Kagan (1992) found that university leaders provide mainly supportive and positive feedback instead of challenging instructors' beliefs about teaching and learning. Moreover, teacher education programs seldom elicit or address beliefs. Teachers need to be given opportunities to reflect on beliefs that were formed before entering the profession (Brownlee, Boulton-Lewis, & Purdie, 2002). Cronin-Jones (1991) found that beliefs are often unchallenged because teacher education program instructors assume that preservice teachers hold beliefs similar to their own. In addition, those who teach in teacher education programs often have not had their own beliefs challenged.

From a research perspective, understanding teacher beliefs is especially challenging because beliefs "cannot be inferred directly from teacher behaviour, because teachers can follow similar practices for very different reasons" (Kagan, 1992, p. 66). Using interviews to collect information on teachers' beliefs allows researchers to elicit details, but teachers may not be able to reflect on their beliefs. Teachers also may not be able to communicate their beliefs to another person or may not want to reveal their beliefs for a variety of reasons. In addition, Kagan stated that teachers' knowledge and beliefs about their area of expertise often is implicit. "[T]eachers are often unaware of their own beliefs, they do not always possess language with which to describe and label their beliefs, and they may be reluctant to espouse them publicly" (p. 66). Although there are limitations to interviews and observations as avenues to elicit teacher beliefs, these methods remain the most reliable ways to collect teacher beliefs data.

Inquiry-Based Instruction

Inquiry includes interconnected processes that scientists and students use to ask questions and to investigate the natural world (Crawford, 2007). It also includes science concepts, science skills, the nature of science, and an inquisitive frame of mind (NRC, as cited by Crawford, 2007). Inquiry-based lessons may be foreign to students who are used to step-by-step instructions in scientific investigations. Therefore, inquiry should be scaffolded over time so that students can adjust to the autonomy and student-driven decisions made during inquiry.

According to Bell, Smetana, and Binns (2005), although inquiry should be viewed as a continuum, inquiry may be scaffolded over time. First is confirmation inquiry, in which the teachers provide the question and methods and knows the conclusion in advance. Next is directed inquiry, in which the teacher has determined the question and methods. Then, guided inquiry starts with a teacher-driven question, but students decide on the methods and conclusion. Finally, open-ended inquiry occurs when students decide the question, methods, and conclusion. To maximize student learning, especially with students who have not previously experienced inquiry, scaffolding from confirmation toward open-ended inquiry is critical.

Theoretical Perspective

This study utilized a pragmatic perspective because it involves methods that best address the research questions (Creswell, 2013). Pragmatism is particularly applicable to this study because it honours the specific assumptions that education researchers hold about knowledge construction. This includes taking into account the role of subjective and objective points of view when investigating phenomena, recognizing that knowledge changes over time, and understanding the importance of implementing different approaches to investigate the natural world (Biesta, 2010; Johnson & Onwuegbuzie, 2004). In a pragmatic perspective, the design and methods used in research are relative to the resulting knowledge claims (Biesta, 2010).

Method

This study utilized qualitative and quantitative measures to understand the participants' conception of the nature of science over a one-year period. The following is a description of the methods used to address the research questions.

Description of iSMART

Integrated Science Mathematics and Reflective Teaching (iSMART) is a two-year cohort-based online master's program that emphasises theories and pedagogies of research-based science and mathematics teaching. iSMART also scaffolds the integration of both content areas over the two-year period. All students in iSMART are practicing middle school (Grades 4–8) science or mathematics teachers who teach in a state in the southern region of the United States. Although the majority of the program occurs online, iSMART begins with a one-week face-to-face summer conference. The conference addresses program expectations, instructions in the navigation of the online platform in which courses take place, technology tools pertinent to the program, and initial data collection. Students also are given the materials necessary for inquiry-based class activities.

All students took two courses per semester during the first academic year. For both semesters, students were enrolled in one science methods course and one mathematics methods course. The courses alternated weeks so that courses met every other week for a total of seven class sessions per semester. Each class session lasted three hours. The online courses occurred synchronously so that everyone in the course was online simultaneously and was able to interact via the Blackboard Collaborate platform. In Collaborate, all participants had access to video, audio, chat, and an interactive white board. The platform also provided access to course readings, assignments, and discussion boards asynchronously. Both science methods courses during fall and spring semesters emphasised the importance of a student-centred frame of mind and inquiry-based instruction. Course lessons were inquiry-based and promoted student-centred and student-driven interactions. After two semesters of online courses, all students met for another one-week summer face-to-face conference in which data were collected again. For a complete description of iSMART, please see Lee, Chauvot, Vowell, Culpepper, and Plankis (2013).

Research Participants

The participants (N = 21) in this study consisted of 12 science and 9 mathematics middle school teachers enrolled in the iSMART program. Of the teachers, 19 were female, and 2 were male; and 18 were Caucasian, 2 were Hispanic, and 1 was African American. The teachers had between 2 and 27 years of classroom experience at the start of the study. There were a total of 9 beginning teachers with between 2 and 5 years of experience, and 12 teachers with 6 to 27 years of experience. Of the participants, 18 worked in public schools, and 3 worked in private schools. All participants in this study gave consent for their relevant data to be included for the purpose of research and publication.

Inquiry-Based Instruction and Student-Centred Frames of Mind

During the one-year time frame of this study, participants engaged in explicit and reflective classroom activities, discussions, readings, and assignments. The author of this paper instructed the first science methods course, and another science education professor instructed the second science methods course. Both classes utilized inquiry-based student-centred lessons to teach the course objectives. In addition, both courses included discussions to highlight and reflect upon the inquiry-based, student-driven lessons that resulted in the co-construction of knowledge about the content objective.

The first course focused on (a) inquiry-based instruction in the middle school classroom, (b) integration of science and mathematics content in the middle school classroom, (c) deeper science content knowledge, and (d) a more sophisticated conception of the nature of science. Specifically for inquiry-based instruction and student-centred framing of teaching and learning, students were instructed via scaffolded inquiry lessons that followed Bell et al.'s (2005) model of inquiry. In all cases, classes began with a discussion about prior conceptions before readings were completed. After activities and readings, the class engaged in discussion to reflect on the entire experience. This was purposefully done to help participants to identify prior conceptions and to compare them with new knowledge developed via course activities, discussions, and readings. In this way, participants were able to explicitly consider how their prior beliefs about teaching and learning compared to research findings about effective instructional models and how students learn.

The second science methods course focused on (a) constructivism and student learning, (b) scientific evidence vs. pseudoscience, (c) greater understanding of the nature of science, and (d) the difference between the nature of science and the nature of mathematics. Beliefs that influence participants' views on scientific concepts were addressed in this course through explicit confrontation. Students engaged in activities that revealed how personal knowledge, beliefs, and experiences affected their acceptance, or non-acceptance, of global climate change and the theory of evolution.

Data Collection

Data were collected in this study via semi-structured annual interviews that were conducted by the author. During the interview, the researcher took notes and digitally audio recorded the interview. There were a total of two annual interviews conducted with each participant during the study. The first time (T0) occurred during the summer conference that took place prior to the start of the iSMART courses. The second time (T1) occurred after the first academic year or the subsequent summer when the participants were at the second summer conference.

The semi-structured interview had three parts (Seidman, 2013). The first part of the interview included general questions that probed for information on the participants' teacher preparation programs, teaching experiences, and types of teaching support. This portion of the interview took approximately 30 minutes. The second portion probed for participants' conception of the nature of science. This portion took approximately 20 minutes. The third portion of the interview was from which the data were drawn. This third portion utilized the Teacher Beliefs Interview (TBI; Luft & Roehrig, 2007).

The TBI is a semi-structured interview that consists of seven prompts that were developed based on beliefs research to reveal an interviewee's beliefs about teaching and learning. The TBI utilizes the semi-structured format because it allows researchers to probe for additional details when necessary (Fylan, 2005). The TBI's validity was established through multiple examinations of the protocol, which resulted in consistent depictions of beliefs (Luft & Roehrig, 2007). The TBI has a Cronbach's α coefficient of 0.77 for reliability (Luft & Roehrig, 2007). iSMART focuses on science and mathematics methods and the integration of both over time. This study examined the science and mathematics teachers' teaching beliefs over the one-year period.

Data Analysis

Completed interviews were coded by two independent researchers in accordance with the rubrics created by Luft and Roehrig (2007) for each TBI question. Each TBI question could be coded as one of five categories that are arranged in a continuum from teacher-centred to student-centred (Table 1). The individual researchers then cross-coded together to reach consensus on the responses for each participant. The final category was then quantitised for a numerical score (Miles, Huberman, & Saldana, 2014; Teddlie & Tashakkori, 2006) for quantitative analysis.

Paired t-tests were used to address the first two research questions. First, a paired t-test was conducted to explore whether the science and mathematics teacher participants' beliefs significantly changed between T0 and T1, i.e., before and after two semesters of online instruction that emphasised student-centred inquiry-based instruction. Paired t-tests also were conducted to examine whether beliefs about teaching and beliefs about learning were significantly different. This was done by separating TBI questions by whether they elicited information about the participants' beliefs about teaching or about beliefs about learning. (Please see Table 2 for TBI questions by beliefs on teaching versus learning.)

Table 1. TBI coding categories and example responses

Category	Orientation	Description	Examples
Traditional	Teacher-centred	Teacher provides information and resources in a structured manner and environment. Teacher decides what students need to do and learn.	• I decide what students need to know • All desks should face me
Instructive	Teacher-centred	Teacher decides experiences and uses subjective evaluation of student actions and performance	• I observe students to know they have learned
Transitional	Teacher considers students	Teacher emphasises teacher-student relationship that includes subjective and affective components. Does not focus on teaching or learning of science	• I use different types of activities for different learning styles • I build relationships with my students and get to know them
Responsive	Student-centred	Teacher focuses on opportunities and collaboration between students and teacher as well as between students as peers. Focus is on development of science learning and content knowledge	• I use small-group activities that provide opportunities to generate questions, create, collaborate, and question • Students have opportunities to engage in discussions
Reform-based	Student-centred	Teacher uses individualized and student-centred methods of learning that includes student interests and abilities. Provides a collaborative environment for students to apply knowledge to novel situations.	• I know that students learn in different ways and have different interests. I teach science so that students can use existing skills and develop new skills • Students to choose their own ways to learn the content

Paired t-tests and independent samples t-tests were conducted to address the third research question. Paired t-tests were run to determine whether science teacher participants' beliefs were statistically different at T1 vs. T0 and whether mathematics teacher participants' beliefs were statistically different at T1 vs. T0. In addition, independent samples t-tests were used to determine whether the science participants' beliefs differed significantly from those of the mathematics participants at T0 and T1.

Table 2. TBI questions 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?		

Finally, paired t-tests and independent samples t-tests were conducted to address the fourth research question. Paired t-tests were run to determine whether the beginning teachers' beliefs were statistically different at T1 vs. T0 and whether those of experienced teacher participants were statistically different at T1 vs. T0. Independent samples t-tests also were conducted to determine whether the beginning teachers and experienced teachers differed significantly in their beliefs at T0 and at T1.

Results

As noted, a paired-samples t-test was conducted to address the first research question. The results indicated that there was a statistically significant difference amongst the participants in regard to their beliefs over the one-year period (Table 3).

Table 3. Paired-samples t-tests for beliefs of all teachers at T0 and T1

Variable	N	M	SD	t	p
Group					
T0 All Teachers Beliefs	21	17.38	1.88	*t*(20) = -4.70	0.00
T1 All Teachers Beliefs	21	19.57	2.27		

The results of two paired-samples t-tests conducted to address the second research question indicated that, for beliefs about teaching, there was a statistically significant difference between scores at T1 vs. T0. For beliefs about learning, the results indicated that there also was a statistically significant difference in scores at T1 vs. T0 (Table 4).

Table 4. Paired-samples t-tests for teaching beliefs vs. learning beliefs

Variable	N	M	SD	t	p
Group					
T0 Beliefs about Teaching	21	9.24	1.39	*t*(20) = -3.64	0.00
T1 Beliefs about Teaching	21	10.52	2.26		
Group					
T0 Beliefs about Learning	21	8.14	0.93	*t*(20) = -3.10	0.01
T1 Beliefs about Learning	21	9.05	1.75		

Paired-samples t-tests and independent samples t-tests were conducted to address the third research question. The paired-samples t-tests revealed a statistically significant difference amongst the science teacher participants at T1 vs. T0. Another set of paired-samples t-tests was conducted to determine whether there was a significant difference in the scores for mathematics teacher participants at T0 vs. T1. The results indicated that there was no statistically significant difference. Independent samples t-tests compared science and mathematics teachers' beliefs at T0 and at T1 and yielded no statistically significance differences at T0 or T1 (Table 5).

Table 5. Paired-samples t-tests and independent samples t-test for science vs. mathematics teachers' beliefs

Variable	N	M	SD	t	p
Group					
T0 Science Teacher Beliefs	12	17.46	3.44	*t*(12) = -4.65	0.00
T1 Science Teacher Beliefs	12	19.85	5.97		
Group					
T0 Mathematics Teacher Beliefs	9	17.25	4.21	*t*(7) = -2.01	0.08
T1 Mathematics Teacher Beliefs	9	19.13	4.13		
Group					
T0 Science Teacher Beliefs	12	17.46	3.44	*t*(14) = -0.24	0.82
T0 Mathematics Teacher Beliefs	9	17.25	4.21		
Group					
T1 Science Teacher Beliefs		19.85	5.97	*t*(17) = -0.73	0.48
T1 Mathematics Teacher Beliefs		19.13	4.13		

Paired-samples t-tests and independent samples t-tests were conducted to address the fourth research question. The results of paired-samples t-test conducted to determine whether there was a difference in the scores for novice teacher at T1 vs. T0 showed a statistically significant difference in their beliefs over the one-year period. The results of another paired-samples t-test revealed that there was a statistically significant difference in experienced teacher participants' beliefs at T1 vs. T0. Independent samples t-tests compared novice and experienced teachers' beliefs at T0 and again at T1, and both tests found no significance at T0 or T1 (Table 6).

Table 6. Paired-samples t-tests and independent samples t-test for novice vs. experienced teachers' beliefs

Variable	N	M	SD	t	p
Group					
T0 Novice Teacher Beliefs	9	2.78	3.44	*t*(8) = -4.43	0.00
T1 Novice Teacher Beliefs	9	19.99	1.86		
Group					
T0 Experienced Teacher Beliefs	12	17.25	4.39	*t*(11) = -2.84	0.02
T1 Experienced Teacher Beliefs	12	19.33	7.88		
Group					
T0 Novice Teacher Beliefs	9	17.56	2.78	*t*(19) = 0.37	0.71
T0 Experienced Teacher Beliefs	12	17.25	4.39		
Group					
T1 Novice Teacher Beliefs	9	19.99	1.86	*t*(17) = 0.60	0.56
T1 Experienced Teacher Beliefs	12	19.33	7.88		

Discussion

This study examined the beliefs of middle school science and mathematics teachers in the United States over a one-year period. In the following, results are addressed by research question.

Research Question 1: To what extent do middle school science and mathematics teachers' beliefs change based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?

The results show that the science and mathematics teacher participants significantly changed their beliefs over the one-year period. It appears that the iSMART courses had an impact on the teachers' beliefs, which moved toward more student-centred positions at T1. This finding supports previous studies that show teacher beliefs can be affected through personal experiences, prior knowledge, and formal education which include teacher education and professional development interventions (Apostolou & Koulaidis, 2010; Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Jones & Leagon, 2014; Pajares, 1992; Richardson, 1996).

This outcome was expected based on two main factors. First, both science methods instructors did not assume the teacher participants held similar beliefs about teaching and learning (Cronin-Jones, 1991). Second, based on this assumption, instructors included activities and assignments that were designed to elicit and challenge teacher beliefs (Brousseau & Freeman, 1998; Horak & Lunetta, 1979; Kagan, 1992). Specifically, both iSMART science methods courses were designed to elicit and challenge teacher beliefs by including explicit and reflective inquiry-based instruction, discussions, readings, and assignments. Activities were designed to challenge students' prior beliefs about science content, the nature of science, and science pedagogies.

Research Question 2: To what extent do middle school science and mathematics teachers' beliefs about teaching and learning change based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?

The results indicate that the science and mathematics teacher participants significantly changed both their beliefs about teaching and their beliefs about learning over the one-year period. The iSMART program provided multiple activities, discussions, and readings about research on the impact of pedagogy in the science classroom and about student learning. The science methods courses also helped participants to recognize the interconnectedness of teaching with learning. Both science methods courses encompassed the knowledge, beliefs, and skills necessary for effective teaching for the learning of science.

The science methods courses, in discussions and explorations of inquiry-based teaching, emphasised the connection between teaching science with inquiry and students' science learning. In fact, repeated discussions were held regarding how inquiry-based instruction and lecture-based methods affect student learning outcomes. The course also emphasised teaching science as inquiry to represent how scientists do science in the field. Numerous pieces of evidence to support the importance of inquiry were integrated through research-based articles, national documents (NGSS Lead States, 2013; NRC, 1996), and the participants' own personal experiences as they implemented inquiry in their classroom. The focus on the connection between teaching science with student-centred inquiry and students' science learning may have led to teachers' beliefs about teaching and about learning to move toward more student-centred positions.

Research Question 3: To what extent are there differences between middle school science teachers' and middle school mathematics teachers' beliefs based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?

The results demonstrate that the science teacher participants significantly changed their beliefs over the one-year period toward views that were more student-centred. The mathematics teachers, however, did not significantly change their beliefs over time. This was surprising because the science methods courses were designed to address the beliefs of both groups of teachers.

There are two potential reasons for this unexpected result. First, closer inspection of the data showed that there was one mathematics teacher whose beliefs scores moved from more student-centred to more teacher-centred over the one-year time frame. Out of curiosity, the researcher removed this outlier and found that the results then were significant at the .01 level. In other words, without the scores from this participant, the results would have indicated a significant change in the mathematics teachers' beliefs between T0 and T1.

The second reason is due to the TBI's design, which reveals beliefs about science teaching and learning. The mathematics teachers may not have developed sufficient formal knowledge to change beliefs about science. As noted, personal experiences, prior knowledge, and formal education have an impact on beliefs (Apostolou & Koulaidis, 2010; Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Jones & Leagon, 2014; Pajares, 1992; Richardson, 1996). The mathematics teacher participants had years of personal experiences as science students but did not teach science or engage in science teaching professional development. Their personal experiences as students may have been in teacher-centred science classrooms that did not implement inquiry-based instruction. The years spent in this environment may have strongly influenced the mathematics teacher participants' beliefs system, making it resistant to change, even though they participated in two semesters of science methods courses.

The results also indicated that, when science teacher beliefs were compared with mathematics teachers' beliefs, there were differences in beliefs at point T0 or T1. This was unexpected, as the results also indicated that science teachers significantly changed between T0 and T1, while the mathematics teachers did not significantly change during the same period. Overall, the science teachers' beliefs and the mathematics teachers' beliefs were not statistically different at the start of the study nor were the science teachers' scores significantly different at the end of the study. It appears that the scores for science and mathematics teachers differed to some degree but that science teachers moved toward student-centred beliefs more so than did their mathematics counterparts.

Research Question 4: To what extent are there differences between beginning (0-5 years) middle school science and mathematics teachers' beliefs and experienced (6 or more years) middle school science and mathematics teachers' beliefs based on two semesters of online instruction that emphasises student-centred inquiry-based instruction?

This study found that both novice and experienced teachers experienced a shift in their beliefs toward more student-centred orientations. This appears to stand in contrast to research by Luft (2001) and Simmons et al. (1999). In both of these studies, however, the researchers found that experienced teachers were less likely to shift in beliefs when compared to their novice peers. Although experienced teachers' beliefs shift less, they do shift nonetheless. This study confirmed that both beginning teachers and experienced teachers' beliefs shifted toward more student-centred orientations. This is important to know when examining the connection between beliefs and practice and when designing teacher education and professional development interventions for a specific population of participants.

Although other researchers have found that experienced teachers' beliefs shift less than do their beginning counterparts', this study did not find that novice teachers' beliefs shifted more than those of the experienced teachers. The novice teachers' and experienced teachers' beliefs were not significantly different at T0 or T1. This appears to indicate that the novice and experienced teachers both experienced similar shifts in beliefs.

Implications

The results of this study support long-established research that teachers' beliefs are a critical area of study. Beliefs have an impact on teacher decisions, including what to teach and how to teach (Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Haney et al., 1996; Nespor, 1987; Simmons et al., 1999). With the strong support for inquiry-based instruction to occur in K–12 science classrooms, understanding how to foster beliefs that align with student-centred instruction is of the utmost importance.

This study also supports the notion that teacher education and professional development interventions can help to shift teachers' beliefs toward more student-centred frames of mind (Apostolou & Koulaidis, 2010; Brickhouse, 1990; Crawford, 2007; Cronin-Jones, 1991; Jones & Leagon, 2014; Pajares, 1992; Richardson, 1996). The results indicate that both science and mathematics teachers' beliefs about science teaching and science learning are malleable through formal education that purposefully elicits and challenges beliefs. In addition, this study found that both novice and experienced teachers' beliefs can be influenced through formal education interventions. These are promising findings, as teacher beliefs affect what and how teachers teach.

In light of the current STEM movement, understanding teachers' beliefs has become increasingly important. It is not enough to understand science teachers' beliefs about science teaching and learning. We now also must understand the beliefs of teachers who integrate science into their curriculum as well as the ways to cultivate student-centred beliefs about science teaching and learning amongst non-science teachers. As Crawford (2007) stated, the beliefs and knowledge required for teaching are intertwined. As noted, in this study, the science teachers' beliefs were affected, while those of mathematics teachers were not. In light of the context of a program that purposefully integrated curricula to elicit and challenge science and mathematics teachers' beliefs, this finding is of concern. If mathematics teachers are to integrate science into their instruction, it is important that they develop student-centred beliefs that foster inquiry-based instruction. This study highlights the need for further study into ways to have an impact on the beliefs of non-science teachers who integrate science into their curricula.

Fundamentally, science teachers need to hold the student-centred beliefs that align with inquiry-based instruction. If teachers do not hold such beliefs about how to teach and how students learn, this will have an impact on classroom practices. Teachers are the negotiators of content and curriculum (Ramsey & Howe, 1969). Therefore, teacher beliefs are a much-needed area of further research. To build on this study, those who teach science, integrate science into their teaching, develop science curriculum, educate preservice and in-service teachers, and serve as education administrators should consider how to foster teachers' student-centred beliefs. Ultimately, working with teachers to develop student-centred beliefs about science and STEM education may increase the implementation of inquiry-based instruction that leads to students' development of scientific literacy.

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