ELECTRONIC JOURNAL FOR RESEARCH
IN SCIENCE & MATHEMATICS EDUCATION
VOL. 24, NO. 1, 86-99

ICRSME
International Consortium for Research in Science & Mathematics Education

An Analysis of Teacher Candidates' Scientific Perspective Among Different Student Groups

Nancy Caukin
Middle Tennessee State University

Angela Google
Middle Tennessee State University

Thomas M. Brinthaupt
Middle Tennessee State University

ABSTRACT

Studies indicate teachers' beliefs about their scientific epistemological views (SEVs) influence their instructional practices. In this study, we measured the SEVs of 291 undergraduate students, emphasizing comparisons based on teacher candidacy status (yes/no) and mathematics/science content area (yes/no). These comparisons examined the role that teacher preparation programs play in the development of future teachers' SEVs. Results indicate that the mathematics/science teacher candidates had, on average, higher SEV scores (more constructivist view of the nature of scientific knowledge rather than a more empiricist view) than their non-mathematics/science and non-teacher candidate counterparts. They also had higher scores on most SEV domains. Implications of measuring college students' SEV and its potential impact on teacher preparation programs are discussed.

Keywords: *science, lifeworld, identity, narrative, inquiry, curriculum*

Introduction

Epistemology is a theory of knowledge. It refers to a way of knowing what is known (Wenning, 2009). The belief of how one knows what is known in science is referred to as scientific epistemology (Wenning, 2009). Research indicates that the beliefs and values of teachers influence their instructional practices and perceptions of student learning (Abd-El-Khalick, Bell, & Lederman, 1998; Brickhouse, 1990; Sağir & Aslan, 2017; Tsai, 2006). Studying scientific epistemological views (SEVs) provides insight on beliefs about what scientific knowledge is, how it is acquired, and how it is originated (Aslan, 2017).

In order to understand the impact of teacher beliefs on the teaching-learning process, teacher education programs are increasingly evaluating the epistemological beliefs of teacher candidates (Köseoğlu & Köksal, 2015; Saylan, Armağan, & Bektaş, 2016). Because teacher candidates hold the dual roles of both student and future teacher, their beliefs about scientific knowledge is an accumulation of their K-12 experiences as well as their university experiences (e.g., teacher preparation courses and content courses). Understanding and monitoring teacher candidates' SEVs is important at this stage, so that educators and researchers can consider how teacher candidates' view the acquisition of science knowledge and how these beliefs can translate potentially into how scientific knowledge should be taught.

Scientific Epistemological Views

The epistemology of science, sometimes referred to as the nature of science (NOS), generally addresses issues including the assumptions, values, and conceptual inventions in science, consensus making in scientific communities, and characteristics of scientific knowledge (Tsai & Liu, 2005; Ryan & Aikenhead, 1992). Scientific epistemological views, or SEVs, are beliefs about how we know what we know in science and the characteristics of that knowledge (Ryan & Aikenhead, 1992). Inherent in how one views the characteristics of the knowledge of science is an understanding of the nature of science, an important aspect in science education (American Association for the Advancement of Science, 1990, 1993, 1998; Ryan & Aikenhead, 1992).

SEVs are evaluated along a continuum ranging from more naïve and empiricist/positivist-oriented beliefs to more sophisticated and constructivist-oriented beliefs. For example, a more naïve and empiricist/positivist-oriented set of beliefs might include: *Scientific knowledge depends mainly on personal efforts, rather than a consensus of scientific thinking* and *Scientific knowledge is absolute, discovered using objective means, and is not dependent on culture or human imagination and creativity*. Constructivist-oriented beliefs examples include the idea that *scientific knowledge is built on consensus, is tentative, is theory-laden and subjective, culturally and socially embedded, and involves human inference, creativity and imagination* (Abd-El-Khalick & Lederman, 1998; Tsai & Liu, 2005). Because teachers' conceptions of scientific knowledge influence students' conceptions knowledge (Lederman, 1992), there is great value in understanding teacher candidates' SEVs.

A constructivist view recognizes that knowledge is constructed by humans, subject to change, requires creativity, is influenced by personal bias, and is culturally dependent (Abd-El-Khalick & Lederman, 2000; Von Glasserfeld, 2001). People who hold a more constructivist view about science are thought to be more likely to "employ meaningful strategies in science learning, and have better attitudes toward science" than people with a more empiricist view (Tsai & Liu, 2005, p. 1622). Science instruction that focuses on a construction of knowledge, rather than focusing on a narrow set of facts or pieces of scientific knowledge, promotes better integration of knowledge and productive understanding of science (Songer & Lin, 1991).

An empiricist or positivist view of science implies the following of rules, assumptions, and methods (Jakobsen, 2013). It is characterized by a belief that science is a personal endeavor (Tsai & Liu, 2005) rather than a collective endeavor. It is also characterized as a collection of facts that represent truth (Griffin & Benson, 1994) compared to the constructionist belief that current scientific knowledge is the best explanation, given what is understood. There is some evidence that teachers who hold empiricist views about science are more likely to employ teacher-centered instructional strategies and rely on rote memorization than those with constructivist views (Tsai, 2006; Edmondson, 1989).

Teachers' and Teacher Candidates' SEVs

There is limited research into the epistemology of science views of students, teacher candidates, and teachers. For example, Edmondson (1989) found that college biology students' scientific epistemology impacted the learning strategies they employed. Those holding a positivist view relied on rote learning strategies and were oriented towards grades, whereas those holding a constructivist view engaged in meaningful learning strategies and focused on deep understanding. Students with combined positivist/constructivist beliefs utilized a variety of techniques as they searched for meaningful approaches to learning. Also studying college students, Liu, Lin, & Tsai (2011) found that scientific epistemology is connected to making socioscientific decisions. Those who are engaged in making more sophisticated decisions (i.e., used higher order thinking) tend to understand science in more constructivist terms, as a human endeavor, being tentative, and requiring creativity.

In the teacher domain, Hashweh (1996) found that constructivist teachers' beliefs tend to be stable over time and have a strong influence in their teaching. These teachers were better prepared to induce students' conceptual change. They employed effective teaching strategies such as "multi-type strategies that help with the acquisition of new conceptions, confront alternate conceptions, and facilitate cognitive restructuring" (p. 61) as compared to teachers with more empiricist beliefs. Additionally, Tsai (2006) measured the coherence of teachers' SEVs with instruction and student views. Results showed that teachers with positivist-aligned SEVs, focused more on student science scores rather than student understanding, adopted more teacher-centered lectures, and held a more passive view of learning. In contrast, teachers with more constructivist-oriented SEVs focused more on student understanding and allocated more time to student-centered inquiry activities.

While knowing experienced teachers' SEVs can help in understanding how they view science and their beliefs about scientific knowledge, knowing this about future teachers could shed light on how they might project their beliefs onto their students and thus influence their students' SEVs. Understanding one's scientific epistemological beliefs is synonymous with understanding one's beliefs about the nature of science. For decades, researchers (e.g., Lederman, 1992) have studied the development of NOS understanding as it relates to education. There is empirical evidence to support the consensus of NOS aspects (i.e., tentativeness, evidence-based, roles of laws and theories, role of culture, creativity of science, etc.) (Lederman, 1992; Liu et al., 2011; McComas, Almazroa, & Clough, 1998), its incorporation into K-12 curriculum (Achieve, 2013), effective teaching strategies for enhancement of NOS understanding (e.g., explicit-reflective approach, Peters, 2009; Wahbeh & Abd-El-Khalick, 2014), and its positive contributions towards scientific literacy (McComas et al., 1998).

Analyzing SEVs helps to clarify teachers' values surrounding what they believe to be the characteristics of scientific knowledge. The study of SEVs can serve multiple goals, including determining beliefs about scientific knowledge (Edmondson & Novack, 1993; Tsai & Liu, 2005), gaining insight into the types of learning strategies most utilized by science teachers (Edmondson & Novack, 1993), predicting instructional practices that might be employed by teachers (Brickhouse, 1990; Tsai, 2006), shedding light into how teachers might respond to socioscientific issues (Liu et al., 2011), and understanding how crucial science knowledge may be interpreted (Schommer-Aikins & Hutter, 2002).

Present Study

The purpose of this study was to determine the SEVs of undergraduate students, particularly mathematics and science teacher candidates who are in a specific mathematics/science teacher preparation program. The goal was to determine any differences in the SEVs of the mathematics and science teacher candidates compared to other undergraduate students, with the intent of considering the mathematics/science teacher preparation program and future classroom practices.

The university in this study has a combined mathematics and science teacher preparation program that is a replicate of the UTeach model from the University of Texas at Austin (https://uteach.utexas.edu/). The secondary teacher training programs at the university in this study (mathematics/science pathway and all other content area pathways) both have an inquiry approach to teacher training; however, there are differences in approach and in degree. Both focus on active learning and have a student-centered environment, where questioning, discovery, analysis, and critical thinking are key components (Bell, Smetana, & Binns, 2005; Michael, J., 2006). Regarding differences, the mathematics/science teacher training program utilizes the 5-E Lesson Plan approach with a focus on teaching using guided inquiry (Martin-Hansen, 2002) throughout all of the teacher preparation courses. While mostly implicit, the emphasis is on promoting and supporting a constructivist set of beliefs about learning mathematics and science. The pathway for all other secondary content areas uses an inquiry approach with an emphasis on problem-based learning strategies in a couple of courses, but it is not emphasized in most courses. Both pathways lead to a Residency I experience, that is tightly grounded in the problem-based learning approach (Hmelo-Silver, 2004), and Residency II (synonymous with traditional student teaching).

The researchers examined mathematics/science teacher candidates' SEVs, other secondary teacher candidates' SEVs, and mathematics or science majors' (who were not teacher candidates) SEVs. Three research questions guided this study:

1. How do SEVQ scores differ between secondary teacher candidates and non-teacher candidates (math or science majors who are not teacher candidates)?

2. How do SEVQ scores differ between mathematics/science teacher candidates and other secondary teacher candidates (non-mathematics/science)?

3. How do SEVQ scores differ between mathematics/science teacher candidates and mathematics or science majors who are not teacher candidates?

Method

Participants

The participants were undergraduate students in the College of Education and the College of Basic and Applied Sciences at a large public university in the southeast United States. Students from the College of Education were enrolled in either the secondary mathematics/science teacher preparation program or in the secondary non-mathematics/science teacher preparation program (candidates in English, history, world language, physical education, health, music, art, theater, etc.). Students from the College of Basic and Applied Sciences were non-teacher candidates enrolled in a mathematics or science course.

Participants were 237 students (139 females, 95 males, and 3 who did not report gender). Among these participants, 184 were education minors (teacher candidates) with 58 of those being math/science teacher candidates (33 women, 24 men, 1 other; 60% having a GPA of 3.1 or higher; 69% 20 years or more of age) and 126 teacher candidates having another major (English, history, physical education, art, etc.) (73 women, 51 men, 2 other; 87% having a GPA of 3.1 or higher; 84% 20 years or more of age). There were 53 math/science majors, non-education minors (33 women, 20 men; 75% having a GPA of 3.1or higher; 85% 20 years or more of age).

Measures

SEVQ. Tsai and Liu's (2005) Scientific Epistemology Views Questionnaire (SEVQ) is a multi-dimensional instrument with 19 statements that measure scientific epistemological views in five domains. The SEVQ is a frequently-used scale with a reported acceptable reliability and validity (α = 0.67; α = 0.62 for this study). Respondents use a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*) to rate each item. All responses in each domain are averaged. Higher scores denote a more constructivist perspective, with lower scores denoting a more positivist perspective.

The Role of Social Negotiation (SN) SEVQ domain refers to the construction of science knowledge through communication and consensus among scientists rather than an individual effort. Examples of items in this domain include "Scientists share some agreed upon ways of looking at and conducting research" and "The discussions, debates, and results that are shared in the science community are one major factor facilitating the growth of scientific knowledge." There are six statements in this domain. The reported Cronbach's alpha score was acceptable (α = 0.71; α = 0.67 for this study).

The Invented and Creative Nature of Science (IC) domain implies that science is created rather than discovered and relies on human creativity. Examples of items in this domain include "Scientists' intuition plays an important role in the development of science" and "The development of scientific theories requires scientists' imagination and creativity." There are four items in this domain, with an alpha score of α = 0.60 (α = 0.67 for this study).

The Theory-Laden Exploration (TL) domain suggests that a scientists' personal views, bias, and assumptions influence science exploration. Sample items for this domain include "Scientists can make totally objective observations, which are not influenced by other factors" (reversed) and "The theories scientists hold do not have effects on the process of their exploration in science" (reversed). There are three items in this domain (α = 0.68). For this study the Cronbach's alpha was very low (α = 0.28) indicating a low reliability measure for this construct.

The Cultural Impacts domain (CU) refers to the cultural dependency of science as opposed to science being a Western endeavor. Items in this domain include "People from different cultural groups have the same method of interpreting natural phenomena" and "Scientific knowledge is the same in various cultures." There are three statements in this domain (α = 0.71; α = 0.50 for this study).

Finally, the Changing and Tentative Feature of Science Knowledge (CT) domain implies that science is dynamic rather than static. Sample items from this domain include "Contemporary scientific knowledge provides tentative explanations for natural phenomena" and "Currently accepted science knowledge may be changed or totally discarded in the future." There are three questions in this domain (α = 0.60; α = 0.50 for this study).

Procedure

After IRB approval was obtained, the researchers sought permission to administer the SEVQ from instructors of targeted courses. Courses included those for the preparation of undergraduate secondary education minors (eight courses in the College of Education, four of which were exclusive to math and science teacher candidates and three exclusive to the non-science/mathematics pathway) and math and science courses (three science classes– biology, chemistry, physics; and two math classes– calculus II and linear algebra). Once the instructors of the targeted classes gave permission, the researchers visited the classes to explain the study and invite students to participate. Students enrolled in the education courses who consented to participate received a paper version of the SEVQ, while consenting students enrolled in the math and science courses received a link to the questionnaire on a commercial online survey program. Participants who took the survey online also received a deadline to complete it.

Completed surveys were entered into a spreadsheet. For any SEVQ statements left unrated, we calculated and inserted the average for all participants on that item. The data were then exported into SPSS for analysis.

Results

On average, students scored above the scale midpoint on the overall SEVQ and on each domain. Table 1 shows the mean scores for the three groups of participants on the SEVQ and each domain. All measures showed a normal distribution of scores as measured by skewness and kurtosis scores between -1.0 and 1.0.

Table 1

Mean scores for total and domain SEVQ for all participants

	M/S TC (N = 58)		Non-M/S TC (N = 126)		NTC (N = 53)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Total SEVQ	3.83	.35	3.73	.32	3.66	.25
Social Negotiation	4.07	.44	3.98	.52	3.88	.46
Invented & Created	3.75	.75	3.73	.70	4.04	.52
Theory Laden	3.58	.67	3.44	.57	3.15	.59
Cultural Impacts	3.81	.77	3.53	.69	3.34	.65
Changing Tentative	3.94	.50	3.95	.56	3.92	.52

Note. SEVQ = Scientific Epistemology Views Questionnaire; scale midpoint = 3 (*neither agree nor disagree*). M/S TC = math/science teacher candidates; Non-M/S TC = non-math/science teacher candidates; NTC = non-teacher candidates.

Research question #1 sought to determine the difference between teacher candidates and non-teacher candidates. Independent *t*-tests compared the SEVQ scores of the two groups (see Table 2). On the total SEVQ score, the difference was insignificant (p = 0.59). There were, however, statistically significant differences in the domains of Invented and Creative Nature of Science (non-teacher candidates outscoring teacher candidates), and Theory-Laden Exploration and Cultural Impacts (teacher candidates outscoring non-teacher candidates).

Table 2
SEVQ comparison of teacher candidates and non-teacher candidates

	Mean	*SD*	*p*	η^2
Total SEVQ				
Teacher Candidates	3.76	.34	.059	0.02
Non-Teacher Candidates	3.66	.25		
Social Negotiation				
Teacher Candidates	4.02	.50	.110	
Non-Teacher Candidates	3.89	.46		
Invented & Creative				
Teacher Candidates	3.73	.71	.003	.038
Non-Teacher Candidates	4.05	.52		
Theory Laden				
Teacher Candidates	3.49	.60	.001	.049
Non-Teacher Candidates	3.16	.59		
Cultural Impacts				
Teacher Candidates	3.60	.73	.026	.021
Non-Teacher Candidates	3.35	.65		
Changing & Tentative				
Teacher Candidates	3.95	.54	.715	
Non-Teacher Candidates	3.92	.52		

Note. N= 84 for teacher candidates and N=53 for mathematics/science majors who are not teacher candidates. Scale midpoint was 3 (*neither agree nor disagree*).

Research question #2 centered on the difference in SEVQ scores between mathematics/science teacher candidates and non-mathematics/science teacher candidates; research question #3 investigated the difference in SEVQ scores between mathematics/science teacher candidates and mathematics or science majors who are not teacher candidates. To address these questions, we conducted one-way ANOVAs to determine significant differences between the three groups on the overall SEVQ and each domain. Table 3 reports the results of the F-tests. These results show statistically significant differences for total SEVQ, as well as the Invented & Creative, Theory Laden, and Cultural Impacts domains.

Table 3

SEVQ scores for mathematics/science teacher candidates (N = 58), non-mathematics/science teacher candidates (N = 126), and mathematics or science majors who are not teacher candidates (N = 53)

Categories	F	p	η^2
Total SEVQ	3.97	.020	.034
Social Negotiation	1.93	.147	.019
Invented & Creative	4.63	.011	.035
Theory Laden	7.00	.001	.061
Cultural Impacts	6.35	.002	.054
Changing & Tentative	0.08	.927	.001

Note. SEVQ = Scientific Epistemology Views Questionnaire; scale midpoint = 3 (*neither agree nor disagree*).

For categories that demonstrated a significant difference in the one-way ANOVA, a Bonferroni post hoc test was run to identify which groups significantly differed. There were statistically significant differences ($p < .05$) in the total SEVQ, Theory Laden, and Cultural Impacts with a borderline difference ($p = .057$) in the Invented and Creative domain. Table 4 shows the groups that differed significantly in SEVQ scores according to these tests.

As Table 1 shows, the mathematics/science teacher candidates outscored their mathematics or science major counterparts (non-teacher candidates) in the overall SEVQ and on four of the five subscales with significance (see Table 4) in total SEVQ, Theory Laden, and Cultural Impacts. There were also statistical differences in the Invented and Creative Nature of Science with non-teacher candidates outscoring non-mathematics/science teacher candidates, in Theory Laden with non-mathematics/science teacher candidates outscoring mathematics or science majors (non-teacher candidates), and in Cultural Impacts with mathematics/science teacher candidates outscoring non-mathematics/science teacher candidates.

Table 4
Significant differences in SEVQ scores between mathematics/science teacher candidates (M/S TC), Non-mathematics/science teacher candidates (Non-M/S TC) and mathematics or science majors who are not teacher candidates (NTC)

	M/STC	Non-M/S TC	NTC	*p*
Total SEVQ	3.83		3.66	.019
Invented & Creative		3.73	4.04	.018
Theory Laden	3.58		3.15	.001
Theory Laden		3.45	3.15	.010
Cultural Impacts	3.81		3.34	.001
Cultural Impacts	3.81	3.53		.039

Note. Math/Science teacher candidates (M/S TC) N=58; Non-math/science teacher candidates (Non-M/S TC) N=126; Non-teacher candidates (NTC) N=53.

Discussion

The purpose of this study was to determine undergraduate students' views of the nature of scientific knowledge. We compared teacher candidates to non-teacher candidates, mathematics/science teacher candidates (M/S TC) to teacher candidates who are not mathematics or science majors (Non-M/S TC), and finally mathematics/science teacher candidates to mathematics or science majors (not teacher candidates- NTC). The results of this study have implications for teacher preparation programs and the potential ways that teacher candidates could impact their own students' SEVs.

Participants in this study overall reported a somewhat moderate constructivist (sophisticated) view of the nature of scientific knowledge. There were differences in the total SEVQ and three of the five domains. Assumptions were made regarding how the scores of the three groups would compare based on the teacher preparation pathway or lack of education courses. For example, we anticipated that the M/S TCs would score the highest on the total SEVQ and subsequent domains since that pathway has the most constructivist approach. We knew that between the M/S TCs and the Non-M/S TCs, both groups shared some of the same content courses in their respective major. We were not certain, however, of their exposure to a constructivist approach to teaching in those courses, but, we knew it would occur in their mathematics/science teacher preparation courses. We also knew that the M/S TCs had theory, pedagogical, and practicum classes that their non-teacher counterparts did not have. Between these two groups, there was a statistically significant difference in the total SEVQ with the mathematics/science teacher candidates outscoring the mathematics/science majors (not teacher candidates). Between mathematics/science teacher candidates and non-mathematics/science teacher candidates, the former did outscore the latter on the total SEVQ, however, it was not significant.

In considering the Non-M/S TC and their MS/TC peers, we know that they tend to not share the same mathematics/science content courses as their M/S TCs peers and may or may not have had a constructivist teaching approach in their general education science or mathematics courses. In addition, while all secondary teacher candidates share the Residency I and Residency II courses together, their pre-Residency course experiences would vary in regards to constructivist-explicit teaching practices, with the mathematics/science teacher preparation program being more explicit in their approach. The only statistically significant difference between M/S TCs and Non-M/S TCs was in the domain of Cultural Impacts (refers to the cultural dependency of science as opposed to science being a Western endeavor) with M/S TCs outscoring Non-M/S TCs. In addition, the M/S TCs significantly outscored the NTCs in this domain. Since the obvious difference between these groups is the mathematics/science teacher preparation pathway, the results could be attributed to courses in this program. While addressing the cultural impacts on science knowledge is not explicit in the curriculum, there is exposure to it through the various science education readings that some of the courses require and the program focuses on actively engaging in science and mathematical practices, inquiry learning, and constructivist strategies.

For the Theory Laden domain (suggests that a scientists' personal views, bias, and assumptions influence science exploration), we assumed that the M/S TCs would score the highest, but probably not significantly different than the NTCs and that the Non-M/S TCs would score the lowest since they would probably have the fewest mathematics and science courses. Interestingly, the M/S TCs scored the highest of all three groups; significantly higher than the NTCs but not significantly higher than the Non-M/S TCs. While there is no clear explanation for this finding, as the mathematics/science teacher candidates were all mathematics/science majors who were taking upper level content courses (some of the same as the mathematics and science majors), the M/S TCs did experience theory, pedagogy, and practicum classes that their non-teacher candidates did not. In addition, the mathematics/science teacher preparation program does address the nature of scientific endeavors implicitly and the non-mathematics/science teacher preparation program does not.

A domain in which NTCs scored higher on average than all of the teacher candidates was in the Invented and Creative Nature of Science domain (implies that science is created rather than discovered and relies on human creativity), significantly higher than Non-M/S TCs. The differences found in this domain could indicate that perhaps the lack of science and mathematics courses that the Non-M/S TCs take could impact their understanding of the Invented and Creative Nature of Science. Or that the general education science and mathematics courses are not exposing students to this aspect of the Nature of Science knowledge. Regarding the mathematics/science teacher preparation program, it could better assist teacher candidates in understanding what the American Association for the Advancement of Science (1990) describes as the logic and imagination aspects of science. Not all hypotheses automatically or naturally derive directly from data, sometimes hypotheses or explanations need to be imagined and invented in order to describe what is occurring (Abd-El-Khalick & Lederman, 2000).

Limitations and Future Research

While this study was conducted at a large public university and contained 237 participants, it has limitations. The study was conducted at only one university. The mathematics/science teacher candidates (N = 58) and non-teacher candidates (N = 53) were small compared to the non-mathematics/science teacher candidates (N = 126). The SEVQ was given at the end of a semester and thus was a single snapshot of students' self-reported answers. Additionally, the participants were from across the spectrum in the timeline of their programs, with some at the beginning of their program, some in the middle, and others at the end.

There are many possibilities for future research that stem from this study. Clarifying the reasons for the observed group differences in SEV domains is one. Capturing teacher candidates' SEVQ scores (and the reasons for their responses) as they progress through their program could paint a picture of their trajectory. Following teacher candidates into their classrooms as they become teachers and measuring their SEVQ and compare it to their students could provide insight into impact.

Implications for Practice

When considering the differences in the SEVQ scores, it gives pause to consider how to better influence teacher candidates' understanding of the nature of scientific knowledge and how teaching practices are impacted by beliefs. For example, regarding the Invented and Creative Nature of Science, we should reflect on how to help teacher candidates understand that science is a human construct rather than discovered with the expectation that this belief would translate in their own teaching. The term "discovery" is commonly used in society to describe advances in science. Perhaps discussions about the term "discovery" and how in certain contexts it represents an invented reality by scientists to best explain a phenomenon could add clarity. Also, being explicit regarding the role of creativity in creating knowledge, could assist in moving teacher candidates towards a more constructivist view.

It may be worthwhile to consider how to incorporate within the general education mathematics and science courses more explicit instruction into the nature of knowledge and scientific research. This focus could include presuppositions that researchers bring to their studies that can influence how they interpret their outcomes, the notion that knowledge is created and viewed in different ways in different cultures, the need to negotiate meaning between groups, and the changing and tentative nature of knowledge. Rowe, Gillespie, Harris, Koether, Shannon, & Rose (2015) in their article, "Redesigning a General Education Course to Promote Critical Thinking" explain how a pre-post study showed that a redesigned, interdisciplinary general education science course that focused on the nature, process, and application of science, produced better critical thinkers than the course that was not redesigned.

Conclusion

Teachers are curriculum constructors and their beliefs impact how they acquire and interpret knowledge, what and how they plan for instruction, their teaching practices, and what they believe about how students learn (Keys & Bryan, 2000). Knowing teacher candidates' beliefs about teaching and learning provides a window into ways in which they will engage future students (Erberle, 2008; Luft & Roehrig, 2007). Monitoring these beliefs during teacher preparation is advisable in order to provide appropriate experiences that will help them move towards a more constructivist view (Edmondson & Novak, 1993; Luft & Roehrig, 2007).

Teacher preparation can play a role in the development of a constructivist view of scientific processes and knowledge. SEVQ score comparisons can be used when thinking about the purpose of science education, not only in K-12 settings as indicated in the National Research Council's (NRC) *A Framework for K-12 Science Education* (NRC, 2012), but also in higher education in the preparation of future teachers. One goal promoted by the NRC is to produce scientifically literate citizens. This goal can apply to future teachers as well as students. Being scientifically literate means understanding the nature of science, being critical consumers of scientific knowledge, and having an ability to meaningfully engage in public discourse on science, technology, engineering, and mathematics (STEM) issues (Liu et al., 2011; NRC, 2012). The American Association for the Advancement of Science (1990) calls for the explicit instruction in the nature of science and recommends that science education foster curiosity, openness to new ideas, and to have informed skepticism, all of which are advanced by a constructivist view of scientific processes and knowledge.

Teacher preparation programs are in a unique position to monitor and potentially impact scientific epistemological views of future teachers. Teacher preparation programs can be instrumental in identifying teacher candidates' epistemologies of science so as to identify misconceptions and gaps in the understanding of the Nature of Science (Barnes, Angle, & Montgomery, 2015). These gaps can then be addressed before future teachers have their own students, since teacher candidates can influence the development of their own future students' understanding of the nature of scientific processes and knowledge (Conley, Pintrich, Vekiri, & Harrison, 2004). Measuring scientific epistemological views of students and considering the outcomes is one way to engage in reflective practice that can inform decision making in higher education and teacher preparation.

Nancy Caukin (Nancy.Caukin@mtsu.edu), Ed.D. is an Associate Professor and the Program Coordinator for the Secondary Ready2Teach Program in the Womack Family Education Leadership Department in the College of Education at Middle Tennessee State University. As a teacher educator, she prepares future teachers in the undergraduate and graduate programs. Her research efforts have been in the areas of science writing heuristics in secondary chemistry classes, teacher candidates' beliefs, the nature of field experiences, and teacher candidate self-efficacy.

Angela Google (Ang5a@mymail.mtsu.edu) is a PhD candidate in Interdisciplinary Sciences Education at Middle Tennessee State University. Inspired by advising undergraduate STEM majors and teaching introductory biology courses, her research seeks to develop a deeper understanding of how undergraduate students overcome barriers to success in college STEM courses, specifically students of color. In this light, she has made scholarly contributions with her research on at-risk undergraduate student preparedness for introductory STEM courses, pre-service STEM teachers' evolution of conceptualization, and engaging undergraduate biology students in authentic scientific practices.

Tom Brinthaupt's (Tom.Brinthaupt@mtsu.edu) primary area of research is the psychology of self and identity, in particular self-talk and individual differences in self-related processes. He also conducts research in personality psychology, measurement and assessment, sport and exercise psychology, and the scholarship of teaching and learning. In addition, he serves as Director of Faculty Development at the Learning, Teaching, and Innovative Technologies Center at MTSU where he promotes and supports the professional development of faculty members.

The authors received no financial support for the research, authorship, and/or publication of this manuscript.

References

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and making instructional practice: Making the unnatural natural. *Science Education, 82*(4), 417-436.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International Journal of Science 22*, 665-701.

Achieve, Inc. (2013). *Next generation science standards*. Washington DC: National Academies Press.

American Association for the Advancement of Science (AAAS, 1990). *Science for all Americans: Project 2061*. Report, New York: Oxford University Press.

American Association for the Advancement of Science. (1993). *Benchmarks for scientific literacy*. Washington, DC: AAAS.

American Association for the Advancement of Science. (1998). *Blueprints for reform: Science, mathematics and technology education*. New York: Oxford University Press.

Aslan, C. (2017). Examining epistemological beliefs of teacher candidates according to various variables. *Eurasian Journal of Educational Research, 67*, 37-50.

Bell, R. L., Smetana, L. & Binns, I. (2005). Simplifying inquiry instruction: Assessing the inquiry level of classroom activities. *The Science Teacher, 72*(7), 30-34.

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

Conley, A. M., Pintrich, P. R., Vekiri, I., & Harrison, D. (2004). Changes in epistemological beliefs in elementary students. *Contemporary Educational Psychology*, *29*, 186-204.

Eberle, F. (2008). Teaching and coherent science: An investigation of teachers' beliefs about and practice of teaching science coherently. *School Science and Mathematics, 108*(3), \ 103-112.

Edmondson, K. M. (1989). The influence of students' conceptions of scientific knowledge and their orientations to learning on their choices of learning strategy in a college introductory biology course. Unpublished doctoral dissertation. Cornell University, Ithaca, N.Y.

Edmondson, K., & Novak, J. (1993). The interplay of scientific epistemological views, learning strategies, and attitudes of college students. *Journal of Research of Science Teaching, 30*(6), 547-559

Griffin, B. E., & Benson. G. D. (1994). Scientific thought as dogmatism. *International Journal of Science Education 16*, 625-637.

Hashweh, M. Z. (1996). Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching*, *33*(1), 47- 63.

Hmelo-Silver, C. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235-266

Jakobsen, T. G. (2013). Theory of science: What is positivism? Popular social science: Bridging the gap. Retrieved from http://www.popularsocialscience.com/2013/02/15/theory-of-science-what-is-positivism/

Keys, C., & Bryan, L. (2000). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching*, *38*(6), 631-645.

Köseoğlu, P., & Köksal, M. S. (2015). Epistemological predictors of prospective biology teachers' nature of science understandings. *Eurasia Journal of Mathematics, Science & Technology Education 11*, 751-763.

Lederman, N. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331-359.

Liu, S. Y., Lin, C. S. & Tsai, C. C. (2010). College students' scientific epistemological views and thinking patterns in socioscientific decision making. *Science Education, 95*, 497-517.

Luft, J., Roehrig, G. (2007). Capturing science teachers' epistemological beliefs: The development of the Teacher Beliefs Interview. *Electronic Journal of Science Education, 11*, 38-63.

Martin-Hansen, L. (2002). Defining inquiry: The many types of inquiry in the science classroom. *The Science Teacher, 69*(2), 34-37

McComas, W. F., Almazroa, H., & Clough, M. P. (1998). The nature of science in science education: An introduction. *Science & Education 7*, 511-532.

Michael, J. (2006). Where's the evidence that active learning works? *Advances in Physiology Education, 30*(4), 159-167.

National Research Council (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington DC: The National Academies Press. Retrieved from: https://doi.org/10.17226/13165

Peters, E. (2012). Developing content knowledge in students through explicit teaching of the nature of science: Influences of goal setting. *Science and Education, 21*, 881-898.

Rowe, M. P., Gillespie, B. M., Harris, K. R., Koether, S. D., Shannon, L.Y., & Rose, L. A. (2015). Redesigning a general education science course to promote critical thinking. *CBE Life Sciences Education, 14*(3). Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4710388/?report=classic

Ryan, A. G., & Aikenhead, G. S. (1992). Students' preconceptions about the epistemology of science. *Science Education, 76*, 559 – 580.

Schommer-Aikins, M., & Hutter, R. (2002). Epistemological beliefs and thinking about everyday controversial issues. *The Journal of Psychology, 136*, 5-20.

Song, N. B. & Lin, M. C. (1991). How do students' views of science influence knowledge integration? *Journal of Research in Science Teaching, 28*(9), 761-784.

Tsai, C. C., & Liu, S. Y. (2005). Developing a multi-dimensional instrument for assessing students' epistemological views towards science. *International Journal of Science Education, 27*, 1621-1638.

Tsai, C. C. (2006). Teachers' scientific epistemological views: The coherence with instruction and students' views. *Science Education, 91*(2), 222-243.

Von Glasserfeld, E. (2001). The radical constructivist view of science. *Foundations of Science 6*, 31-43.

Wahbeh, N. & Abd-El-Khalick, F. (2014). Revisiting the translation of nature of science understandings into instructional practice: Teachers' nature of science pedagogical content knowledge. *International Journal of Science Education, 36*, 425-466.

Wenning, C. (2009). Scientific epistemology: How scientists know what they know. *Journal of Physics Teacher Education, 5,* 3-15