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Knowledge, Monitoring, and Beliefs:

A Comparative Analysis among Preservice Teachers from Three Different STEM-focused Programs

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Abstract: *In the current study, we investigated how preservice teachers (N = 242) from three different teacher-training programs with a STEM focus, namely the Elementary Education (ELM), Science Education, and Mathematics Education, compare with respect to science content knowledge, metacognitive monitoring, and their belief system. Findings revealed that the ELM preservice teachers reported higher levels of science reformed beliefs (e.g., constructivist instruction), but low science content knowledge and teaching efficacy beliefs. Alternatively, Science Education students exhibited the highest levels of content knowledge, accurate monitoring, and higher teaching efficacy beliefs. Implications for teacher education programs with a STEM training focus are discussed.*

Keywords: teacher preparation; content knowledge; monitoring, teacher beliefs.

Currently, there are many calls for action to prepare better teachers with strong content knowledge and reform oriented pedagogical skills (e.g., AACTE, 2007; NAS, 2006). National reports (i.e., NRC, 2011; NSTA, 2004) recommend that teacher training should emphasize inquiry-based learning that focuses on the active construction of knowledge through direct experience. Given the current emphasis on reformed science teaching it is important to ensure an alignment between teachers' reformed beliefs and practices, along with strong content knowledge, high efficacy and calibration, in order to provide support for reformed instructional practices (Schraw et al., 2006).

Research shows that teachers need well-developed content knowledge to successfully teach their students (Hill, Rowan, & Ball, 2005; Kennedy, Ahn, & Choi, 2008). Teachers' coursework during their teacher education program, in addition to teaching experience, are important factors in the development of teachers' content knowledge. In addition to having a rich, interconnected knowledge base it is important to have an accurate understanding of that knowledge. Monitoring accuracy has been linked to study processes, test performance and critical thinking, and is now gaining more attention in classrooms (Hacker, Dunlosky, & Graesser, 2009).

Along with content knowledge, teachers' beliefs have a strong influence on instructional decisions and classroom actions (i.e., Peters-Burton & Frazier, 2012). Often, teachers' beliefs are grounded in their personal and academic experiences, and can explain teachers' views of effective teaching and learning, and their classroom decisions (Sampson & Benton, 2006). Research shows that teachers' instructional beliefs, epistemological and efficacy beliefs have an influence on students' academic achievement (Schraw et al., 2006). Studies demonstrate a direct relationship between teachers' instructional beliefs and innovative instructional practices (Mansour, 2009; Richardson & Liang, 2008). Additionally, epistemological beliefs, along with teachers' self-efficacy beliefs appear to play an important role in teacher science learning and development, as well as a key role in student science achievement (Hechter, 2011; Schraw, Bendixen, & Dunkle, 2002).

Unfortunately, several studies point out that a large number of preservice teachers lack the necessary knowledge and skills to effectively manage their learning (i.e., Kramarski & Michalsky, 2009; Michalsky & Schecheter, 2013). This is extremely alarming when teachers are unable to see themselves as effective learners, do not know how to monitor their learning, and their beliefs do not align with reformed science teaching practices. The aim of the current study was to investigate how preservice teachers from three different STEM (Science, Technology, Engineering and Mathematics) teacher-training programs compare with respect to their content knowledge, monitoring accuracy and beliefs. These programmatic comparisons are necessary in order to fully understand differences and to address weaknesses in various teacher-training models.

Participants were from the Elementary Education (ELM), Science Education, and Mathematics Education programs. Specifically, we compared participants from these three programs with respect to their science content knowledge, monitoring accuracy and beliefs (i.e., beliefs about teaching and learning science, self-efficacy beliefs and epistemological beliefs). The research questions we addressed were the following:

1. How do ELM preservice teachers differ from their peers, Science and Mathematics Education preservice teachers with respect to their *science content knowledge* and *metacognitive monitoring accuracy*?

2. How do ELM preservice teachers differ from their peers, Science and Mathematics Education preservice teachers, with respect to their *beliefs* (i.e., science teaching and learning beliefs, efficacy beliefs and epistemological beliefs)?

3. What are the general relationships between preservice teachers' *science content knowledge*, *monitoring accuracy* and *beliefs*?

METHODS

Participants and Context

Participants for this study included 242 preservice teacher education students from a major research university in the Southeast of United States. Demographic data indicated that 201 were females and 41 were males. Also, 103 participants were from the ELM program, 58 from Science Education, and 81 from Mathematics Education. The bulk of the students were juniors (n = 105) and seniors (n = 80) but the sample also included 8 freshmen, 36 sophomores, and 13 students classified as "other."

All participants in this study were enrolled in a traditional teacher-training program (i.e., a four-year bachelor's degree) at a major research university, and their respective programs had a strong STEM focus. In the STEM-Elementary Education program preservice teachers are required to take a total of 27 credit hours in STEM content courses (including a minimum of 12 hours in mathematics and 12 in science). Students in the Science Education program complete a total of 13 credit hours in mathematics and science; 6 credit hours are allocated for mathematical science courses and 7 credit hours for natural sciences. Students in the Mathematics Education program complete a total of 13 credit hours in general mathematics and science; 6 credit hours are allocated for mathematical science courses and 7 credit hours for natural sciences.

Procedure and Materials

Quantitative data measuring science content knowledge and beliefs (i.e., reformed science beliefs, efficacy and epistemological) were collected in the current study using a survey. All participants (N = 242) were enrolled at the time of data collection in methods courses specific to their teacher education program. The survey consisted in a science content knowledge test and beliefs inventories, all administered in one session. There was a 20-minute time limit for the content knowledge test and no time limits on the beliefs inventories. A summary of measures is presented in Appendix A.

RESULTS AND DISCUSSION

Descriptive statistics for major study variables can be found in Appendix B. The results described in this section are organized according to the primary research questions.

Differences in Content Knowledge and Monitoring Accuracy

A 3 (groups) x 4 (content knowledge and monitoring judgments) MANOVA was conducted to investigate differences between the ELM, Science Education, and Mathematics Education preservice teachers with regard to science content knowledge, confidence estimates, calibration, and response bias. A multivariate main effect for group, Pillai's trace, $V = .24$, $F(6, 456) = 10.51$, $p < .001$, was accompanied by significant univariate effects for all four dependent measures: content knowledge, $F(2, 229) = 78.96$, $p < .001$, ηp2 = .10, confidence, $F(2, 229) = 22.13$, $p < .001$, ηp2 = .16, calibration, $F(2, 229) = 11.60$, $p < .001$, ηp2 = .09, and response bias, $F(2, 229) = 10.17$, $p < .001$, ηp2 = .08.

Pairwise comparisons for science content knowledge revealed that the ELM preservice teachers scored significantly lower than both the Science ($p < .001$) and Mathematics preservice teachers ($p = .009$). However, no significant differences were found between the Science and Mathematics preservice teachers ($p = .118$). Pairwise comparisons for confidence indicated that the ELM preservice teachers had significantly lower confidence judgments than Science preservice teachers ($p < .001$) but not Mathematics preservice teachers ($p = 1.000$). Moreover, the Science preservice teachers had significantly higher confidence estimates than the Mathematics preservice students ($p < .001$). Pairwise comparisons for calibration revealed that the Science preservice students were significantly more calibrated than both the ELM preservice teachers ($p = .002$) and the Mathematics preservice teachers ($p < .001$). No differences were found between the ELM and Mathematics preservice teachers ($p = .325$). Pairwise comparisons for response bias revealed that the ELM preservice teachers were significantly different than both the Science ($p = .046$) and the Mathematics preservice teachers ($p = .045$). In addition, the Science preservice teachers were significantly different than the Mathematics preservice teachers ($p < .001$). Both the ELM and Mathematics preservice teachers were under confident as a whole in their judgments, with Mathematics preservice teachers being more extreme in their response bias. Science preservice teachers, on the other hand, had average scores that tended toward an overconfident response bias.

Differences in Teaching Beliefs

A 3 (groups) x 3 (beliefs measures) MANOVA was conducted to investigate differences between the ELM, Science Education, and Mathematics Education preservice teachers with regard to beliefs about reformed science teaching (BARSTL instrument), science efficacy (STEBI) and epistemological beliefs (EBI). A multivariate main effect for group, Pillai's trace,

$V = .90$, $F(6, 470) = 64.65$, $p < .001$, was accompanied by significant univariate effects for the BARSTL, $F(2, 236) = 44.75$, $p < .001$, ηp2 = .28, STEBI, $F(2, 236) = 259.48$, $p < .001$, ηp2 = .69, and the EBI, $F(2, 236) = 40.09$, $p < .001$, ηp2 = .25.

Pairwise comparisons for participants' scores on their beliefs about reformed science teaching and learning inventory (BARSTL) revealed that ELM preservice teachers scored significantly higher than both the Science ($p < .001$) and Mathematics preservice teachers ($p < .001$), suggesting that ELM students held more reformed beliefs about science teaching and learning than their Science and Mathematics Education peers. However, no significant differences were found between the Science Education and Mathematics Education preservice teachers ($p = .375$).

Pairwise comparisons for participants' scores on their self-efficacy beliefs for science teaching efficacy inventory (STEBI) indicated that the ELM preservice teachers had significantly lower self-efficacy for teaching science than both the Science ($p < .001$) and the Mathematics preservice teachers ($p = .004$).

Moreover, the Science preservice teachers scored significantly higher than the Mathematics peers ($p < .001$).

Pairwise comparisons for participants' scores on their epistemological beliefs inventory (EBI) revealed that the Science preservice teachers had lower scores than both the ELM preservice teachers ($p < .001$) and the Mathematics preservice teachers ($p < .001$), suggesting that Science preservice teachers held more sophisticated epistemological beliefs compared to their ELM and Mathematics preservice teachers. No differences were found between the ELM and Mathematics preservice teachers ($p = .338$) with respect to their epistemological beliefs.

With regard to the epistemological world view (EWV) inventory ANOVA procedures revealed that the three groups of preservice teachers differed significantly only on the first vignette illustrating the realist world view $F(2, 239) = 6.63$, $p = .002$, ηp2 = .05, as the ELM preservice teachers ($M = 2.75$) scored significantly lower than both the Science ($M = 3.21$, $p = .029$) and the Mathematics preservice teachers ($M = 3.30$, $p = .002$). However, no significant differences were found between the Science and Mathematics preservice teachers ($p = .882$) with respect to their scores on the epistemological world view inventory.

General Relationships

Correlations between content knowledge, metacognitive judgments, and beliefs variables are presented in Appendix C. Science content knowledge is significantly related to each of the other six variables with the exception of the reformed science beliefs inventory (BARSTL). Preservice teachers in our sample with higher content knowledge also tended to make more confident judgments, were more accurate in their judgments, and also tended to be more under confident. These students also tended to have higher teaching efficacy and reported to have more complex epistemological beliefs.

CONCLUSION

Study results show that Science Education preservice teachers in the current study exhibited higher levels of science content knowledge, more confidence and more accurate monitoring of that knowledge, and higher levels of science teaching efficacy than ELM preservice teachers. The ELM preservice teachers reported lower science content knowledge and efficacy, but higher levels of reformed beliefs than both Science and Mathematics preservice teachers. Such results might indicate the intense exposure of the ELM preservice teachers to science teaching reform orientations and educational theories that support constructivist approaches to teaching and student-centered instruction. This is not surprising given the fact that K-5 teaching is more oriented towards a student-centered approach and is focused on collaborative, constructivist learning (Poon et al., 2012).

Within group comparisons analysis regarding participants' epistemological world views showed that all three groups of preservice teachers favored the contextualist perspective on teaching (i.e., knowledge is constructed, has authentic applications, and is changeable) over the realist perspective (i.e., knowledge is fixed and unchangeable) or relativist perspective (i.e., knowledge is constructed and is subjective). So, when given the option, most participants did choose an epistemological perspective that aligns with more contemporary reform movements in science education, such as adopting a constructivist perspective in teaching, inquiry-based learning and student-centered instruction. These findings have implications for teacher education, considering that research shows that students with less sophisticated epistemological beliefs generally achieve less than students with more complex, sophisticated epistemological beliefs, even when other variables are constant (Schommer-Aikins, 2002).

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Appendix A

Measures and data sources

Instruments/Measures	Short Description
*Science Knowledge Test (*SKT, Thomson & Nietfeld, 2016)	SKT is a 20-item, four-option multiple-choice test of science knowledge drawn from practice items for the Biology and General Science *Praxis II* test. The overall mean for the test was 12.34 (*SD* = 2.69, α = .56).
Beliefs about Reformed Science Teaching and Learning (BARSTL, Sampson & Benton, 2006)	BARSTL is a 24-item inventory (5-point Likert scale) measuring beliefs about science reform in four categories: *how people learn about science*, *lesson design and implementation*, *characteristics of teachers and the learning environment*, and *the nature of the science curriculum*. A total sum score across the four categories was used in the analysis (α = .70).
Science Teaching Efficacy Beliefs (STEBI, Enochs & Riggs, 1990)	STEBI is a 23-item inventory to measure *personal teaching efficacy* and *outcome expectancy* for teaching science. The 13 items under *personal teaching efficacy* (five-point Likert scale) were used in this study. A sum score was created across the 13 items for the analysis (α = .83).
Epistemic Beliefs Inventory (EBI, Schraw, Bendixen, & Dunkle, 2002)	EBI is a 32-item inventory to measure five different factors regarding the nature of knowledge and the origins of individuals' abilities. The factors include *certain knowledge* (i.e., absolute knowledge exists and will eventually be known), *simple knowledge* (i.e., knowledge consists of discrete facts), *omniscient authority* (i.e., authorities have access to otherwise inaccessible knowledge), for *quick learning* (i.e., learning occurs in a quick or not-at-all fashion), and for *fixed ability* (i.e., the ability to acquire knowledge is fixed). A total sum score was calculated (α = .67) including items (26 total) from all 5 subscales. Higher scores represented less complex views (i.e., beliefs in simple knowledge).
Epistemological World View (EWV, Schraw & Olafson, 2002)	EWV is comprised of three vignettes (one paragraph each) that represent *realist*, *relativist*, and *contextualist* perspectives on learning science. Respondents were asked to report the extent to which they agree with each perspective on a 5-point Likert scale.
Monitoring Accuracy (MA)	MA was measured as part of the science knowledge test. During the science knowledge test participants placed a slash along a 100mm line to indicate confidence in their answer (Schraw & Roedel, 1994). Metacognitive monitoring ability was then calculated with two indices (Schraw, 2009) namely 1) *calibration* (precision of judgments) and 2) *response bias* (the degree of over- or under-confidence in judgments). A calibration score of 0 is perfect accuracy while a score of 1 is perfect inaccuracy (Keren, 1991). Bias, the extent of over or underconfidence, was determined by subtracting the overall performance score (exam percentage) from the average of all confidence judgments. Positive scores indicate overconfidence and negative scores indicate underconfidence (Yates, 1990).

Appendix B

Means and standard deviations of study variables

Group	Science knowledge *M/(SD)*	Science Confidence *M/(SD)*	Science Calibration *M/(SD)*	Science Bias *M/(SD)*	Beliefs about Science Teaching *M/(SD)*	Science Teaching Efficacy *M/(SD)*	Epistemic Beliefs *M/(SD)*
ELM	11.46 (2.54)	54.50 (15.30)	.35 (.07)	-.03 (.14)	85.37 (7.55)	37.25 (3.59)	69.27 (6.96)
SE	13.55 (2.34)	71.19 (15.31)	.31 (.08)	.03 (.15)	76.59 (5.65)	53.47 (5.89)	60.39 (7.53)
ME	12.54 (2.76)	54.44 (18.64)	.37 (.09)	-.09 (.18)	78.22 (4.99)	39.38 (4.26)	71.14 (7.30)
Total	12.34 (2.69)	58.61 (17.96)	.35 (.09)	-.03 (.16)	80.87 (7.44)	41.87 (7.97)	67.80 (8.32)

Note. Confidence scores represent average judgments per item. Lower epistemic beliefs scores represent views that are more complex.

ELM=Elementary Education; SE=Science Education; ME=Mathematics Education

Appendix C

Correlations between major study variables

	Measure	1	2	3	4	5	6	7
1	SKT	----	.48**	-.32**	-.27**	-.02	.22**	-.13*
2	Confidence		----	-.48**	.71**	-.01	.34**	-.20**
3	Calibration			----	-.27**	-.09	-.21**	.12
4	Response Bias				----	.01	.20**	-.11
5	BARSTL					----	-.32**	-.06
6	STEBI						----	-.36**
7	EBI							----

**p* < .05, ** *p* < .01.

SKT=Science Knowledge Test (science content knowledge); BARSTL= Beliefs about Reformed Science Teaching and Learning; STEBI=Science Teaching Efficacy Beliefs Inventory; EBI=Epistemological Beliefs Inventory.