Influence of Affective Factors on Practices in Simulated Authentic Science Inquiry

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Abstract: Science literacy is critically important but some aspects, such as epistemological beliefs about science, are difficult to define and assess. New technologies, such as simulated authentic science inquiry, may allow for better assessment of epistemology. Science Classroom Inquiry (SCI) simulations offer real-time, scalable assessment of student practices in authentic science inquiry and by extension their epistemological beliefs about science. Our previous work demonstrated that undergraduate student practices exist on a continuum of sophistication, which may be explained by differences in epistemological beliefs or affective factors like self-efficacy, metacognition, or identity. Our current study examines the relationship between affective factors and inquiry practices. Preliminary analysis suggests that students with expert-like investigations are more likely to identify as a science person. This study raises provocative questions about the intersection between inquiry practices, epistemological beliefs, and affective factors and highlights the potential of simulation-based assessment to examine abstract constructs such as epistemology.

Keywords: authentic science inquiry, epistemology, simulations, science education

Introduction

Achieving science literacy is an essential part of science education, and involves not only gains in disciplinary knowledge, but also an understanding of the practices of scientists and how those practices are used to generate science knowledge. The beliefs an individual possesses about the nature of science and how science knowledge is generated are known as epistemological beliefs. Epistemological beliefs about science influence how a student perceives, understands, and engages with scientific knowledge and are therefore critical for achieving science literacy (Peffer & Ramezani, Under Review). Although epistemological beliefs about science are recognized as important for attaining science literacy, they are difficult to define and consequently assess. For example, what makes an epistemological belief sophisticated? Existing metrics of epistemology are criticized for their static examination of what an individual knows or believes only at one point in time, design flaws that falsely assume that the participant is interpreting the assessment in the same manner as the survey author, and the lack of reliability and validity (Sandoval, Greene, & Bråten, 2016; Sandoval & Redman, 2015; Sandoval, 2005).

An emerging solution is to examine epistemology via student science practices, such as in the context of argumentation (Deng, Chen, Tsai, & Chai, 2011) or inquiry (Sandoval, 2005). Our previous work (Peffer & Ramezani, Under Review) examined the practices of experts and novices (where expertise was defined as professional experience with authentic science inquiry) in the simulated authentic science inquiry environment provided by Science Classroom Inquiry (SCI) simulations (Peffer, Beckler, Schunn, Renken, & Revak, 2015). Practices served as a proxy for examining the participants' epistemological beliefs situated in authentic science inquiry, or their Epistemology in Authentic Science Inquiry (EASI). We found that experts scored higher than novices on a pre-test assessment on their understanding of science practices, and that these scores predicted practices in authentic science inquiry. Expert-like practices included performing complex investigations aimed at uncovering an underlying mechanism of action, pursuing outside information, spending significant time in preparation before engaging in inquiry, and using tentative language when explaining research results (Peffer and Ramezani, Under Review; Peffer & Kyle, 2017). We also observed that novice practices existed on a continuum of more-or-less expert-like. Do the differences between novice participants reflect variability in their EASI, or do those differences reflect a combination of factors, such as how they identify as a science person or their self-efficacy? For example, self-efficacy has previously been shown to be related to students' epistemic beliefs about science and their motivation to learn science (Tsai, Ho, Liang, & Lin, 2011). However, we do not know how affective factors influence science practices or EASI. Here, we present our preliminary analysis of the relationship of motivation, metacognition, self-efficacy, and science identity to expert-like practices in authentic science inquiry and potentially EASI.

Methods

17 undergraduate students pursuing degrees outside the "hard" sciences (e.g. biology, chemistry, physics) participated in this study. We decided to use non-science majors because little is known about their epistemological beliefs about science and their university science courses are, for many, their last formal science experience and consequently the final opportunity to foster sophisticated epistemological beliefs. Participants included 12 females (70%) and 5 males, of all stages of degree programs (eight freshmen, three sophomores, one junior, and five senior students). All data was collected during a single two-hour session. First, students completed a pre-test. The pre-test included two Likert-style metrics, a measure of science identity (Godwin, Potvin, Hazari, & Lock, 2016) and the motivated strategies for learning questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1993), with motivation and self-regulated learning being the constructs this metric most effectively captures (Credé & Phillips, 2011). Our current analysis of MSLQ items focuses on the subscales in those categories that are most relevant to our research questions: intrinsic goal orientation, self-efficacy, and metacognitive self-regulation. The twelve identity items do not give a composite score, but each measure different constructs within disciplinary identity: recognition, competency, and interest (Godwin, Potvin, Hazari, & Lock, 2016). Out of the twelve identity items on the pre-test, our discussion will focus on the Overall Identity Item, "I see myself as a science person," which captures self-recognition with a science identity. Pre-test items were counter-balanced.

After completing the pre-test, students logged into a SCI simulation module that presents a current biological phenomenon relevant to the western United States: the avian range expansion of a nuisance bird, the Great-tailed Grackle. In the simulation, students were situated as scientists attempting to determine why the Great-tailed Grackle has moved north from its ancestral home in Mexico. Students can pursue any investigative approach that they choose, generate any number of hypotheses, examine any tests available within the simulation, and can use the in-simulation library or Internet searches to seek additional information. Actions, including the students' rationale for each decision, were saved by the SCI simulation engine. On average, the simulation took 25.23 minutes (*SD* = 10.99) to complete. The simulation logs created for each user were reviewed and coded blind by two members of the research team to determine if the investigation was complex or simple in nature. Complex investigations tend to explore multiple cause and effect relationships, often pursuing several tests and seeking information outside the simulation in a logical, systematic manner that describes a putative mechanism. Since complex investigations use a variety of sources of information and various knowledge streams, these simulation activities may indicate epistemological beliefs that science knowledge is tenuous and derived through a variety of experiments. Simple investigations are limited to pursuing a single cause and effect relationship, usually with very few tests performed or information sought outside the simulation. These investigations are also characteristic of simple inquiry as described by Chinn and Malhotra (2002), and may reflect beliefs that science knowledge is certain. Overall agreement was 82%, and differences were resolved through discussion. All statistical analysis was performed using SPSS 23.

Results

We first examined the differences in pre-test scores between students who pursued complex or expert-like investigations and those with less expert-like investigations. The MSLQ subscale categories have a mean response calculated from the relevant survey questions, and the identity metric is scored independently on a scale of 0 to 4. A total of 8 students performed investigations that were coded as complex, and 9 students performed investigations that were coded as simple. We found that students with complex investigations scored on average slightly higher on several of the MSLQ and identity items (Figure 1). Using a t-test to compare the means between these classifications, the Overall Identity Item ("I see myself as a science person") was found to be significantly different between those whose investigation style was coded as simple ($M = 1.33$, $SD = 1.22$) or complex ($M = 2.50$, $SD = 0.76$) ($t(15) = 2.32$, $p = .0345$). Although the MSLQ items did not yield a statistically significant result, students with complex investigations tended to have greater intrinsic goal orientation, self-efficacy, metacognition, critical thinking and help seeking.

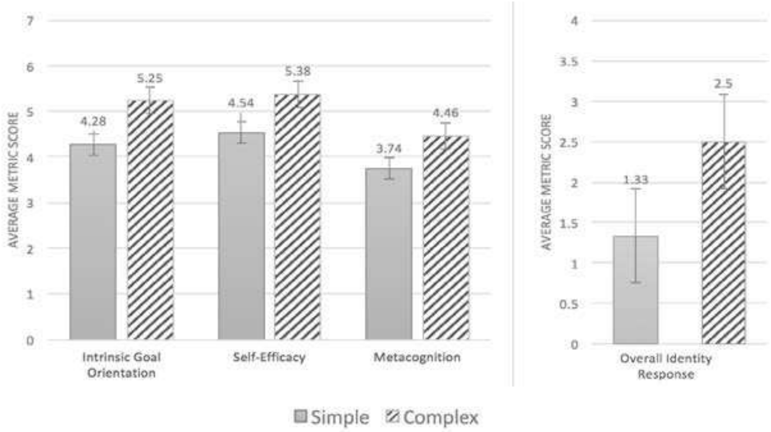

Figure 1. Differences in affective factors between students with complex or simple investigations.

We next examined differences in pre-test scores and expert-like simulation behaviors using Pearson's correlation coefficient; while our sample size was too small to do multiple regression analysis, correlations demonstrate that linear relationships may exist between these variables. We first compared students who pursued information outside their investigation and those who did not. Information seeking is known as an expert practice in both SCI simulations (Peffer & Ramezani, Under Review) and in authentic engineering tasks (Atman et al., 2007). Nine participants chose to seek outside information, while eight did not explore information beyond what the simulation provided. When compared with pre-test metrics, there were no significant differences between those who sought out information versus those who did not. However, when looking at the spectrum of actions, the number of information-seeking actions are correlated with the pre-test metrics of self-efficacy (r = .514, p = .035). Another expert-like practice, the amount of time spent preparing for investigation, which included time spent reviewing introductory material in the simulation, exploring information outside the simulation, and devising a hypothesis and testing strategy, was found to be correlated with self-efficacy (r = .514, p = .035), metacognition (r = .487, p = .047), and overall science identity (r = .512, p = .036) (Figure 2).

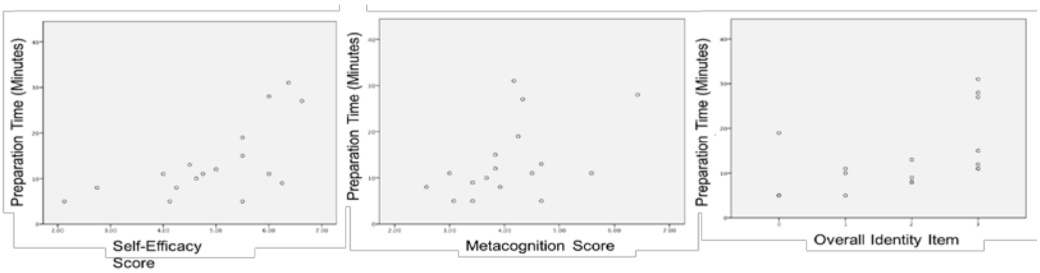

Figure 2. Correlation between Preparation Time (Minutes) and Pre-Test Metric Scores

Conclusions and discussion

While data collection is still in progress, we observed that students who view themselves as competent at science, as seen in both their MSLQ scores and their views of being a "science person," tend to demonstrate more expert-like investigations and consequently may have a more sophisticated EASI. Although the MSLQ data is not statistically significant with our current sample size, it suggests that students with more complex investigations are scoring higher across learning behavior categories. This is consistent with our identity metric, which was statistically significant. This suggests that students who identify as science people, in spite of not pursuing degrees in the sciences, have more sophisticated or expert-like investigations and potentially more sophisticated EASI.

For this study, we only examined three specific practices that may indicate a more sophisticated EASI: pursuing a complex investigative strategy, seeking outside information, and spending time preparing a hypothesis before moving on to the investigation stage of the simulation. Ongoing work will investigate the relationship of affective factors to other measures of expertise in SCI, such as the use of tentative language (Peffer & Kyle, 2017). Future work will expand existing statistical models of EASI (Peffer & Ramezani, Under Review) to include these affective factors. One limitation of this study is that participation was voluntary and students who are already confident in their science ability or who identify as science people may have been more likely to sign up to participate. Repeating this study with a different method of recruitment, such as by using SCI simulations as assignments in non-majors' science classrooms, may increase participation and reduce possible selection bias. Additionally, both identity formation and epistemological beliefs about science are dynamic processes. Since data was collected in one meeting only, we have a static view of their identity and EASI. If a student completes multiple SCI simulations, it may be that their identity, science practices, and EASI may morph over time.

This work describes our preliminary attempt to connect expert-like practices as a proxy for sophisticated EASI with affective factors such as self-efficacy and science identity. Assessing epistemological beliefs about science via practices in authentic inquiry, and the relationship of both to affective factors may provide novel insight into how students understand science, and consequently improve overall science teaching. If students view themselves as science people, or are motivated to learn science, are they more expert-like in their practices because they seek out more science opportunities and may therefore have been exposed to more science experiences? If so, perhaps encouraging a science identity may be a pedagogical focus to encourage the development of sophisticated epistemological beliefs about science. It may be that adoption of a science identity and gaining self-efficacy and motivation towards science is necessary to attain sophisticated epistemological beliefs and consequently science literacy. Since this work was done with non-science majors, perhaps these affective factors are critical for the formation of overall science literacy for all students, not just science majors who seem naturally inclined to their respective disciplines.

In conclusion, this manuscript builds on our previous work that positions SCI simulations as a method for assessing epistemological beliefs as seen via practices in authentic science inquiry. We extend our previous work to include affective measures which could influence practices in the simulation, epistemological beliefs, or both. Although additional work is needed, this work highlights a novel method for how technology can be leveraged and used in combination with existing metrics to better understand difficult to measure constructs and consequently improve educational practice.

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