PROBLEM REPRESENTATION IN SCIENCE: THE NATURE OF SCIENCE AND THE EFFECT OF EXPERIENCE

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This study examined ways in which those with varying levels of experience in the domain of science mentally represent problems within a Nature of Science (NOS) context. A triad judgment task was administered to participants (n=85) to determine whether deep, structural features (i.e. the theoretical underpinnings associated with the problem) and/or surface features (narrative characteristics of the problem) were used to interpret and represent a problem situation. Findings were consistent with results from previous studies examining problem representation and experience within a domain. That is, participants with more experience (as measured by coursework) primarily relied on the deep features to form a mental representation of a problem situation whereas those with less experience tended to rely on surface features to do so under certain conditions.

Keywords: Problem representation, Nature of Science, Science education

INTRODUCTION

This study examined the relationship between experience, as measured by college coursework (credit hours), and problem representation within the field of science, particularly within the context of the Nature of Science (NOS). According to the American Association for the Advancement of Science (1990, 1998), scientific knowledge and/or scientific ways of thinking can best be described through multiple dimensions including 1) the beliefs and attitudes of scientists, 2) the work of scientists using an inquiry approach and 3) the enterprise of science, from the work of an individual to the more complex and collegial endeavour of groups of scientists. These dimensions define NOS and can be conceptualized as general tenets driving scientific practices including the process of peer review of scientists' findings, that the work of scientists share common methods in the quest for knowledge (including data recording, validity and reliability of data) and that outside influences (social, cultural and/or historical) may impact the workings of science (Craven, Hand, & Prain, 2002). Indeed, the scientific professional societies (i.e., National Science Teachers Association, AAAS, National Research Council) have called for the teaching and learning of NOS in the K-16 curriculum (Matthews, 1994; 1998).

However, research findings suggest that those within the field of science education are not adequately prepared to teach students of philosophical tenets of science, a standard for scientific literacy as proposed by the National Science Teachers Association (National Research Council, 1996). As Abd-El-Khalick and Lederman, (2000) argue, explicit instruction may be necessary to prepare teachers for both theirs' and their students' understandings of these scientific tenets. While researchers have examined participant's conceptions of NOS (Chen, 2006; Dagher, Brickhouse, Shipman, & Letts, 2004; Martin-Dunlop & Hodum, 2009) within various contexts, few studies examine participants' concepts of NOS through a cognitive lens (Lederman, Abd-El-Khalick, & Bell, 2002). Clearly, the literature suggests that consensus on appropriate assessment of the NOS remains equivocal (Sadler & Zeidler, 2009). Thus, the authors argue that prior to interventions that "teach" the NOS, the need arises to better understand the features of problems (surface and/or deep) that science teachers use to represent the tenets of science. If the findings are similar to prior research in problem representation (Hogan, 2009; Pretz, Naples, & Sternberg, 2003; Quillici & Mayer, 1996; Wolpert, 1990), researchers may have further reason to design interventions for novices to try and improve their representational skills to better reflect more expert-like approaches, specific to the ways in which one represents the NOS.

RESEARCH STUDY

To assess problem representation, this study consisted of a triad judgment task and was a modified replication of studies in physics, chess, and mathematics to determine if their general findings hold true to those in science education (Chi, Feltovich, & Glaser, 1981; Quillici & Mayer, 1996; Shoenfeld & Hermann, 1982). Specifically, if those with more experience in the domain represent problems in their domain in terms of deep, structural features defined as the theoretical underpinnings of NOS including peer review, repeatability and tentative nature of findings while those with less coursework in the field tend to rely on surface features defined as the narrative characteristics of the problem including the scientific field of study, area of scientific expertise, and the problem being studied.

PARTICIPANTS

Participants (N = 85) consisted of graduate and undergraduate students enrolled in a science teacher preparation program seeking either an elementary education certification (n = 20) or an adolescent certification in science education (n = 38) and undergraduates (n = 27) enrolled in a beginning-level science course offered through the liberal arts and science department at two moderate size comprehensive colleges located in the Northeastern United States. The participant pool was divided into two groups dependent upon the number of science courses completed: those with 0-3 course experiences (n = 41) were considered less experienced (novices) while those with 13 or more courses (n = 44) were considered experienced. The task was administered to participants during a science methods course or an undergraduate biology course.

DESCRIPTION OF TASK

The *Triad Judgment Task* was defined by a triad of scenarios (one target problem and two source problems) and required participants to identify which of two given source problems "goes best" with a target problem (Figure 1). The source problems shared either similar surface features or structural features with the target problem. Surface features were similar in that the story narrative shared common characteristics while similar structural features involved the philosophical tenets of science (i.e. peer review, repeatability and tentative nature of findings).

<table>
<tr><td colspan="2">A geneticist has just completed the analysis of data from a long-term longitudinal study examining the relationship between genetic dispositions and obesity. The purpose of her study was to verify other researchers' findings that have found a positive correlation between these two factors.</td></tr>
<tr><td>A geneticist has just completed the analysis of data collected during a long-term longitudinal study examining the relationship between genetic dispositions and obesity. She has been invited to share her findings before a panel of researchers to see if it merits inclusion in a congressional hearing charged with setting public health policy on this topic.</td><td>A hospital medical doctor wanted to confirm the findings of a study on the detrimental effects of second hand smoke among adolescents living in single and two-parent homes where parents were smokers or non-smokers. She designed a similar study and found that there is indeed an increased rate of asthma for those adolescents living in an environment in which two parents smoked.</td></tr>
</table>

Figure 1: Triad Example (Comparison Type II)

Three sets of comparison types (six triads per type for a total of 18 triads) were developed for participant evaluation. Comparison types (I, II, and II) were defined by whether the source scenarios shared deep, surface or no similarity with the target problem (Table 1). Specifically, Comparison Type I (Similar Surface/Dissimilar Surface and Deep: SimS/DisS&D) was defined as one source problem sharing only surface similarity with the target while the other source shared no common feature with the target (either surface or deep). Comparison Type II (SimS/ SimD) included surface similarity between one source and the target while the other source problem shared deep features with the target and lastly, Comparison Type III (SimD / DisS&D) was defined as one source sharing only deep features with the target while the other source shared no common feature with the target. The purpose for this design was to determine if specific features (either surface or deep) were "weighted" differently under certain situations dependent upon (course) experience within the domain of science when developing a representation. The scenarios presented in the *Triad Judgment Task* represented components from the three dimensions of the NOS as outlined by the document, *Science for All Americans* (1989) and were written by the researchers to exemplify situations that typically emerge from the field of science. Validity of each scenario was ensured.

Problem type	**Source example 1**	**Source example 2**
I SimS / DisS&D	*Similar surface* / Dissimilar deep (Points earned: 1)	Dissimilar surface / Dissimilar deep (Points earned: 0)
II SimS / SimD	*Similar surface* / Dissimilar deep (Points earned: 0)	Dissimilar surface /*Similar deep* (Points earned: 1)
III SimD / DisS&D	Dissimilar surface / *Similar deep* (Points earned: 1)	Dissimilar surface / Dissimilar deep (Points earned: 0)

Table 1: Surface and deep structure of source examples in relationship to target problem by problem type (with points earned for selection by participant in parenthesis)

RESULTS

To determine if participants with more experience in the field of science performed differently from those with less experience on the *Triad Judgment Task*, three sets of comparisons were analyzed through a 3 (comparison type; within-subject) x 2 (experience level; between-subject) design and the data were analyzed using an ANOVA. The analysis indicated a significant main effect of experience level $F\ (1.83) = 4.26,\ p < .04$ for Comparison Type III and Total Score $F\ (1.83) = 3.87,\ p<.05$. Between group differences for Comparison Types I and II were non-significant.

Though significant differences were found between groups for Comparison Type III and Total Score, a planned comparison in which the mean for Comparison Type III was used against the value to test whether the participants in each group were arbitrarily making selections or whether the experienced participants were using deep features as a basis of selection (a value of 3 would represent random selection) was conducted. The mean for experienced (4.61, SD=1.30, [t -(43) = 8.25]) was significantly different from the value of 3 indicating that the participants were making their selections using deep features.

DISCUSSION

Findings in the present study were congruent to studies in other domains (Hardiman, Dufresne, & Mester, 1989; Hogan, 2009, 2008) in that those with experience tended to represent problems on deep features when surface similarity was not present. However, when surface similarity was present, both groups tended to use this feature to mentally define the problem. While this finding is consistent with studies in other domains, its explanation remains somewhat equivocal. However, it has been hypothesized that there is interference in mirroring an expert-like approach to problem representation under conditions such as Comparison II from the natural outcomes connected to schema activation (Hogan, 2008). Surface features remain a part of currently activated schema and thus, may be used initially to represent a problem. And yet, research suggests that the ability to represent problems through principles rather than surface features is important in that deep representation is one of the hallmarks of expertise and necessitates successful problem solving (Novick & Bassok, 2005; Pretz et al., 2003). Thus, further research is needed in this area.

Furthermore, the methodology used in this study (triad judgment task) offers a reliable measure to ascertain performance, specifically by varying the contexts through Comparison Types and adds to the current literature documenting this task (see Hogan, 2009, 2008; Wolpert, 1990). Historically, studies examining problem representation have tended to rely on sorting tasks (see Chi et al., 1981; Quilici & Mayer, 1996) while studies examining conceptions of the NOS have relied on either interviews or attitude surveys (see Chen, 2006; Martin-Dunlop & Hodum, 2009) to discriminate between different populations. Thus, this task may allow for further studies examining problem representation within a specific domain.

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