Emotional Engagement in Agentive Science Learning Environments

Andrew Morozov, Leslie Rupert Herrenkohl, Kari Shutt, Phonraphee Thummaphan, Nancy Vye, Robert Abbott, and Giovanna Scalone, University of Washington, Seattle, WA, USA
Email: {amorozov, leslieh, shuttk, phonrt, nancyvye, abbottr, gscalone} @u.washington.edu

Abstract: As students engage in ambitious intellectual activities, they inevitably manage social interactions and emotional responses in the classroom. In this research, we studied fifth graders' emotional engagement in elementary science classes redesigned to offer more ambitious, agentive learning. We examined student self-reports of affective states to address the following questions: (1) Do students in "Agency" classes report more positive or negative emotional experiences, compared to students in classes that use traditional, kit-based science units? (2) To what extent do students' emotional experiences vary as a function of class? Findings indicate that, after taking classroom differences into account, students in Agency classes generally felt more positive about their experiences in science than students in kit-based classes. Next steps include exploring differences across classrooms and synthesizing research on learning, affect and identity.

Background

Since 2006, we have been engaged in design-based implementation research (Penuel, Fishman, Cheng & Sabelli, 2011) on a model of "agentive" science learning to advance students' science inquiry learning, social-emotional outcomes, and practice-linked identities. Our work involves adapting hands-on science kits in ways that offer greater student agency: Students are provided with the opportunity to direct their own inquiry on a complex problem over a sustained period of time, thereby broadening the range of investigative practices in which they engage, helping build knowledge by connecting experiences across time and place, in and out of school (NRC, 2009) and offering opportunities for original thought (Metz, 2000; Bereiter & Scardamalia, 2009; Herrenkohl & Mertl, 2011). Per Engle and Conant (2002), we encourage students "to be authors and producers of knowledge with ownership over it rather than the mere consumers of it, and [encourage] teachers and other members of the learning community to position students as stakeholders by publicly identifying them with the claims, approaches, explanations, designs, and other responses to problems that they pursue" (p. 404).

Our redesigned science kits are challenge-based (Schwartz, Lin, Brophy, & Bransford, 1999): Each redesigned unit 1) has an overarching challenge (problem) that connects unit lessons; 2) links to students out-of-school science practices and experiences using student self-documentation; 3) offers sustained, in-depth study of science concepts/practices in the context of the overarching problem; 4) involves student-guided inquiry (with teacher scaffolding), and; 5) culminates in a public performance and "call to action" on a local science-related issue. The investigative practices that we embed in these units encompass many of the NGSS practices; for example, students generate their own investigative questions, design investigations to address these questions, engage in argumentation from evidence, construct explanations and used data from investigations to solve problems.

Theoretical Framework and Significance of the Work

Research suggests that providing students with greater agency to wrestle with science questions and problems can benefit learning (e.g., NRC, 2000). Additionally, metacognitive benefits may accrue as students monitor and reflect on their knowledge and progress in the context of solving problems about which they care (Brown, 1978; Herrenkohl, et al., 1999), and if learners are appropriately scaffolded in their efforts (White & Frederiksen, 1998).

Emotional Engagement in Learning

In addition to learning and metacognition, we speculate that there may also be important social-emotional benefits of agentive learning. As students engage in these ambitious intellectual activities, they inevitably manage social interactions and emotional responses in the classroom. Students may develop skills such as motivation, grit and persistence, adaptability and communication, self-concept and identification as science learners, social belonging, and self-regulation together with their conceptual and epistemological skills. Recent economic studies suggest that these social-emotional skills play an important role in long-term social and economic success related to schooling and career choices, employment, and wages (e.g., Heckman, Stixrud, & Krzua, 2006).

Several learning sciences researchers have begun over the past decade to theorize about the connections between social emotional constructs, such as identity, and learning (Herrenkohl & Mertl, 2011; Nasir, Lee, Roseberry & Warren, 2006; Engle et al, 2008; Esmonde & Langer-Osuna, 2007; Gresalfi, 2009). Some have coined terms like "intellective identities" (Greeno, 2002) to emphasize how students' sense of competence intersects with their conceptual and epistemological abilities.

Building on interpretations of Spiro (1982) and Dreyfus (1984), Holland{ XE "Holland" }, Lachicotte{ XE "Lachicotte" }, Skinner, & Cain (1998) examined how expertise and interest develops together in a non-scientific domain. Holland et al.'s study of young women's approaches to romance demonstrated that "salience, identification, and savoir faire appeared to develop together in an interrelated process – a process that was continually supported and shaped in the context of social interaction{ XE "social interaction" }" (p.116). In other words, as women developed greater competence in navigating the romantic scene, their evaluation of the importance of romantic pursuits, their emotional{ XE "emotional" } investment in this activity, and their desire to continue intensified. Holland and her colleagues suggest that positive emotional engagement and expertise function as a system, with one supporting the development of the other. This theoretical stance suggests that the development of expertise in scientific inquiry is inextricably linked to the development of interest and the management of positive emotional responses that support students to seek out further opportunities to engage in scientific practices.

Although these aspects of interest and emotional response are theoretically supported, there is very little empirical data available to examine these relationships. In the present study the relationship of student agency and affect in science is explored. This paper derives from a larger comparative research study conducted in the 2012-13 school year in which three 5th grade Full Option Science System (FOSS) science units (representing a school year long intervention) were redesigned to offer students greater agency for their learning. Outcomes, in the present case affective outcomes, were then compared to outcomes for students participating in the original FOSS units. The study addresses the following two questions: (1) Do students in the redesigned Agency unit report more positive or negative affect, compared to students taking the FOSS unit? (2) To what extent do these emotional experiences vary with the units if classroom effects are taken into account?

Method

Participants

Participants were from an urban/suburban school district in the Pacific Northwest that serves approximately 18,000 students. We collaborated with teachers from several elementary schools in the district to study the effects of the redesigned science units (Agency units), as compared to FOSS' kit-based units.

The participants in this study were 180 fifth grade students from 5 Agency classes across 2 schools, with 21 to 24 students per class (n=113) and 3 FOSS classes across 2 other schools, with 21 to 24 students per class, (n=67). The percentages of Free and Reduced Lunch students were 44% and 25% for the schools with the Agency classes, and 37% and 46% for the schools with the FOSS classes. The percentages of students receiving ELL services were 20% and 37% for schools with the Agency classes, and 16% and 29% for schools with the FOSS classes. The Agency classes were taught by two teachers, one of whom (a Science Specialist) taught four classes at one of the schools. The FOSS classes were taught by different teachers.

Measures

To measure students' affect related to their experiences in science, students were periodically asked to complete an Exit Card (EC) at the end of science class. It contained 10 adjectives: Excited, Frustrated, Challenged in a Good Way, Interested, Bored, Confused, Confident, Helpful, Like a Scientist and Creative. Students were asked to circle all adjectives that described *how they felt today in science class.* The EC took students 1-2 minutes to complete.

Procedure

The findings reported here are based on data collected in January-March 2013 comparing a traditional, kit-based, 5th grade FOSS *Landforms* earth science unit, and one of our redesigned units. In the redesigned version of the FOSS *Landforms* unit, My Skokomish River Challenge (MSRC), students used stream tables to study the impact of various factors on erosion. The generation of empirically testable questions was completed as a whole-class activity. This is followed by three investigation cycles in which students work collaboratively in small groups to select a question, design and conduct an experiment to answer that question, analyze data, and share their findings. Their findings inform their response to the unit challenge – determining which of three construction sites should be chosen in order to cause as few problems due to erosion as possible. Although the purpose for selecting the sites was hypothetical, the sites themselves were real places within driving distance of the schools.

Agency students completed Exit Cards 7 times distributed over the course of the 12-week redesigned Landforms unit; FOSS students completed Exit Cards on 6 occasions. Teachers administered the EC to students; however, students' responses were anonymous to their teachers. Students "signed" their ECs with unique codes that only the research team was able to link with their names/identities.

Analysis

Principal components analysis with varimax rotation was used to calculate two component scores (those with eigenvalues greater than 1) based on the exit card ratings. Hierarchical linear models (HLM) were then used to study the effect of the unit intervention on component scores based on the exit card data, since the ratings by students were nested within classrooms.

Results

Construct Development

Table 1 provides the descriptive statistics of the exit card scores for the overall study sample (n=180). The highest mean score is for the Interest item (Mean=.76), followed by Excitement and Confidence (Mean=.63 and .55 accordingly). The lowest mean scores is for Frustration (Mean=.10), followed by Confusion and Boredom (Mean=.13 and .15, accordingly). Coherence of the exit card measure set is further supported by the strength of the inter-correlations among the individual exit card measures--most variables significantly correlated at the .01 level.

Table 1: Intercorrelations between exit card measures

Exit card measures	Correlation (*r*)									Mean	SD
	1	2	3	4	5	6	7	8	9		
1. Excitement	-									.63	.375
2. Frustration	-.073	-								.10	.188
3. Challenge	.428**	-.052	-							.44	.364
4. Interest	.555**	-.279**	.377**	-						.76	.314
5. Boredom	-.353**	.330**	-.290**	-.452**	-					.15	.255
6. Confusion	-.068	.441**	.002	-.177**	.171*	-				.13	.234
7. Confidence	.549**	-.156*	.391**	.476**	-.312**	-.158*	-			.55	.388
8. Helping	.494**	-.048	.519**	.384**	-.220**	.027	.586**	-		.49	.372
9. Scientist	.565**	-.118	.578**	.425**	-.337**	-.041	.492**	.479**	-	.52	.389
10. Creativity	.551**	-.144*	.500**	.443**	-.256**	-.094	.509**	.590**	.636*	.51	.394

All tests are 2-tailed.
* *p< .05, ** p< .01*

The principal components analysis produced two components, which accounted for 58.7% of the overall variance and was felt to be conceptually appropriate. Component 1 may be conceptualized as *positive-valence feelings*, and includes the items Excited, Challenged in a Good Way, Interested, Confident, Helpful, Like a Scientist, and Creative. Component 2 may be conceptualized as *negative-valence feelings*, and includes the items Frustrated, Bored, and Confused. (Although the learning process may be accompanied by occasional frustration, confusion, or boredom, if too many students in a class feel this way too often, or to a greater extent, this might adversely impact the learning experience over time.) Since the component analysis results found 2 factors: positive and negative domains of feeling, we used each factor as an outcome variable to check whether the student-reported feelings varied significantly depending on unit as well as classroom.

Comparisons Across Units and Classrooms

Finally, HLMs were used to determine whether the differences in component scores were predicted by the unit intervention or not. For this analysis, the exit card component scores were the outcome/dependent variables, and the intervention was the independent variable in level 2. The data analysis involved first modeling the dependent variables of positive or negative feelings across classrooms; this constituted Model I. Model II comprised Model I plus the intervention type (see Table 2).

According to the results, the variance of classroom means in Model I for the positive feeling component is significant at .01 level (χ^2= 22.89, p < .01). This indicates that the positive feelings of students were different among classrooms, with about 9.09% of the variance explained by classroom effects. After taking the treatment (unit intervention) into considerations in Model II, the treatment effect was significant at the .05 level, indicating that the positive feelings of students were significantly higher in the Agency classrooms (Mean=.61), than in the FOSS classrooms (Mean=.47). With regard to the negative feelings component, in

Model II, the treatment effect was not significant, indicating that the negative feelings of students were not significantly different between Agency (Mean=.12) and FOSS classrooms (Mean=.14).

Table 2: Estimated effects of intervention level on positive and negative feeling

	Model I		Model II	
Positive feeling				
Fixed Effect	Coefficient	*t*-ratio	Coefficient	*t*-ratio
Intercept, γ_{00}	0.558665	15.409**	0.469465	10.513**
Intervention			0.142309	2.523*
Random Effect	Variance	χ^2	Variance	χ^2
Intercept	0.00728	22.88838**	0.00272	11.03637
Intervention	0.07277		0.07278	
Negative feeling				
Fixed Effect	Coefficient	*t*-ratio	Coefficient	*t*-ratio
Intercept, γ_{00}	0.127254	10.316**	0.143120	7.078**
Intervention			-0.025273	-0.990
Random Effect	Variance	χ^2	Variance	χ^2
Intercept	0.00000	4.40228	0.00000	3.41998
Intervention	0.02736		0.02736	

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

Discussion

Conclusions

The exit card measures cluster into two components (based on their co-occurrences): positive-valence feelings (Excited, Interested, etc,) and negative-valence feelings (Frustrated, Bored, and Confused). A treatment (Agency/FOSS) effect was found for the positive feelings component, indicating that students in Agency classes had more positive emotional experiences during science instruction. In addition, although students in the Agency classes tended to report more positive feelings, there were also large classroom-level differences in positivity.

On the other hand, no significant differences between students in the Agency and FOSS classes were observed in terms of negative feelings. These findings suggest that classrooms that support student agency and scientific inquiry are more likely to create conditions for positive emotional experiences among the learners.

Findings from the exit card analysis are also supported by the analysis of interview data collected from students in the Agency and FOSS classes (Scalone, 2014). The Agency students viewed science as playful experimentation. These reasons were coupled with enjoyment, with students proclaiming that they "love" science and that "science is fun" – perceiving science as playful experimentation. In addition, Agency students indicated that they like science more than the FOSS students. Their reasons included getting to "learn new things" and "do experiments." The Agency students also identified themselves as scientists, signaling their emotional investment in the doing of science.

Implications for Future Research

The study discussed here examines one of the five redesigned units developed for Grades 2 and 5. Further research will focus on examining students' reports of emotional states across all redesigned and FOSS comparison units. More fine-grained analysis of the exit card data is also under way to better understand students' specific emotional experiences with different units and in different classrooms. In addition, further analyses using the student interview data will allow us to examine the relationship between student report of emotional states and conceptual and epistemological understanding in science. We also plan to triangulate self-reported affect with videotaped episodes of classroom activities to explore the situative aspects of affective, cognitive, and behavioral engagement during collaborative scientific inquiry, including the role of teaching practices (e.g., Engle & Conant, 2002; Herrenkohl & Guerra, 1998). Ultimately this body of work can contribute to testing an empirical model that links developing interest and expertise as important parts of a system to support science learning.

Relevance to Conference Theme

The theme of ICLS this year highlights a movement over the past decade to increasingly connect to ideas of being and becoming processes that include social emotional dimensions mentioned above. Our research on science learning addresses principles for developing students' agency to inquire about personally-relevant, socially-consequential science problems, while also supporting them to cultivate powerful intellectual practices and positive attitudes toward science. The analysis presented in this paper connects to these ideas of learning, being and becoming, by highlighting the emotional dimensions that are often left out of empirical studies.

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