

Student motivation and performance in scientific problem solving simulations

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Abstract. Students do not always use efficient strategies to solve scientific problems. Students' motivation beliefs were assessed through an on-line survey instrument, along with performance on easy and challenging multimedia science problem sets. Results indicated that female students reported lower self-efficacy and higher concerns about their performance than male students. Students' initial strategies predicted overall performance on the harder problem sets. In addition, although there was no difference in initial strategy, students' motivational beliefs predicted overall performance. Results suggest that both cognitive and motivational factors influence students' strategic efficacy.

Introduction

Scientific problem solving is now recognized as an important component of science education, yet recent assessments indicate that American students do not perform well on problem solving tasks [1, 2, 3]. One reason may be that traditional science instruction often fails to integrate scientific content with experiences that provide opportunities for students to develop skills of problem solving. In spite of recent interest in inquiry-based learning, students in the United States still have much more opportunity to learn *about* science than to *do* science [2].

Multimedia simulations can provide students with important opportunities to practice problem solving skills such as identifying relevant information, developing hypotheses, and tracking progress to the solution. IMMEX is a web-based multimedia simulation environment that delivers authentic science problems to students, aligned with academic content standards. For example, in the COINS problem, the student reads a prologue in which he or she is given a handful of strange coins and must identify the metal as part of a job interview at a chemicals firm. Students can request data and order various tests as they develop their hypothesis about the answer, e.g., using a virtual scale to gain information about the coins' mass. There is a cost associated with each request for information. When they submit an answer, they receive immediate feedback. Each problem includes multiple cases with the same general framework, but different specifics. For example, the COINS cases all involve the same goal of identifying a metallic substance, but the type of metal varies from case to case. Thus, the specific set of information needed to solve the problem is unique to each case, and the cases vary in difficulty.

As students solve IMMEX problems, their actions are logged to provide an integrated assessment about their strategic approach, including what information was viewed, what tests were ordered and in what sequence, and the solution accuracy. Previous work using Hidden Markov Models indicates that many students adopt inefficient strategies, such as ordering all available tests or guessing [4]. Students' initial strategies can persist over multiple cases and

problem sets, sometimes for up to four months [5]. A student's overall proficiency is indicated by his or her IRT score.

The goal of the present project was to learn if student motivation might contribute to strategy selection, i.e., students with less confidence in their ability might adopt more cautious strategies, and resist modifying their approach even when the approach was not always successful.

2. Factors influencing students' problem solving strategies

2.1 Assessment of science motivation

We developed the Science Motivation Profile: an on-line instrument based on previous work with paper-and-pencil and on-line assessments [6, 7]. The instrument included items to assess five constructs identified in the motivation literature: SELF EFFICACY IN SCIENCE, EXPECTED SUCCESS IN SCIENCE, PERCEIVED DIFFICULTY OF SCIENCE, LIKING OF SCIENCE, and BELIEF THAT SCIENCE IS IMPORTANT TO LEARN. Students clicked on a Likert-type rating scale to respond. Ratings were averaged across items for each construct, yielding five scores for each student.

2.2 Data sources

The Science Motivation Profile was completed by 406 students before they worked with IMMEX. Students completed cases in COINS and a second more difficult problem set, PERIODIC TRENDS. Initial strategies and overall IRT scores served as performance measures.

3. Results and Discussion

3.1 Science motivation groups

K-means clustering conducted on the Science Motivation Profile scores suggested that there were four groups of students, informally labeled as follows:

- “confident high achievers” (N = 123): These students had the highest self efficacy beliefs, were most likely to view science classes as easy, and liked science more than other students.
- “nervous high achievers” (N = 126): Students in this group placed high value on science and liked it, but had relatively low self efficacy scores.
- “discouraged students” (N = 58): These students had the lowest scores for self-efficacy, expected success and liking of science, and were least likely to view it as valuable.
- “not-interested” (N = 99): These students thought they would do well but did not particularly like science or think it was important to learn.

Table 1. Mean scores for responses on Science Motivation Profile for Clusters

Cluster:	Like science	Ability	Value	Difficulty	Success
“Discouraged”	1.93	2.39	2.49	1.85	2.27
“Nervous”	3.85	4.13	4.30	3.25	4.02
“Not interested”	2.69	3.55	3.23	2.73	3.47
“Confident”	3.36	3.09	3.94	2.06	2.94

A cross-tabulation of gender and Motivation Cluster indicated a significant relation, $\chi^2(3,400) = 25.267, p < .001$. Female students were more likely than males to be Nervous High Achievers; in contrast, Discouraged students were more likely to be male.

3.2 Motivation and problem solving

To evaluate the contribution of initial strategy and motivation to overall performance, a MANOVA was conducted with students' IRT scores (COINS, PERIODIC TRENDS) as the within-subjects factor. Grouping factors were student's initial strategies for COINS and TRENDS, and Motivation Cluster. The results indicated that, consistent with prior work, students performed better on the COINS problem than on TRENDS, $F(1,328) = 232.61$, $p < .001$. Initial problem solving strategy did not predict overall IRT score for COINS, but did predict overall performance for TRENDS, $F(4,328) = 4.10$, $p < .01$. This indicates that as problems become harder, it is more important for students to adopt an effective strategy early on, in terms of how much they learn. In addition, there was a significant contribution of Motivation Cluster, $F(3,328) = 3.79$, $p < .01$. This indicates that students' beliefs about their performance also contribute to their problem solving performance, as indicated by their overall IRT score. Mean scores may be viewed in Table 2. Post-hoc contrasts (alpha set to 0.05) indicated that students with lower self confidence (Discouraged and Nervous students) had lower IRT scores when compared to students with higher self confidence in their ability (Not-interested Achievers and Confident Achievers). There were no significant interactions.

The results indicate that students' overall performance on problem solving tasks is influenced by their initial strategic approach, and also by the constellation of beliefs about their own performance, and the importance of doing well in science.

Table 2. Mean IRT score for COINS and TRENDS problem sets for four Motivation Clusters

Cluster:	COINS	TRENDS
"Discouraged"	58.0	40.3
"Nervous"	59.0	42.8
"Not-interested"	61.2	43.5
"Confident"	62.0	43.2

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