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Skill and will: the role of motivation and cognition in the learning of college chemistry

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This study investigated how students' level of motivation and use of specific cognitive and self-regulatory strategies changed over time, and how these motivational and cognitive components in turn predicted students' course performance in chemistry. Participants were 458 students enrolled in introductory college chemistry classes. Participants' motivation and strategy use were assessed at three time points over the course of one semester using self-report instruments. Results showed an overall decline in students' motivational levels over time. There was also a decline in students' use of rehearsal and elaboration strategies over time; students' use of organizational and self-regulatory strategies increased over time. These trends, however, were found to vary by students' achievement levels. In terms of the relations of motivation and cognition to achievement, the motivational components of self-efficacy and task value were found to be the best predictors of final course performance even after controlling for prior achievement.

Introduction

Why do some students excel academically while other students struggle to pass a class? What drives some students to actually learn and appreciate the course material? Why do some students study and others do not? In short, what are the determinants of academic success? Indeed, the question is straightforward. The answer, however, is far from simple. In the domain of science, from the research on science instruction and schooling practices to the research on conceptual change, investigators have proffered numerous explanations to this exact question. While we do not deny the importance of such accounts, it is our contention that such explanations nevertheless ignore one crucial aspect of the learning process; that is, motivation. Accordingly, the primary objective of this paper was to investigate the role of certain motivational components and their relation to students' learning and achievement outcomes in two college chemistry courses.

Recently, researchers have taken a primarily social cognitive approach to the study of motivation, with an emphasis on the role of students' beliefs and strategies. Theorists have largely conceptualized motivation as a process, rather than a product. As such, it is believed that motivation can be discerned through students' reports of their beliefs as well as through behaviors such as choice of activities, level and quality of task engagement, persistence, and performance.

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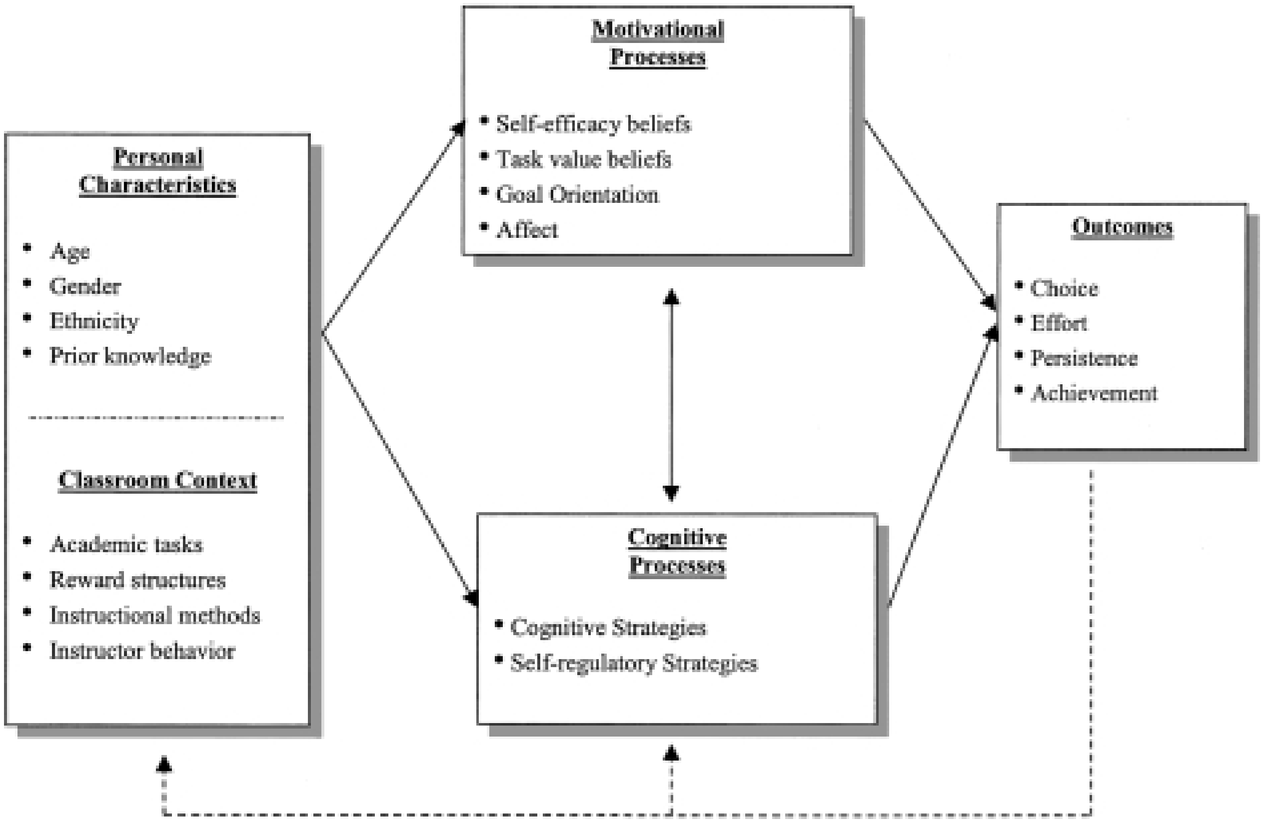

Figure 1. A general model of motivation and self-regulated learning.

Figure 1 displays our general model of achievement motivation and learning that forms the basis of this study. This model proposes that certain personal characteristics such as age, gender, ethnicity, and prior knowledge, along with classroom contextual factors, help to shape how an individual approaches, engages, and responds to an achievement task, which in turn influences students' level of cognitive processing and, ultimately, outcomes such as choice, effort, persistence, and academic achievement. In line with the social cognitive perspective of motivation, this model also assumes that the relationships between the various components are reciprocal and, thus, can mutually influence one another. For example, researchers have demonstrated in numerous studies how one's prior academic successes and failures can influence future levels of engagement and motivation (Pintrich & Schunk, 2002).

For the purposes of this study, we will focus on only three of the components of the model: motivational processes, cognitive processes, and outcomes. In terms of motivational processes, we are concerned with four motivational components. The first is self-efficacy, which can be defined as students' judgments of their capabilities to perform a task, as well as their beliefs about their agency in the course. Generally, researchers have shown that it is more adaptive to have higher efficacy beliefs. Students who believe that they are capable of adequately completing a task and have more confidence in their ability to do so typically display the highest levels of academic achievement, and also engage in academic behaviors that promote learning (Bandura, 1997; Schunk, 1991).

The second motivational component is task value beliefs, or students' beliefs about the utility and importance of a course. Again, it is believed that having higher task value beliefs is favorable; typically, researchers have demonstrated positive relations of task value beliefs to deeper levels of cognitive processing and performance (Pintrich, 1999; Pintrich & Garcia, 1991).

Goal orientation represents the third motivational component in our model. Briefly, goal orientation can be defined as individuals' purposes when approaching, engaging in, and responding to achievement situations. Goal theorists commonly identify two primary achievement goals – mastery and performance goals – as being important determinants of students' motivation and performance. Endorsement of a mastery goal, or the goal to develop competence and task mastery, has been found to be positively related to various learning and motivational indices. In contrast, adoption of a performance goal, or the goal to validate one's competence in relation to others, is generally thought to have a negative effect on students' achievement motivation and academic performance (Dweck & Leggett, 1988).

The last motivational component is affect. Specifically, in this study we define affect in terms of interest and anxiety. Interest, defined as personal interest in course material or general liking of subject matter, has been linked with deeper cognitive processing as well as higher levels of achievement (Pintrich, 1999; Pintrich & Schrauben, 1992). Anxiety, or general worry and negative emotions about doing well in class, has been found to have negative consequences on cognition and performance (Zeidner, 1995).

In terms of cognitive processes, we were mainly concerned with students' self-reported use of specific cognitive and self-regulatory strategies. Strategies can be divided into two main categories: superficial strategies that only require surface-level processing, and those strategies that require more deeper processing of course material. Generally, researchers have shown that it is more adaptive to use deeper processing strategies, in terms of long-term retrieval of information (Pintrich, 2000; Pintrich & Schrauben, 1992). In this study, we examine three cognitive strategies: (1) rehearsal, a surface level strategy, where students focus on memorizing and recall of facts; (2) elaboration, a deeper processing strategy, where students focus on extracting meaning, summarizing, or paraphrasing; and (3) organization, another deeper processing strategy, where students focus on organizing material through the use of outlines or drawing maps. Finally, self-regulatory strategies can be defined as those strategies that help students focus on planning, monitoring, and controlling their cognition. Such strategies can take the form of self-testing, monitoring of one's understanding of course content, or repairing one's understanding by re-reading or doing more problems. Like the deeper processing strategies, researchers have found that it is generally more adaptive to be self-regulating, in terms of subsequent levels of achievement (Pintrich, 2000).

Given this model of motivation and cognition, we focused on the following research questions. First, how does motivation change in chemistry over the course of one semester? Second, how does strategy use change in chemistry? Third, how do the motivational and cognitive components predict performance in chemistry? Given previous research on the decline of motivation and engagement over the course of schooling (Pintrich & Schunk, 2002), we expected declines in motivation and cognitive strategy use over time. In terms of the last question, given prior findings, we expected the motivational components of self-efficacy, task value, and mastery goals to have positive relations with course performance and performance goals, and anxiety to exhibit negative relations with final course grade. As for the cognitive components, we expected use of rehearsal strategies to be negatively related to student grades and use of organization, elaboration, and self-regulatory strategies to lead to higher levels of achievement.

Methods

Participants

Participants were 458 college students (243 female, 215 male) enrolled in two introductory chemistry courses at a large Midwestern university in the USA. The majority of these students were freshmen or sophomores. In terms of ethnicity, approximately 75% of these students identified themselves as 'Caucasian/White', 9% as 'Asian/Asian-American', 3% as 'African-American', and 1% as 'Hispanic'.

Procedure

Over the course of the semester, participants were asked to complete three surveys, which were administered at approximately 5 weeks, 10 weeks, and 15 weeks into the semester. All surveys were administered individually to participants during lectures, and took about 15–20 minutes to complete. The first questionnaire consisted primarily of demographic and other background-related questions (e.g. gender, ethnicity, SAT-mathematics score), in addition to items assessing students' self-efficacy and task value beliefs. The second and third questionnaires assessed participants' goal orientations, self-efficacy and task value beliefs, interest, anxiety, as well as their use of various cognitive and self-regulatory strategies.

Measures

Motivational measures for this study included self-efficacy (seven items regarding perceptions of one's ability to learn the course material; alpha values over three waves = 0.92–0.93), task value (five items concerning the importance and/or utility of the course in general; alpha values over three waves = 0.85–0.88), mastery goal orientation (six items regarding a goal of learning and understanding the course content; alpha values for waves 2 and 3 = 0.84–0.86), performance goal orientation (10 items concerning an approach performance goal of trying to do better than or outperform other students in the course; alpha values for waves 2 and 3 = 0.94), interest (five items concerning personal enjoyment and liking of the course; alpha values for waves 2 and 3 = 0.84–0.85), and anxiety (five items including both emotionality and worry components of anxiety; alpha values for waves 2 and 3 = 0.88).

Cognitive measures included rehearsal (five items regarding surface-level processing/memorization of course material; alpha values for waves 2 and 3 = 0.72–0.73), organization (seven items concerning deeper processing of course material through the use of charts, diagrams, and other organizational tables; alpha values for waves 2 and 3 = 0.83–0.85), elaboration (six items concerning deeper processing of content by relating new ideas in course to other preexisting schemas or concepts; alpha values for waves 2 and 3 = 0.76–0.79), and metacognitive self-regulation (10 items regarding the planning, monitoring, and control of one's cognition and understanding of course material; alpha values for waves 2 and 3 = 0.77).

With the exception of the interest scale, which was adapted from Elliot and Church's (1997) intrinsic motivation scale, all of the motivational measures were adapted from the Patterns of Adaptive Learning Survey (PALS) as well as the Motivated Strategies for Learning Questionnaire (MSLQ). The cognitive measures were drawn solely from the MSLQ. Both the PALS and MSLQ are self-report questionnaires that have been have been validated on numerous samples, from elementary school students to college students (Midgley *et al.*, 1997, 1998; Pintrich, Smith, Garcia, & McKeachie. 1993). All items were assessed on a five-point Likert scale where (1) indicated strongly disagree and (5) indicated strongly agree.

Finally, students' grades were collected at the end of the semester as a measure of participants' course performance. Students' grades in both courses were calculated based a point system, thus eliminating the need to standardize test scores across the two courses. Students' final course grade was determined by summing their one quiz score, three examination grades, and their final examination grade, for a maximum of 600 points in both courses. In addition, students' SAT-mathematics scores were used as a measure of prior achievement. The examinations consisted of both open-ended and close-ended questions. Open-ended questions included short case studies drawn from pharmaceutical chemistry or materials science that required students to represent their understanding of the chemical phenomenon in multiple ways; for example, through numbers, words, pictures, and graphs. Close-ended questions were typically of multiple-choice format, and emphasized a range of recognition and reasoning skills.

Results

Research question 1: how does motivation change in chemistry?

To answer our first research question, repeated-measures analyses of variance (ANOVAS) were conducted on all of the motivational measures. Table 1 presents

Table 1. Means and standard deviations (SD) of motivation and affect measures over time

	Time 1		*Time 2*		*Time 3*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Motivation						
Self-efficacy	3.64_a	0.79	3.49_b	0.84	3.47_b	0.89
Task-value	3.90_a	0.77	3.61_b	0.78	3.50_c	0.87
Mastery goals	–	–	3.28	0.77	3.27	0.78
Performance goals	–	–	2.94_a	0.92	2.84_b	0.93
Affect						
Interest	–	–	2.87	0.82	2.86	0.91
Anxiety	–	–	2.40	0.83	2.40	0.85

Note: Means within a row with different subscripts are significant from one other at the $p < 0.001$ level.

the means and standard deviations for self-efficacy, task value, the two goal orientation scales, and the two affect measures. In general, students' levels of motivation decreased over time. More specifically, there was a decline in students' level of self-efficacy ($F(2,443) = 15.10$, $p < 0.001$). Task value, too, declined over the course of the semester ($F(2, 443) = 91.40$, $p < 0.001$), as did students' endorsement of performance goals ($F(1, 440) = 11.662$, $p < 0.001$). There were no significant differences in students' reports of their mastery goals, interest, and anxiety over time.

Research question 2: how does strategy use change over time?

Table 2 presents the means and standard deviations of students' cognitive strategy use at the two time points. Over the course of the semester, there was a significant decline in students' reported use of rehearsal strategies ($F(1,452) = 77.51$, $p < 0.001$) and elaborative strategies ($F(1, 451) = 180.77$, $p < 0.001$), while students' use of organizational ($F(1, 449) = 251.92$, $p < 0.001$) and metacognitive strategies ($F(1,405) = 18.01$, $p < 0.001$) increased from time 2 to time 3.

Table 2. Means and standard deviations (SD) of cognitive strategy use over time

	Time 2		*Time 3*	
	Mean	*SD*	*Mean*	*SD*
Rehearsal	3.51_a	0.70	3.15_b	0.63
Elaboration	3.70_a	0.66	3.16_b	0.74
Organization	2.78_a	0.63	3.22_b	0.55
Metacognition	3.02_a	0.55	3.11_b	0.59

Note: Means within a row with different subscripts are significant from one other at the $p < 0.001$ level.

Table 3. Zero-order correlations of motivation, cognition, and chemistry achievement

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*
Motivation																							
1. Efficacy, W1	1.0																						
2. Efficacy, W2	0.65*	1.0																					
3. Efficacy, W3	0.53*	0.76*	1.0																				
4. Task value, W1	0.45*	0.27*	0.24*	1.0																			
5. Task value, W2	0.34*	0.49*	0.43*	0.71*	1.0																		
6. Task value, W3	0.26*	0.36	0.53*	0.61*	0.75*	1.0																	
7. Mastery goals, W2	0.39*	0.50*	0.44*	0.48*	0.67*	0.54*	1.0																
8. Mastery goals, W3	0.33*	0.40*	0.51*	0.46*	0.59*	0.71*	0.78*	1.0															
9. Performance, W2	0.08	0.15*	0.12*	0.05	0.14*	0.05	0.07	0.03	1.0														
10. Performance, W3	0.10	0.13	0.15*	0.04	0.06	0.06	−0.01	0.05	0.77*	1.0													
11. Interest, W2	0.32*	0.47*	0.42*	0.54*	0.73*	0.63*	0.64*	0.62*	0.09	0.04	1.0												
12. Interest, W3	0.26*	0.37*	0.49*	0.48*	0.61*	0.77*	0.52*	0.71*	0.09	0.09	0.75*	1.0											
13. Anxiety, W2	−0.30*	−0.40*	−0.36*	−0.03	−0.07	−0.09	−0.09	−0.07	0.33*	0.23*	−0.06	−0.08	1.0										
14. Anxiety, W3	−0.20*	−0.30*	−0.37*	0.02	−0.08	−0.09	−0.07	0.01	0.33*	0.36*	−0.08	0.02	0.73*	1.0									
Strategy use																							
15. Rehearsal, W2	0.44*	0.66*	0.53*	0.53*	0.79*	0.63*	0.70*	0.61*	0.10	0.04	0.77*	0.60*	−0.20*	−0.13	1.0								
16. Rehearsal, W3	−0.04	0.04	0.15*	12	0.18*	0.26*	0.10	0.21*	0.40*	0.48*	0.11	0.21*	0.39*	0.54*	0.17*	1.0							
17. Elaboration, W2	−0.10	−0.10	−0.09	0.25*	0.33*	0.17*	0.16*	0.13*	0.52*	0.37*	0.10	0.06	0.46*	0.39*	0.14	0.42*	1.0						
18. Elaboration, W3	0.17*	0.22*	0.30*	0.52*	0.62*	0.77*	0.47*	0.59*	0.16*	0.18*	0.58*	0.72*	0.12	0.21*	0.50*	0.38*	0.27*	1.0					
19. Organization, W2	−0.04	−0.08	−0.07	0.23*	0.26*	0.19*	0.28*	0.25*	0.52*	0.43*	0.26*	0.21*	0.60*	0.53*	0.18*	0.55*	0.54*	0.37*	1.0				
20. Organization, W3	0.06	0.11	0.20*	0.23*	0.27*	0.37*	0.32*	0.46*	0.42*	0.54*	0.23*	0.33*	0.34*	0.49*	0.24*	0.61*	0.44*	0.49*	.52*	1.0			
21. Metacognition, W2	0.12	0.10	0.09	0.29*	0.36*	0.30*	0.42*	0.41*	0.14	0.06	0.32*	0.29*	0.27*	0.25*	0.33*	0.27*	0.28*	0.30*	.39*	.34*	1.0		
22. Metacognition, W3	0.06	0.04	0.10	0.21*	0.27*	0.33*	0.31*	0.44	0.08	0.09	0.23*	0.32*	0.27*	0.34*	0.23*	0.33*	0.20*	0.32*	.32*	.38*	.67*	1.0	
Achievement																							
23. Grade (%)	0.12	0.35*	0.49*	0.05	0.21*	0.30*	0.16*	0.18*	0.07	0.03	0.14	0.23*	−0.15	−0.22*	0.27*	0.10	−0.01	0.15*	−0.07	.04	.01	−0.06	1.0

* $p < 0.001$.

Research question 3: how does motivational and cognitive processes predict achievement?

Finally, several analyses were conducted to investigate the relations between the motivational and cognitive components and achievement. Table 3 presents the zero-order correlations between the motivational, cognitive, and achievement measures. As predicted, adaptive motivational beliefs such as self-efficacy, task value, and mastery goals were positively related with final course points, while maladaptive motivational beliefs such as anxiety were negatively related with final grade. Contrary to our expectations, use of rehearsal strategies was related positively with achievement. In terms of the relations between motivation and cognitive strategy use, in line with past research findings, students with higher levels of self-efficacy, task value, and mastery goals also reported using deeper-processing cognitive strategies such as elaboration and metacognition. However, contrary to our predictions, these same students also reported using rehearsal strategies, especially at time 2.

Table 4. Means and standard deviations of motivational and cognitive measures by performance

	Low achievers (n = 144)		*Average achievers (n = 144)*		*High achievers (n = 132)*	
Dependent variables	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Motivation						
Self-efficacy T1	3.52_a	0.79	3.61_b	0.80	3.82_c	0.77
Self-efficacy T2	3.12_a	0.82	3.54_b	0.77	3.85_c	0.75
Self-efficacy T3	2.95_a	0.85	3.53_b	0.80	4.00_c	0.70
Task value T1	3.80_a	0.73	3.93_b	0.78	3.93_b	0.77
Task value T2	3.34_a	0.78	3.67_b	0.76	3.80_c	0.75
Task value T3	3.19_a	0.86	3.53_b	0.84	3.78_c	0.84
Mastery T2	3.09_a	0.73	3.25_a	0.78	3.51_b	0.76
Mastery T3	3.09_a	0.73	3.24_a	0.83	3.49_b	0.75
Performance T2	2.84	0.84	2.99	0.92	2.99	0.91
Performance T3	2.81	0.86	2.82	0.95	2.89	0.99
Interest T2	2.73_a	0.81	2.84_a	0.82	3.03_b	0.82
Interest T3	2.61_a	0.90	2.84_a	0.89	3.10_b	0.89
Anxiety T2	2.53_a	0.80	2.44_a	0.87	2.19_b	0.75
Anxiety T3	2.59_a	0.86	2.44_a	0.86	2.11_b	0.76
Cognition						
Rehearsal T2	3.24_a	0.74	3.52_b	0.65	3.78_b	0.65
Rehearsal T3	3.05_a	0.64	3.23_b	0.62	3.17_b	0.66
Elaboration T2	3.66	0.63	3.78	0.70	3.62	0.63
Elaboration T3	3.01	0.74	3.19	0.75	3.26	0.69
Organization T2	2.80	0.59	2.83	0.68	2.72	0.60
Organization T3	3.16	0.60	3.27	0.54	3.20	0.50
Metacognition T2	2.96_a	0.50	3.11_b	0.60	2.95_a	0.57
Metacognition T3	3.11_a	0.57	3.20_b	0.58	3.01_a	0.60

Note: Means within a row with different subscripts are significantly different from one other.

Second, to investigate how students' motivational and cognitive processes varied by performance, the sample was divided into three categories: (a) high-achieving students with average achievement scores above 81%, (b) average-achieving students with mean scores from 70% to 80%, and (c) low-achieving students with average scores below 69%. Repeated-measures ANOVAs were conducted to examine potential variation of students' motivation and cognition by performance. Additionally, we conducted Tukey's *post-hoc* tests comparing the three achievement groups for all significant F values ($p < 0.05$). Table 4 presents the means and standard deviations of the various motivational and cognitive measures by performance. There were no main effects of performance for performance goal orientation, organization, and elaboration. There were, however, several significant performance by time interactions. More specifically, students' ratings of their levels of self-efficacy varied by performance, with high-achieving students' self-efficacy levels increasing over time and low-achieving students' self-efficacy levels decreasing over time ($F(4,420) = 22.99$, $p < 0.001$) (see figure 2). The relatively same pattern emerged for task value, although there was no discernable difference between average-achieving and high-achieving students' ratings of task value at time 1 ($F(4, 418) = 9.764$, $p < 0.001$) (see figure 3). Students' ratings of their interest also varied by their achievement levels; not surprisingly, high achievers expressed increasingly higher levels of interest over time than did both average-achieving and low-achieving students ($F(2, 427) = 3.213$, $p < 0.05$) (see figure 4). Low achievers' level of interest actually decreased from time 2 to three.

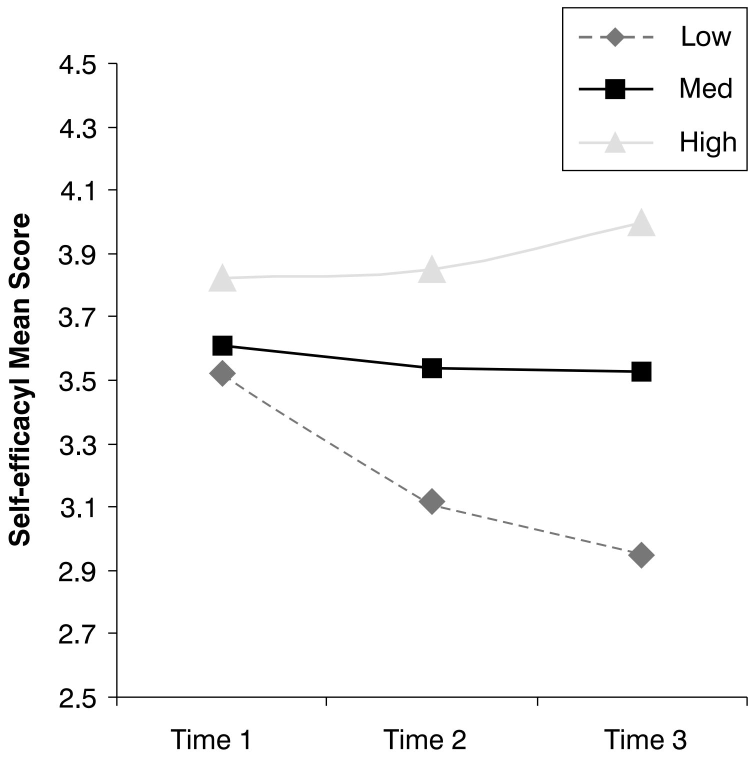

Figure 2. Ratings of self-efficacy by performance.

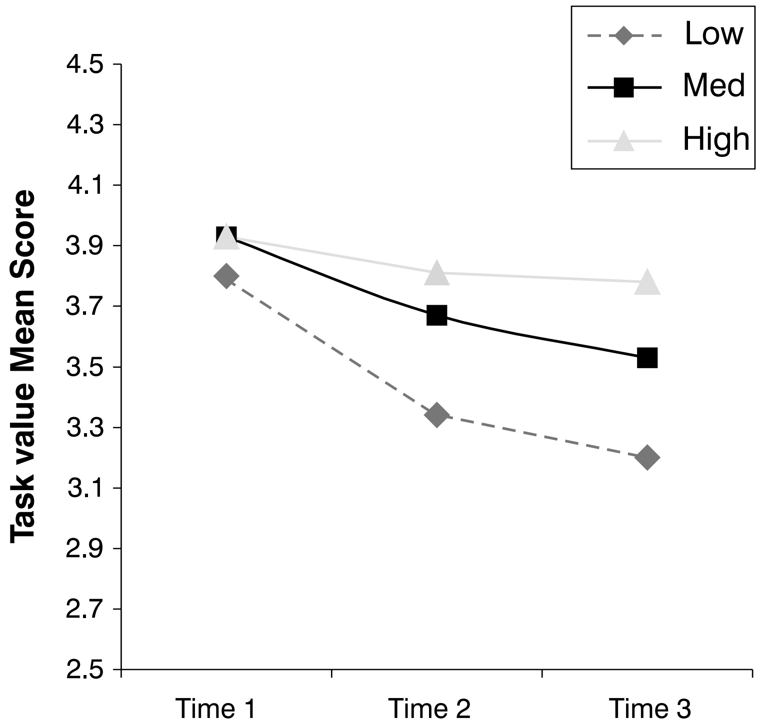

Figure 3. Ratings of task value by performance.

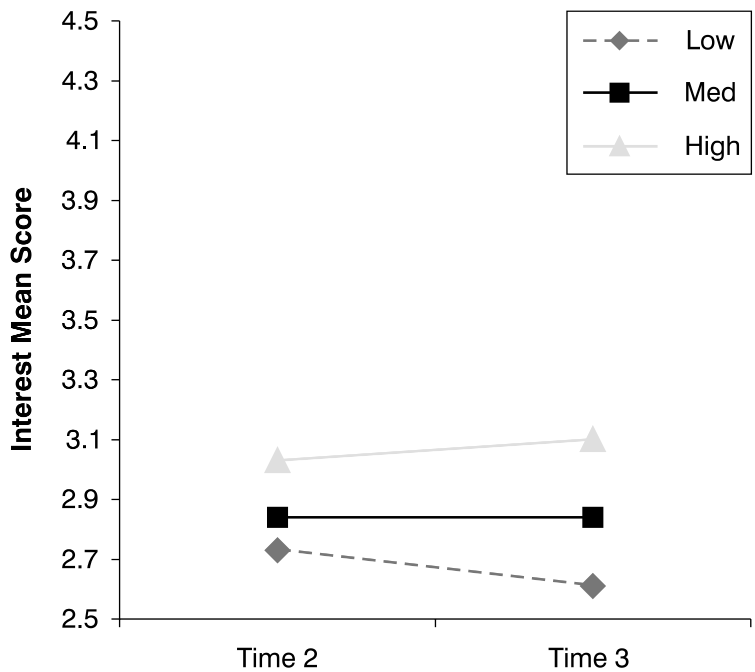

Figure 4. Ratings of interest by performance.

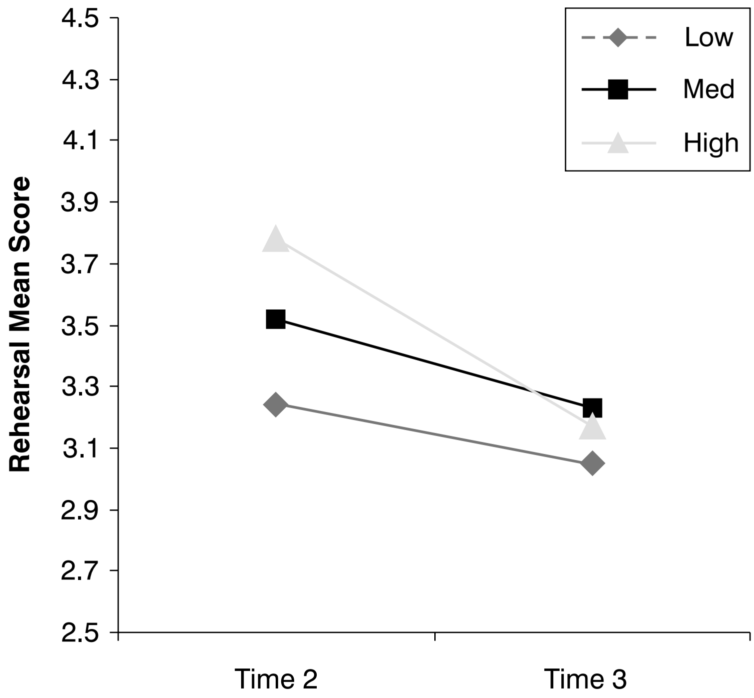

Figure 5. Ratings of rehearsal by performance.

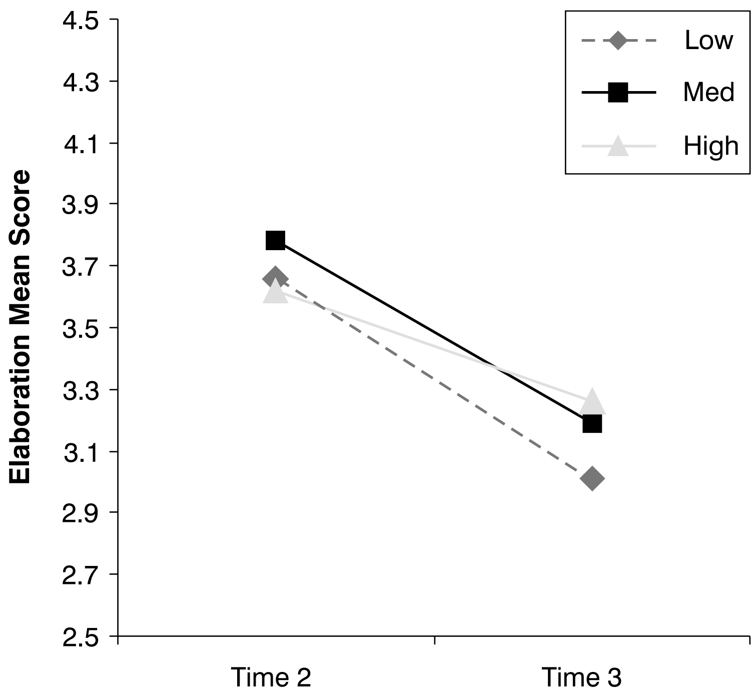

Figure 6. Ratings of elaboration by performance.

In addition, there were two interaction effects for two of the cognitive strategy-use variables; specifically, rehearsal and elaboration. First, in terms of rehearsal strategy use, high achievers reported using significantly more rehearsal strategies at time 2 than average and low achievers. However, their use of rehearsal strategies decreased dramatically at time 3, with more average achievers reporting using rehearsal strategies at time 3 than high achievers ($F(2, 427) = 9.146$, $p < 0.001$) (see figure 5). Finally, students' ratings of elaborative strategy use also fluctuated by achievement levels. There was a general declining trend in the use of elaboration strategies across all three groups over time. However, at time 2, the high achievers reported the lowest use of this particular cognitive strategy in comparison with the other groups. At time 3, however, the high achievers reported using elaboration strategies more than both average achievers and low achievers ($F(2, 426) = 4.548$, $p < 0.05$) (see figure 6).

Finally, a hierarchical regression analysis was conducted, with the five motivational measures and the four cognitive measures at time 3 as predictors of final course points, controlling for prior achievement as indexed by SAT-mathematics scores. Prior achievement was entered first into the model, followed by the motivational variables, and then the cognitive variables. As presented in table 5, prior achievement, self-efficacy beliefs, task-value beliefs, and rehearsal were significant predictors of chemistry performance. Of these predictors, self-efficacy, with a standardized beta coefficient of 0.40, was the best predictor of course performance even after controlling for prior achievement, followed by task-value beliefs with a beta coefficient of 0.22.

Table 5. Standardized regression coefficients of variables predicting chemistry performance

	Model 1	*Model 2*	*Model 3*
Prior achievement			
SAT-mathematics	0.32***	0.22***	0.21***
Motivation			
Self-efficacy T3		0.44***	0.40***
Task value T3		0.14**	0.22**
Mastery goals T3		−0.13	−0.06
Performance goals T3		−0.06	−0.06
Cognitive strategies			
Rehearsal T3			0.13*
Organization T3			−0.12
Elaboration T3			−0.09
Metacognition T3			−0.06
R^2	0.10***	0.29***	0.31***
Change in R^2		0.19***	0.02

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Discussion

In this study, we examined how students' motivation and strategy use changed over the course of one semester, and how these motivational and cognitive components related to final chemistry performance. In general, we found that, over time, students' judgments of their confidence to do well in the class decreased, and students were less likely to believe that chemistry was important or useful to them. This general trend of decreasing motivation has been well documented in the literature (Eccles, Wigfield, & Schiefele, 1998; Pintrich & Schunk, 2002). For example, as students take examinations and receive feedback about their performance in the course, it is not surprising that their confidence levels might also decrease. Researchers have also noted a significant decrease in motivation as students progress through their schooling. At the same time, however, this general decline in motivation seems to be most pronounced among the low achievers in this study. In fact, students characterized as high achievers actually reported higher levels of self-efficacy toward the end of the semester than at the beginning of the term. Such findings suggest the importance of maintaining self-efficacy levels over time.

In terms of cognitive and metacognitive strategy use, students' use of rehearsal and elaboration strategies decreased over time. Students' use of self-regulatory and organizational strategies, however, increased over time. In light of the research linking use of deeper cognitive strategies and self-regulatory strategies to improved learning outcomes, this finding is encouraging.

As for the correlates of success in college chemistry, not surprisingly, students with a history of academic success were more likely to obtain higher scores in chemistry. More importantly, however, this study suggests that students with adaptive motivational beliefs (i.e. students who have high levels of self-efficacy and task value) ultimately do well. In fact, students' ratings of their levels of self-efficacy and task value at time 3 were better predictors of final course performance than was the SAT-mathematics scores. Additionally, contrary to our predictions, it was found that students who employed rehearsal strategies also did well in the course. This finding is most likely related to the nature of the discipline; researchers have typically found positive relations between rehearsal strategies and achievement more among the natural and social sciences than in the humanities (VanderStoep, Pintrich, & Fagerlin 1996; Wolters & Pintrich, 1998). It is important to note, however, that students' use of this particular cognitive strategy also decreased over the time, especially among high-achieving students.

Taken together, these findings suggest that it would indeed be remiss to ignore issues related to students' motivation and affect in the study of students' science learning. As Pintrich, Marx, and Boyle (1993) state, it is not enough to examine issues related to students' 'cold' conceptual change. As educators, we must also consider how students' motivational processes such as self-efficacy and task value influence the learning process.

There are several implications of this study. First, it is important to facilitate adaptive motivational beliefs. For example, one can help maintain self-efficacy levels by communicating the role of effort and strategies. In other words, it is essential for instructors to convey to students that chemistry is indeed learnable, and that one can increase one's knowledge and skill of chemistry by employing specific strategies. It is also vital for chemistry instructors to focus on task value in their pedagogy and explanations of course material, as well as relate instruction and assessment to the relevance and utility of chemistry for everyday life. Second, it is important to facilitate strategy use. Instructors might consider modeling specific strategies or ways of thinking for learning chemistry in class, in addition to encouraging students to share their own strategies for learning the course content.

In terms of the limitations of this study, this study focused more on the relations between motivational and cognitive processes and achievement. Future studies should also consider how these processes might be moderated by classroom context. There is also a need to examine further how personal characteristics such as age, gender, or ethnicity shape students' motivational and cognitive processes as well.

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