Learning and Studying Strategies used by General Chemistry Students with Different Affective Characteristics

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ABSTRACT

Students in general chemistry were partitioned into three groups by cluster analysis of six affective characteristics (emotional satisfaction, intellectual accessibility, chemistry self-concept, math self-concept, self-efficacy, and test anxiety). The at-home study strategies for exam preparation and in-class learning strategies differed among the three groups. Students in the high group (strongly positive affective characteristics) were more autonomous learners, reporting they understood the notes they took in lecture more frequently than the group with low (more negative) affective characteristics. The high group also relied less on tutors and teaching assistants for help when preparing for exams. Participating in explanatory behavior (with self or other students) was correlated positively with stronger exam performance, whereas rapt attention or assiduous note-taking in lecture was negatively correlated. The high and low affective groups were indistinct in their reports of amount of quality time spent studying, but did differ in their approach to using a practice exam as a resource.

KEYWORDS

First-year undergrad, chemical education research, high school/introductory chemistry, testing/assessment, administrative issues, learning theories

INTRODUCTION

Many first-year college students experience difficulty not because they lack ability but because they lack awareness of and skill in learning and studying strategies (King, 1992). An array of cognitive skills and processes are involved, such as recording, organizing, synthesizing, remembering, acquiring, and using information in a way that enhances students' understanding. Low-achieving students often use the same ineffective and narrow set of study approaches for all learning tasks, regardless of content or difficulty (Gettinger & Seibert, 2002). They spend more time memorizing and describing (lower level processes) and less time comparing and integrating (higher level processes), using Bloom's taxonomy (Bloom & Krathwohl, 1956) as a framework. Furthermore, low achieving students often take on a passive role and rely mainly on others (such as teachers, tutors, parents) when learning (Gettinger & Seibert, 2002). In contrast, high achieving students are actively engaged and display self-regulatory behaviors, consistently

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monitoring, regulating, and evaluating their understanding throughout the learning process. They initiate and sustain their own learning processes, have high self-efficacy, are intrinsically motivated, and persist through challenges (Hadwin & Winne, 1996; Purdie & Hattie, 1996; Zimmerman, 1998). Instructors can help low-achieving students develop effective and efficient learning strategies. For example, when first-year general chemistry students were explicitly taught learning strategies in a single 50 minute supplementary class, their average was a full letter grade higher compared to those who did not attend (Cook, Kennedy, & McGuire, 2013). In this intervention, students were exposed to a variety of learning strategies and specific metacognitive study strategies that have been proven to work (Gettinger & Seibert, 2002; Hodges, Simpson, & Stahl, 2012; Hadwin & Winne, 1996). These include paraphrasing and rewriting lecture notes, doing homework problems without following an example, previewing material before lecture, studying in groups, and interacting with peers in the role of "teacher" (Cook, Kennedy, & McGuire, 2013).

Nevertheless, student learning and achievement is not simply a matter of application of conscious mental effort toward mastering the scientific content. There must be an emotional commitment to engage and a belief that one's efforts have a chance of leading to success (Haertel, Walberg, Weinstein, 1983). Students enter each new learning task with an antecedent set of cognitive characteristics (past achievement, reading comprehension, and verbal facility) and affective characteristics (attitude and self-concept) (Bloom, 1976). A student who starts with positive attitudes, strong self-concepts, and thorough prior knowledge, should find learning to be easier, quicker, and lead to higher achievement. Within the learning process, metacognitive behavior (self-regulation) and immediate motivational status (self-efficacy beliefs, goal orientations, task-value beliefs) also affect learning outcomes (Zusho, Pintrich, & Coppola, 2003; Brandriet, Ward, Bretz, 2013). Recent research has brought more attention to this interdependent relationship among chemistry students' content knowledge, cognitive processing, affective characteristics, and motivation (Chan & Bauer, 2014; Xu, Villafane, & Lewis, 2013).

This article extends this effort by exploring student diversity in the affective dimension. Specifically, we explored how students approach the task of learning when they differ in their attitudes toward chemistry, concept of themselves as learners of chemistry, and sense of their ability to be successful at chemistry. Chan and Bauer (2014) looked at students entering the general chemistry course at a medium-sized public research university. Arguably these students are the most vulnerable because they are making the initial transition to college, they are in programs of study for which chemistry is required but often considered a roadblock (e.g. biology), and they have backgrounds (cognitive and emotional) which vary tremendously. This previous study identified from the literature six affective variables that had modest relationships with student outcomes. These variables were used to group students via a cluster analysis procedure. Effectively, individual students were distributed across a six-dimensional space, and then assembled into nearest-neighbor groups. The six variables were emotional satisfaction with chemistry, intellectual accessibility of chemistry, chemistry self-concept, mathematics self-concept, self-efficacy for learning chemistry, and chemistry test anxiety.

The previous study found that three clusters with significantly different characteristics could be delineated. In each cluster, the set of characteristics were found to be uniform in direction, e.g. one group was highest on all characteristics but lowest on test anxiety (called the "high" group), another group (called "low") was lowest on all characteristics but highest on test anxiety, and a middle group was "middle". Given previous reports of correlations among these variables, the overall unanimity in direction across variables was not surprising. Nevertheless, one is left with the impression of a self-reinforcing positive or negative affective profile. Student performance on tests, both early and at the end of a semester, was directly correlated with the affective profile. Furthermore, other characteristics were also found to be consistent with this picture, e.g. student reports of metacognitive behaviors.

In this study, we sought to explore more directly what students do and how much time they spend in class or at home when they engage in chemistry study behaviors as a function of their affective profile. If students with different affective characteristics exhibit distinctly different study strategies, particularly if the strategies are ineffective ones, then it may be possible to offer some remedy and target that to the students who need it most. Thus the following research questions were pursued:

1. To what extent do chemistry students distinguished by different affective characteristics differ in their use of in-class learning and at-home studying strategies?
2. To what extent is time-on-task and type of study strategy correlated with exam achievement? How is this relationship moderated by student affective characteristics?

METHOD

Affective Instruments and Cluster Analysis

Clustering variables were selected from three instruments. The Chemistry Self-Concept Inventory (CSCI) (Bauer, 2005) provided two dimensions of students' concepts of themselves as learners, in chemistry and in mathematics. The shortened version of the Attitude toward the Subject of Chemistry Inventory (ASCIv2) provided two dimensions of attitude toward chemistry, emotional satisfaction and intellectual accessibility (Bauer, 2008; Xu & Lewis, 2011). The Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich & De Groot, 1990) has subscales for the dimensions of self-efficacy and text anxiety. All scales have four to ten response items in Likert format and have been validated with higher-education student populations. A detailed description of the instruments and clustering variables is described elsewhere (Chan & Bauer, 2014). Student responses were collected on-line using Qualtrics survey software. Clustering was accomplished with the following steps. Survey response data from the three separate instruments were converted to Z-scores (subtracting the scale mean and dividing by the standard deviation). This puts each of the six variables onto the same relative scale so each contributes evenly to inter-cluster distances. A procedure called Ward's method was implemented using the commercial product SPSS (original acronym for Statistical Package for the Social Sciences. Ward's method minimizes internal cluster sum-of-squares and maximizes between-cluster sum of squares. This cluster procedure provided a satisfactory and interpretable result; nevertheless, it is important to recognize that other procedures might group the students in alternative yet acceptable ways.

Study Strategies Survey

To ascertain the types of in-class learning and at-home studying strategies used by students, a new study strategies survey (Appendix 1) was developed. The survey consists of both open-ended and forced choice questions assembled from several previously-reported in the literature (Pintrich, Smith, Garcia, McKeachie, 1991; Weinstein & Palmer, 2002). The open-ended questions ask students to list the types of strategies used in two different settings: during lecture and when preparing for exams, with the intention of capturing spontaneous responses and minimizing acquiescence bias. The choice questions come next. They list strategies (generated by one of the authors) in which students rate frequency of use on a 5-point Likert scale (1-never, 2-rarely, 3-sometimes, 4-very often, 5-always). Questions regarding perceived effectiveness of and satisfaction with study strategies were also asked. The Study Strategies Survey was made available online immediately after the first exam when scores had been made known to students.

Course Achievement

Early course achievement was taken as the score on the first exam, approximately four weeks into the semester. This instructor-written, 80-minute exam consisted of 70% written and 30% multiple-choice questions covering topics of atomic theory, chemical elements and compound symbols, nomenclature, molar mass, and stoichiometry.

Office Consultation

To triangulate results gathered from the Study Strategy Survey, students identified in high and low affective profile groups were randomly selected for a short “office hour consultation” with the first author. Random selection was accomplished by generating in Microsoft Excel a random number for the students in each group, and then issuing email invitations using that sequence. Those who were not selected had an equal opportunity to attend any of the professor’s regular office hours. During the invited visit, a short 15-25 minute semi-structured interview was conducted. Questions were designed to get a deeper understanding about the study strategies students were using. Thirty students who had completed all affective instruments and Study Strategies Survey were invited for a consultation (fifteen in high and fifteen in low affective groups). A second round of invitations was sent to students in the low affective group due to low participation, however, this only attracted one additional student. Ultimately, eighteen students agreed to participate (n = 13, high; n = 5, low).

Students were asked to talk about three topics: i) approach to doing practice exams (exams from previous years), ii) use of learning strategies in lecture, and iii) use of studying strategies for exams. The interviews were audio-recorded and transcribed verbatim. The lens through which student comments were reviewed and analyzed was metacognitive self-regulation:

how did students engage with the material and with others, what resources were used and in what order, how much time was spent and when, to what extent were elaboration and rehearsal behaviors used. The focus was on what students do and on whether they made strategic choices about what they do. Behavioral themes were identified and confirmed using the constant comparative method (Glaser and Strauss, 1999). Summary descriptions were created for student behaviors (Appendix 2). Responses were coded by two chemistry education researchers and the first author. After training, all three coders agreed on 91% of the categorizations.

Participants

The study population is identical to the study population previously reported in Chan and Bauer's (2014) paper. The course is the first semester of a two-semester sequence typically required for students in the biological and health sciences, who make up about two-thirds of the enrollment. Students were predominantly in their first-semester at college. All surveys were available on-line: the affective and metacognitive instruments (ASCIv2, CSCI, and MSLQ) for a week at the beginning of the semester and the Study Strategies Survey for a week immediately after the return of the first exam. Of the 554 students in class (three lecture sections), 164 (30%) completed all four surveys and consented to participate. (This constitutes list-wise deletion of students). Students were reminded of survey opportunities throughout the semester by email, announcements in the web-based course management system, and in lecture. As an incentive for completing the surveys or for participating in an interview, students earned extra credit (~1%) toward their course grade regardless of their consent status. This protocol was approved by the authors' Institutional Review Board. Students who completed the survey outperformed the students who did not by about 5% points on exams (significant at $p < 0.05$). Those who completed the survey also were more likely to have course grades that were A or B (about 66%) vs those who did not (about 44%). The consequences of this imbalance are considered in the Conclusion section.

Statistical Analysis

For all statistical analysis, SPSS version 20.0 was used. Where repetitive inferential tests were performed (e.g. survey items), a Bonferonni correction was applied to control for increased risk of Type I error. (When many inferential tests are done, the likelihood that at least one will result in "significantly different" increases. Consequently, reducing the threshold for significance to 0.01 or 0.001 rather than say 0.05 avoids potential false positives.) Because the intent of this study was to see the extent to which learning and studying strategies differed among cluster groups, responses that were extreme relative to the mean on each survey question category were kept. No ceiling or floor effects were observed.

RESULTS

I. Study Strategies Survey: Relationship of items with course achievement

As part of the Study Strategies Survey, students were asked to report the frequency (never to always) of use of twenty-eight possible learning or study behaviors (Appendices 3 and 4). Correlations were calculated for these items with the variable of exam performance. Four items (items 4, 21, 24, and 25) were significantly but modestly correlated with exam scores (Table 1).

Table 1. Correlation of learning behaviors with exam performance (*p <0.001)

Item	r
4. When I copy things down in class, I understand what I'm writing down.	0.44*
21. I memorize answers or steps to solving problems if I don't understand what's going on.	-0.24*
24. I ask myself questions to make sure I understand what I'm studying.	0.18*
25. I practice explaining the material to my friend.	0.26*

II. Study Strategies Survey: Principal Component Analysis

Since the study strategies survey was newly created, it is possible that certain items were related because they measure a common idea (because students responded to them in a similar way). Combining those items could improve reliability of the average. Principal Component Analysis (an option in SPSS factor analysis procedures) with varimax rotation was used to create linear combinations of items that might explain more of the variance in responses. Five major components were found (Table 2), accounting for 46% of the common variance (Appendix 5). Reliabilities (Cronbach) for each component are modest (0.6 to 0.7) and a bit lower than desirable. Further development of survey items, in particular, increasing the number that contribute to each component, would help increase reliability. Weak but significant correlations of two items were found with exam performance for "Questioning/Explaining Behavior" Component 3 ($r(228) = 0.24$, $p < 0.001$) and "Class note-taking" Component 5 ($r(228) = -0.19$, $p < 0.01$) (Table 2, right column). Component 3 includes two of the items previously linked to higher test scores.

Table 2. Five components found from principal component analysis (**p < 0.001, *p < 0.01), Cronbach alpha reliability, and Pearson r correlation with exam scores.

Component	Label	Items	α	r
1	Reviewing/ processing/ organizing/ outlining notes before and after lecture	6. I review my notes within one day after lecture. 9. I review my notes from previous classes before each lecture. 10. After class, I paraphrase, summarize, or reorganize my notes. 11. Before lecture, I skim through the chapters that will be taught. 22. I use flashcards, concept maps, or make outlines of topics covered in class. 27. I read the textbook thoroughly and take notes.	0.75	-0.04
2	Making sure not to miss any part of lecture; using technology in lecture	14. I use my laptop/iPad to take notes. 15. I audiotape the lecture and replay to make sure I don't miss anything. 16. I sit in on another section of Chem 403 (in addition to the one I'm attending).	0.68	-0.04
3	Questioning / explaining material to friends, studying in a group	24. I ask myself questions to make sure I understand what I'm studying. 25. I practice explaining the material to my friend. 26. I study with a group of friends regularly.	0.68	0.24**
4	Studying for exams	17. I usually study the night before the exam to make sure the material is fresh in my mind. 19. I study from the answer keys of past exams. 21. I memorize answers or steps to solving problems if I don't understand what's going on. 23. I rely on past exams to gauge what I need to know for the exam.	0.60	-0.16
5	Taking notes in lecture	1. During class, I write down as much as I can about what I'm hearing and seeing. 2. I try to sit in a spot with less distractions. 13. Instead of taking a lot of notes, I just listen and absorb everything.	0.60	-0.19*

III. Study Strategies Survey: Differences in Studying and Learning Strategies Among Affective Groups

Using individual study strategies survey questions as dependent variables, the three cluster groups (Chan and Bauer, 2014) were compared using one-way multivariate analysis of variance (MANOVA). Two separate MANOVAs were conducted: One for in-class learning strategies (16 items) and another for exam preparation strategies (12 items). Post-hoc pairwise comparisons showed that a major difference between the high and low affective groups was their approach used when taking notes in class ($F(2,162) = 9.6$, $p < 0.001$, $\eta^2 = 0.11$). An eta squared value of 0.11 represents a small effect size. Students in the high group reported more frequent understanding of the notes they take in class (4.0 "very often" response on scale of 1 to 5) compared to students in the low group (3.2, closer to "sometimes").

The affective groups were also compared in terms of their exam preparation strategies. Again, cluster group was the independent variable and survey items were the dependent variables. The groups again were different ($F(2,162) = 8.9$, $p < 0.001$, $\eta^2 = 0.10$). Posthoc analysis indicated that item 23 (Appendix 4) was the major source. The low affective group reported stronger reliance (3.2 "sometimes" to "very often") on tutors, teaching assistants (TAs), and Peer-Led Team Learning (PLTL) leaders for help more frequently compared to the high group (2.4 "rarely" to "sometimes").

The power for the MANOVA analyses (using GPower software) for the conditions of effect size, Type I error rate, sample size, and number of survey items was in the range of 0.7 to 0.8, which is slightly weak given the number of survey items being tested relative to the size of the sample. Reducing the number of variables via principal component analysis should have provided an advantage, but the reliabilities of the components found perhaps worked against this strategy. Nevertheless, the quantitative findings are complemented and confirmed by the student interview work.

IV. Study Strategies Survey: Evaluating the Effectiveness of In-Class Learning and At-Home Studying Strategies Among Affective Groups

Open-ended questions asked students to evaluate the effectiveness of the learning and studying strategies they had been using and reasons they had for modifying or not modifying strategies (Appendix 1). Figures 1 (in-class learning strategies) and 2 (at-home study strategies for exam preparation) summarize these results in pie charts. Each affective group has its own pie chart. For the low affective group, fewer than half of the students reported their strategies have been effective (blue slice: 40% (in-class learning); 48% (at-home studying)). The percentage of students who were satisfied with their strategies increases substantially in the medium and high affective groups. The second largest response category is from students who report that their strategies have not been effective and they plan on modifying them. A very small percentage of students (8% or less in any group) did not plan on modifying their strategies.

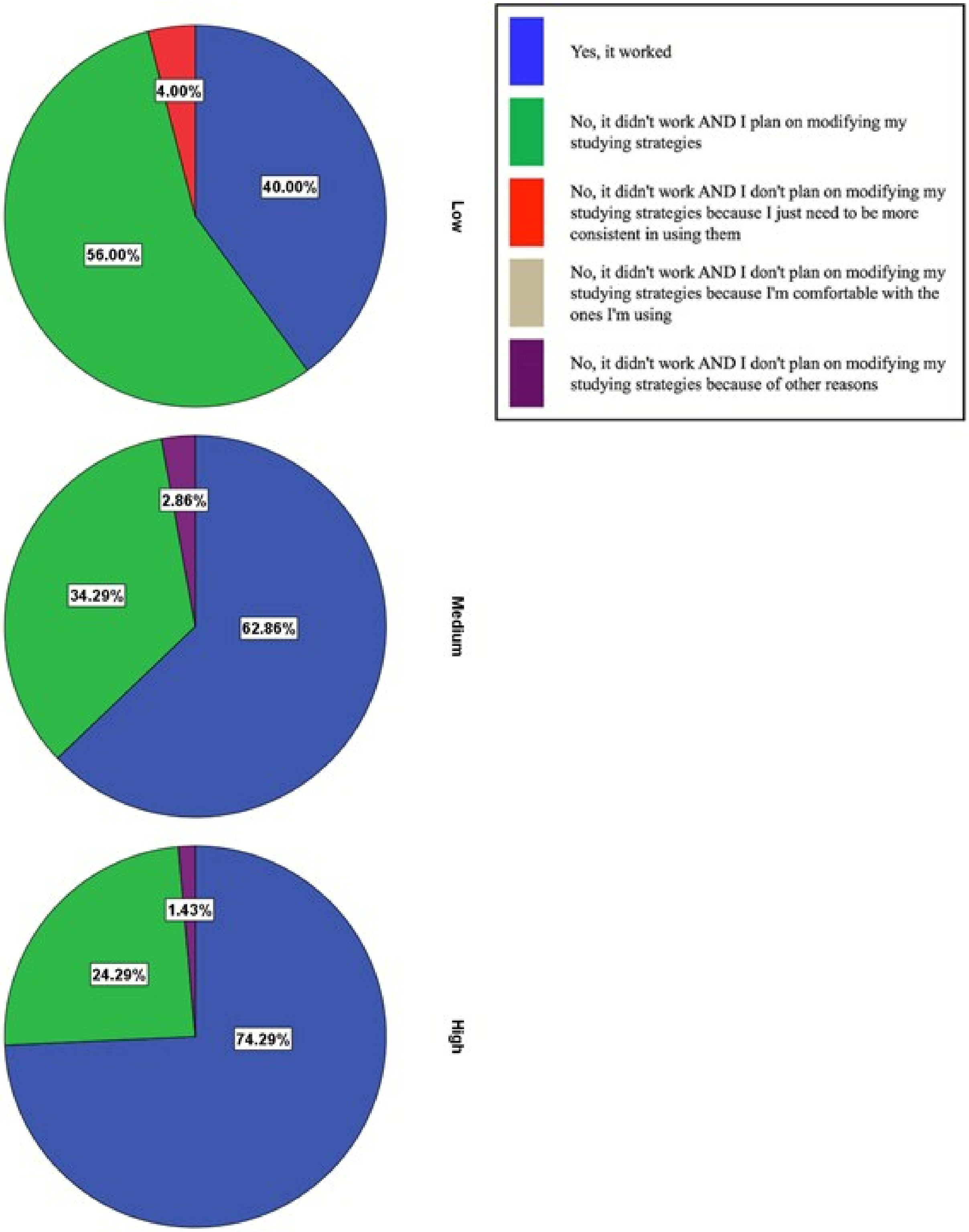

Figure 1. Pie graphs summarizing effectiveness of in-class learning strategies and reasons for modifying strategies (or not) according to affective groups. Refers to questions 4-7 on Study Strategies Survey. (Low: N =25, Medium: N = 70, High: N = 70)

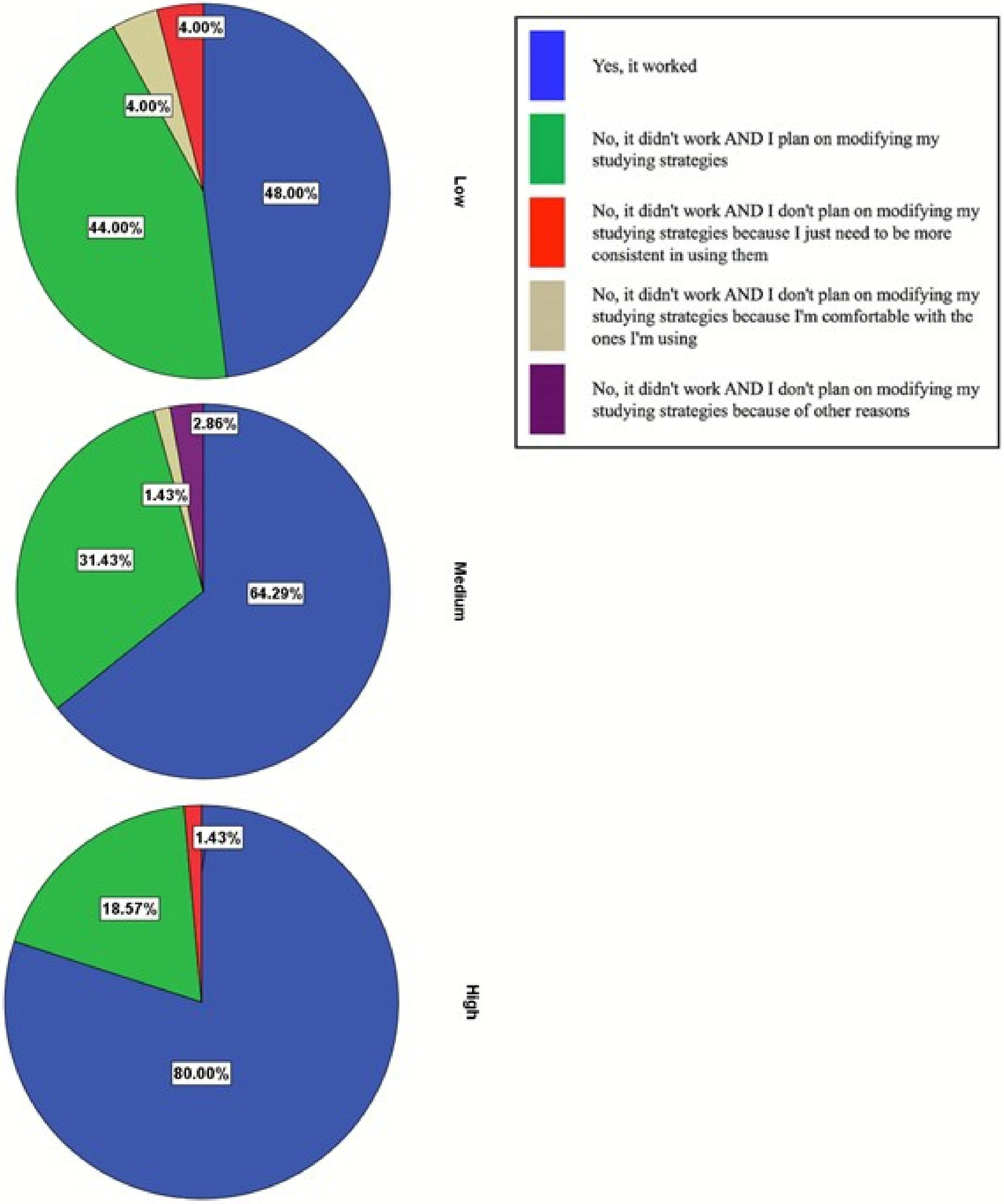

Figure 2. Pie graphs summarizing effectiveness of at-home studying strategies and reasons for modifying strategies (or not) according to affective groups. Refers to questions 10-13 on Study Strategies Survey. (Low: N =25, Medium: N = 70, High: N = 70)

V. Study Strategies Survey: Student Interviews

Students invited for an office consultation were asked to talk about three topics: i) approach to doing practice exams (made available via course website), ii) use of in-class learning strategies, and iii) use of at-home studying strategies when preparing for exams. Table 3 summarizes the reported student behaviors as identified using the category descriptions in Appendix 2. Data for each individual student is listed in Appendix 6. In general, a larger proportion of students in the high affective group were classified as exhibiting stronger intellectual engagement in how they used the practice exam and in their behavior during class. Students in the low affective group either did not exhibit the behavior or did so less frequently. To support these classifications, excerpts from students' transcripts are here organized by the three topics and according to the affective group.

Table 3. Classification of interviewed student behaviors (Appendix 2 has category descriptions)

Affective Group		Practice Exam			In-class activity		General Exam Preparation		
	Category	1	2	3	1	2	1	2	3
High		12	0	1	9	4	10	3	4
Low		0	4	1	2	3	3	2	3

Students used the practice exam in three different ways: they *approached*, *attempted to approach*, or *did not approach* the practice exam like a real exam. In all but one instance, students in the high affective group approached the practice exam as if it were a real exam (code 1). They timed themselves, went to a quiet room, and did all the questions without consulting other resources.

> *[I] wouldn't have the answer key within reach…if stuck, [I] would skip and star [the] question, then look at the answer key as the last resort and look at the steps from the answer key and make note of how problem was solved in my notes and note down what is confusing to me…* [Student 5, high]

Students in the high group mainly relied on themselves and only consulted other resources (notes, textbook, websites, friends) when in desperate need of help. When all of these resources have been used up, they would consult the answer key as the final resource.

> *If [I get] really stuck, [I will] go to my notes and find a problem that has similar structure to the problem I don't get and transfer it over… if still stuck, I will use answer key as the last resource.* [Student 16, high]

> *I would go as far as I can, then refer to notes, [online] problems, or ask friends for help before consulting the answer key…I tried not to look at answer key because it won't be there on the test…* [Student 1, high]

Students in the high group were determined to refer to as few resources as possible when doing the practice exam. Consequently, they felt more confident and secure about the exam material.

> *If I go into the exam knowing I was able to do the practice exam, and that it wasn't the answer key or notes, I'll walk in the exam feeling better and more confident, not stressing myself out, and not second guessing myself* [Student 3, high]

> *Even after finishing the practice exam, I did not refer to the answer key for the questions I got stuck on but used my notes to look up those questions and made sure I understood everything clearly and [have] no second questions… if I do, I would ask for help* [Student 18, high]

Furthermore, students in the high group display characteristics that are typical of autonomous learners (Boud, 1981). These students are independent, responsible, determined, and self-directed learners who function with minimal external guidance.

> *Anything I do not understand I will attempt to understand on my own. If I still do not understand a concept, I will call my dad, who is a chemistry teacher, or work out the problem with a friend who is in the same class. If [still] stuck, I will skip and come back to it, highlight, and write out all the important stuff…I would use the answer key as the final resource after consulting notes and asking dad for help because I want to ensure that I fully understand [the content] and not being taught by other people…* [Student 15, high]

In contrast, students in the low affective group *attempted* to approach the practice exam like a real exam (code 2). These students started off the exam with no resources but referred to resources for assistance when they got stuck. Compared to students in the high affective group, these students gave-up more readily and relied on the answer key more often when they were stuck.

> *…looked at exam, tried to do problems…when stuck, went back to notes/answer key to figure out how to do it…* [Student 12, low]

These students would often go back and forth between answer key and practice exam because they did not want to "memorize" the incorrect way of solving the problem or in other instances they had no idea how to start the problem.

…started to work on it like an actual test…got stuck and then looked at answer key and from there on went through the exam with answer key alongside for questions I did not understand. [Student 11, low]

[For the] first practice exam, I did a problem, didn't get it so went to look up answer…did another problem, checked answer. For the second practice exam, I treated it the same way as the first practice exam…didn't want to commit to memory the incorrect way of solving the problem [Student 10, low]

The final category describes students who *did not approach* the practice exam like a real exam (code 3). Only two students were classified into this category. These students often depended on resources for help, did not time themselves when taking the practice exam, or collaborated with other students when doing the practice exam.

…go through each problem and try to solve, did not time myself, had answers and notes on the side while working on practice exam to reference back if needed… [Student 13, low]

...attempted as a group, worked with notes…if didn't understand, talked with group members and go to answer key to see how the answer was derived… [Student 6, high]

The second theme delineated from the interviews was students' use of learning strategies in lecture. Two codes were assigned: student is actively engaged (code 1) or not (code 2) in lecture. The distinction in this instance is less clear: 9/13 (69%) from the high affective group and 2/5 (40%) from the low affective group described active engagement during class. Some students actively engaged in lecture by processing, elaborating, and interpreting notes simultaneously; asking questions; or highlighting confusing concepts (code 1). When practice problems were presented in lecture, they actively attempted the problem alone or in a group before instructor goes over them.

…take notes but also try to understand the way Prof X constructs and analyzes a problem to solve for an answer…when professor writes down stuff on the board, I try to first process, interpret what he writes and then paraphrase in my own words… [Student 4, high]

…use highlighters to mark important facts and terms, also keep a separate sheet to write down questions [that] need further clarification on… [Student 12, low]

Other students who are not actively engaged in lecture mainly record notes and receive information in lecture, passively follow in class by sitting and paying attention, or copy notes verbatim without much processing and interpretation in lecture (code 2). When practice problems are presented in lecture, these students often wait for instructor's explanation instead of attempting it first.

> *…write everything down that we go over [because] even if I don't understand something, I know I can go back to it later if it's in my notes*
> [Student 7, high]

> *…take notes but try not to paraphrase because don't want to misinterpret what is said so copy [notes] verbatim…sometimes don't understand the notes…*
> [Student 9, low]

The third theme that emerged from the interviews was students' use of study strategies when studying for exams. Three codes were assigned: student reviews lecture notes, does practice exams, or homework problems *and* practice metacognitively self-regulated activities (code 1); student reviews lecture notes, does practice exams, or homework problems without explicit metacognitive engagement (code 2); and student makes use of various available resources to assist their studying (code 3). We distinguished students' use of resources (code 3) from the types of activities they are engaged in when studying for exams (codes 2, 3). In this category, there was no clear distinction between the high and low affective groups. Code 1 describes students who demonstrate metacognitive awareness by monitoring and evaluating their understanding through mental and social interactions such as: self-questioning, self-quizzing, explaining, elaborating, or teaching. Furthermore, he/she is proactive and initiates learning by incorporating a variety of strategies such as: organizing, outlining, or paraphrasing notes, creating study guides, flashcards, or cheat sheets to assist their studying. He/she tend to focus on mastery learning and understanding of the material.

> *Outline notes, handouts; do practice problems…make flashcards of polyatomic ions; make study guide that consists of definitions, steps to do problems, and the problem itself…re-teaching or re-explaining chemistry to freshmen students help me learn concepts again…* [Student 17, high]

> *Go over notes, do homework, make flashcards, use PhET online simulations, go through CONNECT with textbook, review notes, complete practice exams, ask myself questions when solving problems* [Student 10, low]

Alternatively, some students were not as elaborate when studying for exams. These students only completed practice problems, practice exams, or reviewed notes. When students use self-questioning as a learning strategy, they often ask lower-order questions that focus on remembering and understanding ("How do I convert L to mL? What are the six strong acids? What does M stand for?"):

> *…review notes, go through textbook, reword problems by substituting different numbers into questions that were gone over in class, ask questions while studying like how to change from mL to L, g to mol?* [Student 6, high]

> *…look over old tests, notes, work out problems on a white board, memorize important compound names… ask process questions to ensure understanding of material like would I be able to repeat this again with another [similar] problem?* [Student 13, low]

VI. Study Strategies Survey: Differences in Quality Time Spent on Chemistry and Exam Achievement Among Affective Groups

The Study Strategies Survey included a question pertaining to amount of out-of-class study time. Quality time is defined here as the time in which students are fully engaged on a task without distractions (i.e. social media texting, watching TV, etc). Students reported less than 1 hour (3.1 %), 1-2 hours (19.2 %), 3-6 hours (50.2 %), 6-8 hours (21.2 %), or more than 8 hours (6.3 %). We found the amount of "quality time" spent on chemistry outside of the required class was not significantly correlated with exam achievement ($r(244) = -0.078$, $p = 0.23$). In addition, no differences were found among the affective cluster groups. This finding is consistent with other investigations. Weak relationships with test scores were found between total study time and time spent reviewing (Dickinson & O'Connell, 1990). This result is consistent across various disciplines (natural sciences, social sciences, humanities), even after controlling for college aptitude exam scores, such as the SAT (Schuman, Walsh, Olson, & Etheridge, 1985). Many college students believe the more time they spend "studying," the better they will perform on exams, however, our findings confirm other research suggesting this assumption that time alone will help is incorrect.

CONCLUSIONS AND IMPLICATIONS

Students who completed all of the necessary surveys had stronger course performances than the students who did not do so. This student self-selection may affect the MANOVA results by narrowing the range of responses included in the analysis. Consequently, one should be cautious about quantitative generalization to the entire population of students in this course. Nevertheless, it is important that the students in the study did include those with a range of course outcomes (25% A, 40% B, 25% C, 10% D or F). This imbalanced participation does not present a serious problem for this study since we are not making an absolute claim about the frequency of study strategy behaviors. Rather, we are identifying relationships among behaviors, performance, and affective characteristics.

The first research question asked whether students grouped by affective characteristics (emotional satisfaction, intellectual accessibility, chemistry self-concept, math self-concept, self-efficacy, and test anxiety) differed in terms of their in-class learning and at-home studying strategies. Some differences were found. Students in the high affective group reported they understood the notes they took in lecture more frequently than the low affective group. This sense of understanding during information processing is positively correlated with exam performance (Table 1). At the same time, the failure to take notes or simply scribing what happens is negatively correlated (Table 2). This survey result is confirmed by student interviews, which indicate that students in the high affective group are more actively engaged during lecture. These results suggest that the depth of processing is important. Furthermore, the high affective group (and consequently high achievers) shows characteristics typical of autonomous learners, that is they initiate their own learning with minimal external guidance (i.e. from tutors, TAs, and PLTL leaders) and challenge themselves to rely on their own thinking when given a practice exam opportunity. Over 70% of students within the high affective group report the strategies they have been using to be effective, while a lower percentage was reported for students in the low affective group (40-48%). For the most part, students who report that their strategies have not been working successfully plan on modifying their strategies in the future, suggesting they have a desire or motivation to improve and perform better.

Regarding the second research question, the amount of uninterrupted time spent studying chemistry outside of lecture time did not correlate with exam performance and did not appear different among the affective groups. On the other hand, the survey results showed that stronger performance was related to processing information by elaboration and self-questioning or explaining ideas to others.

Triangulation of survey and interview data was necessary to assemble a picture of the learners in this sample of general chemistry students. The results suggest that learning and studying behaviors are different for students who exhibit higher vs lower sets of affective characteristics, and that those behaviors are linked to better exam performance. These results regarding attitude, motivation, and self-concept complement the work of others, reported in the introduction, which primarily considered student achievement measures. The Study Strategies Survey seems to have provided some insight regarding student learning approaches, but its psychometric characteristics should be more strongly developed and established in future work.

What are the practical implications of the findings from this research? The primary message is that students need assistance in becoming aware that what they do is not so important as what they are thinking while they are doing it. Instructors of chemistry must provide explicit opportunities for students to engage in challenging work that asks them to discuss, explain, and elaborate (Simbo, 1988; Chi et al., 1989), and to work as much as possible without the crutch of having an answer or tutor in front of them. Some students are prepared for this because of their affective profile, and others are not. Of the six affective variables we have considered, test anxiety and self-efficacy seem most accessible as characteristics that could be manipulated.

Anxiety about science has been recognized as an issue for students for a long time (Mallow, 1981) and there are approaches that instructors can use to address it, for example, writing about those anxieties (Ramirez and Beilock, 2011). Similarly, self-efficacy is the perception that one is able to accomplish a specific learning task (Zimmerman, 1998). Students need to see pathways and strategies that can lead to more successful outcomes. Peer-Led Team Learning, in which successful students model and guide the learning of other students, may be one approach to achieving this. (Chan and Bauer, 2015).

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Appendices

Appendix 1. Study Strategies Survey

Study Strategies Survey

The following survey includes questions about the types of study strategies you use to assist your learning and your goals for this course. Please answer the following questions as thoroughly as possible. Your response is important and informative to us as it will assist us in our instruction strategy to better assist your needs.

Thank you for your time and participation.

Julia Chan
PhD Candidate
Department of Chemistry

1) Quality time is described as time fully engaged on a task without any distractions (i.e. facebook, texting, watching TV, etc.) On average, estimate how many hours of quality time you spend on this course outside of the required class time per week.

   Please consider the **lecture portion of Chem 403** only when answering this question.
   - No more than 1 hour
   - 1-2 hours
   - 3-6 hours
   - 6-8 hours
   - More than 8 hours

2) How do you learn in Chem 403 lecture? What are some strategies/approaches you use t assist your **learning in lecture?** Please list below.

3) Below is a list of strategies some students use to assist their learning in lecture. Please indicate how often you use the following strategies **in lecture.**

   (1 Never, 2 Rarely, 3 Sometimes, 4 Very Often, 5 Always)

   Before lecture, I skim through the chapters that will be taught.
   I review my notes from previous classes before each lecture.

I sit in on another section of Chem 403 (in addition to this one).
I audiotape the lecture and replay to make sure I don't miss anything.
I use my laptop/iPad to take notes.
I ask questions in class when I don't understand the material.
During class, I write down as much as I can about what I'm hearing and seeing.
I note down the concepts that are unclear to me in class and make sure I look them up after class or ask someone for clarification.
After class, I paraphrase, summarize, or reorganize my notes.
When I copy things down in class, I understand what I'm writing.
I try to sit in a spot that does not have many distractions.
I identify the "smart" people in class and sit with those people.
When I sit with my friends, they tend to distract me from paying attention to lecture.
I review my notes within one day after the lecture.
Instead of taking a lot of notes, I just listen and absorb everything.
I cannot focus in class. I often find myself daydreaming about other things.

4) Have your **learning strategies in lecture** worked in relation to your exam performance?
   - Yes, they have been working.
   - No, they have not been working.

5) If you answered NO in the previous question, do you plan on modifying your studying strategies?
   - Yes, I plan on modifying my studying strategies.
   - No, I don’t plan on modifying my studying strategies.

6) If you answered NO in the previous question, select the statement that best applies to you.
   - I don’t plan on modifying my strategies because I’m comfortable with the strategies I’m using.
   - I don’t plan on modifying my strategies because I just need to be consistent with my strategies.
   - I don’t plan on modifying my strategies because of other reasons.

7) If you answered **YES** in the previous question, how do you plan on modifying your studying strategies? Describe in detail in the text box below.

8) How do you **study for an exam** in Chem 403? What are some strategies/ approaches you use to **prepare for an exam**? Please list below.

9) Below is a list of strategies some students use when **studying for an exam.** Please indicate how often you use the following strategies when **preparing for an exam.**

(1 Never, 2 Rarely, 3 Sometimes, 4 Very Often, 5 Always)

I read the textbook thoroughly and take notes.
I use flash cards, concept maps, or make outlines of topics covered in class.
I rely on past exams to gauge what I need to know for the exam.
I use other resources (online tutorials, other textbooks, wikipedia, scientific journals, etc.) to verify my understanding.
I usually study the night before the exam to make sure the material is fresh in my mind.
I study from the answer keys of past exams.
I memorize answers or steps to solving problems if I don't understand what's going on.
I rely on my tutor/TA/PLTL leader for help.
I visit my instructor's office hour on a regular basis to ensure I understand everything.
I practice explaining the material to my friend(s).
I study with a group of friends regularly.
I ask myself questions to make sure I understand what I'm studying.

10) Have your **strategies for studying for exams** worked in relation to your exam performance?
   - Yes, they have been working.
   - No, they have not been working.

11) If you answered **NO** in the previous question, do you plan on modifying your **studying strategies for preparing for exams**?

   - Yes, I plan on modifying my studying strategies.
   - No, I don't plan on modifying my studying strategies.

12) If you answered **NO** in the previous question, please check the statement that best applies to you.
   - I don't plan on modifying my strategies because I'm comfortable with strategies I'm using.
   - I don't plan on modifying my strategies because I just need to be consistent with my strategies.
   - I don't plan on modifying my strategies because of other reasons.

13) If you answered YES in the previous question, how do you plan on modifying your **studying strategies for preparing for exams?** Describe in detail in the text box below.

Appendix 2. Behavioral categorization of student study strategies

Questions	Behavioral Code	Characteristics
Approaches to doing practice exam	(1) The student *approaches* the practice exam like a real exam.	The student treats the practice exam like a real exam. They would complete the practice exam alone in a quiet room and time themselves. He/she uses self as a primary resource, then other available resources (notes, textbook, on-line help sites) when necessary. Once all these resources have been used, they will consult the answer key as the final resource. This student uses self as a primary resource and displays autonomous behavior.
	(2) This student *attempts* to do the practice exam like a real exam.	The student starts off the exam with no resources, attempts questions but when stuck, will likely refer to other resources such as notes and answer key for assistance. Sometimes, he/she will have the answer key on the side and go back and forth between answer key and practice exam.
	(3) This student *does not* approach the practice exam like a real exam.	The student refers to readily available resources when doing the practice exam. Rather than working individually and treating it like a real exam, he/she may work in a group.
Learning strategies in class	(1) This student is actively engaged in lecture.	This student is actively engaged in lecture. He/she follows through lecture by processing, elaborating, and interpreting notes simultaneously. He/she notes down key concepts that are confusing and asks questions in class. When practice problems are presented in lecture, he/she actively attempts the problem alone or in a group before instructor goes over them.
	(2) This student is *not* actively engaged in lecture.	This student mainly records notes and receives information in lecture. He/she passively follows in class by sitting and paying attention. He/she tends to copy notes verbatim without much processing and interpretation in lectures but tries to make sense of the material later (in their own time). When practice problems are

		presented in lecture, this student often waits for instructor's explanation instead of attempting it first.
Study strategies for exams	(1) This student reviews lecture notes, does practice exams, or homework problems *and* practice metacognitively self-regulated activities.	This student demonstrates metacognitive awareness by monitoring and evaluating their understanding through mental/social interactions such as self-questioning, self-quizzing, explaining, elaborating, or teaching. Doing these activities verify the extent to which students truly comprehend the material the way they think they understand it and serves to reinforce understanding. Furthermore, he/she is proactive and initiates learning by incorporating a variety of strategies such as organizing, outlining, or paraphrasing notes; creating study guides; flashcards; or cheat sheets to assist their studying. He/she tends to focus on mastery learning and understanding of the material.
	(2) This student reviews lecture notes, does practice exams, or homework problems *only*.	This student only does practice problems/practice exam or reviews notes when studying for exams. If he/she uses metacognitive learning strategies, they often utilize them superficially. For instance, when students form questions regarding the study material (self-questioning), they often ask lower-order questions that focus on remembering and understanding ("How do I convert L to mL? What are the six strong acids? What does M stand for?")
	(3) This student makes use of various available resources to assist their studying.	This student makes use of multiple resources when studying for exams (i.e. looks online for additional references in addition to using textbook, attends TA/professor office hour, help/ review sessions).

Appendix 3. One-way MANOVA results for types of learning strategies used in or in preparation for lecture according to cluster groups, *p<0.001. The numbers represent the relative frequency on a scale of 1 (never) to 5 (always). Organized highest to lowest mean for Low group.

Fall 2013	Low (N = 25)		Medium (N = 70)		High (N = 70)		F	η^2
	Mean	SD	Mean	SD	Mean	SD		
1. During class, I write down as much as I can about what I'm hearing and seeing.	4.48	0.77	4.17	0.90	4.04	1.08	1.9	0.02
2. I try to sit in a spot that does not have many distractions.	4.28	0.89	4.06	0.90	4.20	0.97	0.7	0.01
3. I note down the concepts that are unclear to me in class and make sure I look them up after class or ask someone for clarification.	3.84	1.03	3.76	1.04	3.99	0.99	0.9	0.01
4. When I copy things down in class, I understand what I'm writing.	3.24[a]	0.60	3.60[a/b]	0.91	4.00[b]	0.74	**9.6***	0.11
5. I ask questions in class when I don't understand the material.	2.96	1.34	2.64	1.09	2.73	1.13	0.7	0.01
6. I review my notes within one day after the lecture.	2.72	1.10	2.74	1.15	3.06	1.05	1.7	0.02
7. I identify the "smart" people in class and sit with those people.	2.56	1.16	2.38	1.17	2.44	1.31	0.2	0.00
8. I cannot focus in class. I often find myself daydreaming about other things.	2.56	1.12	2.33	0.94	2.04	0.98	3.0	0.04
9. I review my notes from previous classes before each lecture.	2.48	0.87	2.50	1.00	2.44	0.99	0.1	0.00
10. After class, I paraphrase, summarize, or reorganize my notes.	2.32	1.25	2.63	1.02	2.56	1.06	0.8	0.01
11. Before lecture, I skim through the chapters that will be taught.	2.20	1.15	2.17	1.01	2.11	1.15	0.1	0.00
12. When I sit with my friends, they tend to distract me from paying attention to lecture.	1.76	1.01	2.23	1.14	1.73	0.90	4.6	0.05
13. Instead of taking a lot of notes, I just listen and absorb	1.64	0.70	2.26	1.22	2.34	1.20	3.6	0.04

everything.								
14. I use my laptop/iPad to take notes.	1.28	0.84	1.51	0.91	1.29	0.66	1.7	0.02
15. I audiotape the lecture and replay to make sure I don't miss anything.	1.16	0.62	1.34	0.80	1.11	0.53	2.2	0.03
16. I sit in on another section of Chem 403 (in addition to this one).	1.16	0.47	1.30	0.79	1.10	0.46	1.9	0.02

i) $F(32,294) = 2.03$, $p<0.001$; Wilks' Lambda = 0.67; $\eta^2 = 0.18$

ii) Within a row, different letters between cluster groups indicate a significant difference ($p<0.001$). Same letters between cluster groups indicate no significant differences among pairwise tests.

Appendix 4. One-way MANOVA results for types of studying strategies used when preparing for exams according to cluster groups, *p<0.001.

Fall 2013	Low (N = 25)		Medium (N = 70)		High (N = 70)		F	η^2
	Mean	SD	Mean	SD	Mean	SD		
17. I usually study the night before the exam to make sure the material is fresh in my mind.	4.40	0.76	3.99	1.01	4.44	0.85	4.9	0.06
18. I rely on past exams to gauge what I need to know for the exam.	3.64	0.95	3.66	0.96	3.59	1.11	0.1	0.00
19. I study from the answer keys of past exams.	3.52	1.29	3.16	1.14	3.23	1.21	0.9	0.01
20. I use other resources (online tutorials, other textbooks, wikipedia, scientific journals, etc.) to verify my understanding.	3.44	0.96	3.51	0.99	3.51	1.51	0.1	0.00
21. I memorize answers or steps to solving problems if I don't understand what's going on.	3.36	1.11	2.93	1.11	2.93	1.27	1.4	0.02
22. I use flash cards, concept maps, or make outlines of topics covered in class.	3.36	1.29	2.86	1.16	2.96	1.24	1.6	0.02
23. I rely on my tutor/TA/PLTL leader for help.	3.24[a]	1.04	3.09	1.16[a/b]	2.44[b]	1.21	8.9*	0.10
24. I ask myself questions to make sure I understand what I'm studying.	3.20	1.04	3.43	1.10	3.61	1.07	1.5	0.02
25. I practice explaining the material to my friend(s).	2.96	1.24	3.07	1.23	3.20	1.15	0.4	0.01
26. I study with a group of friends regularly.	2.72	1.21	3.06	1.35	2.84	1.24	0.8	0.01
27. I read the textbook thoroughly and take notes.	2.56	1.19	2.68	0.97	2.76	1.31	0.3	0.00
28. I visit my instructor's office hour on a regular	1.84	1.14	1.87	1.03	1.70	0.84	0.6	0.01

basis to ensure I understand everything.								

i) $F(24,302) = 1.99$, $p<0.005$; Wilks' Lambda = 0.75; $\eta^2 = 0.14$.

ii) Within a row, different letters between cluster groups indicate a significant difference ($p<0.001$). Same letters between cluster groups indicate no significant differences among pairwise tests.

Appendix 5.Weights of each item on principal components after varimax rotation. Items with weights less than 0.5 were excluded.*

Items	Component 1	Component 2	Component 3	Component 4	Component 5
6	0.71	-------	-------	-------	-------
11	0.70	-------	-------	-------	-------
27	0.67	-------	-------	-------	-------
10	0.63	-------	-------	-------	-------
9	0.57	-------	-------	-------	-------
22	0.54	-------	-------	-------	-------
15	-------	0.75	-------	-------	-------
16	-------	0.66	-------	-------	-------
14	-------	0.62	-------	-------	-------
25	-------	-------	0.81	-------	-------
24	-------	-------	0.64	-------	-------
26	-------	-------	0.64	-------	-------
19	-------	-------	-------	0.74	-------
21	-------	-------	-------	0.61	-------
17	-------	-------	-------	0.58	-------
23	-------	-------	-------	0.51	-------
1	-------	-------	-------	-------	0.72
13	-------	-------	-------	-------	0.70
2	-------	-------	-------	-------	0.56
% explained variance	16.3 %	10.5 %	7.8 %	6.4 %	5.0 %

* Items 3, 4, 5, 7, 12, 18, 20, and 28 are not shown in this table because their weights were less than 0.5.

Appendix 6. Identified affective groups and assigned codes for each student.

		Codes		
Student ID #	Affective Group	Approaches to doing practice exam	Learning Strategies in Class	Studying Strategies for Exam
1	High	1	1	1
2	High	1	1	1,3
3	High	1	1	1
4	High	1	1	1
5	High	1	1	1
6	High	3	2	2
7	High	1	2	1,3
8	High	1	2	2
14	High	1	1	2
15	High	1	1	1,3
16	High	1	2	1,3
17	High	1	1	1
18	High	1	1	1
9	Low	2	2	2,3
10	Low	2	2	1
11	Low	2	2	1,3
12	Low	2	1	1,3
13	Low	3	1	2