Investigating Students’ Basic Needs and Motivation in College Chemistry Courses with the Lens of Self-Determination Theory

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Investigating Students’ Basic Needs and Motivation in College Chemistry Courses with the Lens of Self-Determination Theory

by

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DEDICATION

I would like to dedicate this dissertation to my parents Xiaofeng and Hongzhen. They hardly got any education, but their eagerness to learn new skills has inspired me to keep learning new knowledge and making progress all through my life.
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ABSTRACT

More graduates in science, technology, engineering, and mathmetics (STEM) fields are needed to keep our nation’s preeminance in the global fields of technology and science. However, fewer than 40% of students who intend to major in STEM fields when entering college complete a STEM degree. Therefore, it is important to explore factors to improve student persistence in STEM fields at the college level as well as to understand the interrelationship between student motivation, academic achievement, and persistence. Motivation is strongly associated with student achievement and persistence; meanwhile, academic achievement can also affect persistence. Self-determination theory (SDT) represents a framework of several mini-theories to explore how social context interacts with people’s motivation. The three studies in this dissertation aim to investigate student motivation using instruments based on SDT and to explore the viability of the theory in a reform environment.

In Study 1, the Academic Motivation Scale – Chemistry (AMS-Chemistry) was developed as an instrument based on the self-determination continuum to measure seven types of student motivation toward specific chemistry courses. Data gathered with AMS in college chemistry courses showed that AMS was a suitable candidate for modification. Based on expert panel discussions and cognitive interviews, AMS-Chemistry was developed. AMS-Chemistry was administered to university students in a general chemistry course as pre/post-test. Internal structure validity evidence was also collected. Results showed that students were more
extrinsically motivated toward chemistry on average, and there was an overall motivational difference favoring males with a medium effect size. Correlation studies revealed that intrinsic motivation subscales were positively associated with student academic achievement at the end of the semester. Results also showed that students who persisted in class attendance scored significantly differently on the set of motivation subscales. This study suggests that AMS-Chemistry is easy to administer and can be used to better understand students’ motivation status and how it might change across the curriculum. Faculty interested in promoting student intrinsic motivation may also use AMS-Chemistry to evaluate the impact of their efforts.

In Study 2, AMS-Chemistry was used to examine student motivation and determine how motivation is related to academic achievement at different points in time in organic chemistry courses. This study was conducted in two organic chemistry courses where one course was primarily lecture-based and the other implemented flipped classroom and peer-lead team learning (Flip-PLTL) pedagogies. Descriptive statistics showed that students in both courses were more extrinsically motivated and their motivation moved in negative directions across the semester. Factorial multivariate analysis of covariance revealed a main effect of pedagogical approach. Students in the Flip-PLTL environment were significantly less lack of motivation toward chemistry at the end of the semester while controlling for the motivation pre-test scores; however, there was no evidence for sex main effect and interaction effect between sex and pedagogical approach. Correlation results revealed variable relationships between motivation subscales and academic achievement at different time points. In general, intrinsic motivation subscales were significantly and positively correlated with student academic achievement; Amotivation was negatively correlated with academic achievement. The findings in this study
showed the importance of Flip-PLTL pedagogies in improving student motivation toward chemistry.

In Study 3, students’ perceptions of basic psychological needs and intrinsic motivation were studied using instruments in accordance with SDT in first-year college chemistry courses. The interrelationships among the variables were also investigated. Students’ self-reported scores showed that they had positive perceptions with respect to the motivational variables where Process Oriented Guided Inquiry Learning (POGIL) was being implemented. Students’ written comments also provided evidence for their positive perceptions. Structural equation modeling results showed that it was viable to use SDT in the POGIL context, since the three basic needs explained a significant amount of variance in intrinsic motivation. The findings could help instructors become more aware of students’ perceptions of the learning environments in active learning settings, and therefore, instructors wishing to target student engagement are encouraged to implement active learning pedagogies, such as POGIL.

The research studies presented in this work contribute to our understanding of motivation as an important factor influencing student persistence in STEM fields in both traditional classroom and different active learning environments at the college level. Each study provided psychometric evidence for the use of instruments based on SDT in college chemistry courses. Chemistry educators can use these assessments to understand the nuances of student motivation. Findings from these assessments can then be used to design strategies to help students learn and/or to be more motivated toward chemistry. Also, this work highlights the importance of looking at the motivation of different groups of students, such as the underrepresented students, because their response trends may be different. Being aware of students’ different needs will
help chemistry educators to understand how we can better increase students’ intrinsic motivation in our chemistry courses.
CHAPTER ONE

Introduction

The persistence problem

There is a great need for approximately 1,000,000 more professionals in the Science, Technology, Engineering, and Mathematics (STEM) fields in the United States (U.S.) in the next 10 years to retain our nation’s historical preeminence in science and technology according to the report to the President by the President’s Council of Advisors on Science and Technology (PCAST) (PCAST, 2012). In particular, the number of STEM jobs in the U.S. will increase by one million between 2008 and 2018 (Carnevale, et al., 2010) and 92% of the jobs will require some postsecondary education and training (Carnevale, et al., 2011). Therefore, researchers are called to find out strategies to increase the STEM student retention rate, especially during the first two years in the postsecondary education as it is the most critical time for STEM persistence. However, fewer than 40% of students who intend to major in STEM fields when entering college actually complete a STEM degree. Women and members of minority groups, who are underrepresented among students receiving bachelor degrees in STEM subjects, leave STEM majors at a higher rate than others (PCAST, 2012). Therefore, we face the challenge to increase student retention in general as well as for women and under-represented minority students. According to PCAST report, there are three major aspects that affect student persistence: (1) intellectual engagement and achievements, (2) motivation, and (3) identification with a STEM fields.
Student motivation is an important affective variable in education because it is related to student learning (Lavigne, et al., 2007; Areepattamannil, et al., 2011; Griffin, et al., 2013; Sturges, et al., 2016), persistence in science (Lavigne, et al., 2007; Ricard and Pelletier, 2016; Shirley, et al., 2016), student retention (Alivernini and Lucidi, 2011), and science literacy (Glynn, et al., 2011). Therefore, not only does motivation have a direct effect on persistence but also have an indirect effect through student academic achievement as displayed in Figure 1.1. One of the strategies to achieve greater student engagement, higher achievements, and intrinsic motivation, which refers to “doing an activity for the inherent satisfaction of the activity itself” (Ryan and Deci, 2000), is to adopt active learning pedagogies to engage students in learning. This dissertation aims to use the lens of self-determination theory (SDT) to measure student motivation and to examine the interrelationships between student motivation and academic achievements in college chemistry courses in various learning environments, especially active environments.

**Figure 1.1** The inter-relationship among student motivation, academic achievement, and persistence.

**Self-determination theory**

Self-determination theory (SDT) represents a broad framework of a set of smaller motivation theories to understand the interplay of relationships between sociocultural conditions
and human personality (Deci and Ryan, 2000; Deci and Ryan, 2008). SDT regards motivation as a multi-dimensional construct. An important feature of SDT is that the theory also provides applicable strategies to be implemented based on people’s motivation profiles. This work is mainly based on two mini-theories in SDT. The first mini-theory is the basic psychological needs theory, which highlights the importance of meeting people’s basic needs. The second mini-theory is the organismic integration theory, which highlights different types of extrinsic motivation which align on the self-determination continuum.

Basic psychological needs theory elaborates the concept of evolved psychological needs and the relations to psychological health and well-being (Ryan and Deci, 2000). In SDT, needs are defined as “innate psychological nutriments that are essential for ongoing psychological growth, integrity, and well-being” (Deci and Ryan, 2000). There are three basic needs: autonomy, competence, and relatedness. Autonomy refers to the desire to begin an action and “have a sense of acting in accord with one's own sense of self” (Deci, 1998). Competence refers to the desire to produce valued outcomes and to affect the environment (Deci, 1998). Relatedness refers to “the desire to feel connected to others - to love and care, and to be loved and cared for” (Deci and Ryan, 2000). This mini-theory speculates that psychological well-being and optimal functioning can be predicated on the status of the three basic needs (Orsini, et al., 2015). Contexts that support versus thwart these needs would impact wellness. According to this theory, all three needs are essential to promote intrinsic motivation.

In organismic integration theory, there are four types of extrinsic motivation that are aligned on the self-determination continuum with amotivation and intrinsic motivation at each end as displayed in Figure 1.2 (Ryan and Deci, 2000). Amotivation refers to a state in which
people lack the intention to behave; therefore, amotivation is a state of lack of motivation. Extrinsic motivation is to do an activity solely because of the consequences. Extrinsic motivation is very important for students in college because students learn by doing repetitive practices and a great deal of learning activities are not inherently interesting. The four subtypes of extrinsic motivation are external regulation, introjected regulation, identified regulation, and integrated regulation, ranging from least self-determined to most self-determined type of motivation. External regulation is a typical type of extrinsic motivation, suggesting students do an activity in order to obtain the rewards or to avoid certain punishments. Introjected regulation behaviors are those that are performed “to avoid guilt or anxiety or to attain ego enhancements such as pride” (Ryan and Deci, 2000). Identified regulation means that people have identified the value and importance of the activities. Integrated regulation is very similar to intrinsic motivation, but it “is based on the importance of activity for the person’s internalized values and goals” (Reeve, et al., 2004). Based on this mini-theory, people can have different motivation profiles with different levels of motivation subtypes because people are motivated to do an activity by different reasons and experience different level of satisfaction when engaging in the activity.

<table>
<thead>
<tr>
<th>Types of Regulation</th>
<th>Types of Motivation</th>
<th>Amotivation</th>
<th>Extrinsic Motivation</th>
<th>Intrinsic Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non Regulation</td>
<td>External Regulation</td>
<td>Internalized</td>
<td>Identified Regulation</td>
<td>Integrated Regulation</td>
</tr>
<tr>
<td>Regulation</td>
<td>Introjected Regulation</td>
<td>Identified Regulation</td>
<td>Intrinsic Regulation</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1.2** The self-determination continuum
SDT is concerned with social environments that enhance or prevent the internalization of the regulation. According to the theory, supporting people’s relatedness need is critical for the internalization. This is because sometimes people’s behaviors are influenced by significant others to whom they feel attached or related. Supporting the autonomy need is also important as it allows individuals to actively transform values into their own. SDT is relevant for chemistry faculty who seek to create active learning environments that encourage student engagement. However, the application of SDT in college chemistry courses is sparse (Black and Deci, 2000; Southam and Lewis, 2013; Smith, et al., 2014; Weaver and Sturtevant, 2015). Therefore, this work adds to the literature of the application and interpretation of SDT in post-secondary chemistry educational backgrounds.

Motivation and academic achievement

As motivation is related to student academic achievements (Lavigne, et al., 2007; Areepattamannil, et al., 2011; Griffin, et al., 2013; Cerasoli, et al., 2014; Sturges, et al., 2016), a number of studies have been conducted exploring how motivation is related to students’ academic achievement. The results are mixed partially due to different research contexts with various student levels and subjects (Taylor, et al., 2014). For example, for college students, no significant relationships were reported for second-year psychology students in United Kingdom (Baker, 2004); while positive correlations were found for one cohort of general chemistry students in a historically Black college in U.S. (Hibbard, et al., 2016). Despite the mixed results, generally more motivated students were reported achieve better (Tseng and Tsai,
2010; Griffin, et al., 2013). This suggests it is important to explore this issue in specific research context, which is also one of the validity evidence for instruments.

**Measurement**

Psychometric evidence of instruments indicates the validity of the interpretation made from the test scores, and the quality of the instruments affect the quality of the interpretation. Therefore, it is important to collect validity and reliability evidence, which are the two most important aspects of measurements whenever we use test scores to answer our research questions. Based on the Standards for Educational and Psychological Testing (Association, et al., 1999), four types of validity evidence are often explored. The four types of validity are test content, response processes, internal structure, and relations to other variables (Arjoon, et al., 2013). Test content refers to the format and wording of the questions and the guidelines about administration and scoring. Response processes refer to the cognitive activities which respondents utilize to answer the questions. Internal structure refers to the relationships among the items and how well the items are aligned with the theoretical framework. Relations to other variables examine how the constructs of interest are related with other constructs or variables. There are few studies at postsecondary college chemistry courses using the SDT framework, and there are even fewer instruments that are based on the self-determination continuum (Black and Deci, 2000). Therefore, it is crucial to collect psychometric evidence for the instruments (existing or new) before we interpret our results.
Active learning pedagogies

Active learning is generally defined as a pedagogical method to engage students in the learning process (Prince, 2004). More specifically, active learning includes learning activities, such as reading, writing, discussion, or problem solving that encourage students to analyze, synthesize, and categorize content (http://www.crlt.umich.edu/tstrategies/tsal). The active learning interventions vary widely in intensity and implementations. Various active learning approaches include cooperative learning, occasional group problem-solving, worksheets or tutorials completed during class, use of personal response systems with or without peer instruction, and studio or workshop course designs. Compared with traditional teaching methods, where instructors in the introductory STEM courses mainly lecture to students and students passively listen to the lecture and do few practices, students in active learning environments are more engaged, do more problem-solving practices. Therefore, students’ critical thinking, performances, and retention are enhanced (Prince, 2004; Carlson, et al., 2016; Warfa, 2016). Here, three specific active learning pedagogies are introduced, which are part of the research contexts in this work.

Peer-Led Team Learning (PLTL)

Peer-led team learning (PLTL) is an educational reform to actively engage students in learning (Gosser and Roth, 1998). Peer leaders are employed as leaders to facilitate active learning. They are students who have successfully completed a target course and are trained purposefully to engage students in small groups, who collaborate, seek group consensus, explain their work, and are pointed to resources when they get stuck. PLTL has led to improved passing rates and enrollments in follow-up courses (Mitchell, et al., 2012), student achievement (Lewis
and Lewis, 2005; Hockings, et al., 2008; Lewis and Lewis, 2008; Popejoy and Asala, 2013; Drane, et al., 2014; Carlson, et al., 2016), and retention rates (Lewis, 2011; Mitchell, et al., 2012; Popejoy and Asala, 2013; Drane, et al., 2014; Lewis, 2014). Therefore, PLTL has been extensively implemented and evaluated in first-semester general chemistry courses and the implementation has been extended to other more advanced college chemistry courses, such as organic chemistry (Tien, et al., 2002; Lyle and Robinson, 2003; Wamser, 2006; Arrey, 2012), where PLTL has showed similar positive outcomes.

**Process Oriented Guided Inquiry Learning (POGIL)**

Process Oriented Guided Inquiry Learning (POGIL) utilizes a guided-inquiry framework, which encourages students to work in defined teams to construct their own knowledge, to discuss with peers, and to learn from an instructor who serves as a facilitator rather than an expert source of information. The questions are deliberately designed around the learning cycle where students explore the model (E), are introduced the concept and its definition (I), and apply the concept to new situations (A). This E $\rightarrow$ I $\rightarrow$ A cycle is repeated throughout an activity to achieve the desired learning outcomes (Moog, et al., 2009). Students in POGIL classrooms compared with traditional classrooms, irrespective of students’ previous scores on comparable measures such as SAT (Lewis and Lewis, 2008) learning better. For example, a number of studies have found increases in student performance in the targeted courses using same or similar interventions (Wamser, 2006; Mitchell, et al., 2012; Freeman, et al., 2014; Warfa, 2016).
**Flipped classroom**

The flipped classroom is another active learning pedagogy developed to engage students before and during class. In flipped classrooms, some content are moved outside of class and students do a lot of practices during class (Smith, 2013; Fautch, 2015; Flynn, 2015; Seery, 2015; Eichler and Peeples, 2016). Students are usually assigned electronic resources, e.g., recorded lectures, videos or tutorials. A lot of research has focused on how well flipped classroom can improve student learning and usually researchers reported more positive or comparable outcomes in contrast with traditional teaching methods (Love, *et al.*, 2013; Jensen, *et al.*, 2015; Weaver and Sturtevant, 2015; Hibbard, *et al.*, 2016).

Despite the assessments of student learning in the active learning environments, there are few studies that assess students’ affects, such as motivation, to determine the effects of innovations. Chan and Bauer (2014, 2015, 2016) have studied students’ motivation and attitudes in general chemistry courses in the PLTL environments and used the factor scores to explore students at risk and students’ learning strategies. Vishnumolakala *et al.* (2017) have also studied student attitude and self-efficacy in classrooms implementing modified POGIL activities. Southam and Lewis (2013) studied students’ motivation using SDT framework in the POGIL environments. The attitude in an organic chemistry course with flipped classroom implemented in lecture time and PLTL implemented outside of classroom was recently studied and researchers found attitude toward chemistry changed to a positive direction (Mooring, *et al.*, 2016). The attitude to the electronic resources (videos or tutorials) and the course in flipped classrooms are also studied, but the findings were usually based on surveys (Fautch, 2015; Flynn, 2015; Jensen, *et al.*, 2015; Eichler and Peeples, 2016). As chemistry educators are motivated to implement the
active learning strategies, more assessments of students’ affective variables should be conducted in addition to the assessments of the content (Bauer, 2005).

**Purpose and overview of the dissertation**

The purpose of the study is to examine student academic motivation with the lens of SDT. Specifically, the dissertation is to study the importance of the fulfilment of basic psychological needs on promoting student intrinsic motivation. The work also investigates the associations between different types of motivation with student academic achievement and persistence. This work contains three studies, and each study was conducted in different college courses in different research contexts. The first two studies are mainly based on the self-determination continuum in the organismic integration theory, and the last study is mainly based on the basic psychological needs theory.

The first study, “Development and evaluation of a chemistry-specific version of the academic motivation scale (AMS-Chemistry)”, was published in *Chemistry Education Research and Practice* (Liu, *et al.*, 2017). This study includes the pilot study of an existing instrument Academic Motivation Scale (AMS) and the development and evaluation of a new instrument Academic Motivation Scale toward Chemistry (AMS-Chemistry) to measure student motivation toward taking a specific chemistry course. This purpose of the pilot study is to collect psychometric evidence for AMS (Vallerand, *et al.*, 1992) in general chemistry courses. The ultimate goal of the study is to develop a theory-based instrument to measure seven types of student motivation toward chemistry and collect psychometric evidence before exploring how motivation is related with student academic achievement and attendance in college chemistry classrooms. The study also explored student motivation by subgroups of males of females
regarding their motivation toward education and motivation toward a specific subject by conducting multivariate analysis of variance (MANOVA) chemistry.

The second study, “The effect of flipped classroom - peer led team learning environment on student motivation in organic chemistry”, is expected to be submitted to *Chemistry Education Research and Practice*. This study evaluates student motivation in organic chemistry courses using AMS-Chemistry. Specically, student motivation is studied in two learning environments before and after an education reform: one was lecture based, and the other implemented both flipped classroom and PLTL (Flip-PLTL) in the same course. The purpose of the study is to collect more psychometric evidence for AMS-Chemistry and explore the effect of Flip-PLTL and sex on student motivation over a semester while controlling student pre-motivation scores by conducting factorial MANCOVA. The longitudinal study also explores how the relationship between students’ motivation and their academic achievement may change over a semester.

The third study, “Exploring motivation in Australian college chemistry courses implementing Process Oriented Guided Inquiry Learning”, is expected to be submitted to *Chemistry Education Research and Practice*. This study explored how students’ basic needs of autonomy, competence, and relatedness could be met in the POGIL environment, and how the basic needs could support students’ intrinsic motivation. The purpose of the study is to investigate students’ motivation in first-year college chemistry courses with two instruments that measure intrinsic motivation and three basic needs in accordance with the SDT (McAuley, *et al.*, 1989; Williams and Deci, 1996). This study also explores the effect of student prior learning experience on student motivation.

The first two studies mainly focus on collecting psychometric evidence for AMS-Chemistry and evaluating student motivation in different learning environments using AMS-
Chemistry as a tool. The third study aims to study if active learning environments can indeed promote student intrinsic motivation by meeting students’ basic needs. Therefore, all three studies try to examine the application of SDT in college chemistry courses in order to encourage more research to explore the inter-relationship of student motivation, academic achievement, and student persistence in STEM fields and contribute to the production of one million more STEM graduates.

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CHAPTER TWO

Methodology

Instruments that are based on self-determination theory (SDT) are used to measure student motivation in all the three studies in this work. In addition to quantitative data, qualitative data are also used while developing a sound instrument to measure motivation toward chemistry in Study 1 as well as to triangulate the quantitative results in Study 3. This chapter will summarize the general methodology used in the work. First, the instruments and participants are described, which is followed by the data analysis methods used in this work. Table 2.1 summarizes the instruments used and the research contexts for each study.

Table 2.1 Summary of research context

<table>
<thead>
<tr>
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<th>Data Collection</th>
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<td>Gen Chem in W US</td>
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<td></td>
<td>AMS-Chemistry</td>
<td>Gen Chem in SE US</td>
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<td>2</td>
<td>AMS-Chemistry</td>
<td>Org Chem in SE US</td>
<td>Pre/Post</td>
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<tr>
<td>3</td>
<td>LCQ</td>
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<tr>
<td></td>
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Note: W = Western, SE = Southeastern, US = United States, AU = Australia
AMS = Academic Motivation Scale, LCQ = Learning Climate Questionnaire, IMI = Intrinsic Motivation Inventory
Instruments and participants

Four instruments that are based on self-determination theory (SDT) are used in this work. Each instrument is discussed here in terms of the number of items, the specific scales, sample items, and the response Likert scale. All four instruments were administered to students as paper-and-pencil tests during lecture time. The students bubbled their answers to machine-readable forms, which were then scanned into Microsoft Excel files before data analysis.

Academic Motivation Scale (AMS)

AMS is an instrument based on the organismic integration theory in SDT to measure motivation toward education in general (Vallerand, et al., 1992). The college version measures the motivation toward going to college specifically, which is a type of motivation at the contextual level (Vallerand, 1997). There are 28 items to answer the question “why do you go to college?” Based on the theory, these 28 items measure seven types of motivation: amotivation, three types of extrinsic motivation (external regulation, introjected regulation, and identified regulation), and three types of intrinsic motivation (to know, to accomplish, and to experience), each measured by four items. The whole instrument is available in Appendix A. One sample item to measure external regulation is “Because with only a high-school degree, I would not find a high-paying job later on”. A 7-point Likert scale is used to measure the amount of motivation, ranging from 1 (does not correspond at all) to 7 (corresponds exactly).

AMS was administered to students enrolled in first and second semester general chemistry courses at a large public research university in the western United States (W US) in Spring 2012. 242 students responded to AMS, and 238 students’ responses were available for data analysis after checking for missing and careless responses (e.g. the same response for all the
The students were in a variety of majors (more than 23 majors), mostly (77.8%) were in their first two years of study, whites (75.2%), and females (60.9%). The whole AMS instrument and the details of the demographic information of students are presented in Study 1 and Appendix A.

**Academic Motivation Scale - Chemistry (AMS-Chemistry)**

As part of the work in Study 1, AMS-Chemistry is developed to measure motivation toward chemistry, which is motivation at the situational level (Vallerand, 1997). There are 28 items to answer the question “Why are you enrolled in this chemistry course?” The same seven types of motivation are measured as in the AMS. The whole instrument is available in Study 1. One sample item to measure external regulation is “Because without having chemistry I would not find a high-paying job later on”. The response scale is modified to be a 5-point Likert scale, between 1 (not at all) and 5 (exactly).

In Study 1, AMS-Chemistry was administered to one class of students enrolled in first semester general chemistry course at a large southeastern public research university in the United States (SE US). Data were collected twice during a semester in spring 2013. Frist time data collection was during the 4th week with 208 students’ responses for data analysis, and the second time data collection was during the 14th week with 94 students’ responses for data analysis. Students enrolled in this course were in various majors and more than half were females (~62%), whites (54%), first-year or sophomore students (68 – 78% for the two data collection), and in biomedical and biology related majors (~60%).

In Study 2, AMS-Chemistry was also administered to students enrolled in two first semester organic chemistry classes in SE US. In Fall 2014 the class was taught with lecture-
based method and in Fall 2015 the class was taught with a combined flipped classroom and peer-led team learning (Flip-PLTL) pedagogical approach. Data were collected twice in each class, with first data collection before Exam 1 and the second data collection after Exam 4 and before final exam. The sample size ranged from 190 to 235 in the four data collections with available identifiers and the response rate ranged from 79% to 91%. The students with both pre- and post-scores in these two courses were in various majors, about half were whites, and more than half were females (> 60%), junior and senior students (~ 90%), and in biomedical and biology related majors (~ 81%). The details of the demographic information of students can be found in Study 2 and Appendix B.

Learning Climate Questionnaire (LCQ) and Intrinsic Motivation Inventory (IMI)

A modified 15-item LCQ is used to measure an instructor’s autonomy support of students (Williams and Deci, 1996). A sample item is “I feel my instructor provides me with choices and options”. A 7-point Likert scale is used, ranging from 1 (strongly disagree) to 7 (strongly agree). A modified 21-item IMI is used to measure relatedness, competence, and intrinsic motivation (McAuley, et al., 1989). The enjoyment/interest subscale is regarded as the only measure of intrinsic motivation (Pat-El, et al., 2012; Vaino, et al., 2012; Van Nuland, et al., 2012) and therefore it is coded as intrinsic motivation in this work. One sample item to measure intrinsic motivation is “I would describe these activities as very interesting!” A 7-point Likert scale is used, ranging from 1 (not at all true) to 7 (very true). Both LCQ and IMI were used in Study 3 and the whole instruments are available in Appendix C.

LCQ and IMI were administered to students enrolled in introductory general and organic chemistry courses in a large public university in Perth, Western Australia (W AU). Data were
collected at the end of Term 1 in 2012 and at the beginning of Term 2 in 2012 in four different classes where Process Oriented Guided Inquiry Learning (POGIL) activities were implemented for selected chemistry topics. The students in Term 1 were enrolled in a first-semester general chemistry course for science and engineering majors (Class A) and in a general and organic chemistry course for pharmacy students (Class B). The students in Term 2 were enrolled in second-semester general and organic chemistry courses for science and engineering students (Class C) and for nutrition and biomedical science students (Class D). The sample size in the four courses ranged from 35 to 92 with identifiers provided; the response rate ranged from 14% to 46%. The students were 20-21 years old on average, other detailed demographic information (e.g. sex and majors) for the participants is available in Study 3.

**Qualitative data collection**

Cognitive interviews were conducted when developing AMS-Chemistry in Study 1. The participants were recruited via announcements during lectures in general chemistry courses in W US. The volunteers were selected at random and eleven participants were interviewed from the pool of volunteers in Fall 2012. The students were asked to complete the AMS-Chemistry instrument, read aloud each item, and explain their reasoning for their response to each item. The students were also probed to clarify their interpretations and ratings of the items.

Instructors’ teaching evaluations were used in Study 3 to triangulate the quantitative research findings regarding students’ basic needs and intrinsic motivation perceptions. Students provided the written comments in the teaching evaluations voluntarily and anonymously at the end of each term. The students were asked about the instructors’ teaching and the learning environments in the teaching evaluations.
Data analysis

Quantitative data

Psychometric evidence

For each instrument, psychometric evidence is collected before descriptive statistics and inferential statistical tests by factors are conducted. For all four instruments, internal structure validity is examined by conducting confirmatory factor analysis (CFA) in Mplus 5.2. A maximum likelihood estimator is used if the items are approximately normally distributed. If the items are not normally distributed, for example, the data are heavily skewed; a robust maximum likelihood estimator is used instead (Brown, 2006). As chi-square tends to be inflated if the sample size is big, three other fit indices are explored: Comparative Fit Index (CFI), Root Mean Square Error of Approximation (RMSEA), and standardized root mean squared residual (SRMR). CFI measures the “goodness of fit”, which varies from 0 to 1. RMSEA is an absolute measure of fit based on the non-centrality parameter, which varies from 0 to infinity. SRMR measures the “badness of fit”, which varies from 0 to infinity. Based on the literature, a reasonable fit is reached when CFI > 0.90, SRMR < 0.10, and RMSEA < 0.08 (Hu and Bentler, 1995; Cheng and Chan, 2003).

In addition to internal structure validity, three other validity evidence (content validity, response process validity, and relationship with other variables validity) are also explored for AMS-Chemistry in Study 1 (Arjoon, et al., 2013).

Internal consistency reliability is explored to show the relevance of items in the same subscale. Cronbach’s alpha coefficients are examined for the subscales of each instrument in SPSS 22.0, which is to show how reliable the scores are. When Cronbach’s alpha coefficients are above 0.7, the scores are generally regarded as reliable (Murphy and Davidshofer, 2005).
**Descriptive statistics**

The data are analyzed for descriptive statistics of the factors in SPSS 22.0. The descriptive statistics are presented in each study to show the status of students’ motivation before any inferential statistical analyses are conducted. The mean is the arithmetic average. The mean of each subscale is calculated by averaging the means of the items in each subscale. The standard deviation is interpreted as the typical amount that a score deviates from the mean. It is the most commonly used descriptive measure of variability and is based on every score in the distribution. The skewness and kurtosis are also presented to show the distribution of the scores (Glass and Hopkins, 1970). Skewness shows the degree of asymmetry and kurtosis shows if there are more or fewer extreme scores than expected.

**Relationships among variables**

Product moment correlation coefficients (r) are calculated in SPSS 22.0 to display how motivation subscales are related with other variables of interest, such as with students’ academic achievement in Study 1 and Study 2. Effect sizes are also included to show the strength of the relationship. The following standards for effect sizes are used: \( r = 0.1 \) for a small effect size, \( r = 0.3 \) for a medium effect size, and \( r = 0.5 \) for a large effect size (Cohen, 1988).

Structural equation modeling is conducted in SAS 9.3 to show how the variables are related with each other based on a theoretical framework. The model is evaluated with the same criteria of CFA. In Study 3, SEM is used to examine the relationships between the three basic needs and intrinsic motivation in order to examine if SDT is viable in college chemistry courses with an active learning environment. Due to the small sample size, a path analysis instead of a full model is conducted in Study 3.
**Inferential tests**

Multivariate analysis of variance (MANOVA) is conducted at an alpha level of 0.05 to compare groups based on a set of dependent variables while controlling the type-I error in SAS 9.3. Assumption tests are performed before the multivariate analyses and the results are available in Appendices A and C. Follow up analysis of variance (ANOVA) is conducted to find out on which motivation types the groups differ from each other with adjusted $p$-values (Holm, 1979). Effect sizes are also calculated to show the magnitude of the differences. $f^2$ is calculated based on the following equation (Figure 2.1) for multivariate analysis and Cohen’s $d$ is also calculated for comparisons between two groups (Cohen, 1988).

\[
\text{Cohen’s } d = \frac{M_1 - M_2}{S_{\text{pooled}}}
\]

where $S_{\text{pooled}} = \sqrt{\left[ (S_1^2 + S_2^2) / 2 \right]}$

\[
f^2 = \Lambda^{-1} S^{-1}
\]

where

\[
S = \frac{p^2(k-1)^2 - 4}{p^2 + (k-1)^2 - 5}
\]

**Figure 2.1** Equations for effect sizes Cohen’s $d$ and $f^2$

Note: $M$ = Mean, 1 = Group 1, 2 = Group 2, $S$ = Standard deviation

d for small effect size = 0.2, $d$ for medium effect size = 0.5, $d$ large effect size = 0.8

$p$ = the number of dependent variables, $k$ = the number of groups,

$f^2$ for small effect size = 0.02, $f^2$ for medium effect size = 0.15, $f^2$ large effect size = 0.35

In order to adjust the means of the groups based on the initial scores, multivariate analysis of covariance is performed where the pre-scores are used as covariates when comparing the post-scores for a set of dependent variables. When there are two independent variables and interaction effect between the two independent variables is possible, factorial multivariate
analysis of covariance (MANCOVA) is conducted at an alpha level of 0.05 (Stevens, 2002) in SPSS 22.0.

Qualitative data

All the interviews are transcribed for data analysis. The transcripts are coded for significant statements and grouped by emergent themes, based on each item and its corresponding subscale (Creswell, 2007).

The written comments in the teaching evaluations are analyzed by themes of autonomy support, perceived competence, and intrinsic motivation based on the self-determination theory. The comments are also grouped in terms of positive or positive comments for the themes. Note that the comments for relatedness are missing, as the teaching evaluation did not ask questions regarding their relationship to their peers.

References


CHAPTER THREE

Development and evaluation of a chemistry-specific version of the academic motivation scale (AMS-Chemistry)

This chapter is a published article in journal Chemistry Education Research and Practice. The article can be accessed via http://pubs.rsc.org/en/content/articlepdf/2017/rp/c6rp00200e.

Introduction

In a report to the President by the President’s Council of Advisors on Science and Technology (PCAST) (2012), universities in the United States are called on to produce one million additional college graduates with degrees in science, technology, engineering, and mathematics (STEM) over the next decade if the United States is to retain its historical preeminence in science and technology. The same report points out that one of the three aspects of a student’s experience that affects persistence in STEM is motivation, which is a complex construct and is often accessed from different (or multiple) theoretical perspectives (Koballa and Glynn, 2007), such as social-cognitive theory (Pintrich et al., 1993; Glynn et al., 2009, 2011), expectancy-value theory (Wigfield, 1994; Wigfield and Eccles, 2000), and self-determination theory (Deci and Ryan, 2000, 2008). Motivation has been linked to student learning (Chiu and Chow, 2010; Yen et al., 2011; Gonzalez and Paoloni, 2015). Motivation has also been identified
as one of the factors that can affect students’ scientific literacy (Glynn et al., 2011; Vaino et al., 2012), and the need to enhance students’ scientific literacy has been well-established (American Association for the Advancement of Science (AAAS), 1993; National Research Council (NRC), 1996; OECD, 2009; EURYDICE, 2011; Lam and Lau, 2014). Therefore, research on student motivation should be promoted to help us better understand how to improve scientific literacy as well as students’ persistence in STEM areas. Indeed, motivation has been highly valued by researchers because of its consequences (Deci and Ryan, 2000). Studies have shown positive effects of academic motivation on student retention (Lau, 2003; Tinto, 2006; Huett et al., 2008; Alivernini and Lucidi, 2011) and students’ persistence in science education (Lavigne et al., 2007). The effect of academic motivation on students’ learning and academic achievement has been studied widely; however, the results vary across student level, subject matter, and cultural context, even when the same tool is used to measure motivation (Taylor et al., 2014). For example, no significant associations were found between extrinsic or intrinsic motivation and second-year psychology students’ grade point average (GPA) for the eight modules taken in their second and third year at university in the United Kingdom (Baker, 2004), yet studies of high school and college students in Canada and Sweden revealed a persistent linkage between intrinsic motivation and GPA (Taylor et al., 2014). In one recent case, a relationship between motivation toward chemistry and academic achievement was observed only for one cohort of general chemistry students at a historically Black college in the United States (Hibbard et al., 2016). However, across a range of studies in different learning contexts with different measurement tools, generally students of higher motivation are able to do better on knowledge tests and get higher achievement scores. For specific examples, see research with chemistry students from ten different high schools in Turkey (Akbaş and Kan, 2007), with Taiwanese
college students in an online learning environment (Tseng and Tsai, 2010), and with Bavarian 10th graders engaged in a one-day outreach laboratory experience on plant genetics (Goldschmidt and Bogner, 2016).

Students’ class attendance is a recurring research topic because attendance has been found to be an important general predictor of academic performance (Crede et al., 2010). Poor attendance patterns predict poorer grades even as early as elementary school in the United States (Morrissey et al., 2014). At the college level, attendance to lectures is one of the factors associated with high academic achievement for undergraduates as disparate as prospective doctors in Saudi Arabia and prospective teachers in Sweden (Abdulghani et al., 2014; Alzhanova-Ericsson et al., 2015). However, the relationship between attendance and performance may not be straightforward. For example, two different studies of the relationship between attendance and academic performance for microeconomics students, one in Italy and one in Taiwan, drew different conclusions. In both studies, individual student attendance was a robust predictor of academic performance (Stanca, 2006; Chen and Lin, 2015), but for the Taiwan study, total attendance – class size on any given day – was actually negatively associated with performance (Chen and Lin, 2015). One possible confound for attendance studies is that motivation has long been identified as relating to attendance (Wegge and Kleinbeck, 1993; Devadoss and Foltz, 1996; Moore et al., 2008). Indeed, for the Taiwan study, the researchers surmise that the relationship between motivation and attendance was not sufficiently strong, such that the unmotivated students gained a benefit from attending class but had a negative impact on their more motivated peers by changing the overall class environment. A qualitative study of business students’ reasons for missing lectures at a university in Ireland revealed that the majority of rationales could be ascribed to low motivation (Moore et al., 2008). Research has also
found that motivation is positively related to attendance for college sophomores, juniors, and seniors in agriculture-related courses (Devadoss and Foltz, 1996); however, the relationship between attendance and motivation for first year college chemistry students has not been studied extensively.

With regard to students’ motivational characteristics toward a specific science domain, there is evidence that even in pre-primary school, children express some differences in their motivation toward different specific tasks and topics (Schunk et al., 2008) and science disciplines (Mantzicopoulos et al., 2008). If the majority of students (about 96%) do not express the wish to study chemistry at university, neutral and negative attitudes indicating a low motivation to study and learn chemistry are expected (Salta and Tzougraki, 2004). Individual interest in a specific content area has, however, been identified as a potentially malleable factor, depending strongly on the social environment (Schiefele, 1991). Some research has indicated that gender is the most significant variable influencing attitudes towards science/chemistry (Osborne et al., 2003). Females are under-represented in science fields (Ong et al., 2011), so it is important to investigate females’ motivation status in the context of science courses. When looking into female and male subgroups in different research contexts, a lot of discrepancies were found. Some studies of the sex effect in Germany (Ziegler and Heller, 2000) and the United States (Desy et al., 2011) found males to be generally more motivated in secondary school, while others working in a Greek context found that secondary school girls had higher motivation relative to boys (Salta and Koulougliotis, 2015). Student motivation may also change with time. Studies of attitudes toward science at different time points in multiple countries show decreases by age or school year, and the decline may sharply increase for students in their mid-teens (Osborne et al., 2003). Decreases in student motivation with increasing time in school have been
reported for university students in the United States (Brouse et al., 2010). Decreases have also been observed even within a single term for nursing students in Sweden (Nilsson and Warrén Stomberg, 2008) and engineering students in the United States (He et al., 2015).

Motivation toward chemistry specifically is of interest to chemistry instructors and chemistry education researchers. However, the current availability of individual scales to measure student motivation in college chemistry is limited (Pintrich et al., 1993; Glynn et al., 2009, Ferrell and Barbera, 2015; Ferrell et al., 2016). Bauer and colleagues (Chan and Bauer, 2014, 2016) used the 81-item Motivated Strategies and Learning Questionnaire (MSLQ) (Pintrich et al., 1993) in an entry level general chemistry course utilizing a peer-led active learning environment. The researchers found that motivation scores, together with other affective factors, could be used to identify at-risk students and that students of high- medium- and low-affective clusters had different learning strategies. The Science Motivation Questionnaire (SMQ) can be administered to science and non-science majors to measure motivation toward science including self-efficacy, self- determination, intrinsic motivation, career motivation, and grade motivation (Glynn et al., 2011; Hibbard et al., 2016). Ferrell and Barbera (2015) studied three different constructs (student interest, effort belief, and self-efficacy) connected to the expectancy-value theory (Wigfield, 1994; Wigfield and Eccles, 2000) of motivation in general chemistry courses and found that chemistry majors reported higher levels on the constructs than the non-chemistry majors. They also explored the relationships among the constructs and with students’ academic achievement (Ferrell et al., 2016). However, no construct of extrinsic motivation was explored. The MSLQ and SMQ have motivational scales that can be adapted for a chemistry context (see, for example, Salta and Koulougliotis, 2015, and Hibbard et al., 2016); however, none of the above instruments were designed based on self-determination theory.
Clarity regarding the theoretical underpinnings of an instrument can prevent miscommunication about the interpretation of specific findings. In any case, to explore student motivation toward chemistry, it is very important to have a sound assessment that yields reliable and valid interpretations (Arjoon et al., 2013). While developing an instrument from scratch is possible, the adaptation of an existing theory-based instrument is more practical as the modified instrument is expected to maintain alignment with theory. The ultimate purpose of the study is to develop and provide validity evidence for a self-determination-theory-based instrument to explore student motivation toward chemistry in college chemistry courses.

**Self-determination theory**

While most theories have treated motivation as a one-dimensional construct that varies only in amount (Deci and Ryan, 2008), self-determination theory (SDT) has regarded motivation as a multidimensional concept that can vary not only in amount but also in type (Deci and Ryan, 2000; Ryan and Deci, 2000).

SDT is a broad framework to study human motivation and personality (Ryan and Deci, 2000; Baker, 2003; Reeve et al., 2004; Jang et al., 2009; Liu et al., 2014). According to SDT, when certain basic needs are satisfied, students are more psychologically healthy and intrinsically motivated (Black and Deci, 2000; Vaino et al., 2012; Hagger et al., 2015; Kiemer et al., 2015). SDT makes a basic distinction between intrinsic motivation, extrinsic motivation, and amotivation, with each placed along a continuum, as shown in Figure 3.1. Amotivation, at one end of the continuum, is not necessarily accompanied by lack of effort. Amotivation would also describe doing an activity with only forced responsibility and no interest at all. Intrinsic motivation, on the other end of the continuum, describes doing an activity out of interest,
“deriv[ing] spontaneous satisfaction from the activity itself” (Gagné and Deci, 2005). Intrinsic motivation has been linked to positive consequences for students. For example, students who are intrinsically motivated are more likely to perform better in primary and secondary school (Lepper et al., 2005), more likely to persist in science for high school students (Vallerand et al., 1997; Lavigne et al., 2007) and STEM fields for undergraduates (French et al., 2005; Maltese and Tai, 2011), and less likely to drop out from college (Vallerand, 1992; Allen, 1999; Morrow and Ackermann, 2012).

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Nonself-Determined</th>
<th>Extrinsic Motivation</th>
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<td>Introjected Regulation</td>
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<tr>
<td>Types of Regulation</td>
<td>No Regulation</td>
<td>External Regulation</td>
<td>Introjected Regulation</td>
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**Figure 3.1** The self-determination continuum, showing types of motivation and associated types of regulation

In the middle of the continuum, human motivation can be nonintrinsic but can vary in the degree to which the value and regulation of the active behaviour have been internalized. One of the mini-theories within SDT, organismic integration theory, further categorizes extrinsic motivation into four different types (Deci and Ryan, 2000). As shown in Fig. 1, the four types of extrinsic motivation are external regulation, introjected regulation, identified regulation, and integrated regulation, ranging from most external to more internal types of regulation. External regulation is the least self-determined form and results from external rewards or constraints. Introjected regulation is more self-determined than external regulation; at this level people begin to internalize the reasons for their actions. Identified regulation means that people begin to value and judge the importance of their actions, and their behavior becomes internalized. Integrated regulation is the highest level of self-determination in the external motivation category. It means...
that a person’s behavior is fully autonomous. This level is similar to intrinsic motivation. However, integrated regulation is based on the importance of the behavior for the person’s internalized values, while intrinsic motivation is based on the person’s inner interests (Reeve et al., 2004).

The learning environment plays an important role in the formation of student motivation (Potvin and Hasni, 2014), and students exhibit different characteristics with different types of motivation. According to SDT, when teachers are perceived as being controlling during their teaching, students are likely to be less autonomous with respect to studying, a prediction which was borne out in a study of secondary schools in Belgium (Soenens et al., 2012). SDT also predicts that, when teachers are perceived as high on autonomy support, students will be more autonomous with respect to studying, which has also been observed in Belgian secondary schools (Vansteenkiste et al., 2012). In an autonomy-supported context, where students are provided with choices to do different things in class and the instructors are encouraging, intrinsic motivation will be stimulated and maintained (Lepper and Henderlong, 2000; Chirkov and Ryan, 2001; Reeve, 2012). Students who have intrinsic motivation tend to learn because of their inner curiosity and interest and are more active in learning (Zimmerman, 2000; Deci and Ryan, 2008). Students with high levels of intrinsic motivation usually learn better, as expressed by higher academic achievement (Tseng and Tsai, 2010). In a more controlled context, where students have few or no choices regarding class activities, intrinsic motivation will be blocked and extrinsic motivation will be more likely to be developed (Deci and Ryan, 2000). Students who have extrinsic motivation tend to learn or complete assignments because of external pressure (e.g., my parents want me to learn) or reward (e.g., for a high grade) (Felder and Brent, 2005). In
controlled classroom situations accompanied by little external pressure or little hope of reward, one can also imagine significant movement toward amotivation.

**Academic motivation scale**

The motivation continuum implies that students can have different degrees of the different types of motivation, and SDT suggests that social contextual events can enhance or diminish intrinsic motivation (Ryan and Deci, 2000). Measuring differences in degree for the different types of motivation would enable researchers to study motivation in different instructional contexts and to determine to what extent these relationships are present; however, only a few instruments that are based on the motivational continuum currently exist. For example, the learning self-regulation questionnaire (srq-learning) has items reflecting *external regulation, introjected regulation, identified regulation,* and *intrinsic motivation* and has been used by many researchers in original and modified forms (Ryan and Connell, 1989; Goudas et al., 1994; Black and Deci, 2000; Levesque et al., 2004; Vansteenkiste et al., 2004, 2012; Soenens et al., 2012). Scores from the instrument are intended to indicate *autonomous* versus *controlled* motivation, but there are no items to measure *amotivation* or *integrated regulation.* The Situational Motivation Scale is intended to measure *amotivation, external regulation, identified regulation,* and *intrinsic motivation* (Guay et al., 2000), but there are no items to measure *introjected regulation* or *integrated regulation.*

The Academic Motivation Scale (AMS) has subscales to measure *amotivation,* three different types of extrinsic motivation, and three different types of intrinsic motivation (Vallerand et al., 1992), as displayed in Figure 3.2. *Amotivation,* in particular, seems relevant to college chemistry courses, which often feature quite high withdrawal rates, signaling that a
student has decided there is little hope for achieving a passing grade (Maltese and Tai, 2011; Matz et al., 2012). Because integrated regulation and identified regulation are both classified as autonomous within the extrinsic motivation portion of the continuum (Ryan and Deci, 2000), the authors of the AMS chose to keep only the identified regulation items. Intrinsic motivation was classified into subcategories: to know, to accomplish, and to experience. These three types of intrinsic motivation were based on intrinsic motivation literature (Deci, 1975), suggesting people are intrinsically motivated for different reasons, but not meaning one type is more self-determined than another. In educational contexts, “to experience” means that students choose to do the specific activities necessary to learn in order to experience stimulating sensations (e.g. pleasure, fun, excitement). “To accomplish” is different: in this case the choice to engage in behavior that will lead to learning is because students enjoy the process of achieving, in and of itself, and, for example, may choose to extend an activity beyond what was requested in order to gain a greater sense of accomplishment. “To know”, the third type of intrinsic motivation, refers to engaging in the activities that produce learning out of pleasure and satisfaction gained from seeking an understanding of something previously unknown or unclear. The AMS, therefore, aims to enable researchers to measure different types and degrees of motivation in detail. According to a motivational hierarchy described by the developers, the target of the AMS, motivation toward going to college, is considered to be at the “contextual” level, because motivation status in this case is expected to relate more to an individual’s set of educational experiences rather than to a personality trait or to a specific situation (Vallerand, 1997; Vallerand and Ratelle, 2002). Since the AMS was first developed in 1992, it has been used in many settings, including with college students with no majors identified (Nunez et al., 2005; Guay et al., 2015), and in specific college courses, e.g., in business (Smith et al., 2010), psychology
(Cokley et al., 2001), and physical education (Spittle et al., 2009), and in dental school (Orsini et al., 2016). The construct validity of the AMS has also recently been found wanting for a group of Black college students from a variety of majors and institutions (Cokley, 2015). However, the AMS has rarely been used in STEM courses.

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Nonself-Determined</th>
<th>Self-Determined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types of Motivation</td>
<td>Amotivation</td>
<td>Extrinsic Motivation</td>
</tr>
<tr>
<td>Subscales</td>
<td>Amotivation</td>
<td>External Regulation</td>
</tr>
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<td></td>
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</tbody>
</table>

**Figure 3.2** The seven types of motivation measured by AMS

Since the AMS is well-aligned with the motivation continuum based on SDT and has good psychometric evidence, it has been adapted from a global education scale to measure a discipline-specific motivation in Human Anatomy & Physiology, physics, mathematics, and nutrition (Maurer et al., 2012, 2013; Lim and Chapman, 2015; Sturges et al., 2016); therefore, it is a good candidate to be modified into a measure of student motivation toward chemistry specifically. Invariance across gender has been found (Grouzet et al., 2006; Caleon et al., 2015), which suggests the use of the AMS to test hypotheses of gender differences in relation to academic motivation. The studies with college students have revealed higher degrees of self-determination for female students. For example, Vallerand et al. (1992), reported an ANOVA result showing that females from a Canadian university had significantly higher values for all three intrinsic motivation types, introjected regulation, and identified regulation; however, the effect sizes were small ($d = 0.15–0.34$) (Cohen, 1988). The results from a Spanish university sample showed that female students scored significantly higher on identified regulation and the three scales of intrinsic motivation, but lower on external regulation than male students (Nunez
et al., 2005). This study was conducted using *t*-tests at an alpha level of 0.01; the effect sizes were between 0.31–0.39 (small) except for the *to know* subscale ($d = 0.52$, medium). When the participants were pre-chemistry teachers in Turkey, females got higher scores in all motivation types; however, the results showed only significant differences between males and females on the *to experience* subscale ($d = 0.56$, medium effect size) (Eymur and Geban, 2011). A meaningful difference between males and females has been detected in elementary pre-service teachers on the subscales of extrinsic motivation and *amotivation* (Acisli, 2012). Results from Spittle *et al.* (2009), a study based on participants in a regional university in Australia, showed that female students scored significantly higher on the *to know* ($d = 0.43$) and *to accomplish* subscales ($d = 0.30$).

When the participants are college students from the United States, studies show higher degrees of self-determination for female students but with differences on detailed motivation type through the same *t*-tests at alpha level of 0.001. A sample of students (75% undergraduate students, 25% graduate students) in business courses (Smith *et al.*, 2010) showed significant differences on *amotivation*, three extrinsic motivation subscales, two intrinsic motivation subscales (*to know* and *to accomplish*), but the effect sizes were small, ranging from 0.09 (*to know*) to 0.43 (*identified regulation*). On the other hand, a sample of students enrolled in undergraduate college psychology courses showed motivational scores favoring females with effect sizes ranging from 0.02 (*to experience*) to 0.40 (*identified regulation*), but there was no evidence that male students and female students differ on any of the motivation types, which may be due to a smaller sample size in this study (Cokley *et al.*, 2001). Since the findings regarding differences between males and females are not consistent across context, more studies are needed to explore specific contexts.
Researchers have reported positive relationships between intrinsic motivation subscales and academic achievement (Areepattamannil et al., 2011), especially for to know and to experience subscales (Eymur and Geban, 2011). For students in an introductory organic chemistry course, their interest/enjoyment scores, which are regarded as the measure of intrinsic motivation in the Intrinsic Motivation Inventory (McAuley et al., 1989), were positively correlated with their academic achievement consisting of average grades of four exams and final course grade (Black and Deci, 2000). Sometimes intrinsic motivation fails to show the expected positive relationship with achievement in chemistry. For example, studies in Slovenia found only weak evidence that intrinsic motivation to learn chemistry is positively associated with elementary students’ (Devetak et al., 2009) or first-year pre-service primary school teachers’ (Jurišević et al., 2008) chemistry achievement. In some cases, both extrinsic and intrinsic motivation have been positively associated with students’ overall academic achievement, e.g., for tertiary level GPA in South Africa (Goodman et al., 2011), but a negative predictive effect of extrinsic motivation on overall academic achievement has also been observed, e.g., for Indian immigrant adolescents in Canada (Areepattamannil et al., 2011).

General chemistry is challenging (Stuckey et al., 2013; Thomas and McRobbie, 2013; Villafañe et al., 2014; Gonzalez and Paoloni, 2015) and students often struggle with the chemistry concepts covered in a typical course (Cooper, 2010). It has also been documented that general chemistry courses have low retention rates (Lifton et al., 2007; deProphetis Driscoll et al., 2010). Students need to achieve well enough to pass this course to register for more advanced chemistry/science courses, and motivation toward chemistry will be a potential variable affecting student academic achievement. Therefore, it is crucial to study motivation in college chemistry courses to measure the status and changes of student motivation because
students of different degrees of self-determined motivation may express different degrees of engagement in activities and different association with academic achievement. In addition, student motivation is likely to change according to the learning environment. This level of information can help faculty and education researchers to understand why general chemistry is challenging for some students and results in low retention rates. Having robust information about student motivation embedded in a solid base of theory will allow chemistry instructors to make informed decisions regarding the strategies they use to engage students in learning chemistry.

**Research purpose**

The present study has several goals. First, in a pilot study, we use the AMS in college chemistry courses to determine if the AMS functions in those courses according to the theory, and whether the AMS is sufficiently sensitive to pick up potential differences by sex. Second, we modify the AMS to a theory-based and chemistry-relevant instrument (AMS-Chemistry) through discussions and cognitive interviews, gather additional validity evidence, and proceed with score interpretation regarding student motivation toward chemistry. We note that this effort moves the instrument more toward the intent to measure a situational level of motivation rather than the contextual level of the original AMS (Vallerand, 1997; Vallerand and Ratelle, 2002). Finally, we determine how student motivation toward chemistry is associated with lecture attendance and academic achievement earlier and later in the semester.

In accordance with these goals, the current study addresses six specific research questions. The first two questions relate to the pilot study with the AMS:

1. How does the AMS function with general chemistry students? To what extent are the scores aligned with SDT as intended by the measurement model?
(2) What is the “motivation toward college” status of these students as measured by the AMS? When looking at female and male subgroups, how do they differ on motivation toward college?

The remaining four questions concern the AMS-Chemistry:

(3) What validity evidence supports the use of a modified AMS (AMS-Chemistry) to examine “motivation toward chemistry” in general chemistry?

(4) What is the motivation toward chemistry status of these students over a semester? When looking at female and male subgroups, how do they differ on motivation toward chemistry?

(5) How is motivation toward chemistry correlated with student academic achievement earlier and later during the semester?

(6) How is motivation early in the semester associated with students’ attendance later in the semester?

Method

The study includes three stages: (1) a pilot study with the AMS, (2) instrument modification and gathering of validity evidence for the modified instrument (AMS-Chemistry), and (3) score interpretation with the AMS-Chemistry data from general chemistry students. The details for each stage will be outlined separately in the subsequent sections.
Pilot study

The purpose of the pilot study was to make sure the AMS functioned in accordance with self-determination theory in college chemistry courses and therefore was a suitable candidate to be modified to measure motivation toward chemistry. The AMS (Vallerand et al., 1992) asks:

*Why do you go to college?*

The 28 items measure amotivation, three types of extrinsic motivation, and three types of intrinsic motivation. Sample items include “For the pleasure that I experience when I feel completely absorbed by what certain authors have written” and “I don’t know; I can’t understand what I am doing in school”. A seven-point Likert scale was used, with 1 for “does not correspond at all”, 2 and 3 for “correspond a little”, 4 for “corresponds moderately”, 5 and 6 for “corresponds a lot”, and 7 for “corresponds exactly”. Please see Appendix A1 (in Appendix A) for all items.

Participants

During stage 1, a quantitative approach was used to gather evidence for internal structure validity and internal consistency reliability. The pilot study was conducted at a large public research university in the western United States. The AMS was administered to general chemistry students during class time in Spring 2012, as a paper and pencil test. The administration took place during the 9th week of the semester, two weeks after Exam 2 and two weeks prior to Exam 3. Students were given 20 minutes to complete the 28-item instrument and demographics form. To ameliorate stereotype threat (Steele and Aronson, 1997), the four demographic items were placed at the end of the survey on a separate page. The item formats included multiple choice for year in school (four categories plus a free response option), gender
(two categories), race/ethnicity (six categories plus a free response option), and free response for declared major.

Students enrolled in first- and second-semester general chemistry courses took part in the study. The participants were adult students (18 years or older). The data were not sensitive in nature and accidental disclosure would not place the participants at risk; no identifiers linked individuals to their responses. Consent to use the student data was gathered using a cover page on the survey, clearly stating that participation in the study was voluntary and anonymous. A total of 242 responses were collected with consent forms from four classes, with a response rate between 60% and 78% in each class. After checking for missing data and careless responses (e.g., the same response for all the questions), a total of 238 students had complete responses to the AMS, which were used for data analysis. Among these 238 students, about ¾ (77.8%) were freshmen and sophomores, and 60.9% were females. About 34 of the students (75.2%) reported to be White. Students were from more than 23 majors, including Biological Sciences (29.0%), Sports and Exercise Science (24.7%), Chemistry (12.6%), and Athletic Training (6.3%).

Instrument modification and validity evidence

The AMS-Chemistry is designed to probe course-specific motivation and therefore asks students:

*Why are you enrolled in this chemistry course?*

All 28 items were retained from the original AMS and modified to fit the context of a chemistry course. A five-point-Likert scale is used, with 1 for “not at all”, 2 for “a little”, 3 for “moderately”, 4 for “a lot”, and 5 for “exactly”. In many cases, the word “chemistry” was simply substituted for the word “college”. With others, more global changes to the wording were
necessary to make the statements more relevant to a chemistry student population. Evidence for content validity was gathered by having an expert panel, comprised of the authors of this manuscript and an educational psychologist with expertise in achievement motivation, review the modified items. The AMS-Chemistry items were then used in a series of student interviews to determine if the original intent of the items were retained, and therefore, if further revisions were needed.

**Interview participants**

In stage 2, students were recruited from a first-semester general chemistry course at a public university in the western United States during the fall of 2012. Interview participants were recruited via an announcement during lecture. In accordance with Institutional Review Board policy, students were informed that their participation had no impact on their course grade and that they would be volunteering for a research study regarding their academic motivations. Interested students volunteered by adding their name to a sign-up sheet passed out and collected by one of the authors (BF). Volunteers were selected at random and contacted via email to arrange a 30 minute interview time-slot. From the pool of volunteers, eleven students were interviewed.

**Interview protocol**

All interviews took place in a private interview room to ensure both participant confidentiality and audio quality. Prior to completing any of the AMS-Chemistry items, students

Note: The interviews were conducted by author Brent Ferrell.
were asked about their past experiences in chemistry courses, their reasons for enrolling in the course, and their perceptions of how chemistry relates to their future goals. Following the initial discussion, students were asked to complete the AMS-Chemistry instrument, consisting of 28 items.

Upon completion of the instrument, the students read each item aloud and explained their reasoning for the answer choice they made. If a student’s reasoning did not match their answer choice, probing questions were asked in order to clarify their interpretation of the item and how it matched their answer choice and reasoning. This methodology is important in establishing evidence for the response process validity (Arjoon et al., 2013) of the modified instrument, ensuring proper readability and consistency between students’ answer choices and reasoning among the target population (Barbera and VandenPlas, 2011). In addition to asking probing questions regarding a single item and its interpretation, clarity was sought when a student’s response to an item did not match their responses to the other items in the same subscale (e.g., to experience). As the instrument contains four items per subscale, each item should be measuring similar aspects of student motivation and thus elicit similar responses.

Survey participants

In stage 3, the AMS-Chemistry was administered as a paper-and-pencil survey to students enrolled in one section of general chemistry. The students were given 10 minutes during lecture time to complete the 28-item survey. The survey was administered twice; “Time 1” (fourth week of classes) data was used to investigate internal structure, and both “Time 1” and “Time 2” data were used for score interpretation. Participants were students enrolled in a first semester general chemistry course for science majors during Spring 2013 at a large southeastern
public research university in the United States. The study protocol was submitted to the Institutional Review Board for review. Standard procedures were followed: students were informed that responding to the survey was voluntary and their responses would have no impact on their course grade. To avoid stereotype threat, demographic information (sex, major, year in school, race/ethnicity) was obtained from institutional records.

At Time 1, 222 students took the survey during the fourth week of classes. 14 students had missing data or careless responses (e.g., “3” for all the items), which yielded 208 students with usable complete data. Of the 208 students, 62.0% were females; 25.5% were Biology majors and 33.7% were Biomedical Science majors; 54.3% were White and 19.2% were Hispanic students; and 78.4% were first-year or sophomore students.

At Time 2, 100 students took the survey during the 14th week of classes. Six students had incomplete or all “3” for their responses; therefore, 94 students’ responses were available for data analysis. For the 94 students, 62.8% were female; 23.4% were Biology and 38.3% were Biomedical Science majors; 54.3% were White and 20.2% were Hispanic students; and 68.1% were first-year or sophomore students.

The section that participated in the study was from a larger population who were enrolled in the first semester general chemistry course in Spring 2013 in the institution. Based on the available demographic information (Appendices A2–A4 in Appendix A), students who responded to the survey at Time 1 were very similar to all students enrolled in terms of sex, race/ethnicity, and prior achievement as determined by standardized tests (e.g., SAT), but a little more representative of sophomores and Biomedical Science majors. Students who responded to the survey at Time 2 were slightly more representative of males, Biomedical Science majors, and juniors.
Chemistry academic achievement measures

There were four instructor-created exams and a final exam in Spring 2013. All of the questions were multiple choice. Exam 1 was administered two days after the first administration of the AMS-Chemistry. Exam 3 was administered three days after the second administration. Since motivation can change on the basis of the immediate social context, only Exam 1 and Exam 3 grades were used as measures of chemistry academic achievement for this study.

Data analysis

The quantitative data were evaluated via statistical analyses. For internal structure validity, confirmatory factor analysis (CFA) was conducted on the instrument scores in Mplus 5.2. A minimum of five to ten respondents per item is often recommended for factor analysis (Brown, 2006, p. 413) and all the items were set to load on their assumed factors only. The model was identified by fixing the first item on each factor at 1. If the target model is very close to the best possible model, $\chi^2$ will not be large and significant; however, as $\chi^2$ is likely to be inflated if a model is based on a large number of scores in general, additional fit statistics are often examined. The Comparative Fit Index (CFI) varies from 0 to 1 where 1 suggests a perfect fit for the model. A value > 0.95 is considered adequate fit (Hu and Bentler, 1999), and > 0.90 is considered as acceptable fit (Cheng and Chan, 2003). The Root Mean Square Error of Approximation (RMSEA) can range from 0 to infinity and is a measure of the approximate model fit in the population (Steiger, 1990). In general, RMSEA values < 0.05 are considered close fit and < 0.08 are considered reasonable fit (Browne and Cudeck, 1992; MacCallum et al., 1996).
The standardized root mean squared residual (SRMR) is not sample size dependent. The value ranges from 0 to 1 and is a “badness of fit” measure based on the standardized fitted residuals. By standardizing the residuals, the scale of the variables is taken into account (Schermelleh-Engel et al., 2003). Hu and Bentler (1995) suggested that an SRMR value of < 0.05 is indicative of good fit and < 0.10 is acceptable fit. Based on what is commonly accepted in the literature, we used the following cut-off values as an evaluation of reasonable model fit beyond the chi-square test statistic: RMSEA < 0.08, SRMR < 0.10, CFI > 0.90 (Hu and Bentler, 1999; Cheng and Chan, 2003).

The internal consistency of the AMS and AMS-Chemistry was examined by using Cronbach’s alpha coefficients. A benchmark of 0.7 (Murphy and Davidshofer, 2005) is usually suggested. The Cronbach’s alpha coefficients for the subscales of AMS were analyzed through SPSS software version 22.0. Descriptive statistics of the items and subscales were obtained using SAS 9.3. Univariate and multivariate normality, outliers, and homogeneity of variances were also examined. To examine whether females and males differ on the set of motivational variables, multivariate analysis of variance (MANOVA) and follow-up univariate analysis of variance (ANOVA) were performed using SAS 9.3. MANOVA and ANOVA were also conducted to determine if there were any statistically significant differences on the seven subscales by attendance using SAS 9.3. MANOVA was conducted at an alpha level of 0.05 and the follow-up ANOVAs were conducted at an alpha level of 0.007 (0.05/7) to control type-1 error. The multivariate assumption tests and outlier assessment results are provided in Appendix A7.

Regarding the qualitative data, all interviews were audio recorded and transcribed. The transcripts were then coded for significant statements and emergent themes, based on each item
and its corresponding subscale (Creswell, 2007). The strategy for coding was guided by the associations between the items and the subscales to which each item belonged (see Appendix A5 in Appendix A and Table 3.4 for alignment of items to subscales). This coding scheme allowed for evaluation of how the students interpreted each item within a subscale and how each item compared to other items in the same subscale.

**Results**

**Pilot study**

The pilot study addressed the first two research questions: (1) how does the AMS function with general chemistry students? and (2) what is the “motivation toward college” status of the students?

**Validity evidence for AMS internal structure**

The internal structure of the data was evaluated to determine whether the seven-factor proposed model for the AMS functions well in a general chemistry context. Using the variance–covariance matrix for the 28 items, a robust maximum-likelihood method of estimation (Satorra and Bentler, 1994; Bentler, 1995; Brown, 2006, p. 379) was employed for a confirmatory factor analysis because the data were not normally distributed. The analysis yielded fit values of 0.90 for CFI, 0.069 for RMSEA, and 0.066 for SRMR, although the proposed model did not reach statistical nonsignificance (SB $\chi^2 = 698.67$, df = 329, $p < 0.001$). The loadings for each item were significant and ranged from 0.582 to 0.902.

Correlations between pairs of measured-variable residuals were added to the proposed model after inspection of the modification indices, since similar wording, reverse wording, or
formatting in items (Brown, 2006, p. 167), adjacency of items, and respondents’ misunderstanding of differences between items/factors could result in correlations between the item residuals (e.g., Gerbing and Anderson, 1984; Cole et al., 2007). For example, item 11 (For the pleasure that I experience when I read interesting authors) and item 18 (For the pleasure that I experience when I feel completely absorbed by what certain authors have written) have similar wording and item format; therefore, the residuals of these two items could highly correlate with each other. Some students could possibly not be able to differentiate item 8 (In order to obtain a more prestigious job later on) from item 10 (Because eventually it will enable me to enter the job market in a field that I like) since these two items both reflect extrinsic motivation. When four such correlated residuals were added to the model, the results showed that the model fit the data reasonably well: CFI 0.92, RMSEA 0.061, and SRMR 0.060. The new loadings were between 0.586 and 0.907 (Appendix 5 in Appendix A), the biggest change in loading was 0.1, and the biggest change in correlation between factors was 0.081, suggesting the added correlations between item residuals had little effect on the model. Although the model still did not reach statistical nonsignificance (SB $\chi^2 = 609.32$, df = 325, $p < 0.001$), the improvement in fit was significant: difference in chi-square 89.35, df = 4, $p < 0.05$. Other more parsimonious models were tried, but the model fit (Appendix 6 in Appendix A) was not as good as for the seven-factor model.

**Internal consistency for AMS**

The Cronbach’s alpha coefficients for subscales of AMS are displayed in Table 3.1. For the seven subscales, the alpha coefficients were between 0.77 (identified regulation) and 0.90 (amotivation), suggesting the internal consistency was good for all seven subscales.
Table 3.1 Internal consistency and characteristics of the seven factors of the AMS (n = 238)

<table>
<thead>
<tr>
<th></th>
<th>Amotivation</th>
<th>External regulation</th>
<th>Introjected regulation</th>
<th>Identified regulation</th>
<th>To experience</th>
<th>To accomplish</th>
<th>To know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cronbach’s α</td>
<td>0.90</td>
<td>0.83</td>
<td>0.87</td>
<td>0.77</td>
<td>0.89</td>
<td>0.89</td>
<td>0.89</td>
</tr>
<tr>
<td>M</td>
<td>1.40</td>
<td>5.80</td>
<td>5.38</td>
<td>6.10</td>
<td>3.74</td>
<td>5.06</td>
<td>5.57</td>
</tr>
<tr>
<td>SD</td>
<td>0.87</td>
<td>1.10</td>
<td>1.37</td>
<td>0.88</td>
<td>1.45</td>
<td>1.28</td>
<td>1.10</td>
</tr>
<tr>
<td>Sk</td>
<td>3.13</td>
<td>-1.29</td>
<td>-1.00</td>
<td>-1.47</td>
<td>0.09</td>
<td>-0.64</td>
<td>-0.78</td>
</tr>
<tr>
<td>Ku</td>
<td>10.90</td>
<td>1.54</td>
<td>0.57</td>
<td>2.86</td>
<td>-0.77</td>
<td>-0.04</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Note: sk = skewness; ku = kurtosis

Both the confirmatory factor analysis and internal consistency results provided good psychometric evidence for the seven-factor model of the AMS; therefore, score interpretation using the model can be supported.

AMS motivation status and sex differences

The Likert-style response options for the AMS items range from 1 to 7; a mean greater than 4 for a subscale suggests the statement corresponds a lot or exactly to the students’ reasons for going to college. For six of the subscales, a higher score indicates students are more motivated. For *amotivation*, on the contrary, a higher score indicates students are less motivated. The mean, standard deviation, skewness, and kurtosis for each subscale are given in Table 3.1 for the students in general and in Table 3.2 for males and females. In general, students are motivated, with averages above 5 for all extrinsic motivation subscales and two of the three intrinsic motivation subscales (*to experience* was lower), and an average below 2 for *amotivation*. According to the data in Table 3.2, female students scored slightly higher on all subscales except for *amotivation* and *external regulation*.
Table 3.2 The mean, standard deviation, skewness, and kurtosis of the motivation variables in AMS by sex (F = Females, M = Males)

<table>
<thead>
<tr>
<th>Variables</th>
<th>F</th>
<th>SD</th>
<th>Sk</th>
<th>Ku</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amotivation</td>
<td>5.79</td>
<td>5.54</td>
<td>6.18</td>
<td>3.82</td>
</tr>
<tr>
<td>External regulation</td>
<td>1.05</td>
<td>1.21</td>
<td>0.75</td>
<td>1.42</td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>-1.32</td>
<td>-1.02</td>
<td>-1.23</td>
<td>0.08</td>
</tr>
<tr>
<td>Identified regulation</td>
<td>2.09</td>
<td>0.78</td>
<td>1.66</td>
<td>-0.78</td>
</tr>
<tr>
<td>To experience</td>
<td>5.19</td>
<td>1.17</td>
<td>-0.69</td>
<td>0.25</td>
</tr>
<tr>
<td>To accomplish</td>
<td>5.65</td>
<td>1.04</td>
<td>-0.77</td>
<td>0.71</td>
</tr>
<tr>
<td>To know</td>
<td>0.25</td>
<td>0.71</td>
<td>0.71</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Note: sk = skewness; ku = kurtosis

MANOVA was conducted to examine the overall sex effect on student motivation. The difference in means on the set of seven subscales was statistically significant, \( \Lambda = 0.932 \), \( F(7,230) = 2.38, p = 0.0229 \). The size of the multivariate effect was between small and medium \((f^2 = 0.07)\) \((f^2 = 0.02 \text{ small}, 0.15 \text{ medium}, 0.35 \text{ large})\) (Cohen, 1988). Univariate follow-up tests (Table 3.3) using a Bonferroni approach (Holm, 1979) revealed sex differences for amotivation, \( F(1,236) = 12.55, p = 0.005 \). The mean for males on amotivation was higher with a medium effect size, \( d = 0.48 \) (Cohen, 1988).

Table 3.3 Results of univariate follow-up tests by sex based on AMS

<table>
<thead>
<tr>
<th>Variables</th>
<th>( F(1, 236) )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amotivation(^a)</td>
<td>12.55</td>
<td>0.0005</td>
</tr>
<tr>
<td>External regulation</td>
<td>0.01</td>
<td>0.9367</td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>5.29</td>
<td>0.0223</td>
</tr>
<tr>
<td>Identified regulation</td>
<td>3.24</td>
<td>0.0729</td>
</tr>
<tr>
<td>To experience</td>
<td>1.08</td>
<td>0.3008</td>
</tr>
<tr>
<td>To accomplish</td>
<td>3.80</td>
<td>0.0525</td>
</tr>
<tr>
<td>To know</td>
<td>1.69</td>
<td>0.1954</td>
</tr>
</tbody>
</table>

\(^a\)Significantly different at 0.0071 level

Because the data were non-normal, the scores for amotivation were transformed \((\log(\text{amotivation}))\). For the transformed variable, \( M = 0.23, SD = 0.41, Sk = 1.99, Ku = 3.41, \) suggesting the distribution for the new variable was more normal. MANOVA was run with the
transformed variable, and the significant difference test results did not change. Please see Appendix 7 in Appendix A for details.

**Instrument modification**

After the pilot study, the AMS was modified to be a chemistry specific instrument, AMS-Chemistry. The third research question requires examination of validity evidence associated with the modified instrument. The three main types of validity evidence gathered before score interpretation relate to content, response processes, and internal structure.

**AMS-Chemistry content validity**

Content validity was examined by expert panel discussion, with minor modification of the items to make sure the statements were readable and suitable for students in the target chemistry courses. Members of the expert panel included authors of this paper (two established researchers with extensive general chemistry teaching experience and two chemistry graduate students) as well as a professor of educational psychology with an active research program in achievement motivation. The psychology expert provided guidance regarding the alignment of the items with theory. Several rounds of discussion enabled the panel to reach consensus.

**AMS-Chemistry response process validity evidence**

Transcripts from eleven interviews were reviewed and coded to produce results informing the readability, response consistency, and interpretation of the AMS-Chemistry items. With regard to the readability of items, all 28 items produced good results. That is, no
participants struggled with the words or phrasing used, as indicated by clear reading (i.e., no stumbling or re-reading), of the items.

With regard to response consistency and item interpretation, most items produced consistent results. That is, students’ response explanations matched their chosen scale responses and their explanations were consistent across subscales. Two items (13 and 14, shown below) required wording changes to address subscale consistency. These wording changes were relatively minor, but were deemed necessary based on discussions with a number of the participants.

Item 13 (original): For the satisfaction I experience while succeeding in my academic goals.

Item 13 (revised): For the satisfaction I experience while succeeding in chemistry.

Item 14 (original): Because when I succeed in chemistry I feel important.

Item 14 (revised): Because when I succeed in chemistry I feel smart.

When several of the students compared these items to others in the same subscale, there were inconsistencies in their Likert-scale responses as well as how they interpreted the items. For example, when comparing categorically identical items 6 and 13 (to accomplish), one student stated, “Well, my overall academic goals are different than my satisfaction with understanding chemistry. I don’t think that those are the same at all.”

Several other participants had different Likert-scale responses to items 6 and 13. This repeated discrepancy prompted discussion in almost every interview. We found that most participants interpreted “understanding chemistry” (from item 6) differently than success in their “academic goals” (from item 13). Because we are interested in how students view their motivation in chemistry specifically, it is important that the student answers each item according
to their experience in the chemistry classroom. Therefore, to focus student responses on their chemistry experiences the modification from “my academic goals” to “chemistry” was made.

The original version of item 14 posed a different problem. Many students were reluctant to choose the Likert responses “corresponds a lot” or “corresponds exactly” on this item because they viewed the relationship between academic success and self-perception of importance to be negative. One student commented, “When I read, ‘I feel important’, to me, it sounds like I’m saying, ‘Oh, I know chemistry, I understand chemistry better than you do’ or something. So, I don’t feel that way.” Other students regarded ‘feeling important’ as something with an external origin, a judgment placed on them by others. This is not consistent with other items in this subscale (introjected regulation), as they are directed toward measuring one’s self-derived reasons for taking the course, independent of others’ views. We feel that the wording change to ‘feel smart’ is more aligned with other items in the introjected regulation subscale and places more of a personal dimension to judging oneself.

All other items were left unchanged based on the responses we received from the participants. The Likert-scale responses for the remaining items and the reasoning given for the responses seemed to match well for items of the same subscale. The changes made above to items 13 and 14 were based on many similar responses among the participants that reflected incongruence within a particular subscale. Although there was not total agreement between participant responses for the remaining items, no consistent issues were found. In addition, no problems of poor readability were reported for any of the items; therefore, none of the phrasing required modification. The final items in AMS-Chemistry are displayed in Table 3.4.
<table>
<thead>
<tr>
<th>Item</th>
<th>Factor loading</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q5</td>
<td>0.868</td>
<td>Honestly, I don't know; I really feel that I am wasting my time taking chemistry courses.</td>
</tr>
<tr>
<td>Q12</td>
<td>0.430</td>
<td>I once had good reasons for taking chemistry courses; however, now I wonder whether I should continue.</td>
</tr>
<tr>
<td>Q19</td>
<td>0.652</td>
<td>I don’t know why I take chemistry courses, I couldn't care less about them.</td>
</tr>
<tr>
<td>Q26</td>
<td>0.631</td>
<td>I don't know; I can't understand what I am doing taking chemistry courses</td>
</tr>
<tr>
<td>Q1</td>
<td>0.683</td>
<td>Because without having taken chemistry I would not find a high-paying job later on.</td>
</tr>
<tr>
<td>Q8</td>
<td>0.867</td>
<td>In order to obtain a better job later on.</td>
</tr>
<tr>
<td>Q15</td>
<td>0.859</td>
<td>Because I want to have a well-paying career.</td>
</tr>
<tr>
<td>Q22</td>
<td>0.832</td>
<td>In order to have a better salary later on.</td>
</tr>
<tr>
<td>Q7</td>
<td>0.837</td>
<td>To prove to myself that I am capable of succeeding in chemistry.</td>
</tr>
<tr>
<td>Q14</td>
<td>0.867</td>
<td>Because when I succeed in chemistry I feel smart.</td>
</tr>
<tr>
<td>Q21</td>
<td>0.767</td>
<td>To show myself that I am an intelligent person.</td>
</tr>
<tr>
<td>Q28</td>
<td>0.883</td>
<td>Because I want to show myself that I can succeed in studying chemistry.</td>
</tr>
<tr>
<td>Q3</td>
<td>0.745</td>
<td>Because I think that chemistry courses will help me better prepare for the career I have chosen.</td>
</tr>
<tr>
<td>Q10</td>
<td>0.625</td>
<td>Because taking chemistry will enable me to enter the job market in a field that I like.</td>
</tr>
<tr>
<td>Q17</td>
<td>0.636</td>
<td>Because taking chemistry courses will help me make more informed choices about my career options.</td>
</tr>
<tr>
<td>Q24</td>
<td>0.824</td>
<td>Because I believe that chemistry courses will improve my skills in my chosen career.</td>
</tr>
<tr>
<td>Q4</td>
<td>0.807</td>
<td>For the feelings I experience when I am communicating chemistry ideas to others.</td>
</tr>
<tr>
<td>Q11</td>
<td>0.752</td>
<td>For the pleasure that I experience when I perform chemistry experiments.</td>
</tr>
<tr>
<td>Q18</td>
<td>0.725</td>
<td>For the enjoyment I experience when I think about the world in terms of atoms and molecules.</td>
</tr>
<tr>
<td>Q25</td>
<td>0.905</td>
<td>For the satisfaction I experience while learning about various chemistry topics.</td>
</tr>
<tr>
<td>Q6</td>
<td>0.872</td>
<td>For the satisfaction I experience while improving my understanding of chemistry.</td>
</tr>
<tr>
<td>Q13</td>
<td>0.818</td>
<td>For the satisfaction I experience while succeeding in chemistry.</td>
</tr>
<tr>
<td>Q20</td>
<td>0.862</td>
<td>For the satisfaction I feel as I work toward an understanding of chemistry.</td>
</tr>
<tr>
<td>Q27</td>
<td>0.835</td>
<td>Because chemistry courses allow me to experience satisfaction in my quest for knowledge.</td>
</tr>
<tr>
<td>Q2</td>
<td>0.697</td>
<td>Because I experience pleasure and satisfaction while learning new things.</td>
</tr>
<tr>
<td>Q9</td>
<td>0.866</td>
<td>For the pleasure I experience when I learn new things about chemistry.</td>
</tr>
<tr>
<td>Q16</td>
<td>0.908</td>
<td>For the pleasure that I experience in broadening my knowledge about chemistry.</td>
</tr>
<tr>
<td>Q23</td>
<td>0.617</td>
<td>Because studying chemistry allows me to continue to learn about things that interest me.</td>
</tr>
</tbody>
</table>
AMS-Chemistry internal structure validity evidence

The dataset at Time 1 was used to examine the internal structure validity of the AMS-Chemistry. For all the 28 items, the skewness is between 1.63 and -1.47, and kurtosis is between 2.04 and -0.90 except for item 5 (Sk = 1.87, Ku = 3.13), suggesting the data is approximately normally distributed; therefore, maximum likelihood was used to conduct confirmatory factor analysis. For the seven-factor internal structure, the loadings as shown in Table 3.4 for each item are significant and range from 0.617 to 0.908 except that item 12 has a standardized loading of 0.430. The CFI value (0.94) as displayed in Table 3.5 met the suggested criterion of greater than 0.90, the SRMR value (0.058) met the suggested criterion of smaller than 0.08, and RMSEA value (0.059) met the suggested criterion of smaller than 0.06. Although the model did not reach statistical nonsignificance ($\chi^2 = 565.33$, df = 329, $p < 0.001$), the results showed that this model is very close to the true underlying model of the data.

| Table 3.5 Fit indices of the confirmatory factor analysis of AMS-Chemistry ($n = 208$) |
|-----------------------------------------|---------|-------|-----|-----|-----|
| Seven-factor                          | 565.33  | 329   | 54.01 | 11  | 0.94 | 0.058 | 0.059 |
| Five-factor                           | 619.34  | 340   |       |     | 0.93 | 0.061 | 0.063 |
| One-factor                            | 1655.44 | 350   |       |     | 0.69 | 0.118 | 0.134 |

Two parsimonious models were tried to test the robustness of the seven-factor model. The five-factor model has *amotivation, external regulation, introjected regulation, identified regulation,* and *intrinsic motivation* (comprising *to experience, to accomplish, and to know*), while the one-factor model groups all 28 items into one factor. The results showed that the seven-factor model showed the best fit. The five-factor model also showed good fit indices; however, the $\chi^2$ change of 54.01 with a change of degrees of freedom of 11 suggested that the seven-factor model fits the data significantly better than the five-factor model. Therefore, the seven-factor model is more appropriate for data interpretation. The sample size ($n = 94$) at Time
2 was too small for confirmatory factor analysis as a minimum of five to ten respondents per item is often recommended for factor analysis (Brown, 2006, p. 413); therefore, CFA was not conducted at Time 2.

**Internal consistency reliability**

The internal consistencies of the subscales were estimated by Cronbach’s alpha coefficients. Results showed satisfactory levels of internal consistency at both Time 1 and Time 2 as shown in Table 3.6. Regarding the seven subscales, the alpha coefficients were between 0.74 and 0.91. At Time 2, the alpha coefficients were between 0.79 and 0.90 for the seven subscales. The psychometric evidence suggested that the scores from AMS-Chemistry were sufficiently reliable and valid for our interpretation.

**Table 3.6 Internal consistency reliability for the seven factors of the AMS-Chemistry**

<table>
<thead>
<tr>
<th></th>
<th>Cronbach’s alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time 1 (n = 208)</td>
</tr>
<tr>
<td>Amotivation</td>
<td>0.74</td>
</tr>
<tr>
<td>External regulation</td>
<td>0.88</td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>0.90</td>
</tr>
<tr>
<td>Identified regulation</td>
<td>0.79</td>
</tr>
<tr>
<td>To experience</td>
<td>0.88</td>
</tr>
<tr>
<td>To accomplish</td>
<td>0.91</td>
</tr>
<tr>
<td>To know</td>
<td>0.86</td>
</tr>
</tbody>
</table>

**AMS-Chemistry score interpretation**

The quantitative data gathered at Time 1 and Time 2 was also used to address research questions 4–6 regarding student motivation status at the two time points, possible differences between male and female students, and relationships with academic achievement and attendance.
General motivation status

We hypothesized that the students in our sample would be more likely to be extrinsically motivated than intrinsically motivated as only about 1% declared a major in Chemistry, with the majority (about 60%) majoring in Biology or Biomedical Science. Regarding students’ motivation structure, the means of the subscales were examined. The Likert-style response options for the AMS-Chemistry items range from 1 to 5; a mean greater than 3 for a subscale indicates the statements tended to correspond a lot or exactly to the students’ reasons for enrolling in this chemistry course.

Motivation structure earlier in the semester. When the AMS-Chemistry was administered at Time 1, the skewness values for the subscale scores were between -0.88 and 1.30 (Table 3.7), and kurtosis values were between -0.63 and 1.51; therefore, the subscale scores were approximately normally distributed. The mean of amotivation was 1.64, suggesting that students were generally motivated to enroll in the first semester of general chemistry. The three extrinsic motivation subscales had means greater than 3 with the highest mean for identified regulation (3.94). The three intrinsic motivation scales had means equal or lower than 3, and to experience showed the lowest mean of 2.45. These results appear to be consistent with the hypothesis.

Table 3.7 The descriptive statistics for the subscales of AMS-Chemistry at Times 1 and 2

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Time 1 (n = 208)</th>
<th>Time 2 (n = 94)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Amotivation</td>
<td>1.64</td>
<td>0.74</td>
</tr>
<tr>
<td>External regulation</td>
<td>3.81</td>
<td>0.94</td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>3.39</td>
<td>1.07</td>
</tr>
<tr>
<td>Identified regulation</td>
<td>3.94</td>
<td>0.82</td>
</tr>
<tr>
<td>To experience</td>
<td>2.45</td>
<td>1.00</td>
</tr>
<tr>
<td>To accomplish</td>
<td>2.95</td>
<td>1.04</td>
</tr>
<tr>
<td>To know</td>
<td>3.00</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Note: sk = skewness; ku = kurtosis
Motivation structure later in the semester. When the AMS-Chemistry was administered at Time 2, the absolute values of skewness and kurtosis for the subscale scores were less than 1, so the data were approximately normally distributed. For the 94 students (Table 3.7), the means of the subscales showed that students were still motivated to be enrolled in this course, as the mean of amotivation was 1.81. Students still scored higher on extrinsic motivation subscales (means between 3.13 and 3.68) than on intrinsic motivation sub-scales (means between 2.56 and 3.08), again consistent with the hypothesis.

For the students who had complete responses at both Time 1 and Time 2 (n = 76), the motivational structure at each time was very similar to that displayed in Table 3.7 (see Table 3.10 for details). The largest difference, for amotivation, was still quite small, approximately one tenth of a standard deviation.

Sex differences

Time 1 data has been separated by sex in Table 3.8, revealing that female students scored higher on introjected regulation and identified regulation but lower on the three intrinsic motivation subscales. The MANOVA results for the sex subgroups showed that the difference in means on the set of seven subscales was statistically significant, \( \Lambda = 0.85, F(7,200) = 5.04, p < 0.001 \), with a medium multivariate effect size \( f^2 = 0.17 \) (Cohen, 1988). Univariate follow-up tests using a Bonferroni approach (Holm, 1979) were conducted; however, there were no statistically significant sex differences for any of the individual sub-scales at 0.007 alpha level. The effect sizes for differences between females and males, as shown by Cohen’s \( d \) values in Table 3.8, were between 0 and 0.38 (small). For the second administration of AMS-Chemistry, the sample size was too small for inferential tests; therefore, the differences by sex were not
examined at Time 2. These results are not conclusive with respect to sex differences for the
students in this study, but do suggest that, with a reasonably large sample, AMS-Chemistry has
the potential to be sufficiently sensitive for making these comparisons.

**Table 3.8** Female and male students’ motivation structure at Time 1 based on AMS-Chemistry

<table>
<thead>
<tr>
<th></th>
<th>F, n = 129</th>
<th>M, n = 79</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Amotivation</td>
<td>1.64</td>
<td>1.64</td>
<td>0</td>
</tr>
<tr>
<td>2. External regulation</td>
<td>3.80</td>
<td>3.82</td>
<td>0.02</td>
</tr>
<tr>
<td>3. Introjected regulation</td>
<td>3.46</td>
<td>3.27</td>
<td>0.18</td>
</tr>
<tr>
<td>4. Identified regulation</td>
<td>3.99</td>
<td>3.85</td>
<td>0.17</td>
</tr>
<tr>
<td>5. To experience</td>
<td>2.33</td>
<td>2.64</td>
<td>0.31</td>
</tr>
<tr>
<td>6. To accomplish</td>
<td>2.92</td>
<td>3.00</td>
<td>0.08</td>
</tr>
<tr>
<td>7. To know</td>
<td>2.87</td>
<td>3.22</td>
<td>0.38</td>
</tr>
</tbody>
</table>

**Motivation and chemistry achievement**

As academic achievement is another important factor for student persistence in STEM, the relationship with academic achievement is examined here. Given the timing of exams with respect to the administration of the AMS-Chemistry, we assume motivation scores at Time 1 should correlate most strongly with Exam 1 scores, and motivation scores at Time 2 should correlate most strongly with Exam 3. Based on results in the literature (Taylor *et al.*, 2014), we hypothesize that, if there is a correlation, it would be strongest for the intrinsic motivation subscales. The correlation results are displayed in Table 3.9.

**Table 3.9** Correlation of AMS-Chemistry subscales with Exam scores

<table>
<thead>
<tr>
<th></th>
<th>Exam 1, n = 208</th>
<th>Exam 3, n = 94</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Amotivation</td>
<td>-0.08</td>
<td>-0.22</td>
</tr>
<tr>
<td>2. External regulation</td>
<td>-0.03</td>
<td>0.07</td>
</tr>
<tr>
<td>3. Introjected regulation</td>
<td>-0.04</td>
<td>0.13</td>
</tr>
<tr>
<td>4. Identified regulation</td>
<td>0.03</td>
<td>0.16</td>
</tr>
<tr>
<td>5. To experience</td>
<td>0.02</td>
<td>0.34</td>
</tr>
<tr>
<td>6. To accomplish</td>
<td>0.08</td>
<td>0.35</td>
</tr>
<tr>
<td>7. To know</td>
<td>0.07</td>
<td>0.33</td>
</tr>
</tbody>
</table>

*a* Correlation is significant at 0.01 level (two-tailed)

*b* Correlation is significant at 0.05 level (two-tailed)
The magnitudes of the correlations as shown in Table 3.9 were small (0.08 or less) and nonsignificant for Exam 1. Exam 3 scores, however, were significantly and positively correlated with three intrinsic motivation subscales, and $r$ ranged from 0.33 to 0.35, a medium effect (Cohen, 1988). A small negative correlation was also seen for Exam 3 and amotivation with $r = -0.22$. The beginning of the semester may be too early to expect a relationship, but closer to the end of the term, the expected relationship can be observed.

In order to examine how the relationship between academic achievement and motivation may change over time, we need to look at data from students with responses to the AMS-Chemistry at Time 1 and Time 2. The results for these students ($n = 76$) are displayed in Table 3.10. The correlations showed similar trends compared with Table 3.9. Exam 1 scores did not show significant correlations with motivation scores at Time 1, but Exam 3 scores significantly and positively correlated with three intrinsic motivation scores. This result supports the supposition that the beginning of the term may be too early to expect a relationship.

Note: The sample size in Table 3.10 fluctuates because exam grades may be missing.
Motivation and attendance

For the last research question (how is motivation earlier in the semester associated with students’ attendance later in the semester?), students’ attendance was examined in relation to motivation scores. The syllabus describes attendance as mandatory, but in practice attendance is monitored by personal response system during each lecture and students are given points toward a maximum that will serve as their attendance grade. The point system is sufficiently generous that by Time 2, most students had earned their full quota of points toward their attendance grade. Given this context, which students were still motivated to attend class? We asked whether the students’ motivation scores at Time 1 could predict their attendance later in the semester, i.e., at Time 2. Table 3.11 shows the motivation status at Time 1 of two groups of students: those who responded to the AMS-Chemistry at Time 2 (“attenders”) and those who did not (“absent”). The results indicate that students who persisted in attending class displayed lower scores on amotivation, external regulation, and introjected regulation, and higher scores on three intrinsic motivation subscales and identified regulation, with small effect sizes.

Table 3.11 The means and standard deviations of the subscales of AMS-Chemistry at Time 1 for students who attended or were absent at Time 2

<table>
<thead>
<tr>
<th>Attendance</th>
<th>Attenders, n = 83</th>
<th>Absent, n = 125</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>1. Amotivation</td>
<td>1.51</td>
<td>0.67</td>
<td>1.72</td>
</tr>
<tr>
<td>2. External regulation</td>
<td>3.62</td>
<td>0.94</td>
<td>3.93</td>
</tr>
<tr>
<td>3. Introjected regulation</td>
<td>3.31</td>
<td>0.97</td>
<td>3.44</td>
</tr>
<tr>
<td>4. Identified regulation</td>
<td>3.97</td>
<td>0.76</td>
<td>3.91</td>
</tr>
<tr>
<td>5. To experience</td>
<td>2.53</td>
<td>0.98</td>
<td>2.39</td>
</tr>
<tr>
<td>6. To accomplish</td>
<td>3.02</td>
<td>1.00</td>
<td>2.90</td>
</tr>
<tr>
<td>7. To know</td>
<td>3.11</td>
<td>0.97</td>
<td>2.93</td>
</tr>
</tbody>
</table>

MANOVA conducted with “attenders” and “absent” groups showed that the difference in means on the set of seven subscales was statistically significant, $A = 0.927$, $F(7,200) = 2.26$, $p = 0.031$, with a small-to-medium multivariate effect size ($f^2 = 0.08$) (Cohen, 1988). Univariate
follow-up tests using a Bonferroni approach (Holm, 1979) did not reveal any significant differences for any of the subscales at an alpha level of 0.007. Thus, while there is sufficient evidence to conclude that the motivational profiles of attenders were different from those of the absent students, there is no conclusive evidence from this data regarding the specific nature of the differences.

As a check, the students’ academic achievement (Exam 1 and Exam 3 grades) by attendance was compared. Results showed that the attenders scored 3–4 points (out of 250 points possible) higher on each exam; however, based on independent t-tests, there was no evidence of a significant difference between the two groups of students by attendance: $t(196) = -0.708, p = 0.48$ for Exam 1; and $t(190) = -0.443, p = 0.66$ for Exam 3.

**Discussion**

The pilot study of the AMS in general chemistry courses provided evidence that the original survey generally functioned in accordance with self-determination theory. The seven-factor model had reasonable fit to the data and the internal consistency for each subscale was good. Overall, students were found to be more extrinsically motivated regarding going to college. Female students scored significantly lower on amotivation than male students, with a medium effect size. Compared to other studies with samples from the United States (Cokley et al., 2001; Smith et al., 2010), the pilot study’s clear finding of lower amotivation for females enrolled in a college chemistry course was not completely consistent with findings associated with college students in psychology and business courses, suggesting that context may be quite important for motivational studies. In studies with secondary students, other researchers have found that females scored significantly lower on amotivation, but with a small effect size
(Grouzet et al., 2006; Caleon et al., 2015). Investigations of whether a motivational gap between males and females becomes larger at the college level may be warranted. These mixed findings in literature, however, underscore that it is important and necessary for researchers interested in motivation of science majors to gather data in science courses, because students’ motivation is likely to depend on the courses they are enrolled in at the time. Since our interest was eventually to be able to determine students’ motivation status toward chemistry courses rather than toward college, our pilot study provided sufficient evidence that it would be promising to move forward and modify the AMS into a chemistry-specific theory-based measure of motivation for college chemistry courses.

With the assistance of an expert panel review process and information from cognitive interviews with students, the AMS was successfully modified into the AMS-Chemistry. Confirmatory factor analysis of data gathered in a college chemistry course provided validity evidence for the internal structure of the instrument, showing that the seven-factor AMS-Chemistry model had reasonable fit to the data. No correlated errors were included in the model, and the fit indices were better than those of the AMS, indicating that the modified items work well and the AMS-Chemistry functioned even better than the AMS in a similar setting. The model fit and the correlations between subscales (Appendix 8 in Appendix A) demonstrate that the AMS-Chemistry still functions in accordance with SDT. Internal consistency reliability as estimated by Cronbach’s alpha remained good for each separate subscale. The quality of the validity evidence was sufficient to warrant interpreting AMS-Chemistry scores with regard to seven types of motivation.

Regarding motivation toward chemistry courses, the current study showed that the students enrolled in a first semester college general chemistry course at a large public research
university in the southeastern United States are mainly extrinsically motivated toward that course. With a finding such as this, instructors can be made aware that assigning students grades for homework and other assignments, reminding them about deadlines, and focusing on points as a reward for attendance could support these extrinsically motivated students to some degree, but may not be helping them to develop intrinsic motivation (Deci et al., 1999). The motivational status observed for these students with this new instrument was different from former studies using the AMS to probe college students enrolled in a variety of courses, where Canadian and Argentinean students generally had higher means on intrinsic motivation subscales regarding going to college (Ratelle et al., 2007; Stover et al., 2012). This different observation for the AMS-Chemistry in a college general chemistry course makes sense given the required nature of that course for all students who intend to major in some area of science, not necessarily in chemistry, and was consistent with studies of motivation toward chemistry in which few students intended to study chemistry (Salta and Tzougraki, 2004; Salta and Koulougliotis, 2015). At the end of semester, students were still extrinsically motivated toward chemistry but with decreased motivation. The decrease of motivation over a semester was consistent with findings in other college courses in literature (Nilsson and Warrén Stomberg, 2008; He et al., 2015). When examining female and male subgroups, the current study showed an overall difference but did not provide any evidence of difference for a specific subscale. Compared with studies in non-U.S. settings where female high school students were similarly or more motivated than males toward chemistry (Akbaş and Kan, 2007) and had greater self-determination regardless of age (Salta and Koulougliotis, 2015), the current study suggested a sex difference in motivation toward chemistry favoring males, but additional investigation is necessary.
The correlation between motivational variables and exam grades differed at two time points within a semester. Specifically, the results showed no evidence of association between students’ motivation scores and their academic achievement on the first exam, but three intrinsic motivation subscales correlated significantly and positively with academic achievement later in the semester. Compared with other studies on motivation toward chemistry, each using a different measure, where only weak associations with chemistry achievement were found at the end of a term (Jurišević et al., 2008; Devetak et al., 2009), the association was present for only one cohort of students (Hibbard et al., 2016), or the association was similarly strong (Akbaş and Kan, 2007), it seems necessary to continue to investigate this issue by using AMS-Chemistry in additional research contexts. The observed increase in association between achievement and motivation in this study over a semester also suggests that it would be valuable to examine student motivation and achievement at multiple time points, not just near the beginning and end of one term. As we would like to see students be motivated toward the chemistry courses they are taking, it will be important to explore what learning environments can increase student intrinsic motivation scores, even in large classroom settings. Based on SDT, when the three psychological basic needs are met, intrinsic motivation can be promoted (Black and Deci, 2000; Vaino et al., 2012; Hagger et al., 2015; Kiemer et al., 2015). Therefore, instructors may want to utilize active-learning methods such as group work and demonstrate their concern for students by providing guidance and positive feedback, to create a sense of relatedness both to other students and to the instructor. Instructors may also want to work toward developing course materials that are appropriately scaffolded yet challenging, so that students can develop a sense of competence with the subject. Finally, to support the development of a sense of autonomy, instructors may
want to explore options such as cafeteria grading or open inquiry experiments to create more opportunities for students to make choices (Reeve, 2012; Orsini et al., 2016).

Reeve (2009) has proposed five instructional behaviors that instructors should use in order to be autonomy supportive. First, instructors can capitalize on students’ natural interests, for example by providing opportunities for student-selected projects or creating immersive student-driven technology-based learning activities. Second, instructors can explain their choices in teaching methods, and describe why the chosen activities are worth doing. Third, instructors can choose permissive language, inviting student viewpoints and discussion, instead of issuing verbal directives. Fourth, instructors can create conditions that enable self-paced learning, for example, by implementing a flipped classroom teaching method (Seery, 2015). Last, instructors can acknowledge and accept students’ emotions, whether positive or negative, for example, by employing verbal mirroring strategies to demonstrate understanding without judgment.

The study also showed that motivation scores could predict the attendance of students, as students whose autonomous motivation was higher at the beginning of semester had better attendance later in the semester, which aligns with findings for college students enrolled in agriculture-related courses (Devadoss and Foltz, 1996). These quantitative results were also consistent with a qualitative study linking non-attendance to lectures with low motivation (Moore et al., 2008). Given the study in Taiwan suggesting a negative overall effect on achievement if less motivated students attend class alongside their more motivated peers (Chen and Lin, 2015), the true remedy, rather than compulsory attendance, may be to promote intrinsic motivation. Therefore, we can try to motivate students by connecting chemistry concepts with real life and their future careers to move them toward the more self-determined end of the
motivation continuum, and in that way increase attendance while maintaining achievement in introductory college chemistry courses.

**Limitations**

This study has several limitations. For example, the samples were convenient and were drawn from particular courses at particular institutions; therefore, the results may only represent the students in these unique contexts but not be applicable to other situations. Accordingly, we recommend that instructors use this instrument to gather data from their own classes for interpretation, and we also hope that other researchers will continue to investigate the psychometric properties of scores obtained with different samples. As is usual for motivation studies, self-reported scores from students were used for the analysis. Participants’ self-reported scores may or may not be evaluating their real motivation type and level, for example because of social desirability or through lack of self-awareness. As the instrument continues to be used, continuing to gather evidence regarding the relationship between instrument scores and other variables thought to be related to motivation will be helpful. From the discussion of data cleaning and missing data, it should be clear that not all students responded to the instruments, so response bias might exist because it is possible that the students responding to the survey were more motivated. Finally, the sample size was not large enough for evaluation of the invariance of the measurement model for male and female subgroups, so those comparative findings should be taken with caution. A measurement invariance study (Xu et al., 2016) based on large-scale data collection would be a useful next step for this instrument, either to identify needed modifications or to build the body of psychometric evidence.
Conclusion

First, the validity evidence gathered in this study (content, response process, internal structure, and relationships with other variables) suggests that the AMS-Chemistry can be used in other college chemistry courses to examine student motivation toward chemistry. While from a developmental validity perspective there is much work to be done gathering additional evidence with multiple samples, with this initial study AMS-Chemistry has been well-positioned to serve as a theory-based instrument to measure motivation along the SDT continuum in order to identify nuances in student motivation. Second, multiple administrations of the AMS-Chemistry within a course and across the curriculum, for a longitudinal or cross-sectional study, are likely to be a fruitful way to examine changes in motivation as students progress through a degree program. Because SDT has multiple mini-theories that augment the description of the motivation continuum, it is a good source for the development of testable interventions that intend to fulfill students’ basic needs for autonomy, competence, and relatedness in order to provide a productive environment for the development of greater intrinsic motivation. The AMS-Chemistry can be used before and after student-centered educational reforms are implemented to explore students’ motivational perceptions for the effect of educational reform. Seeing evidence that student scores increase on the subscales at the more self-determined end of the continuum over time would be affirmation that a targeted reform is having the intended effect. Last, being able to track the situational level motivation scores in this way may help to address other important issues such as scientific literacy and persistence in science education, most particularly to shed light on the pressing problem of attrition of students from college chemistry courses.

Furthermore, scores from AMS-Chemistry may be interpreted in other ways in the future, with support from alternative measurement models. One approach in the literature categorizes
identified regulation and intrinsic motivation as autonomous motivation (Vansteenkiste et al.,
2004), and external regulation and introjected regulation as controlled motivation
(Vansteenkiste et al., 2012), and may also measure amotivation as a separate construct (Ratelle
et al., 2007). The comparison between a z-score for autonomous motivation and a z-score for
controlled motivation has been called the Relative Autonomy Index (RAI) (Black and Deci,
2000). Another approach sums weighted subscale scores, with intrinsic motivation scales
weighted positively and external motivation scales weighted negatively, either to create Self-
Determination Indices (SDI) that represent the overall level of an individual’s self-determination
(Levesque et al., 2004), or to create a different type of RAI (Goudas et al., 1994; Soenens et al.,
2012). An exploration of measurement models that would support these interpretations would be
interesting and potentially valuable future work with AMS-Chemistry data.

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CHAPTER FOUR

The effect of flipped classroom - peer led team learning environment on student motivation in organic chemistry

Introduction

Students struggle with organic chemistry (Lynch and Trujillo, 2011). Students are often intimidated and anxious when entering organic chemistry courses. There is a widely recognized problem with attrition and student learning in the course (Tien, et al., 2002). Many of the students who are enrolled are premedical or biological majors, and they take the course to satisfy a major requirement. In exploration of motivation in organic chemistry courses, motivation has shown associations with student academic achievement (Black and Deci, 2000; Lynch and Trujillo, 2011), sex differences in the associations (Lynch and Trujillo, 2011), and increased students’ perceptions of intrinsic motivation over the semester in organic chemistry courses implementing peer-led team learning (PLTL) (Black and Deci, 2000).

In the past few decades, active learning pedagogies have been extensively developed and implemented in college settings, leading to a number of positive outcomes compared with traditional classroom experiences, as has been documented in several reviews and meta-analyses (Prince, 2004; Freeman, et al., 2014; Warfa, 2016; Wilson and Varma-Nelson, 2016; Apugliese and Lewis, 2017). Observed outcomes included increased academic achievement (Prince, 2004; Freeman, et al., 2014; Warfa, 2016; Wilson and Varma-Nelson, 2016; Apugliese and Lewis,
2017), student retention (Wilson and Varma-Nelson, 2016), attitudes toward science, technology, engineering, and mathematics (STEM) disciplines (Brandriet, et al., 2011; Chonkaew, et al., 2016; Vishnumolakala, et al., 2017), and benefits for students who actively responded to questions in class on a regular basis and those who did not (Obenland, et al., 2013). Self-determination theory hypothesizes that in more autonomous learning environments, such as often found to be associated with active learning environments, students feel they have obtained the desired effects and outcomes and developed more internalized, or intrinsic, motivation (Deci and Ryan, 2000; Reis, et al., 2000; Ryan and Deci, 2000). Without internalization of motivation, people won’t persevere through difficulty (Ryan and Deci, 2000; Prince, 2004). Research has explored the impact active learning pedagogies have on achievement (Prince, 2004; Freeman, et al., 2014; Warfa, 2016; Wilson and Varma-Nelson, 2016; Apugliese and Lewis, 2017) and motivation (Black and Deci, 2000; Prince, 2004; Obenland, et al., 2013; Abeysekera and Dawson, 2015; Cicuto and Torres, 2016). For example, biochemistry students in the active learning environment were found generally motivated and their motivation scores were higher than or equal to those in other courses, which suggested that the active learning environment had a positive impact on students’ motivation (Cicuto and Torres, 2016).

In this study, flipped classroom and peer-led team-learning (Flip-PLTL) were integrated and implemented in an organic chemistry by author JRR as a means to increase student motivation. Author JRR accomplished this goal through small group work during the lecture period. Students in the Flip-PLTL course interacted with peer-leaders and author JRR during small work time. Peer leaders were trained to serve as facilitators of learning rather than expert sources of information. To examine the effect of the Flip-PLTL pedagogy, motivation toward
chemistry was measured at the beginning and end of a lecture-based and Flip-PLTL course, both taught by author JRR, using the AMS-Chemistry instrument (Liu, et al., 2017).

**Motivation**

Motivation refers to the desire to act. Motivation has been found to be one of the important factors to improve students’ persistence in STEM and to promote better academic achievement (Guay, et al., 2010; PCAST, 2012; Griffin, et al., 2013; Kusurkar, et al., 2013; Taylor, et al., 2014; Sturges, et al., 2016). Motivation is a complex multidimensional construct ranging from amotivation (no motivation), to extrinsic motivation, and finally intrinsic motivation, along a self-determination continuum based on self-determination theory (SDT) (Deci and Ryan, 2000; Ryan and Deci, 2000). When students are amotivated, they lack the desire to perform any activity. For these students, it is necessary to provide incentives to extrinsically motivate them for learning to occur (Deci and Ryan, 2000). Extrinsic motivation means that people do an activity because of its consequences, such as rewards or punishments. SDT includes four types of extrinsic motivation: external regulation, introjected regulation, identified regulation, and integrated regulation, ranging from least self-determined to more self-determined form of motivation (Deci and Ryan, 2000; Ryan and Deci, 2000). External regulation is to act in order to get rewards or to avoid punishment. Introjected regulation is to act to feel worthy or to avoid feeling guilty. Identified regulation is to act because one has identified the importance and value of the activity. Integrated regulation means the importance has been fully internalized and becomes an identity of the people. Extrinsic motivation differs from intrinsic motivation: When students enjoy an activity and find the activity inherently satisfying, this is defined as intrinsic motivation (Ryan and Deci, 2000). People are differently motivated between tasks due to the
level of satisfaction experienced when engaging in the activity and the reasons for doing the activity.

Motivation is closely associated with social environments. Social contexts either support or thwart the natural tendencies toward engagement (Vansteenkiste, *et al.*, 2006). When students take a consumerist approach to higher education, there is a shift from intrinsic to extrinsic motivation (Labaree, 1999). In an active learning environment, where students are provided with meaningful rationales for doing the learning activities, given opportunities to interact with one other, and the instructors are encouraging and respecting of students, intrinsic motivation is promoted (Black and Deci, 2000; Lepper and Henderlong, 2000; Chirkov and Ryan, 2001; Vansteenkiste, *et al.*, 2006; Su and Reeve, 2011; Reeve, 2012; Vaino, *et al.*, 2012; Jang, *et al.*, 2016; Jang, *et al.*, 2016). For example, Black and Deci found that organic chemistry students, who attended full-class lectures and randomly assigned PLTL groups in a small, eastern university in the U.S., had a positive but nonsignificant change on the enjoyment and interest (Black and Deci, 2000), which is regarded as a measure of *intrinsic motivation* in the Intrinsic Motivation Inventory (McAuley, *et al.*, 1989), by the end of a semester. In another study, Viano et al found that basic and high school students in Estonia had higher levels of intrinsic motivation when context-based modules are implemented in chemistry courses (Vaino, *et al.*, 2012).

Motivation may decrease over time (Zusho, *et al.*, 2003; Nilsson and Warrén Stomberg, 2008; Brouse, *et al.*, 2010; He, *et al.*, 2015). A decline in students’ motivational levels (i.e., self-efficacy, task value) was found for college students enrolled in introductory chemistry courses in a large Midwestern university in the U.S. over the course of a semester (Zusho, *et al.*, 2003). Freshmen students from Canada had higher levels of intrinsic and extrinsic motivation compared with seniors in college courses (Brouse, *et al.*, 2010). Motivation decreased during a single term
course for nursing students in Sweden (Nilsson and Warrén Stomberg, 2008). Students in an
electrical engineering course also had a decline in motivation that was associated with a decrease
in exam scores (He, et al., 2015). Researchers have found that changes in students’ perceptions
of other affective variables, such as attitude and self-concept, change across a course (Chan and
Bauer, 2015). The findings from previous literature suggest that motivation may decrease over
time.

Sex differences in motivation levels have been reported. Female college students usually
reported higher motivation levels than males (Vallerand, et al., 1992; Cokley, et al., 2001;
Spittle, et al., 2009; Brouse, et al., 2010; Smith, et al., 2010; Eymur and Geban, 2011). Females
are under-represented in STEM fields (Ong, et al., 2011; Villafane, et al., 2014). It is even more
important to investigate females’ motivation levels toward science as sex has been found as an
important factor on academic achievement in science (Osborne, et al., 2003). In a U.S. general
chemistry course, females were found to be less motivated toward chemistry than male students
(Liu, et al., 2017). To date, sex differences in motivation in organic chemistry courses has not
been explored; therefore, we were curious about how motivation may differ at the end of the
semester by sex taking into considerations of students’ initial motivation levels.

Mixed results were reported in the literature regarding associations between motivation
and academic achievement in chemistry courses; one of the possibilities for such variable
findings is the use of multiple definitions of motivation and achievement measures across the
studies. Cerasoli et al. reviewed 40 years of publications finding an average correlation
coefficient of 0.24-0.31 between intrinsic motivation and academic achievement for college-aged
samples (Cerasoli, et al., 2014). Juriševič et al. found that Slovenian and Polish vocational and
technical high school students with higher motivational scores on intrinsic motivation, regulated
motivation, and controlled motivation scored higher on their tests of knowledge of visible spectrometry (Jurisevic, et al., 2012). In an introductory organic chemistry course, students’ motivation scores as measured by interest/enjoyment, were positively correlated with students’ academic achievement expressed by average grades of four in-term exams and final course grade (Black and Deci, 2000). In contrast, two studies in Slovenia found weak evidence that intrinsic motivation was positively associated with chemistry achievement for elementary students (Devetak, et al., 2009) and for first-year pre-service primary school teachers (Jurisevic, et al., 2008). Associations between extrinsic motivation and academic achievement are also mixed (Lynch and Trujillo, 2011; Liu, et al., 2017). For example, organic chemistry students’ extrinsic goal, a type of motivation, was negatively correlated with academic achievement for females but the correlation was not significant for males (Lynch and Trujillo, 2011). In general chemistry, extrinsic motivation toward chemistry was not significantly correlated with exam scores at the beginning of the semester but positively correlated with exam scores at the end of the semester (Liu, et al., 2017).

**PLTL and flipped classroom**

Peer-led team learning (PLTL) is an educational reform to actively engage students in learning through small-group work led by students who successfully completed the target course (Gosser and Roth, 1998; Wilson and Varma-Nelson, 2016). Peer leaders are trained to guide and engage students to facilitate collaboration, seek group consensus, ask students to explain their work, and point to resources (Tien, et al., 2002; Hockings, et al., 2008; Drane, et al., 2014; Robert, et al., 2016). The impact of PLTL includes improved pass rates (Mitchell, et al., 2012), increased student achievement (Lewis and Lewis, 2005; Hockings, et al., 2008; Lewis and
Lewis, 2008; Popejoy and Asala, 2013; Drane, et al., 2014; Carlson, et al., 2016; Robert, et al., 2016), and increased retention in STEM degree programs (Lewis, 2011; Mitchell, et al., 2012; Popejoy and Asala, 2013; Drane, et al., 2014; Lewis, 2014). PLTL has been extensively implemented and evaluated in first-semester general chemistry (Lewis and Lewis, 2005; Hockings, et al., 2008; Lewis and Lewis, 2008; Lewis, 2011; Popejoy and Asala, 2013; Drane, et al., 2014; Lewis, 2014; Chan and Bauer, 2015; Carlson, et al., 2016). The implementation has been extended to other more advanced college chemistry courses (Tien, et al., 2002; Lyle and Robinson, 2003; Wamser, 2006; Arrey, 2012; Mitchell, et al., 2012; Lewis, 2014; Robert, et al., 2016). There are fewer implementations of PLTL in organic chemistry courses (Tien, et al., 2002; Lyle and Robinson, 2003; Wamser, 2006; Arrey, 2012; Robert, et al., 2016). PLTL has showed positive outcomes in organic chemistry courses (Tien, et al., 2002; Lyle and Robinson, 2003; Wamser, 2006; Arrey, 2012; Robert, et al., 2016). For example, students experiencing PLTL workshops had increased performance and retention compared with students experiencing traditional recitation sessions in first semester organic chemistry courses (Tien, et al., 2002). Wamser reported higher success rates and persistence for students who participated in the PLTL organic chemistry workshops (Wamser, 2006). Moreover, in an intensive course implementing PLTL, students performed better than students in courses with traditional semester format (Arrey, 2012). Studies on PLTL mainly focus on cognitive learning (Lewis and Lewis, 2005; Hockings, et al., 2008; Lewis and Lewis, 2008; Popejoy and Asala, 2013; Drane, et al., 2014; Carlson, et al., 2016; Robert, et al., 2016), fewer studies have focused on affect (Gafney and Varma-Nelson, 2008). Chan and Bauer studied students’ attitude, self-concept, and motivation in general chemistry taught with PLTL; they found that students had negative changes on their
attitude and self-concept with small to medium effect sizes; they did not observe any significant differences in traditional and PLTL environments (Chan and Bauer, 2015).

The flipped classroom is an instructional strategy developed to engage students in the course material before and during class in ways different from a traditional classroom (Seery, 2015). In flipped classrooms, students are required to study resources, e.g., recorded lectures, videos, tutorials, textbooks, worksheets, etc. before coming to class. Content is moved outside of class to allow for more time to do other activities during class such as problem-solving sessions, small-group work, or classroom discussions (Morrison, 1976; Smith, 2013; Fautch, 2015; Flynn, 2015; Seery, 2015; Eichler and Peeples, 2016; Canelas, et al., 2017). Most research has focused on how well flipped classroom pedagogies improve cognitive learning. In general, researchers have reported increased or comparable outcomes compared with traditional teaching methods (Love, et al., 2013; Jensen, et al., 2015; Weaver and Sturtevant, 2015; Hibbard, et al., 2016; Robert, et al., 2016; Ryan and Reid, 2016; Shattuck, 2016). The attitude towards study materials (in particular videos or tutorials) has been considered (Fautch, 2015; Flynn, 2015; Jensen, et al., 2015; Eichler and Peeples, 2016; Reid, 2016). Students responded that out-of-class videos used in the studies were effective and helpful (Seery, 2015; Hibbard, et al., 2016; Reid, 2016; Shattuck, 2016). Recently researchers found that students in an organic chemistry that utilized flipped classroom and PLTL pedagogies had positive changes on attitudes towards chemistry (Mooring, et al., 2016). However, motivational perceptions are rarely studied in both PLTL and flipped classroom environments. A recent study found that general chemistry students, taught by flipped classroom pedagogy in a historically Black college and university for women in the southeast U.S., had positive motivation perceptions toward chemistry as displayed by high scores on intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation
subscales (Hibbard, et al., 2016). However, in this study very few students (n = 27) took the motivation instrument.

In PLTL and flipped classroom environment, students could develop more intrinsic motivation. In PLTL environment, students have more chance to interact with their group members and peer leaders, and the activities are well designed, and peers and instructors are autonomy supportive. Therefore, according to the SDT, students can have their basic needs of autonomy, competence, and relatedness met, which will promote intrinsic motivation (Deci and Ryan, 2000; Ryan and Deci, 2000). Abeysekera and Dawson have made a similar argument that flipped approaches might improve student motivation (Abeysekera and Dawson, 2015). The study materials that students are required to study are carefully selected, or created, and scaffolded, which helps student learn and therefore is good for students’ competence. The students can choose when to and how often to study the materials, which can meet student autonomy need. Again when students’ basic needs are met, we can promote student intrinsic motivation. When we integrate flipped classroom and PLTL in the same course, the instructor has more class time for learning activities in small groups because part of the content is moved outside of the lecture; students have more options and study resources in and outside of classroom, We, therefore, expect that our study of duel implementation of flipped classroom and PLTL pedagogies (Flip-PLTL) will have a positive effect on motivation.

**Research questions**

In this study, motivation will be studied in a lecture-based course and a Flip-PLTL course using the AMS-Chemistry instrument (Liu, et al., 2017). The following research questions will be addressed:
1. How does AMS-Chemistry function in two differently taught organic chemistry courses?

2. What is the student motivation status at the beginning and end of a semester in organic chemistry courses?

3. How do changes on motivation differ by pedagogical approaches and by sex?

4. How is motivation associated with student academic achievement in the organic chemistry courses?

Method

Research context

This study was conducted in two first-semester courses of a yearlong organic chemistry course, which were taught a year apart by author JRR at a large research-intensive university in the southeast United States. The course consisted of two 75-minute lecture periods and a 50-minute recitation period weekly for 15 weeks. Lectures were held in a large classroom (~300 seats); recitations were held in small classrooms (~35 students). While the two courses covered the same material, the two courses were taught with different pedagogical approaches (i.e. lecture-based pedagogy and Flip-PLTL pedagogy).

The first course was taught with a lecture-based pedagogy. Author JRR utilized a classroom response system (i.e., clicker) to promote discussion in pairs, small groups, and amongst the classroom. Author JRR was interactive and dynamic, posing questions and eliciting answers from the students throughout the weekly lecture periods. Attendance in lecture was tied to the classroom response system, of which points were awarded for both attendance and answer correctness. Recitation sessions were structured by teaching assistants; students had the
opportunity to ask questions about difficult content, see additional worked examples, and request assistance with homework and suggested problems from the textbook. There were four during-the-term examinations and a final cumulative examination.

The second course was taught with a hybrid of lecture, flipped, and peer-led team learning (PLTL) pedagogies (Flip-PLTL). Author JRR continued to utilize a classroom response system, as with the first course, to promote discussion and learning in one of two lecture periods each week. In addition, students were assigned American Medical Association Commissioned Khan Academy videos (via YouTube) to watch before the second lecture period each week. For the second lecture period, students completed a worksheet with the assistance of peer leaders (i.e., students who had successfully completed the course with an A or better); there was approximately one peer leader for every 12 to 16 students in the course. Author JRR provided little lecture during the second lecture period other than to explain clicker questions. Again, attendance during these two lecture periods was tied to the classroom response system; points again were awarded for attendance and correctness. Recitation sessions continued to be teaching assistant led. There were four during-the-term examinations. The ACS Organic Chemistry First-Term Examination (2014) was used as the final examination for the second course.

**Instrument**

Academic Motivation Scale - Chemistry (AMS-Chemistry) (Liu, et al., 2017), a theory-based instrument, was developed by modifying the items in Academic Motivation Scale (Vallerand, et al., 1992). AMS-Chemistry measures student motivation toward chemistry in chemistry courses, a type of situational level of motivation (Vallerand, 1997; Vallerand and Ratelle, 2002). Students respond to 28 possible reasons for being enrolled in the target chemistry
course; reasons are aligned on the self-determination continuum of SDT. A five-point Likert scale ranging from “1” (not at all) to “5” (exactly) is used to show the degree of agreement with each reason. Seven motivation subscales are measured by AMS-Chemistry (see Figure 4.1): amotivation, three types of extrinsic motivation (external regulation, introjected regulation, and identified regulation), and three types of intrinsic motivation (to know, to accomplish, and to experience). Sample items for each scale are displayed in Table 4.1.

![The seven types of motivation measured by AMS-Chemistry](image)

**Figure 4.1** The seven types of motivation measured by AMS-Chemistry

**Table 4.1** Sample items of AMS-Chemistry

<table>
<thead>
<tr>
<th>Subscales</th>
<th>Sample item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amotivation</td>
<td>I don’t know; I can’t understand what I am doing taking chemistry courses.</td>
</tr>
<tr>
<td>External regulation</td>
<td>Because without having taking chemistry I would not find a high-paying job later on.</td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>To prove to myself that I am capable of succeeding in chemistry</td>
</tr>
<tr>
<td>Identified regulation</td>
<td>Because taking chemistry will enable me to enter a job market in a field that I like.</td>
</tr>
<tr>
<td>To experience</td>
<td>For the enjoyment I experience when I think about the world in terms of atoms and molecules</td>
</tr>
<tr>
<td>To accomplish</td>
<td>For the satisfaction I feel when I work toward an understanding of chemistry.</td>
</tr>
<tr>
<td>To know</td>
<td>Because study chemistry allows me to continue to learn about many things that interest me.</td>
</tr>
</tbody>
</table>

Validity (including content, response process, internal structure, and relationships to other variables) and internal consistency reliability psychometric evidence (Arjoon, et al., 2013)
has been collected for AMS-Chemistry in the context of a general chemistry course. Results suggested that the AMS-Chemistry scores are valid and reliable and could be interpreted in terms of the seven motivational subscales, females are significantly less motivated than males, and motivation and its association with exam scores varied across a course (Liu, et al., 2017). This previous work suggests that the AMS-Chemistry is appropriate to measure motivation and identify potential motivational movement along the self-determination continuum across a course; therefore, it used in this study in the organic chemistry context and with different pedagogical approaches.

Exam 1 was used as the first achievement measure. Exam 4 was used as the second achievement measure. Final course grade was used as the last achievement measure. The two exams were out of 100 points. Final Exam (cumulative and out of 150 points) and Final Score (the final course grade in percentages) were also used to examine if the motivation is associated with the students’ overall academic achievement.

**Data collection and participants**

The AMS-Chemistry was administered as paper-and-pencil test in the target organic chemistry courses. The students were given 10 minutes during lecture to complete the survey. Students who completed the survey received a small amount of exam credit towards their final exam grade.

Data were collected at two time points during lecture time in Fall 2014 and Fall 2015 semesters. There were 257 students enrolled in the first course taught by lecture-based instructional pedagogy in 2014, coded as the “Lecture-Based” course. The pre-semester data collection (Pre1) was during the second week of class before Exam 1 in 2014. After checking for
missing data and careless responses (e.g. the same response for all the 28 items), 235 students’ responses (93% of the all the responses) were used for data analysis. The post-semester data collection in 2014 (Post1) was during the last (15th) week of class following Exam 4, and all the 224 students who responded to the survey had complete responses (response rate = 87%), which were used for data analysis. Both Pre1 and Post1 datasets were used to answer the first research question. In addition, a matched-pair sample (n = 204), who had compete responses for the two administration of AMS-Chemistry, was used to examine the status of student motivation, effects of pedagogical approach and sex, and association with academic achievement (Research Questions 2-4). For the 204 students, 61.3% are females; 51.5% are White, 17.2% are Hispanic or Latino, 7.8% are Black or African American, and 15.2% are Asian; 10.3% are sophomores, 43.1% are juniors, and 44.6% are seniors; 55.4% of the students are biomedical science or health related majors, 26.0% are biology or biology related majors, and only 4% are chemistry or chemistry engineering majors; the average SAT math and verbal scores for this class are 592.9 and 573.4. The demographic information and SAT backgrounds for students who are enrolled in the course (n = 257) are displayed in Appendices 1 and 2. The overall pass rate (C or above) in this course was 73.5%.

In 2015, there were 240 students enrolled in the class, coded as “Flip-PLTL”. The pre-semester data (Pre2) was during the fourth week of class after Exam 1. The post data (Post2) was during the 14th week after Exam 4. Nine students had incomplete responses and one student had no identifier, which resulted in 217 students’ responses for Pre2 with a response rate of 90%. In the Post2 dataset, all 190 students who responded to the survey had complete responses for data analysis, which resulted a response rate of 79%. Pre2 and Post2 datasets were used to answer Research Question 1. A matched-pair sample (n = 166), with compete responses for the two
administration of AMS-Chemistry in the Flip-PLTL class, was used to answer Research Questions 2-4. For the 166 students, 63.9% are females; 44% are Whites, 22.3% are Hispanic or Latino, 6.6% are Black or African American, and 20.5% are Asian; 9.6% are sophomore, 37.3% are juniors, and 53% are seniors; 60.8% of the students are biomedical science or health related majors, 22.2% are biology-related majors, and only 3% are chemistry or chemistry engineering majors; the average SAT math and verbal scores are 601.9 and 585.1. The demographic information and SAT backgrounds for students who are enrolled in the course are displayed in Appendices 1 and 2. The overall pass rate (C or above) in this course was 95.4%.

Data analysis

Collected data for this study were evaluated using different statistical analyses. First, the scores of the AMS-Chemistry from Pre1, Post1, Pre2, and Post2 were analyzed to evaluate the internal structure validity of the instrument through confirmatory factor analysis (CFA) in Mplus 5.2. A Comparative Fit Index (CFI) greater than 0.90 is considered as an acceptable fit (Cheng and Chan, 2003). A Root Mean Square Error of Approximation (RMSEA) smaller than 0.08 is considered as a reasonable fit (Browne and Cudeck, 1992; MacCallum, et al., 1996). A standardized root mean squared residual (SRMR) smaller than 0.10 is considered as an acceptable fit to the data (Hu and Bentler, 1995). In summary, we used the following cut-off values as an evaluation of a reasonable model fit beyond the chi-square test statistic: RMSEA < 0.08, SRMR < 0.10, CFI > 0.90.

The internal consistency of the seven subscales was assessed using Cronbach’s alpha coefficient through SPSS 22.0; a benchmark of 0.7 is suggested for research purposes (Murphy and Davidshofer, 2005). SPSS 22.0 was also used for descriptive statistics of the items and
subscales, correlation studies, and multivariate analysis of variance. To compare if the correlation coefficients are significantly different in the two courses, two-tailed Z-tests for independent correlations coefficients were conducted (Glass and Hopkins, 1970) while using Bonferroni procedures to control for the family-wise type-1 errors (Holm, 1979). A factorial multivariate analysis of covariance (MANCOVA) (Stevens, 2002) at an alpha level of 0.05 and post hoc comparison (Bonferroni approach) (Holm, 1979) at an alpha level of 0.007 (0.05/7) were conducted to examine the effect of sex and pedagogical approach on the seven types of motivation at the end of the semester, with pre-test motivation scores as covariates to eliminate the effect of any existing pre-test differences on the results.

Results and discussion

Internal structure validity and internal consistency reliability

To answer the first research question, how does AMS-Chemistry function in two differently taught organic chemistry courses, the internal structure validity and internal consistency reliability of AMS-Chemistry were examined to evaluate how the instrument functioned for students in the two courses. Most AMS-Chemistry items were normally distributed with skewness and kurtosis between -2 and +2; therefore, a maximum-likelihood method of estimate is employed for the confirmatory factor analysis (CFA). The sample size at each time point was within the range of 190-235 (i.e., a minimum of 5 responses per AMS-Chemistry item) and therefore appropriate for CFA (Brown, 2006). A seven-factor model was examined (Figure 4.1). Fit indices for each administration are listed in Table 4.2; CFI values are between 0.91 and 0.93, RMSEA values between 0.068 and 0.077, and SRMR values between 0.060 and 0.064. Similar to the findings in a general chemistry course (Liu, et al., 2017), the
seven-factor model, rooted in SDT, showed reasonable fit to the data for each of the four data collections.

**Table 4.2** Confirmatory factor analysis fit indices of the seven-factor model in two organic chemistry courses

<table>
<thead>
<tr>
<th>Dataset</th>
<th>$n$</th>
<th>$\chi^2$</th>
<th>Df</th>
<th>p-value</th>
<th>CFI</th>
<th>RMSEA</th>
<th>SRMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre1</td>
<td>235</td>
<td>709.79</td>
<td>329</td>
<td>&lt; 0.001</td>
<td>0.91</td>
<td>0.070</td>
<td>0.061</td>
</tr>
<tr>
<td>Post1</td>
<td>224</td>
<td>672.27</td>
<td>329</td>
<td>&lt; 0.001</td>
<td>0.93</td>
<td>0.068</td>
<td>0.062</td>
</tr>
<tr>
<td>Pre2</td>
<td>217</td>
<td>657.15</td>
<td>329</td>
<td>&lt; 0.001</td>
<td>0.93</td>
<td>0.068</td>
<td>0.064</td>
</tr>
<tr>
<td>Post2</td>
<td>190</td>
<td>695.74</td>
<td>329</td>
<td>&lt; 0.001</td>
<td>0.92</td>
<td>0.077</td>
<td>0.060</td>
</tr>
</tbody>
</table>

Evidence of the internal consistency of the AMS-Chemistry was examined by using Cronbach’s alpha coefficients. The Cronbach’s alpha coefficients (see Table 4.3) are between 0.72 (*identified regulation*) and 0.90 (*to accomplish*) for the Pre1 dataset and between 0.78 (*identified regulation*) and 0.92 (*to accomplish*) for the Post1 dataset. The coefficients range from 0.78 (*identified regulation*) to 0.93 (*to accomplish*) for the Pre2 dataset. The alpha coefficients are from 0.84 (*identified regulation*) to 0.93 (*to accomplish*) for Post2 dataset. The results were similar to those in the general chemistry course (Liu, *et al.*, 2017), and showed acceptable internal consistency (Murphy and Davidshofer, 2005).

**Table 4.3** Cronbach’s alpha coefficients for the four datasets in two organic chemistry courses

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Pre1</th>
<th>Post1</th>
<th>Pre2</th>
<th>Post2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n = 235$</td>
<td>$n = 224$</td>
<td>$n = 217$</td>
<td>$n = 190$</td>
</tr>
<tr>
<td>Amotivation</td>
<td>0.77</td>
<td>0.87</td>
<td>0.85</td>
<td>0.86</td>
</tr>
<tr>
<td>External regulation</td>
<td>0.87</td>
<td>0.86</td>
<td>0.89</td>
<td>0.89</td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>0.88</td>
<td>0.88</td>
<td>0.89</td>
<td>0.91</td>
</tr>
<tr>
<td>Identified regulation</td>
<td>0.72</td>
<td>0.78</td>
<td>0.78</td>
<td>0.84</td>
</tr>
<tr>
<td>To experience</td>
<td>0.87</td>
<td>0.86</td>
<td>0.84</td>
<td>0.89</td>
</tr>
<tr>
<td>To accomplish</td>
<td>0.90</td>
<td>0.92</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td>To know</td>
<td>0.85</td>
<td>0.88</td>
<td>0.87</td>
<td>0.90</td>
</tr>
</tbody>
</table>
The CFA results together with Cronbach’s alpha coefficients suggested that motivation can legitimately be explored by calculating the means for each subscale of the AMS-Chemistry instrument.

**Motivation status**

To answer the second research question, what is the student motivation status at the beginning and end of a semester in organic chemistry courses, means and standard deviations of students’ motivation subscale scores were presented. Response scales ranged from 1 “not at all” to 5 “exactly”. A higher score for extrinsic motivation subscales means that students are more extrinsically motivated to take this organic chemistry course. The same goes for the intrinsic motivation subscales. A higher score for *amotivation* would mean that students lack any motivation. Descriptive statistics for students with complete responses at the beginning and end of two organic chemistry classes are displayed in Appendix B3. Subscales are approximately normally distributed, according to skewness and kurtosis values, except for *amotivation* subscale in the Pre2 dataset. While the descriptive statistics in Appendix B3 are like those who have responded to AMS-Chemistry twice over a semester (Table 4.4), our focus herein is only on the matched dataset in both courses.

In both courses, students scored higher on extrinsic motivation subscales. For example, at the beginning of the semester in the Lecture-Based course, the means on extrinsic motivation subscales ranged from 3.48 (*introjected regulation*) to 4.09 (*identified regulation*), while the intrinsic motivation subscales ranged from 2.67 (*to experience*) to 3.34 (*to know*). In both courses, students scored higher on *amotivation* and lower on extrinsic and intrinsic motivation subscales at the end of the semester. For example, in the Lecture-Based course, students scored
Table 4.4 Mean and standard deviations of motivation scores and the changes over a semester in two organic chemistry courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Subscale</th>
<th>Pre M (SD)</th>
<th>Post M (SD)</th>
<th>M difference (Effect Size)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture-Based</td>
<td>Amotivation</td>
<td>1.41 (0.63)</td>
<td>1.85 (1.00)</td>
<td>0.44 (0.53)</td>
</tr>
<tr>
<td></td>
<td>External regulation</td>
<td>3.77 (0.97)</td>
<td>3.74 (0.97)</td>
<td>-0.03 (0.03)</td>
</tr>
<tr>
<td></td>
<td>Introjected regulation</td>
<td>3.48 (0.99)</td>
<td>3.14 (1.08)</td>
<td>-0.34 (0.33)</td>
</tr>
<tr>
<td></td>
<td>Identified regulation</td>
<td>4.09 (0.73)</td>
<td>3.79 (0.89)</td>
<td>-0.29 (0.36)</td>
</tr>
<tr>
<td></td>
<td>To experience</td>
<td>2.67 (1.10)</td>
<td>2.52 (1.10)</td>
<td>-0.15 (0.14)</td>
</tr>
<tr>
<td></td>
<td>To accomplish</td>
<td>3.19 (1.06)</td>
<td>2.97 (1.13)</td>
<td>-0.21 (0.20)</td>
</tr>
<tr>
<td></td>
<td>To know</td>
<td>3.34 (0.99)</td>
<td>3.11 (1.03)</td>
<td>-0.23 (0.23)</td>
</tr>
<tr>
<td>Flip-PLTL</td>
<td>Amotivation</td>
<td>1.36 (0.66)</td>
<td>1.56 (0.80)</td>
<td>0.20 (0.27)</td>
</tr>
<tr>
<td></td>
<td>External regulation</td>
<td>3.62 (1.05)</td>
<td>3.46 (1.03)</td>
<td>-0.15 (0.14)</td>
</tr>
<tr>
<td></td>
<td>Introjected regulation</td>
<td>3.44 (1.01)</td>
<td>3.25 (1.04)</td>
<td>-0.19 (0.19)</td>
</tr>
<tr>
<td></td>
<td>Identified regulation</td>
<td>3.86 (0.87)</td>
<td>3.64 (0.93)</td>
<td>-0.22 (0.24)</td>
</tr>
<tr>
<td></td>
<td>To experience</td>
<td>2.59 (0.91)</td>
<td>2.61 (1.01)</td>
<td>0.02 (0.02)</td>
</tr>
<tr>
<td></td>
<td>To accomplish</td>
<td>3.13 (1.05)</td>
<td>2.96 (1.04)</td>
<td>-0.17 (0.16)</td>
</tr>
<tr>
<td></td>
<td>To know</td>
<td>3.26 (0.94)</td>
<td>3.07 (0.99)</td>
<td>-0.19 (0.20)</td>
</tr>
</tbody>
</table>

1.41 on amotivation at the beginning of the semester, while at the end of the semester in the same course, the mean on amotivation increased to 1.85 and the extrinsic motivation subscales ranged from 3.14 (introjected regulation) to 3.79 (identified regulation), and the intrinsic motivation subscales were from 2.52 (to experience) to 3.11 (to know).

Higher scores on extrinsic motivation subscales suggest that students are more extrinsically motivated in both the Lecture-Based and Flip-PLTL courses. In particular, students are motivated because they have identified the value of organic chemistry to their future careers as students scored the highest on identified regulation subscale. We speculate the followings are the possible reasons that students were more extrinsically motivated in the two courses: Most students are medical science majors and no one in the course took the course as elective; The students take the course for entrance graduate school and profession studies, and the students
need to get “A” to be competitive. Students’ higher scores on extrinsic motivation subscales was consistent to the speculation that students may have taken a consumerist approach to higher education (Labaree, 1999). Furthermore, according to SDT, when most tasks are not inherently interesting and satisfying and that learning requires a lot of repetitive practices, students need some extrinsic stimulus to perform learning activities (Ryan and Deci, 2000). Comparable results were found in general chemistry (Liu, et al., 2017). As students are more extrinsically motivated, researchers have speculated that instructors can use course policy to influence students’ extrinsic motivation, e.g. through policy regarding attendance, in-class assignments, and other activities, but it is hard to influence students’ intrinsic motivation (Maurer, et al., 2012; Maurer, et al., 2013; Sturges, et al., 2016).

When closely examining the motivation scores in each course, we found that the magnitude of changes on motivational scores was different over the course of a semester. In the Lecture-Based course, amotivation scores increased by 0.44 on average with a medium effect size (Cohen’s $d$: small = 0.20, medium = 0.50, large = 0.80) (Cohen, 1988). This suggests that motivation levels decreased over a semester. All other motivation scores decreased with decreases ranging from 0.03 (external regulation) to 0.34 (introjected regulation) with small to medium effect sizes ($d = 0.03$ to 0.36). This suggests that students were less motivated by external reasons and internal satisfactions over a course of a semester. In the Flip-PLTL course, a similar trend was noticed, but the effect sizes were smaller ($d = 0.02$ to 0.22). The decline in motivation was consistent with prior literature that motivation changes over time and decreases in motivation occur in particular contexts (Zusho, et al., 2003; Nilsson and Warrén Stomberg, 2008; Brouse, et al., 2010; He, et al., 2015; Sturges, et al., 2016; Liu, et al., 2017). There are many possible reasons that students were demotivated. For example, Nilsson and Warrén
Stomberg found that unstimulating curriculum, negative attitudes towards the studies, bad life situations, and difficulties with concepts are among the reasons for the decrease in motivation (Nilsson and Warrén Stomberg, 2008). Under-studied factors, such as fatigue (Smets, et al., 1995) and exhaustion (Karatepe and Tekinkus, 2006), may be another possible reason that students were demotivated over time.

**Sex and course effects**

To answer the third research question, how do changes on motivation differ by pedagogical approaches and by sex, a factorial MANCOVA was conducted (Stevens, 2002; Nakajima and Freesemann, 2013). Motivation has been found to relate with math ability (Ablard and Lipschultz, 1998; Leaper, et al., 2012); we, therefore, first examined if students differ on their math ability (i.e., SAT-Math score) in the two courses and if SAT-Math is an appropriate covariate for a factorial MANCOVA. We found that students’ SAT-Math differed by 9.1 points in the two courses for students in the matched datasets. Two one-tailed independent t-tests (Schuirmann, 1987; Lewis and Lewis, 2005) showed that the two courses were not equivalent based on SAT-Math: \(t_1= 2.26 > 1.29, t_2= 0.62 < 1.29\) at an alpha level of 0.10. However, assumption tests showed that there was no evidence for a significant relationship between SAT-Math and the dependent variables: \(\Lambda = 0.977, F(7,285) = 0.948, p = 0.47\). Therefore, SAT-Math was excluded as a covariate for the factorial MANCOVA.

The purpose of the factorial MANCOVA test was to examine the effects of sex and pedagogical approach on student motivation post-test scores, with pre-test motivational scores as covariates to eliminate the effect of any existing pre-test differences on the results. In this analysis, post scores of the seven motivation subscales are the dependent variables. Sex and
pedagogical approach are the independent variables, and the pre-test scores of the seven types of motivation are the covariates. The interaction effect of sex and pedagogical approach was also examined. Results (see Table 4.5) did not provide evidence for a significant main effect of sex or the interaction effect for sex and pedagogical approach, suggesting females and males scored similarly at the end of the semester in the Lecture-Based and Flip-PLTL courses, while controlling for the pre-test motivation scores. Our results were different from prior literature which found that female college students tend to have higher levels of motivation than males in various contexts (Vallerand, et al., 1992; Cokley, et al., 2001; Spittle, et al., 2009; Brouse, et al., 2010; Smith, et al., 2010; Eymur and Geban, 2011). The results also differed from previous findings in which females reported being less motivated toward chemistry than males in a first-semester general chemistry course (Liu, et al., 2017). Due to our convenience sample in a single institution, these results regarding a lack of sex differences in self-reported motivation levels should be interpreted with caution.

<table>
<thead>
<tr>
<th>Effect</th>
<th>$\Lambda$</th>
<th>$F(7,353)$</th>
<th>$P$</th>
<th>Partial $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>0.975</td>
<td>1.291</td>
<td>0.254</td>
<td>0.025</td>
</tr>
<tr>
<td>Pedagogical approach</td>
<td>0.928</td>
<td>3.906</td>
<td>&lt; 0.001</td>
<td>0.072</td>
</tr>
<tr>
<td>Sex * pedagogical approach</td>
<td>0.985</td>
<td>0.792</td>
<td>0.594</td>
<td>0.015</td>
</tr>
</tbody>
</table>

The factorial MANCOVA indicated a significant main effect of pedagogical approach after adjusting for the covariates: $\Lambda = 0.928, F(7,353) = 3.906, p < 0.001$. This suggests that the students scored significantly differently on the set of motivation variables at the end of the semester taught by different pedagogical approaches, while controlling for motivation pre-test scores. Based on the multivariate findings, univariate analyses of variance were done for each
motivation subscale. Table 4.6 summarizes the significance levels for each of the variables. Results show that students scored similarly on all the intrinsic and extrinsic motivation subscales, but students taught with the Flip-PLTL pedagogical approach scored significantly lower on amotivation at an alpha level of 0.007 while controlling type-1 error (Holm, 1979). Students in the two courses were similar based on their demographics (e.g. sex), when they enrolled in the course they knew which professor was going to teach but they were not aware of pedagogical changes; therefore, we speculate that the differences on student motivation could be due to the different pedagogical approaches. This suggests that different pedagogical approaches can differently affect student motivation (Ryan and Deci, 2000). Perhaps only one semester is insufficient for students to show gains in intrinsic motivation or differences in extrinsic motivation. Self-determination theory suggests that if basic needs of autonomy, competence, and relatedness are met, students can develop intrinsic motivation (Deci and Ryan, 2000; Ryan and Deci, 2000). We speculate that in a Flip-PLTL classroom, students have more chance to interact with their peers and the instructor and peer-leaders function more like facilitators in class and students have freedom regarding when to and how often to explore the study materials; therefore, like other active learning pedagogy (Black and Deci, 2000; Prince, 2004; Obenland, et al., 2013; Abeysekera and Dawson, 2015; Cicuto and Torres, 2016), Flip-PLTL pedagogies can have a positive effect on student motivation given long enough time according to theory (Deci and Ryan, 2000; Ryan and Deci, 2000; Abeysekera and Dawson, 2015).
Table 4.6 Univariate analysis of main effect of pedagogical approach on seven motivation subscales of AMS-Chemistry

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>$F(1,359)$</th>
<th>$p$</th>
<th>Partial $\eta^2$</th>
<th>Observed power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amotivation</td>
<td>11.735</td>
<td>0.001</td>
<td>0.032</td>
<td>0.927</td>
</tr>
<tr>
<td>External regulation</td>
<td>4.884</td>
<td>0.028</td>
<td>0.013</td>
<td>0.596</td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>3.81</td>
<td>0.052</td>
<td>0.011</td>
<td>0.495</td>
</tr>
<tr>
<td>Identified regulation</td>
<td>0.06</td>
<td>0.806</td>
<td>&lt; 0.001</td>
<td>0.057</td>
</tr>
<tr>
<td>To experience</td>
<td>3.195</td>
<td>0.075</td>
<td>0.009</td>
<td>0.430</td>
</tr>
<tr>
<td>To accomplish</td>
<td>0.564</td>
<td>0.453</td>
<td>0.002</td>
<td>0.116</td>
</tr>
<tr>
<td>To know</td>
<td>0.085</td>
<td>0.771</td>
<td>&lt; 0.001</td>
<td>0.060</td>
</tr>
</tbody>
</table>

**Motivation and academic achievement**

To answer the fourth research question, how is motivation associated with student academic achievement in the organic chemistry courses, the associations motivation with academic achievement were studied in the two courses. Four academic achievement measures were used: Exam 1, Exam 4, Final Exam, and Final Score (the final course percentages). Matched samples were used for the correlation study in order to compare the associations in the two courses. Intrinsic and extrinsic motivation subscales had no significant correlations with Exam 1; however, *amotivation* was negatively correlated with Exam 1 with a small effect size ($r$: small = 0.1, medium = 0.3, large = 0.5) (Cohen, 1988) at the beginning of both courses (Tables 4.7 and 4.8).
Table 4.7 Association of motivation with academic achievement in the Lecture-Based course (n = 204)

<table>
<thead>
<tr>
<th>Subscales</th>
<th>Exam 1</th>
<th>Final exam&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Final score&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Exam 4</th>
<th>Final exam&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Final score&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amotivation</td>
<td>-0.15*</td>
<td>-0.11</td>
<td>-0.13</td>
<td>-0.35**</td>
<td>-0.33**</td>
<td>-0.38**</td>
</tr>
<tr>
<td>External regulation</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.02</td>
<td>0.00</td>
<td>-0.02</td>
<td>0.04</td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>-0.08</td>
<td>0.05</td>
<td>0.02</td>
<td>0.13</td>
<td>0.16*</td>
<td>0.18**</td>
</tr>
<tr>
<td>Identified regulation</td>
<td>-0.06</td>
<td>0.05</td>
<td>0.04</td>
<td>0.22**</td>
<td>0.19**</td>
<td>0.24**</td>
</tr>
<tr>
<td>To experience</td>
<td>0.06</td>
<td>0.18**</td>
<td>0.18*</td>
<td>0.25**</td>
<td>0.24**</td>
<td>0.29**</td>
</tr>
<tr>
<td>To accomplish</td>
<td>0.08</td>
<td>0.20**</td>
<td>0.17*</td>
<td>0.26**</td>
<td>0.27**</td>
<td>0.31**</td>
</tr>
<tr>
<td>To know</td>
<td>0.06</td>
<td>0.17*</td>
<td>0.17*</td>
<td>0.28**</td>
<td>0.30*</td>
<td>0.32**</td>
</tr>
</tbody>
</table>

*Significant at 0.05 level (two-tailed test), ** Significant at 0.01 level (two-tailed test), <sup>a</sup>with pre-motivation scores, <sup>b</sup>with post-motivation scales

Table 4.8 Association of motivation with academic achievement in the Flip-PLTL course (n = 166)

<table>
<thead>
<tr>
<th>Subscales</th>
<th>Exam 1</th>
<th>Final exam&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Final score&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Exam 4</th>
<th>Final exam&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Final score&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amotivation</td>
<td>-0.20*</td>
<td>-0.20**</td>
<td>-0.28**</td>
<td>-0.19*</td>
<td>-0.21**</td>
<td>-0.23**</td>
</tr>
<tr>
<td>External regulation</td>
<td>-0.03</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.07</td>
<td>-0.03</td>
<td>-0.06</td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>0.03</td>
<td>0.07</td>
<td>0.02</td>
<td>0.12</td>
<td>0.09</td>
<td>0.06</td>
</tr>
<tr>
<td>Identified regulation</td>
<td>-0.03</td>
<td>-0.00</td>
<td>0.04</td>
<td>0.11</td>
<td>0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>To experience</td>
<td>0.02</td>
<td>0.12</td>
<td>0.08</td>
<td>0.17*</td>
<td>0.15</td>
<td>0.13</td>
</tr>
<tr>
<td>To accomplish</td>
<td>0.12</td>
<td>0.20*</td>
<td>0.16*</td>
<td>0.18*</td>
<td>0.15</td>
<td>0.13</td>
</tr>
<tr>
<td>To know</td>
<td>0.08</td>
<td>0.19*</td>
<td>0.15</td>
<td>0.20**</td>
<td>0.17*</td>
<td>0.13</td>
</tr>
</tbody>
</table>

*Significant at 0.05 level (two-tailed test), ** Significant at 0.01 level (two-tailed test), <sup>a</sup>with pre-motivation scores, <sup>b</sup>with post-motivation scales

For the Lectured-Based course, beginning of the semester intrinsic motivation subscales were significantly and positively correlated with Final Exam and Final Score (see Table 4.7); correlations ranged from 0.17 to 0.20 with small effect sizes. At the end of the semester, intrinsic motivation subscales were significantly and positively correlated with Exam 4, Final Exam, and Final Score: $r = 0.24$-$0.32$, with medium effect sizes; introjected regulation and identified
regulation also had positive correlations with the exam grades, with \( r \) values ranging from 0.16 to 0.24.

For the Flip-PLTL course, amotivation was significantly and negatively correlated with exam grades (see Table 4.8). At the beginning of the semester, both \textit{to know} and \textit{to accomplish} subscales were significantly and positively correlated with Final Exam; the \textit{to accomplish} subscale was significantly and positively correlated with Final Score. At the end of the semester, \textit{to know} and \textit{to accomplish} subscales were significantly and positively correlated with Exam 4; only the \textit{to know} subscale was significantly and positively correlated with Final Exam. There was no evidence for significant correlations between extrinsic motivation subscales and academic achievement throughout the semester.

Two-tailed Z-tests of independent correlation coefficients (Glass and Hopkins, 1970) did not provide evidence for differences in correlation coefficients between the two courses \((p > 0.05\) for all the two-tailed Z-tests), suggesting the association trend between motivation and academic achievement is very similar in the two courses. The variable correlations over time were consistent to the findings in general chemistry course (Liu, \textit{et al}., 2017). Positive correlations between intrinsic motivation subscales and students’ exam grades are consistent with prior findings in the literature (Black and Deci, 2000; Jurisevic, \textit{et al}., 2008; Devetak, \textit{et al}., 2009; Cicuto and Torres, 2016; Liu, \textit{et al}., 2017), which suggest that students who were more intrinsically motivated toward chemistry have higher levels of achievement (Lynch and Trujillo, 2011). Extrinsic motivation had no significant correlations with academic achievement in the Flip-PLTL course, suggesting that while providing some minor rewards could help student extrinsic motivation, merely relying on extrinsic rewards may not be enough for students to achieve. This is consistent with a hypothesis by Lynch and Trujillo that students have difficulty
keeping up studies if they are primarily concerned with grades (Lynch and Trujillo, 2011), a key indicator of high extrinsic motivation. Negative correlations between amotivation and academic achievement suggest that it would be beneficial to stimulate all forms of motivation in chemistry. Intrinsic motivation has a stronger association with student academic achievement. Therefore, we suggest instructors to take efforts to promote student intrinsic motivation. For example, instructors can provide choices to students and rationales for assignments. Instructors can also acknowledge students’ feelings and give them a sense of independence. Moreover, instructors can provide students’ positive feedback to help them be confident and grow in their abilities, as well as helping them to feel a sense of belonging by encouraging collaborations in small groups. According to SDT, when students’ basic needs for autonomy, competence, and relatedness are met, intrinsic motivation development is supported (Deci and Ryan, 2000; Ryan and Deci, 2000).

**Conclusion**

The purpose of the present study is to investigate the effect of pedagogical approaches by using AMS-Chemistry to explore motivational perceptions before and after the implementation of flipped classroom and PLTL (Flip-PLTL). To achieve this purpose, we first gathered psychometric evidence to suggest that the AMS-Chemistry can be used to measure motivation in the target organic chemistry courses that utilized different teaching pedagogies. AMS-Chemistry scores were used to evaluate the effectiveness of Flip-PLTL on student motivation; results suggest that AMS-Chemistry has potential to evaluate the impact on motivation of other research-based instructional pedagogies. Results suggest that students are less amotivated in a Flip-PLTL instructional environment; we conclude that the reformed pedagogy is having the intended effect on motivation. Additional, we observe that one semester is not long enough to
observe meaningful positive changes in the extrinsic and intrinsic subscales of the AMS-Chemistry; a longitudinal study over multiple semesters would lend evidence to support that claim that the AMS-Chemistry data are invariant across time and can be used to articulate changes across time.

**Limitations**

This study has several limitations, which suggest that other researchers should be cautious about comparing our results with findings in other contexts. First, the samples were conveniently taken from the two target courses and from courses at a single institution. The inferential results may be due to the particular sample and unreflective of causal associations between changes in motivation and instructional environments. Second, the sample size was too small for measurement invariance testing (Xu, et al., 2016) and limited the power of the statistical analysis reported. Third, results were primarily based on quantitative data. In the future, qualitative studies should be conducted to triangulate these findings. For example, interviews could uncover how the curriculum, fatigue, and exhaustion may have influenced motivation.

**Implications**

Our findings have multiple implications for the chemistry education community. Our work found a positive effect of Flip-PLTL on student motivation; therefore, we encourage faculty to implement such a pedagogical approach to their instructional practices. According to SDT, when instructors support the autonomy of students, students develop more intrinsic motivation and identified regulation (Deci and Ryan, 2000; Ryan and Deci, 2000). For example,
autonomy-supportive interventions could be used to help faculty develop this instructional technique (Su and Reeve, 2011). Reeve has suggested that instructors to use informative and permissive language while communicating with students and acknowledge and accept students’ feelings; such communication techniques enhance the support of autonomy (Reeve, 2009). Instructors should provide students with optimally challenging tasks and tools necessary for success, resources for self-paced learning, positive feedback, be respectful, and create opportunities for students to interact with each other (Kusurkar, et al., 2011; Su and Reeve, 2011; Jang, et al., 2016; Jang, et al., 2016); these behaviors also meet students basic needs of autonomy, competence, and relatedness, therefore support the development of intrinsic motivation according to SDT (Deci and Ryan, 2000; Ryan and Deci, 2000; Orsini, et al., 2015). When students are motivated, more positive outcomes are expected, for example, better academic achievement and persistence in STEM fields (PCAST, 2012).

Scores from AMS-Chemistry can be interpreted using different mini-theories in SDT. First, using the seven-factor model, we can show nuances of motivation and potential movement along the self-determination continuum based on the organismic integration theory. Second, with the support of alternative models, the data collected from AMS-Chemistry can also be interpreted in terms of autonomous and controlled motivation using causality orientations theory, another mini-theory in SDT (Deci and Ryan, 2000; Ryan and Deci, 2000; Deci and Ryan, 2008; Jurisevic, et al., 2008; Guay, et al., 2010; Kusurkar, et al., 2013), which can be used to produce simplified student motivation profiles and enhance our understanding of SDT in in college chemistry courses.
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CHAPTER FIVE

Exploring student basic needs and motivation in Australian college chemistry courses implementing Process Oriented Guided Inquiry Learning

Introduction

The role of a traditional didactic lecture in higher education is well defined within a model of student learning (Trigwell and Prosser, 1997). In a didactic lecture the instructor teaches through explanation and example, and the students learn through recording of information and repetition of examples. Social discourse is discouraged during class time, and interaction between teacher and students is highly controlled. In Australia, job titles are often drawn from the intended method of instruction (e.g., lecturer/reader), which reinforces the traditional lecture method. However, constructive alignment suggests that learning is improved when students are actively involved in the construction of their own knowledge (Biggs, 1999).

To move from the traditional lecture to a new paradigm of engaging students in active learning pedagogies requires disruption of the traditional roles of instructor and students. The consequences of such changes are not immediately clear, particularly when the social fabric is radically altered and crucial to the desired pedagogical implementation. The implementation of active learning pedagogies can be informed by social constructivism (Vygotsky, 1978), which considers the teacher-student and peer interactions as well as the individual motivation for learning (Biggs and Tang, 2007).
Social interaction, autonomy, and competence are considered important basic psychological needs required to mediate motivation (Deci and Ryan, 2000). According to self-determination theory (SDT), active learning pedagogies can support the conditions necessary to meet each basic need (Reeve, et al., 2004), that is to enable a student to feel that “one can effectively bring about desired effects and outcomes” (Reis, et al., 2000), and thereby internalize motivation (Ryan and Deci, 2000). The internalization of motivation is obviously a desirable outcome in any learning experience, but questions remain about what role the methods of instruction might play in facilitating students’ basic needs and what tools are suitable to assess these relationships.

In this study, an active learning pedagogy, Process Oriented Guided Inquiry Learning (POGIL), based on a constructivist learning cycle paradigm, was implemented in place of traditional didactic instruction in a tertiary chemistry setting. POGIL utilizes a guided-inquiry framework, which enables students to work in defined teams to construct their own knowledge by encouraging peer discussion and by promoting learning from an instructor who serves as a facilitator rather than an expert source of information. The purpose of the study is to examine students’ perceptions of the basic needs and their intrinsic motivation in chemistry courses implementing POGIL with adapted instruments in order to understand whether self-determination theory is relevant to the instructional environment in a POGIL context.

**Three basic needs and intrinsic motivation**

According to the basic psychological needs theory within SDT, the basic needs are “innate psychological nutriments that are essential for ongoing psychological growth, integrity, and well-being” (Deci and Ryan, 2000). According to the theory, when these three needs are
satisfied during an activity, people tend to feel the enjoyment of the activity, and thus intrinsic motivation, which is defined as “doing an activity for the inherent satisfaction of the activity itself” (Ryan and Deci, 2000) rather than for some separable consequence, will be integrated (Gagné and Deci, 2005) or enhanced (Ryan and Deci, 2000). The basic psychological needs theory has been used in different contexts, including the workplace (Gagné and Deci, 2005; Fernet, et al., 2013), sport (Gillet, et al., 2009), and education (Southam and Lewis, 2013; Cerasoli, et al., 2016; Rocchi, et al., 2017; Wang and Li, 2017). Researchers in educational fields have found that the satisfaction of the three basic needs has significant effects on academic achievement (Guiffrida, et al., 2013; Cerasoli, et al., 2016), psychological well-being (Reis, et al., 2000; Reeve, 2012; Rocchi, et al., 2017), persistence (Guiffrida, et al., 2013), engagement (Park, et al., 2012; Reeve, 2012), and life satisfaction (Sheldon, et al., 2009). Furthermore, meeting the basic needs can promote student motivation (Jang, et al., 2009; Katz, et al., 2009; Vaino, et al., 2012; Orsini, et al., 2016; Wang and Li, 2017).

The need for autonomy can be described as the need to be self-determined and to have a choice in the initiation and regulation of one’s behavior (Ryan and Deci, 2002). Basic psychological needs theory posits that people have a fundamental need to feel autonomous – to feel that they have the freedom to choose their own actions. Within the SDT framework, personal motivation toward various activities is strongly influenced by personal perceptions of autonomy with respect to those activities. When the need for autonomy is satisfied, self-determined motivation toward an activity is enhanced with a perception that the activity is fulfilling inner interests (Gillet, et al., 2012; Southam and Lewis, 2013; León, et al., 2015). In educational contexts, research has proposed that students can gain autonomy support from different sources, e.g. from family (Hui, et al., 2011) and instructors (Vallerand, et al., 1995; Su
and Reeve, 2011; Pan and Gauvain, 2012; Reeve, 2012; Southam and Lewis, 2013; Caleon, et al., 2015; Jang, et al., 2016; Jang, et al., 2016; Orsini, et al., 2016; Katz, 2017). Specific pedagogical approaches have been implemented to meet the need of autonomy. For example, at tertiary level, implementing context-based modules and group work could provide autonomy support for high school chemistry students in Estonia (Vaino, et al., 2012) and college students in organic chemistry courses in the United States (Black and Deci, 2000). Moreover, students in a third-year undergraduate spectroscopy course with a POGIL environment from Australia had positive perceptions of autonomy support from their instructor (Southam and Lewis, 2013). At pre-tertiary level, implementing context-based modules could provide autonomy support for high school chemistry students in Estonia (Vaino, et al., 2012). Korean ninth graders were found having positive autonomy in their self-identified highly satisfying learning experience and the autonomy support had a positive effect on their intrinsic motivation (Jang, et al., 2009). The perceived autonomy support of students in ninth grades from Israel also could positively predict their motivational outcomes (Katz, 2017). Conversely, controlling classrooms have been shown to significantly undermine students’ self-determined motivation and their tendency to engage in school-related tasks (Vallerand, 1997), which is also found true for Canadian undergraduate students performing tasks in computers (Ratelle, et al., 2005). According to the theory, meeting the autonomy need can promote intrinsic motivation, which is found true by providing students with choices (Guay, et al., 2001; Kusurkar, et al., 2011) in autonomy-supportive classrooms (Deci, et al., 1981; Reeve, 2009).

Besides autonomy, perceived competence (Guay, et al., 2001) and relatedness (Ryan and Deci, 2002) have also been linked to intrinsic motivation. The perception of competence describes the feeling of effectiveness at a given activity (Ryan and Deci, 2002); thus, positive
feedback signifies the satisfaction of competence and enhances intrinsic motivation. Relatedness means the desire to feel connected to and be accepted by others (Ryan and Deci, 2002). In a school context students’ perceptions of relatedness can include relatedness to peers (Cox, et al., 2008; Laghi, et al., 2009; Carreira, 2012; Pan and Gauvain, 2012; Flunger, et al., 2013), to teachers (Katz, et al., 2009), or to both peers and teachers (Beachboard, et al., 2011; Guiffrida, et al., 2013). For example, high school students in Estonia have reported higher perceived competence and relatedness in chemistry classes with context-based modules (Vaino, et al., 2012). Similar results were found for Korean ninth graders when they are engaged in educational experiences, which they rate as highly satisfying (Jang, et al., 2009). This study examines basic needs fulfillment and the status of intrinsic motivation in a changing learning environment.

**Structural equation modeling**

Structural equation modeling (SEM), a multivariate data analysis approach, can be used to explore the relationships among variables based on theoretical frameworks. SEM has been used to explore the relationship of student learning/chemistry achievements together with other variables such as 3D virtual reality features, self-efficacy, and presence (Merchant, et al., 2012), attitude (Brandriet, et al., 2013; Xu, et al., 2013) for general chemistry students in the United States, and autonomy support and motivational variables (e.g. interest, expectancy, etc.) for undergraduate students enrolled in introductory chemistry courses with degrees in science and technology in Spain (Gonzalez and Paoloni, 2015). According to SDT, all the three basic needs have positive influences on intrinsic motivation. In literature, Slovenian and Polish vocational and technical high school students with higher autonomy support from instructors scored higher on intrinsic motivation and performed better in chemistry knowledge tests (Juriševič, et al.,...
2012), but sometimes autonomy failed to show its significance on intrinsic motivation, e.g. for students in stratified selected secondary vocational education in the Netherlands (Pat-El, et al., 2012); therefore, it is important to study the three basic needs at the same time in the specific context to examine how the three basic needs can contribute to intrinsic motivation individually.

Similar to autonomy support, the effect of relatedness on intrinsic motivation has also not been uniform. On one hand, SDT suggests that relatedness plays a role (Pat-El, et al., 2012) – albeit a more “distal” one (Deci and Ryan, 2000) – in the maintenance of intrinsic motivation. For example, secondary vocational education students studying commerce and business administration from the Netherlands undertook collaborative group work, whose relatedness to peers positively predicted their interest in the project (Minnaert, et al., 2011). Another study with psychology undergraduate students found that relatedness was positively associated with prosocial interest (Pavey, et al., 2011). On the other hand, research results sometimes fail to show the theoretically anticipated significant relationships between relatedness and other constructs in SDT. For example, a path analysis with data gathered from ninth graders in Korea did not indicate this significant effect (Jang, et al., 2009). Students in pre-vocational secondary education in the Netherlands showed a positive effect of relatedness on their intrinsic motivation for a familiar task but a negative effect six months later (Van Nuland, et al., 2012). In several studies relatedness was not included (Williams and Deci, 1996; Black and Deci, 2000; Guay, et al., 2001) and its effect on intrinsic motivation was unknown. The SEM literature is sparse in studies of all three basic needs and intrinsic motivation in college level settings.

In a POGIL context, where students work together on carefully designed activities in small groups and where the instructors act as facilitators, it is posited that students’ basic needs are likely to be fulfilled, setting the stage to enhance intrinsic motivation. The nature of this
pedagogy specifically provides opportunities for meaningful relatedness between students, giving this aspect of the basic needs the opportunity to flourish; therefore, we will study the three basic needs and intrinsic motivation simultaneously. We expect relatedness will have a significant effect on intrinsic motivation in our context.

**The POGIL intervention**

In a POGIL setting, groups of two to four students work on activities designed around a learning cycle, with each student assigned a pre-defined team role. The small groups are guided by the instructor as a facilitator of learning (Farrell, *et al.*, 1999). The implementations of POGIL activities can be different (Chase, *et al.*, 2013). POGIL activities are often used to replace all (Minderhout and Loertscher, 2007) or part (Murphy, *et al.*, 2010) of the didactic classroom presentation. POGIL was also implemented outside of lecture time (Brandriet, *et al.*, 2013) and can be facilitated by instructors and/or peers (Lewis and Lewis, 2005; Moog and Spencer, 2008; Vishnumolakala, *et al.*, 2017).

There are two primary pedagogical domains utilized in the design of POGIL activities: The first domain is a process-based concept that is introduced through a model or series of models, and second domain is a series of guided questions that allow the students to interrogate the information presented in the model. The questions are deliberately designed around the learning cycle where the students explore the model (E), are introduced the concept and its definition (I), and apply the concept to new situations (A). This cycle, in the E → I → A sequence, is repeated throughout the activity to achieve the desired learning outcomes (Moog, *et al.*, 2009). These learning outcomes may be defined as concepts and/or processes, depending on the intended aim of the activity (Cole and Bauer, 2008).
There are demonstrated benefits to the use of pedagogies such as POGIL in place of didactic presentation (see e.g., Lewis and Lewis, 2005). In a quasi-experiment there were significant and observable improvements in student performance over a three-year implementation phase in POGIL classrooms compared with a traditional classrooms, irrespective of students’ previous scores on comparable measures such as SAT (Lewis and Lewis, 2008). More studies have found increases in student performance in the targeted courses using same or similar interventions (Freeman, et al., 2014; Warfa, 2016; Wilson and Varma-Nelson, 2016), but a need is called to implement and evaluate curricular-wide reform (Lewis, 2014). Moreover, POGIL students had higher attitude toward the learning environment (Brandriet, et al., 2011; Chase, et al., 2013; Vishnumolakala, et al., 2017), and instructors utilizing POGIL report improved student engagement with the subject, each other, and the instructor (Hein, 2012). This engagement can lead to a learning environment that develops valuable and transferrable skills (Hanson and Overton, 2010), such as effective communication and teamwork (Straumanis and Simons, 2008). From the basic principles of POGIL’s guided-inquiry implementation approach, we also expect students in a POGIL classroom to experience a sense of autonomy, to develop relationships with their peers, and to become competent in learning chemistry.

**Context**

This study took place in a large public university in Perth, Western Australia. In this intervention, two instructors opted to teach with POGIL in place of traditional pedagogies in their first year chemistry courses. This study examined the following four courses during two 12-week terms spanning February to June 2012 (Term 1) and July to November 2012 (Term 2):

- **Term 1: Class A**: A general chemistry course for science and engineering students
who intend to major in the discipline. The topics taught with POGIL by Instructor 1 were in weeks 2-3, 7-8, and 11-12 of the term, respectively.

- **Term 1: Class B**: A general and organic chemistry course for pharmacy students. The topics taught with POGIL by Instructor 2 were in weeks 2-6 and 11-12 of the term, respectively.

- **Term 2: Class C**: A general and organic chemistry course for science and engineering students who intend to major in the discipline. The topic taught by Instructor 1 with POGIL was in weeks 1 and 2 of the term. Students in Class C had taken a previous course in Term 1 which also used POGIL topics.

- **Term 2: Class D**: A general and organic chemistry course for nutrition and biomedical sciences students. The topics taught with POGIL by Instructor 1 were in weeks 1-4 and 11-12 of the course, respectively. Students in Class D had taken a traditional course with didactic lecturing in Term 1.

During the period of the intervention, where ordinarily there would be didactic presentation during the two or three hours per week allocated for lectures, these two instructors implemented POGIL for at least two hours periodically in the above specific weeks during the term in the courses they taught. This represents approximately 40% of the formal class time for these four courses.

This instruction took place in tiered lecture theatres, with the students organized into groups by the instructor. Each student was given a team role and the teams self-managed their progress through the activity, prompted by instructor questions facilitated by a classroom response system. Instructor 1 also utilized a blended environment by recording a didactic presentation that students could independently access after each POGIL activity. These recorded
didactic presentations, for example in Class D, had 152 unique and 212 cumulative views with an average completion of 82%.

While the affective benefits of collaborative learning within social interdependence theory have been studied (Johnson and Johnson, 2009), questions still remain about relationships between the social aspects of learning and perceptions of competence. In a POGIL environment, students work in small groups and interact with each other more often than in a traditional didactic lecture, and therefore, they have a better chance to feel connected and accepted by their group members. When discussion among peers happens often, students can learn from each other, and theoretically, they may feel more confident about their capacity to solve problems. Lastly, when the instructor acts as a facilitator instead of lecturing most of the time, students have more opportunities to interact with their instructor and the instructor can provide help when necessary; therefore, the students should feel more autonomous. When the needs of autonomy, competence, and relatedness are fulfilled, we expect students’ intrinsic motivation can be maintained or enhanced according to SDT.

**Present study**

This study has two purposes: (1) To explore student motivation in the context of these mixed and blended POGIL implementations, gathering information about student perceptions of their experiences in each affected course; (2) to refine the Learning Climate Questionnaire (LCQ) and the Intrinsic Motivation Inventory (IMI) in order to measure basic needs and intrinsic motivation with a lens of SDT in an Australian college chemistry settings. It is hoped that this study will further efforts to evaluate the effects of new curricula on students’ motivation and their healthy psychological growth.
To find out students’ perceptions of the instructional environment, we will answer the following research questions:

(1) How do the modified LCQ and the IMI function in a college chemistry setting, with respect to internal consistency reliability and internal structure validity of the scores?

(2) What are student basic needs and intrinsic motivation statuses at the end of Term 1 and at the beginning of Term 2 as measured by IMI and LCQ? And how students’ comments on course evaluations indicate that their basic needs are met?

(3) According to structural equation modeling results, to what extent do the relationships among variables predicted by SDT fit student experiences in a POGIL classroom?

(4) Do students’ perceptions of the POGIL environment differ based on their previous learning experience? And how students’ comments on course evaluation support the change?

Method

In order to examine how well students’ basic needs are met and the status of students’ intrinsic motivation at a large public university in Perth, Western Australia, a mixed-method approach is used. Quantitative data from the LCQ and IMI surveys and qualitative data from the teaching evaluations are used to answer the research questions when necessary.

Instruments

The instruments used in this study were drawn from the available literature on SDT and adapted for the purposes of this research. The sample items are summarized in Table 5.1 and the full instruments were in Appendix C1-C2. Learning Climate Questionnaire (LCQ) is used to
measure students’ perceived autonomy support (Williams and Deci, 1996). Items in LCQ were amended to refer to the specific instructor in each class as the classes had different instructors in different classes. LCQ measures students’ perceptions about the degree to which the classroom context is autonomy supportive versus controlling. Students answered questions on a seven-point Likert scale from 1 (strongly disagree) to 7 (strongly agree). The LCQ has a single underlying factor, and the score for an instructor’s autonomy support is calculated by the mean of item scores. A higher in the mean suggests a higher level of perceived autonomy support.

**Table 5.1** Description of the instrumentation, subscales, and items used in this study

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Subscale</th>
<th>N. of items</th>
<th>Sample item</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCQ</td>
<td>Autonomy Support</td>
<td>15</td>
<td>I feel that my instructor provides me choices and option</td>
</tr>
<tr>
<td>IMI</td>
<td>Intrinsic Motivation</td>
<td>7</td>
<td><em>These activities</em> were fun to do</td>
</tr>
<tr>
<td>IMI</td>
<td>Perceived Competence</td>
<td>6</td>
<td>I think I am pretty good at <em>these activities</em></td>
</tr>
<tr>
<td>IMI</td>
<td>Relatedness</td>
<td>8</td>
<td>I feel close to <em>my group</em></td>
</tr>
</tbody>
</table>

Note: LCQ = Learning Climate Questionnaire, IMI = Intrinsic Motivation Inventory

A modified 21-item Intrinsic Motivation Inventory (IMI) is used to measure students’ interest/enjoyment, perceived competence, and relatedness on a seven-point Likert scale from 1 (not at all true) to 7 (very true) (McAuley, *et al.*, 1989). Interest/Enjoyment subscale is regarded as the only subscale measuring intrinsic motivation and it has been used to represent students’ perceptions of intrinsic motivation by many researchers (Pat-El, *et al.*, 2012; Vaino, *et al.*, 2012; Van Nuland, *et al.*, 2012). Thus, this subscale is coded as intrinsic motivation for the research purpose of the study. The items in IMI were specifically rephrased to include “the/these activities” when speaking about the POGIL activities in the intrinsic motivation and perceived competence subscales, and “my group” when referring to the groups the students worked together in during the activities in the relatedness subscale.
Participants

The Instructor 1 and Instructor 2 in this study are both male experienced teachers of chemistry in the higher education sector in Australia, and both had four years of experience with POGIL instruction at the time of this study. Instructor 1 is an early- to mid-career faculty member who has used POGIL as the predominant pedagogy in place of much of his instruction for four out of the five years of his independent career. Instructor 2 is a mid- to late-career faculty member who has used POGIL for the same period, although he has a 25-year independent career. Both instructors have an interest in chemistry education research and were cognizant of the purpose of this study during the intervention.

At Time 1, 285 students were enrolled in Class A (a general chemistry course for science and engineering students). Students were 20.16 (SD = 3.39) years old on average, 28% were females, 40% were in Engineering majors, and 59% were in Science majors. 102 students responded to the survey with consent forms. After data screening for missing data, 95 student responses were available for data analysis but only 92 students had identifiers. The 92 students in Class A were 19.58 (SD = 3.29) years old on average, 34% were females, 25% were in Engineering majors, and 74% were Science majors, suggesting the students were similar to all the students enrolled in this class by age but more representative of science majors.

At Time 1, 118 students were enrolled in Class B (a general and organic chemistry course for pharmacy students). Students were 19.95 (SD = 3.38) years old on average, 65% were females, and 90% were pharmacy majors. 58 students answered the two instruments with consent forms at Time 1. After data screening for missing data, 54 student responses were available for data analysis. These 54 students were 20.05 (SD = 3.96) years old on average, 61%
were females, and 95% were Pharmacy majors, suggesting these students were very similar to the students enrolled in this class by age, sex, and majors.

At Time 2, 250 students were enrolled in Class C (a general and organic chemistry course for science and engineering students). Students were 21.27 (SD = 4.54) years old on average, 28% were females, 52% majored in Engineering, and 37% majored in Science. 43 students responded to the survey. After checking for missing data, 37 student responses were available for data analysis, but two of them did not provide identifiers. The 35 students were 20.61 (SD = 3.61) years old on average, 49% were females, 46% were in Engineering majors, and 54% were in Science majors, suggesting the students were similar to all the students enrolled in this class by age, but more representative of females who were science majors.

At Time 2, 111 students were enrolled in Class D (a general and organic chemistry course for nutrition and biomedical science students). They were 21.37 (SD = 4.67) years old on average, 82% were females, 63% were in Nutrition, and 37% were Biomedical Sciences majors. 52 students responded to the survey. After checking for missing data, 49 students had complete responses for data analysis, but two students did not provide identifiers. The 47 students were 21.17 (SD = 5.20) years old on average, 81% were females, 45% majored in Nutrition, and 53% were Biomedical Sciences majors, suggesting the students were similar to all the students enrolled in this class by age, but less representative of Nutrition majors who were females.

**Data collection**

The students in Classes A-D were allowed 10 minutes to complete the questions in LCQ and IMI during lecture time. The students’ scores from LCQ and IMI were used to examine their basic needs and intrinsic motivation status. At the end of each term, students in the four classes
were asked to write comments on the teaching evaluations for each instructor on their roles and their implementation of POGIL activities. Students volunteered and anonymously commented on the strengths and suggested areas to improve for each instructor. The written comments were analyzed to get student perceptions of the instructors and the implementation of POGIL activities.

**Data analysis**

**Quantitative data**

The negatively stated items were recoded before data analysis. Collected data for this study was analyzed using different methods of statistical analysis to answer the research questions. First, the scores of the LCQ and IMI were analyzed to evaluate the internal structure of the instruments through confirmatory factor analysis (CFA) in Mplus 5.2. Because the students were all university students in Perth in chemistry classes and were of similar ages, and students in Classes A and B responded to the survey at a similar time and students in Classes C and D answered the survey at a similar time, we combined Classes A and B at Time 1 and Classes C and D at Time 2, which resulted a sample size of 149 at Time 1 and 86 at Time 2. To determine how well the data fit the model, several indices were examined. Chi-square ($\chi^2$) are reported, but chi-square is very sensitive if models are based on a large number of scores (Bollen and Long, 1993). Therefore, additional fit indices including Comparative Fit Index (CFI) and Standardized Root Mean-Square Residual (SRMR) are examined because neither is sensitive to sample size. If the CFI is greater than 0.90 (Cheng and Chan, 2003) and SRMR is less than 0.10 (Hu and Bentler, 1995), the model is considered a reasonable fit to the data (Hu and Bentler, 1999).
Both Cronbach’s alpha coefficients and descriptive statistics for the LCQ and subscales of the IMI were conducted in SPSS software version 22.0. The internal consistency of the LCQ and the subscales of IMI was assessed using Cronbach’s alpha coefficients, where a benchmark of 0.7 or greater is usually suggested (Murphy and Davidshofer, 2005). Multivariate analysis of variance (MANOVA) was conducted in SAS 9.3 at an alpha level of 0.05. Structural equation modeling (SEM) was performed using the TCALIS procedure in SAS 9.3 to investigate both model fit and parameter estimates, with the same fit indices and criteria as for CFA. Because of the relatively small sample size and relatively large number of items, a path model with observed scores and no measurement error was tested instead of a full model with measurement paths. SEM analysis parameters, such as model specification, standardized parameter estimates, and predicted variance indicated by $R^2$, were also reported. The standardized path coefficients between 0.05 and 0.10 are regarded small but meaningful influences, between 0.11 and 0.25 are regarded moderate influences, and above 0.25 are regarded large influences (Keith, 1993). In the path model, an arrow from X to Y suggests X has an effect on Y, and a double-headed arrow represents the correlation between two variables. If the parameter estimate is significant, a star is placed close to it.

**Qualitative data**

Principles of SDT were used to guide the data analysis of written comments from teaching evaluations. The written comments were coded by themes of autonomy, competence, and intrinsic motivation. As students were only asked to comment on the strengths and improvements of the instructor’s teaching in the teaching evaluation, no written comments on relatedness were present in the data.
Results

Instrumentation functionality in our context

In order to examine students’ perceptions of this instructional environment, we chose to use surveys adapted from existing instruments. It is important to make sure that the adapted instruments could generate reliable and valid scores in our context to support our intended interpretations (Arjoon, et al., 2013). Therefore, our first step in the data analysis was to evaluate the psychometric evidence of LCQ and IMI in terms of internal structure validity by confirmatory factor analysis. The purpose is to find out if the original three-factor model of IMI and one-factor model of LCQ could apply to the data gathered in these Australian university chemistry courses with the modified items. A minimum of five to ten respondents per item is often recommended for factor analysis (Brown, 2006); therefore, only the responses at Time 1 were used for CFA analysis. Using the variance-covariance matrix of the items, maximum-likelihood methods of estimate was employed because the scores were approximately normally distributed. All the items were set to load on their assumed factors only. The models were identified by fixing the first item on each factor at 1.

The confirmatory factor analysis results are summarized in Table 5.2. At Time 1, for the 15-item LCQ did not provide good fit to the data. There were several problematic items. For example, Item 13 (“I don't feel very good about the way my instructor talks to me”) was found to have a low standardized loading of 0.19. Item 15 (“I feel able to share my feelings with my instructor”) seemed not work in our context since discussion of feelings would be quite rare in a university chemistry course in Australia. Item 11 (“My instructor handles people’s emotions very well”) does not work conceptually in our setting, either. After the deletion of these problematic items, a 12-item LCQ showed good fit at Time 1: $\chi^2 = 119.34$, df = 54, $p = 0.00$, CFI = 0.93, SRMR = 0.05, and the loadings of the items are equal to or greater than 0.59 except that Item 14
(“My instructor tries to understand how I see things before suggesting a new way to do things”) has a loading of 0.48.

The 21-item IMI did not show good fit to the data at Time 1. On the basis of inspection of the modification indices and the items, five items (Item 2, 6, 11, 18, 19) were deleted, and the results showed that the model fit the data reasonably well. For the 16-item IMI, $\chi^2 = 206.79$, df = 101, $p = 0.0000$, CFI = 0.92, SRMR = 0.076, and the loadings of the items are equal to or greater than 0.63 except that item 21 (“I’d really prefer not to interact with my group in the future!”) has a loading of 0.50. Therefore, CFA results showed reasonable fit to the data and the scores from the shortened instruments provided internal structure validity evidence for the purposes of this study. Due to the small sample size ($n = 86$) at Time 2, CFA was not conducted with responses collected at Time 2.

Table 5.2 Fit indices of confirmatory factor analyses at Time 1 ($n = 149$)

<table>
<thead>
<tr>
<th>Instrument</th>
<th>N. of items</th>
<th>$\chi^2$</th>
<th>df</th>
<th>$p$</th>
<th>CFI</th>
<th>SRMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMI</td>
<td>21</td>
<td>517.05</td>
<td>186</td>
<td>&lt;0.001</td>
<td>0.82</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>206.79</td>
<td>101</td>
<td>&lt;0.001</td>
<td>0.92</td>
<td>0.076</td>
</tr>
<tr>
<td>LCQ</td>
<td>15</td>
<td>245.15</td>
<td>90</td>
<td>&lt;0.001</td>
<td>0.86</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>119.34</td>
<td>54</td>
<td>&lt;0.001</td>
<td>0.93</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Evidence of the internal consistency of the subscale scores in the shortened IMI and LCQ was examined with Cronbach’s alpha coefficients at both Time 1 and Time 2, and the results are displayed in Table 5.3. The Cronbach’s alpha coefficients were between 0.83 and 0.92 at Time 1 and between 0.77 and 0.91 at Time 2, which were thought of as or close to “very good (DeVellis, 2003) and satisfactory internal consistency reliability.
Table 5.3 Internal of the factors of the IMI and LCQ at Times 1 – 2

<table>
<thead>
<tr>
<th>Subscale</th>
<th>N. of items</th>
<th>Cronbach’s alpha</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Time 1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Time 2&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Autonomy Support</td>
<td>12</td>
<td>0.92</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>Intrinsic motivation</td>
<td>6</td>
<td>0.89</td>
<td>0.91</td>
<td></td>
</tr>
<tr>
<td>Perceived competence</td>
<td>5</td>
<td>0.84</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Relatedness</td>
<td>5</td>
<td>0.83</td>
<td>0.77</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> n = 149, <sup>b</sup> n = 86

Based on the internal structure validity and internal consistency reliability, the 12-item LCQ and 16-item IMI were used hereafter in this study for consistent interpretation of the scores at Time 1 and Time 2.

Basic needs and motivation status

Descriptive statistics were used to examine the status of basic needs and intrinsic motivation for students at the end of their first semester of chemistry curriculum at Time 1. Table 5.4 displays the mean, standard deviation, skewness, and kurtosis for the basic needs and intrinsic motivation for students in Classes A and B in general at Time 1 (end of Term 1). The absolute values of skewness and kurtosis of the subscales were all smaller than 1, suggesting that the scores were approximately normally distributed, and suitable for further statistical treatment. The means were out of 7, with 4 as neutral. The means for all the motivational variables were between 4.40 (perceived competence) and 5.31 (relatedness) on seven-point Likert scales. For autonomy support, students scored 4.85 out of 7 on average. For the three subscales of IMI, relatedness had the highest mean of 5.31 out of 7. Intrinsic motivation had a mean of 4.51 (out of 7). At the beginning of Term 2 at Time 2, students in Class C, who had experienced two more
weeks of POGIL than those in classes A and B, and students in Class D, who had only experienced two weeks of POGIL, scored equally or higher on the motivational variables (please see Table 5.6 for the descriptive statistics), suggesting all the students had positive perceptions on the basic needs and intrinsic motivation in the POGIL environment.

**Table 5.4** Descriptive statistics of subscales at Time 1 (end of Term 1, n = 149)

<table>
<thead>
<tr>
<th>Subscale</th>
<th>N. of items</th>
<th>M</th>
<th>SD</th>
<th>Sk</th>
<th>Ku</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic motivation</td>
<td>6</td>
<td>4.51</td>
<td>1.22</td>
<td>-0.58</td>
<td>0.17</td>
</tr>
<tr>
<td>Autonomy support</td>
<td>12</td>
<td>4.85</td>
<td>0.96</td>
<td>-0.26</td>
<td>0.69</td>
</tr>
<tr>
<td>Perceived competence</td>
<td>5</td>
<td>4.40</td>
<td>1.12</td>
<td>-0.34</td>
<td>0.19</td>
</tr>
<tr>
<td>Relatedness</td>
<td>5</td>
<td>5.31</td>
<td>1.16</td>
<td>-0.52</td>
<td>-0.08</td>
</tr>
</tbody>
</table>

Note: Sk = Skewness, Ku = Kurtosis

In order to better understand students’ perceptions on the basic needs and intrinsic motivation in the instructional environment of POGIL, students’ comments on instructors and the courses were studied for in-depth information. In general, students expressed more positive (92%) than negative comments (8%) about their motivational perceptions, which was consistent with their positive perceptions of autonomy, competence, and intrinsic motivation.

**Autonomy support**

Autonomy support is reflected by several students’ comments:

... *I found [Instructor 1] very easy to approach and ask questions :)*

... *[Instructor 2] is concerned about students' ability to understand.*

... *I think it was really good that [Instructor 2] was interested in our learning and often walked around the lecture to see if students needed help.*

... *You offer help but do not explain just answer with a question...*
As evidenced by the first three preceding written comments, autonomy support is function of as facilitation rather than lecturing and provision of understanding and responsiveness to students’ questions. The last quotation is an example of negative perception of the autonomy support.

**Perceived competence**

The positive perception of student competence is reflected by the following sample written comments:

... *Doing the activities and questions in lectures makes retaining information easier.*

*The active learning method that [Instructor 1] teaches with is a great way to learn practical skills and do work for yourself...*  

*The tutorial activities we worked on as groups was really good in helping me understand topics rather than individually and being stuck on something for a long time you could ask your group mates.*

*Your activity system is only beneficial to those with a strong understanding of chemistry so you disadvantage weak chemistry students who need to be lectured to understand...*

According to the students’ written comments, the POGIL activities helped students understand chemistry topics, retain information, and learn practical skills, which could potentially help students’ problem-solving skills: the competence. However, some students, in particular weak students didn’t think the activities were beneficial to their learning.

**Intrinsic motivation**

*His content delivery was always concise and interesting....*
Very entertaining and motivating.

Answering the worksheets ... during lecture kept my interest and made us listen

...In a few of the lectures I felt a bit lost as to what I was actually doing, and I think that a quick 15 min overview of what we were doing in the activities would of been good.

According to students’ written comments, the activities (answering the worksheets) and the methods through which the activities were facilitated in the POGIL environment intrigued and motivated the students. However, some students felt lost, showing negative perceptions.

Viability of SDT

In order to test how viable the use of SDT is to understand student experiences in a POGIL classroom, structural equation modeling was conducted when the sample size was adequate at Time 1 for students who had experienced POGIL for about one term. Two models were tried to examine the significance of the effect of the three basic needs on intrinsic motivation. In Model 1, relatedness is a predictor of intrinsic motivation. In Model 2, the path between relatedness and intrinsic motivation is excluded. Since research has also showed that students in an autonomous environment are more likely to improve their competence, we assumed that autonomy support also has an effect on students’ perceived competence in both models. The fit indices and the variance of intrinsic motivation explained by each model at Time 1 are shown in Table 5.5, and the path diagrams with standardized solutions are shown in Figure 5.1. The solid single arrow represents the path between two variables, and the number adjacent to the arrow represents the standardized coefficients path or the direct effect with standard errors in the bracket for each independent variable.
Model 1

The fit indices (Table 5.5) show that this model fits the data adequately (Hu and Bentler, 1999). The direct effect of autonomy support on intrinsic motivation is 0.24, suggesting autonomy support has a moderate direct influence on intrinsic motivation. The indirect effect of autonomy support on intrinsic motivation is 0.19; therefore, the total effect of autonomy support on intrinsic motivation is 0.43, suggesting a large overall effect (Keith, 1993). Perceived competence has a direct and large effect (β = 0.49) on intrinsic motivation, and relatedness has a smaller but still moderate direct effect (β = 0.21) on intrinsic motivation. The results showed that the three basic needs could explain 45% of variance of intrinsic motivation and SDT is viable in our context, as the model can explain almost 50% of the variance of intrinsic motivation.

Table 5.5 Fit indices and predicted variance for intrinsic motivation

<table>
<thead>
<tr>
<th>SEM model</th>
<th>n</th>
<th>$\chi^2$ (df)</th>
<th>p-value</th>
<th>SRMR</th>
<th>CFI</th>
<th>Predicted variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>149</td>
<td>0.89 (1)</td>
<td>0.34</td>
<td>0.03</td>
<td>1.00</td>
<td>45%</td>
</tr>
<tr>
<td>2</td>
<td>149</td>
<td>12.10 (2)</td>
<td>0.0024</td>
<td>0.08</td>
<td>0.91</td>
<td>41%</td>
</tr>
</tbody>
</table>

Figure 5.1 Path diagram with standardized solution to explain intrinsic motivation for Model 1 (left) and Model 2 (right) at Time 1
Model 2

SDT has suggested that all three basic needs are important to intrinsic motivation; the effect of relatedness on intrinsic motivation, however, is not consistent across studies. Therefore, we proposed Model 2 (as shown in Figure 5.1, right) where the path from relatedness to intrinsic motivation is excluded to examine how this path can affect the overall model fit and the predicted variance of intrinsic motivation. For Model 2, the fit indices suggested reasonable fit to data. Since Model 2 is a nested model within Model 1, the change in $\chi^2$ can be used to compare the models (West, et al., 2012). The change in $\chi^2$ is = 11.21 with a change in degrees of freedom of 1, which indicates that the data fits Model 1 significantly better than Model 2 at an alpha level of 0.001. As shown in Figure 5.1 and Table 5.5, with one less predictor, the model can only explain 41% of the variance of intrinsic motivation. An $F$-test (Pedhazur, 1997) indicated the unique contribution of relatedness is significant to the prediction of intrinsic motivation ($F(1,145) = 10.55$, $p < 0.01$).

Motivational scores by previous learning experience

Students in Class C experienced two more weeks of POGIL than those at Time 1; therefore, we hypothesize that the students have similar perceptions of the motivational variables. When comparing the descriptive statistics, students in Class C scored almost the same on intrinsic motivation and relatedness, lower on autonomy support ($d = 0.26$, small effect size) ($d$: 0.20 = small, 0.50 = medium, 0.80 = large) (Cohen, 1988), and slightly higher on perceived competence ($d = 0.21$, small effect size). Therefore, on average, students seemed not to differ on their perceptions of the motivational variables in general.
Table 5.6 The means (standard deviation) and effect sizes of the subscales in Classes C and D

<table>
<thead>
<tr>
<th></th>
<th>Class C(^a)</th>
<th>Class D(^b)</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic motivation</td>
<td>4.51 (1.19)</td>
<td>4.70 (1.25)</td>
<td>0.16</td>
</tr>
<tr>
<td>Autonomy support</td>
<td>4.62 (0.83)</td>
<td>5.22 (0.76)</td>
<td>0.75</td>
</tr>
<tr>
<td>Perceived competence</td>
<td>4.61 (0.89)</td>
<td>4.68 (1.09)</td>
<td>0.07</td>
</tr>
<tr>
<td>Relatedness</td>
<td>5.30 (0.90)</td>
<td>5.90 (0.93)</td>
<td>0.66</td>
</tr>
</tbody>
</table>

\(^a\) n = 37, \(^b\) n = 49

Students in Classes C and D mainly differed on their course experience as students in Class C had POGIL experience in Term 1 and students in Class D experienced traditional lecturing in Term 1. We hypothesize that students in Class D would value POGIL environment more positively as many students are in need of extra resources and help in a challenging chemistry course. As shown in Table 5.6, the students in Class D scored higher on all the subscales than students in Class C. After outlier assessment and examination of the assumptions (Appendix C3), MANOVA was conducted to determine if there was a significant difference on the set of motivational variables between Classes C and D. The difference in means on the set of four subscales was statistically significant, \(A = 0.774\), \(F(4,81) = 5.92\), \(p < 0.001\), suggesting that the two classes differed on this set of motivation variables. The size of multivariate effect was between medium and large (\(f^2 = 0.26\)) (\(f^2\): 0.02 = small, 0.15 = medium, 0.35 = large) (Cohen, 1988). Univariate follow-up tests, using a Bonferroni approach (Holm, 1979), revealed significant differences on two of the subscales at an alpha level of 0.0125 (Table 5.7). In particular, the ANOVA results showed that students in Class D scored significantly higher on autonomy support than students in Class C (\(M = 5.22\) in Class C and 4.62 in Class D), with a large effect size (Cohen, 1988). The results also showed that students in Class D scored significantly higher on relatedness than students in Class C (\(M = 5.90\) vs 5.30) with a medium effect size (Cohen, 1988), suggesting students felt closer to their group members in Class D.
The written comments also provide us information regarding students’ feeling about the active learning environment after experiencing traditional lecturing in the prior academic term. The following written comments reflected the students’ differing perceptions regarding the exposure to the POGIL environment versus the traditional lecturing environment:

*at first i was very unsure about your teaching methods, by the end of the semester i realised they were useful. As difficult as [Class E] is, i preferred your teaching methods.*

*His lecture style made us think about the concepts during the lecture and he was able to give feedback and answer questions while we were working on problems in the actual lecture. Everyone should teach Chem like him!!!*

Class E was a course in Term 1, which had primarily traditional lectures and students had taken before taking Class D. The comments showed that students who were new to the POGIL environment really valued this new teaching method.

**Discussion**

This study reported results based on adapted LCQ and IMI instruments and teaching evaluation comments written by students in college chemistry classes in Australia where POGIL activities were being implemented. The research questions were answered. The fit indices from the confirmatory factor analysis suggested that the shortened instruments (12-item LCQ and 16-item IMI) showed reasonable internal structure validity, but in our view, the shortened

<table>
<thead>
<tr>
<th>Subscale</th>
<th>$F(1,84)$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic motivation</td>
<td>0.51</td>
<td>0.48</td>
</tr>
<tr>
<td>Autonomy support</td>
<td>12.26</td>
<td>0.001</td>
</tr>
<tr>
<td>Perceived competence</td>
<td>0.11</td>
<td>0.74</td>
</tr>
<tr>
<td>Relatedness</td>
<td>8.92</td>
<td>0.004</td>
</tr>
</tbody>
</table>
instruments would benefit from further testing with larger sample sizes and alternate samples in order to make sure the set of items function well in different contexts. Some items may have not functioned well due to the unique Australian context; suggesting collecting other type of validity is necessary (Arjoon, et al., 2013; Ferrell and Barbera, 2015; Liu, et al., 2017). The reliability study showed that scores from both instruments had good internal consistency. These alpha coefficients were all high as measures of affective constructs have 0.64, on average (Murphy and Davidshofer, 2005). Therefore, the results were interpreted at factor level in this study.

The means were all above neutral (4) on the 7-point Likert scale for all the factors, which suggested that students had positive perceptions of the basic needs and intrinsic motivation. This means that students felt having choices, e.g. in doing the group work, confident in solving problems, connected with their group members, and enjoyment in doing the group activities. Such results demonstrate that the three basic needs can be met in the POGIL environment. The positive perceptions of the motivational variables were consistent with the findings that students from the United States were more motivated in organic chemistry courses with active learning environments (Liu, et al., 2017). The results were also consistent with the positive perceptions of the basic needs and intrinsic motivation in other active learning environment of chemistry courses at college (Black and Deci, 2000; Southam and Lewis, 2013) and secondary-school settings (Vaino, et al., 2012). The results were also similar to the students’ higher attitudinal perceptions toward the learning environment in general chemistry courses with POGIL environment (Brandriet, et al., 2011; Chase, et al., 2013; Vishnumolakala, et al., 2017).

The positive perceptions from the quantitative data were triangulated with students’ written comments in the teaching evaluations. That is students provided more positive than negative comments about their instructors and the course in the teaching evaluation reports when
analyzed with the lens of basic psychological needs theory. The written comments showed that the students thought the instructors were very supportive by providing care, help, understanding, and answers to students’ questions, which defined autonomy support in SDT (Deci and Ryan, 2000), which is consistent with the qualitative findings in the clinical setting in a dental school in the United States (Orsini, et al., 2016). Students’ written comments also reflected that the POGIL activities helped them understand chemistry topics and learn practical skills, again consistent to the literature (Hanson and Overton, 2010), which could help student learn and improve their competence. Students also thought that group work was more helpful for them to understand the concepts than working individually (Straumanis and Simons, 2008). The qualitative comments also reflected that POGIL activities motivated them, engaged them, and made them pay attention, consistent to meta-analysis results (Su and Reeve, 2011) and findings in organic chemistry (Hein, 2012) and clinic settings in a dental school (Orsini, et al., 2016). In the future, instructors could implement more adapted POGIL activities in more chemistry courses and explore if students’ basic needs can still be met and intrinsic motivation be promoted.

Based on the significant change in chi-square value and the explained variance, the model with all the three basic needs having effects on intrinsic motivation can better explain the relationships among the variables. Therefore, the inclusion of three basic needs can better explain intrinsic motivation, illustrating that the use of SDT was viable in our POGIL context and that relatedness was an important variable (Deci and Ryan, 2000). The results were similar to the study of motivation to create content to share in social media with diverse participants from China and the United States (Wang and Li, 2017). Autonomy support showed a positive effect on perceived competence, which is different from Pat-El’s study (Pat-El, et al., 2012) where autonomy support failed to predict student intrinsic motivation, suggesting the need to
investigate the basic needs and intrinsic motivation in a specific context. The total effect of autonomy support on intrinsic motivation is large, suggesting that it is important for instructors to support students’ autonomy need and hence be intrinsically motivated. Therefore, instructors can be autonomy supportive to meet students’ needs, engage students, and help students learn (Reeve, 2009; Su and Reeve, 2011; Reeve, 2012; Jang, et al., 2016; Jang, et al., 2016; Orsini, et al., 2016). In our setting, relatedness was a positive predictor of intrinsic motivation in our college chemistry setting, which was consistent with the findings (Pat-El, et al., 2012; Van Nuland, et al., 2012) and a recent study with diverse participants from China and United States (Wang and Li, 2017). The positive coefficients of the basic needs on intrinsic motivation suggest that it is important to create a learning environment to meet students’ basic needs and therefore intrinsically motivate and engage students (Reeve, 2012; Orsini, et al., 2016).

The significant difference on the set of motivational variables between Classes C and D suggested that students who were in the POGIL environment for the first time had more positive perceptions of the studied variables. It suggests students felt more positive of being provided with care and choices and connected with their group members when involved in the active POGIL environment. Perhaps after being taught with didactic lectures for their first term, students were very sensitive of and enjoyed a lot of the environmental changes. They felt the active learning environment can meet their needs for autonomy, competence, and relatedness far better than in a more controlling learning environment. The results are consistent with other studies that active learning pedagogy, such as POGIL, could engage students (Hein, 2012), and help them learn (Lewis and Lewis, 2008; Freeman, et al., 2014; Warfa, 2016; Wilson and Varma-Nelson, 2016), although the latter needs to be further examined by using some content tests. Some students’ comments showed how their thinking changed over this time regarding the
active learning environment. The written comments also suggested that students who have prior learning experience in a traditional teaching environment may need some time and guidance to get used to the active learning environment, but they liked the active learning environment and benefited from it eventually. Such results were consistent with the recommendations and research findings that students may be overwhelmed at the beginning of a semester by the new and active learning pedagogy, such as flipped classroom, thus they need time to adjust to the new learning environment and find it beneficial at the end of the semester (Christiansen, 2014; Fautch, 2015; Shattuck, 2016).

The fact that students whose learning environment had changed from traditional to active environment had more positive perceptions on the motivational variables suggest promises for instructors to implement more active learning pedagogies. It is important to remind instructors that students could feel uncomfortable at the beginning of the transition and instructors should care students’ feelings and provide help so that they can adjust into the active learning environment and benefit from it. For example, the instructor should provide guidance in group work and timely and constructive feedback to build students’ confidence in their competence, encourage interactions among peers, and build a more autonomy supportive environment by having students see the importance of the activities and providing care and support to students (Reeve, 2009; Kusurkar, et al., 2011; Reeve, 2012; Orsini, et al., 2016). In order to maintain and continue to meet students’ basic needs and motivate and engage students in the POGIL environment, it is important to optimize the implementation including improving on areas students point out, e.g. time management, and perhaps to versatile teaching by implementing other active learning methods so that students won’t get bored and can keep being interested in the activities.
Limitations

There are some limitations in this study. For instance, the sample was convenient. The students were from specific courses in a specific institution; therefore, the researchers should be cautious when comparing with other literature findings. The biggest limitation is that the response rate and the percentages of the responses with complete data and identifiers were really low (32%, 46%, 14%, and 42% for Courses A, B, C, and D respectively) which reflected the attendance, since class attendance cannot be required in this institutional context. There is potential bias in the study as participants’ self-reported scores may or may not represent their real motivation level, and the students who responded to the surveys may just be more motivated than the ones who did not respond. Although the students who responded in each class were very similar to the students enrolled in the courses in some aspects, the participants in the study may not be totally representative of students enrolled in the chemistry classes. The sample size was relatively small for confirmatory factor analysis, especially at Time 2. We did not have enough responses to complete the SEM analysis at Time 2 and to check factorial invariance (Xu, et al., 2016) in order to determine if the two instruments functioned similarly in different classes before performing the inferential tests. Few students responded to the teaching evaluations and there are no written comments regarding relationships with their group members, which precluded triangulation of the relatedness variable. In the future, in-depth interviews could be used to get more in-depth perceptions from the students regarding the instructional environment besides collecting quantitative data. Despite all the limitations, this study can provide us some evidence that SDT functions well in the POGIL active learning environment.
Conclusion

In the mixed and blended POGIL implementation environment, the students displayed positive perceptions of the three basic needs and *intrinsic motivation* according to the data from LCQ and IMI, which were also triangulated by the students’ written comments. The results also showed that the use of SDT is viable in this context and the results from the path models were consistent with SDT because all the three basic needs had significant effects on *intrinsic motivation*: students’ basic needs could be fulfilled in the autonomous POGIL learning environment and such fulfillment can lead to high *intrinsic motivation*. The model showed that *autonomy support* has a large effect on students’ *intrinsic motivation*; therefore, it is necessary for instructors to build an autonomy supportive learning environment. The path models also showed that *relatedness* had a moderate direct effect on *intrinsic motivation* in the active learning environment. The model with three predictors had better model fit and better prediction of *intrinsic motivation*, and group work helped students learn the chemistry concepts; therefore, it is necessary engage students working in groups to help students over the difficulties in learning chemistry, perform better, and persist in the science, technology, engineering, and mathematics (STEM) fields.

The students in the POGIL environment felt their basic needs were met and they enjoyed the group activities. The students were very sensitive to the change into an active learning environment, but instructors should guide them and help them adjust to the change. Implementing different active teaching methods could potentially engage students more and promote more positive intrinsic motivation. We encourage instructors to collect data and examine students’ perceptions of needs in their own classroom and therefore they can think about strategies to meet specific needs of students based on the students’ responses.
In the future, more validity evidence, including response process validity evidence should be gathered to optimize the instruments and better measure the basic needs and intrinsic motivation in the study context. More data will be collected to conduct invariance tests before comparing groups of students on this set of variables. A full model of structural equation modeling can also be conducted to test the relationships between the variables when a bigger sample size is available to explore SDT in POGIL and to examine the efficacy of POGIL on students’ perceptions of basic needs and intrinsic motivation and on their academic achievement. In-depth interviews are also needed to get more in-depth data to triangulate the research results from the quantitative data.

Implications

There are several implications from the results of this current study. First, SEM is a multivariate data analysis approach used to study complex relationships among variables; therefore, the current study is a good addition to the scarcity literature of SEM studies in chemistry education. More importantly, researchers can apply the SDT model in college chemistry courses based on the SEM results. The basic psychological needs were met and students had positive intrinsic motivation in a POGIL active learning environment. Therefore, we would suggest practitioners to implement more student-centered teaching pedagogies where instructors could facilitate student learning and students could have more time to interact with their peers and engage themselves in learning. We would also suggest practitioners to adopt POGIL activities based on their discipline and courses, so that students could connect with their experiences and learn practical skills, which not only could help student learn concepts, but also could help student pay attention in class and be motivated toward the subject. This could
contribute to the efforts to produce more STEM graduates in the next ten years (PCAST, 2012). Students who have been exposed to traditional teaching in the past perhaps may not get used to the active learning environment at the beginning; therefore, we would remind practitioners and researchers to be aware and allow more time for students to get used to the transition to active learning environments.

Acknowledgements

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CHAPTER SIX

Conclusions and implications

This work investigated student motivation in college chemistry courses based on both quantitative and qualitative data. The quantitative data were collected using instruments based on the SDT. The qualitative data was collected through teaching evaluations and cognitive interviews. The first purpose of this work is to collect psychometric evidence for four instruments: Academic Motivation Scale (AMS), Learning Climate Questionnaire (LCQ), Intrinsic Motivation Inventory (IMI), and the newly developed Academic Motivation Scale toward Chemistry (AMS-Chemistry). The ultimate purpose of the work is to study student academic motivation profiles by sex and by pedagogies and to explore their relationships with student academic achievement. The results add to the current literature about student motivation in traditionally lecture-based and active learning environments at tertiary level. This work also extends our understanding of the important factors that could affect student motivation, specifically, factors to promote student intrinsic motivation and to improve student persistence in the STEM fields. Three studies were conducted. Their conclusions are summarized here.

AMS was piloted in general chemistry courses in Study 1. The results provided evidence that the AMS generally functioned well according to the SDT and the scores were reliable; therefore, we could examine the seven types of student motivation. The descriptive statistics suggested that students were more extrinsically motivated toward education in general chemistry courses. Results also showed that students were intrinsically motivated to go to college as well
because they felt enjoyment while learning new knowledge and accomplishing assignments. Female students were more motivated than males; in particular, females scored significantly lower on *amotivation* than male students in the general chemistry courses. Such results were consistent with the findings in other studies with U.S. samples (Cokley, *et al*., 2001; Smith, *et al*., 2010), but were unique with the observation that females differed from males only on *amotivation* with a medium effect size. In other studies with secondary students, researchers have found that females scored significantly lower on *amotivation* with small effect sizes (Grouzet, *et al*., 2006; Caleon, *et al*., 2015). It seems that the motivational gap between males and females has become wider at the college level. This suggests that it is important and necessary to measure motivation in science courses because the students’ motivation may change depending on the courses they are enrolled in. Therefore, it is best to examine student motivation toward a specific science course. This work focuses on student motivation in college chemistry courses.

AMS-Chemistry was successfully developed as a theory-based instrument to measure student motivation toward chemistry. In Study 1, a variety of validity evidence was collected in general chemistry courses before using the motivational scores for interpretation. The validity evidence included content validity supported by expert panel discussions, response processes validity supported by cognitive interviews, and internal structure validity supported by confirmatory factor analysis (Arjoon, *et al*., 2013). The validity evidence suggested that AMS-Chemistry functioned according to the SDT and could be interpreted using the seven types of motivation. Regarding the internal consistency reliability, the Cronbach’s alpha coefficients were all above 0.70 for the seven subscales, suggesting the scores were reliable (Murphy and Davidshofer, 2005). Study 2 provided more psychometric evidence for AMS-Chemistry in
organic chemistry courses with both lecture-based and Flip-PLTL learning environments where flipped classroom and PLTL were implemented in the same course. The validity and reliability evidence suggested that AMS-Chemistry also functioned well in organic chemistry courses. Therefore, AMS-Chemistry has a great potential to be used to study student motivation in various college chemistry courses in both traditional and active learning environments.

Regarding the status of student motivation toward chemistry, Study 1 and Study 2 showed that the students were more extrinsically motivated to take the general and organic chemistry courses. We speculate that it is because the chemistry subject was difficult, making many activities in class not intrinsically interesting, so students took a consumerist approach to higher education (Labaree, 1999; Ryan and Deci, 2000). In particular, students were most motivated by the value identified with regard to their future career paths. Additionally, they were motivated by rewards (e.g. grades) and by avoiding feeling guilty while performing activities in the courses. Instructors could motivate students in the course by assigning them grades for homework and other assignments and by reminding them about deadlines, although this might not help their intrinsic motivation (Maurer, et al., 2012; Maurer, et al., 2013). This trend was different from former studies where students generally scored higher on intrinsic motivation subscales with regard to going to college (Ratelle, et al., 2007; Stover, et al., 2012), but was consistent with studies where few students intended to study chemistry (Koballa and Glynn, 2007). In Studies 1 and 2, students were found to become demotivated over a semester in both general and organic chemistry courses. Such results were consistent with the findings in other college courses in literature (Nilsson and Warrén Stomberg, 2008; Brouse, et al., 2010; He, et al., 2015).

Regarding student motivation by sex and by pedagogical approach, student motivation at
the end of semester was examined while controlling students’ pre-motivational scores in Study 2. The results showed a main effect of pedagogical approach, and students in Flip-PLTL course scored significantly lower on *amotivation* at the end of the course. In terms of sex difference, Study 1 showed an overall motivational difference at the beginning of semester in general chemistry course with overall scores favoring males. In Study 2, there was no evidence for a sex main effect, indicating that females had similar motivation profiles to males at the end of the semester while controlling their pre-motivational scores. Results in Study 1 and Study 2 were different from research findings with high school students that females were similarly or more motivated than males toward chemistry (Akbaş and Kan, 2007). Such results suggest that it is important to investigate student motivation by sex in the specific research context of interest.

In general and organic chemistry courses, the correlations between motivational subscales and students’ exam grades showed different relationships at different time points over a semester in Study 1 and Study 2. At the beginning of the semester, students’ motivation scores were hardly associated with their Exam 1 in general chemistry course and organic chemistry courses. Intrinsic motivation subscales were significantly and positively correlated with their Final Exam and Final Score in organic chemistry courses. The positive correlations were consistent with prior research findings in the literature, for example, Hibbard, *et al.*’s study (2016) with one cohort of general chemistry students in a historically Black college, Griffin *et al.*’s study with freshmen students in U.S. (Griffin, *et al.*, 2013), and Tseng and Tsai’s study (2010) with Taiwan college students. Moreover, in both general chemistry and lecture-based organic chemistry courses, intrinsic motivation subscales at the end of the semester had stronger positive correlations with students’ academic achievement. Furthermore, results showed that *amotivation* was negatively correlated with students’ academic achievement, suggesting it is
important to stimulate any student motivation for better performance in the college chemistry courses. Extrinsic motivation subscales had some positive correlations with students’ academic achievement in the lecture-based organic chemistry course. However, the correlations became non-significant in the Flip-PLTL organic chemistry course, consistent with the mixed results regarding extrinsic motivation and academic achievement in the literature.

The different associations between motivation type and student academic achievement in different college chemistry courses and time points in Study 1 and Study 2, together with the mixed results in studies with different measure of motivation and academic achievement (Jurisevic, et al., 2008; Devetak, et al., 2009) suggest it is necessary to study the interrelationships between motivation subscales and academic achievement in the context of interest. The change of associations over a semester in this work also suggests that it would be interesting to examine if there are changes in student motivation and the associations with their academic achievements at different time points, for example before and after an exam. Based on SDT, when the three psychological basic needs are met, intrinsic motivation could be promoted (Black and Deci, 2000; Vaino, et al., 2012; Hagger, et al., 2015; Kiemer, et al., 2015); therefore, it is necessary to investigate if SDT is viable in college chemistry courses implementing active pedagogies and if students’ basic needs can be met in active learning environment. It is because meeting the basic needs can promote intrinsic motivation and students with higher intrinsic motivation scores tend to perform better on the exams.

Motivation scores and attendance of students were explored in Study 1. Results showed that students having higher intrinsic motivation and identified regulation scores at the beginning of semester had better attendance to lectures later in the semester. The results were similar with the study with no freshmen involved (Devadoss and Foltz, 1996). Our quantitative results were
also consistent with qualitative findings that students who were absent from lectures indicated low student motivation (Moore, et al., 2008). Therefore, we can try to motivate students by connecting chemistry concepts with real life and their future careers to improve attendance in introductory chemistry courses, which could help student persistence in school and STEM fields in the long run.

Students’ perceptions of intrinsic motivation and basic needs were explored in a research context with POGIL being implemented in some first-year college chemistry classes in Study 3. The findings showed that the shortened LCQ and IMI instruments had reasonable fit to the data and therefore could measure the three basic needs and intrinsic motivation. The quantitative results indicated the students had positive perceptions of the three basic needs and intrinsic motivation, consistent with the findings in a Southam and Lewis study with a POGIL instructional context (Southam and Lewis, 2013). In comparison to students who experienced POGIL in their previous semester, students who were in traditional lecture-based learning environment had more positive perceptions of the basic needs and intrinsic motivation in new POGIL environment, suggesting the promising effect of transforming traditional classrooms into active learning environment. The themes in the students’ written comments in the teaching evaluations showed similar results to the quantitative data. Structural equation modeling (path models) results showed students’ basic needs had positive effects on student intrinsic motivation, which was consistent with the basic psychological needs theory, suggesting the SDT is viable in this context. The model showed that autonomy support has a large overall positive effect on students’ intrinsic motivation, consistent with several mini-theories in SDT that autonomy is crucial to students’ motivation and wellbeing (Ryan and Deci, 2000); therefore, it is necessary for instructors to build an autonomy supportive learning environment. The path models also
showed that relatedness had a moderate direct effect on intrinsic motivation in the POGIL environment, suggesting relatedness is important to student psychological health and intrinsic motivation, consistent with the basic psychological needs theory (Ryan and Deci, 2000; Deci and Ryan, 2014). The model with three predictors had better model fit and better prediction of intrinsic motivation, and group work helped students learn the chemistry concepts according to the written comments in the teaching evaluations; therefore, it is necessary to engage students to work in small groups to help students overcome the difficulties in learning chemistry, perform better, and persist in STEM fields. In conclusion, students’ basic needs could be fulfilled in the autonomous POGIL learning environment and such fulfillment can lead to positive intrinsic motivation. Therefore, instructors can guide students and help them adjust to the pedagogy change. Implementing different active teaching methods could potentially engage students more and promote more positive intrinsic motivation (PCAST, 2012).

In conclusion, the three studies indicated that SDT framework could be applied in college chemistry courses to understand how and why students are motivated. The mixed methods approach helped us develop good instruments and understand student motivation better. The first two studies provided a great deal of psychometric evidence for the newly developed AMS-Chemistry; therefore, we can choose to use this instrument to examine student motivation in different college chemistry courses in either traditional or active learning environments. The instrument can measure nuances of different types of motivation and was sensitive enough to pick up differences by sex and by pedagogical approach. Active learning environments could meet students’ basic psychological needs of autonomy, competence, and relatedness, and thus could better support student intrinsic motivation as well as help students learn chemistry. The mixed methods approach should be encouraged so that researchers can use qualitative data to
triangulate the quantitative results; therefore, we can get to know not only “what” but also “why” from our research.

**Limitations**

This work has limitations. First, the samples in the three studies were convenient and were drawn from particular courses at particular institutions; therefore, the results may only represent the students in the specific contexts but could not be generalized to other contexts.

Second, not all students responded to the instruments, especially, the response rate in Study 3 was very low (15%-46%), so response bias might exist because it was possible that the students responding to the survey were more motivated. The sample sizes were not large enough to evaluate measurement invariance to make sure the items were interpreted the same by males and females in Study 1 and Study 2 or to make sure the two instruments (LCQ and IMI) functioned similarly in different classes in Study 3 before performing the inferential tests. Furthermore in Study 3, we also don’t have enough sample size to conduct a full SEM model and few students responded to the teaching evaluations and there are no comments regarding relationships with their group members, which precluded triangulation of the relatedness variable.

Third, the results were mainly based on quantitative data, which limited our understanding of the differences in student motivation between different groups of students by sex. In addition, we were unsure of the specific reasons why students were demotivated over a semester in general and in organic chemistry courses. Therefore, researchers who follow up this work could interview students besides collecting quantitative data.
Another limitation is that there is lack of knowledge of the implementations. There is data to show the fidelity of the implementation of PLTL, flipped classroom, and POGIL.

Implications

The research findings have implications for the chemical education community. First, the psychometric evidence (content, response processes, internal structural, and relationship with other variables validity and internal consistency reliability) for AMS-Chemistry suggests that it can be used in other college chemistry courses to examine student motivation toward chemistry. AMS-Chemistry can serve as a theory-based instrument to measure motivation along the SDT continuum to identify the nuances in student motivation. Multiple administrations of AMS-Chemistry within a course and across the curriculum for a longitudinal study could help to examine changes along with students’ college life. AMS-Chemistry can be used before and after student-centered educational reforms are implemented to explore students’ motivational perceptions for the effect of educational reform. As a result of sharing findings with instructors, we can guide students based on their motivation profiles, e.g. to work with students with low motivation to improve attendance. Last, the motivation scores may help to address other important issues such as scientific literacy and persistence in science education and to shed light on the retention of students in chemistry.

Fewer restrictions should be imposed on instructors. When instructors felt pressured to comply with a curriculum or to meet performance standards, they were less likely to implement evidenced-based teaching methods (Pelletier, et al., 2002). If instructors feel less controlled toward teaching, they are more active to create an autonomy supportive environments, and
students can develop more autonomous motivation (intrinsic motivation and identified regulation) in such an environment according to SDT.

We suggest instructors to implement more student-centered pedagogies, where instructors could facilitate student learning instead of lecturing in front of students, and encourage students have more time to interact with their peers. In an autonomy supportive learning environment, we can provide choices and meaningful rationales for doing learning activities, to support students’ autonomy needs. In addition, we can provide students optimal challenging tasks, needed tools/resources, and positive feedback to support their competence needs. We should also respect and care for students and create opportunities for them to interact with each other to meet their relatedness needs (Kusurkar, et al., 2011; Su and Reeve, 2011; Jang, et al., 2016; Jang, et al., 2016). When students’ basic psychological needs are met, they can develop and maintain their intrinsic motivation (Ryan and Deci, 2000; Orsini, et al., 2015). When students are motivated, more positive outcomes are expected; for example, the outcomes include better academic achievements and improved persistence in STEM fields.

We also suggest instructors to adopt student activities, such as POGIL activities based on their discipline and course, so that students could connect with their experiences and learn practical skills, which not only help students learn concepts, but also help students pay attention in class and be motivated toward the subject. This could contribute to the efforts to produce more STEM graduates in the next ten years (PCAST, 2012). Students who have been exposed to traditional lecture-based teaching in the past perhaps may not be acclimated to the active learning environment at the beginning; therefore, we would remind instructors and researchers to be aware, provide guidance, and allow more time for students to get used to the transition to active learning environments.
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Appendix A

Appendices for Chapter Three

Appendix A1. Academic Motivation Scale (AMS) (Vallerand et al., 1992)

WHY DO YOU GO TO COLLEGE?

Using the scale below, indicate to what extent each of the following items presently corresponds to one of the reasons why you go to college. Circle your response directly on this form.

<table>
<thead>
<tr>
<th>Does not correspond at all</th>
<th>Corresponds a little</th>
<th>Corresponds moderately</th>
<th>Corresponds a lot</th>
<th>Corresponds exactly</th>
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<td>1</td>
<td>2</td>
<td>3</td>
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<td>6</td>
<td>7</td>
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**WHY DO YOU GO TO COLLEGE?**

1. Because with only a high-school degree I would not find a high-paying job later on.  
   1 2 3 4 5 6 7

2. Because I experience pleasure and satisfaction while learning new things.  
   1 2 3 4 5 6 7


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<tr>
<td>3.</td>
<td>Because I think that a college education will help me better prepare for the career I have chosen.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4.</td>
<td>For the intense feelings I experience when I am communicating my own ideas to others.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5.</td>
<td>Honestly, I don't know; I really feel that I am wasting my time in school.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6.</td>
<td>For the pleasure I experience while surpassing myself in my studies.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7.</td>
<td>To prove to myself that I am capable of completing my college degree.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8.</td>
<td>In order to obtain a more prestigious job later on.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9.</td>
<td>For the pleasure I experience when I discover new things never seen before.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10.</td>
<td>Because eventually it will enable me to enter the job market in a field that I like.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>11.</td>
<td>For the pleasure that I experience when I read interesting authors.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>12.</td>
<td>I once had good reasons for going to college; however, now I wonder whether I should continue.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>13.</td>
<td>For the pleasure that I experience while I am surpassing myself in one of my personal accomplishments.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>14.</td>
<td>Because of the fact that when I succeed in college I feel important.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>15.</td>
<td>Because I want to have &quot;the good life&quot; later on.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16.</td>
<td>For the pleasure that I experience in broadening my knowledge about subjects which appeal to me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>17.</td>
<td>Because this will help me make a better choice regarding my career orientation.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>18.</td>
<td>For the pleasure that I experience when I feel completely absorbed by what certain authors have written.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>19.</td>
<td>I can't see why I go to college and frankly, I couldn't care less.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20.</td>
<td>For the satisfaction I feel when I am in the process of accomplishing difficult academic activities.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>21.</td>
<td>To show myself that I am an intelligent person.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>22.</td>
<td>In order to have a better salary later on.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
23. Because my studies allow me to continue to learn about many things that interest me. 1 2 3 4 5 6 7
24. Because I believe that a few additional years of education will improve my competence as a worker. 1 2 3 4 5 6 7
25. For the "high" feeling that I experience while reading about various interesting subjects. 1 2 3 4 5 6 7
26. I don't know; I can't understand what I am doing in school. 1 2 3 4 5 6 7
27. Because college allows me to experience a personal satisfaction in my quest for excellence in my studies. 1 2 3 4 5 6 7
28. Because I want to show myself that I can succeed in my studies. 1 2 3 4 5 6 7

Appendix A2. Demographics of participants compared with all the students enrolled (population) for AMS-Chemistry

<table>
<thead>
<tr>
<th></th>
<th>Participants at Time 1 (n = 208)</th>
<th>Participants at Time 2 (n = 94)</th>
<th>Population (n = 1039)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>62.0%</td>
<td>62.8%</td>
<td>60.4%</td>
</tr>
<tr>
<td>Male</td>
<td>38.0%</td>
<td>37.2%</td>
<td>39.6%</td>
</tr>
<tr>
<td>Freshmen</td>
<td>34.6%</td>
<td>31.9%</td>
<td>39.0%</td>
</tr>
<tr>
<td>Sophomore</td>
<td>43.8%</td>
<td>36.2%</td>
<td>32.4%</td>
</tr>
<tr>
<td>Junior</td>
<td>13.9%</td>
<td>19.1%</td>
<td>18.8%</td>
</tr>
<tr>
<td>Senior</td>
<td>5.8%</td>
<td>9.6%</td>
<td>6.4%</td>
</tr>
<tr>
<td>Whites</td>
<td>54.3%</td>
<td>54.3%</td>
<td>51.8%</td>
</tr>
<tr>
<td>Hispanic or Latino</td>
<td>19.2%</td>
<td>20.2%</td>
<td>20.1%</td>
</tr>
<tr>
<td>Black or African American</td>
<td>11.1%</td>
<td>7.4%</td>
<td>12.6%</td>
</tr>
<tr>
<td>Asian</td>
<td>11.1%</td>
<td>16.0%</td>
<td>12.2%</td>
</tr>
<tr>
<td>Biology</td>
<td>25.5%</td>
<td>23.4%</td>
<td>26.2%</td>
</tr>
<tr>
<td>Biomedical</td>
<td>33.7%</td>
<td>38.3%</td>
<td>25.9%</td>
</tr>
</tbody>
</table>

Appendix A3. Examination of the academic background of all the students enrolled in first semester general chemistry for AMS-Chemistry, n = 1039

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>Sk</th>
<th>Ku</th>
</tr>
</thead>
<tbody>
<tr>
<td>SATV</td>
<td>800</td>
<td>544.89</td>
<td>76.09</td>
<td>0.17</td>
<td>0.57</td>
</tr>
<tr>
<td>SATM</td>
<td>800</td>
<td>548.81</td>
<td>67.86</td>
<td>-0.09</td>
<td>0.69</td>
</tr>
<tr>
<td>SATT</td>
<td>800</td>
<td>1093.70</td>
<td>125.01</td>
<td>-0.13</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Note: Sk = skewness, Ku = kurtosis
Appendix A4. Examination of the academic background of all the students with complete usable data for AMS-Chemistry at Time 1.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>Sk</th>
<th>Ku</th>
</tr>
</thead>
<tbody>
<tr>
<td>SATV</td>
<td>179</td>
<td>549.61</td>
<td>72.07</td>
<td>-0.29</td>
<td>-0.22</td>
</tr>
<tr>
<td>SATM</td>
<td>179</td>
<td>554.08</td>
<td>72.08</td>
<td>-0.29</td>
<td>1.09</td>
</tr>
<tr>
<td>SATT</td>
<td>179</td>
<td>1103.69</td>
<td>127.30</td>
<td>-0.39</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Note: Sk = skewness, Ku = kurtosis

Appendix A5. Standardized loading from the confirmatory factor analysis for AMS (n = 238)

<table>
<thead>
<tr>
<th>Item</th>
<th>Amotivation</th>
<th>External regulation</th>
<th>Introjected regulation</th>
<th>Identified regulation</th>
<th>To experience</th>
<th>To accomplish</th>
<th>To know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q5</td>
<td>0.869</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q12</td>
<td>0.878</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q19</td>
<td>0.907</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q26</td>
<td>0.825</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q1</td>
<td>0.586</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q8</td>
<td>0.772</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q15</td>
<td>0.751</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q22</td>
<td>0.892</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q7</td>
<td></td>
<td>0.727</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Q14</td>
<td></td>
<td>0.792</td>
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<td></td>
</tr>
<tr>
<td>Q21</td>
<td></td>
<td>0.809</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q28</td>
<td></td>
<td>0.845</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.619</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.616</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.748</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.726</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q4</td>
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<td></td>
<td>0.739</td>
<td></td>
</tr>
<tr>
<td>Q11</td>
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<td></td>
<td></td>
<td></td>
<td>0.784</td>
<td></td>
</tr>
<tr>
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<td></td>
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<tr>
<td>Q25</td>
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<td></td>
<td>0.845</td>
<td></td>
</tr>
<tr>
<td>Q6</td>
<td></td>
<td></td>
<td>0.762</td>
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<td></td>
<td>0.811</td>
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<td></td>
<td></td>
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<td>Q20</td>
<td></td>
<td></td>
<td>0.835</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q27</td>
<td></td>
<td></td>
<td>0.869</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q2</td>
<td></td>
<td>0.731</td>
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<td></td>
<td></td>
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<td>Q16</td>
<td></td>
<td>0.846</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q23</td>
<td></td>
<td>0.843</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. There were correlated errors between q2 and q6, q8 and q10, q11 and q18, q12 and q19
Appendix A6. Fit indices of the confirmatory factor analysis of AMS (n = 238)

<table>
<thead>
<tr>
<th></th>
<th>SBχ^2</th>
<th>df</th>
<th>CFI</th>
<th>SRMR</th>
<th>RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five-factor</td>
<td>1073.81</td>
<td>340</td>
<td>0.80</td>
<td>0.075</td>
<td>0.095</td>
</tr>
<tr>
<td>One-factor</td>
<td>2095.31</td>
<td>350</td>
<td>0.52</td>
<td>0.134</td>
<td>0.145</td>
</tr>
</tbody>
</table>

Appendix A7. Multivariate assumptions and MANOVA

**Multivariate assumption tests and outlier assessments for sex difference based on AMS.**

The tests of the multivariate normality assumption [B_1p = 23.0371, χ^2 (df = 84, n = 238) = 928.14, p < 0.001; B_2p = 102.98, z_{upper} = 27.47, z_{lower} = 25.96] suggested violation of the normality assumption. However, the deviation from multivariate normality has only a small effect on Type I error (Stevens, 2002, p. 262), and given the sample size, multivariate analysis of variance (MANOVA) was expected to be robust to this violation (Stevens, 2002, p. 262). An outlier assessment test revealed two outliers with Mahalanobis distances of 52.36 and 44.14. The MANOVA was rerun without the outliers, but the significant difference test results did not change. Therefore, the complete data set was used for analysis and interpretation.

MANOVA was run with the transformed variable (log(amo\textit{tivation})) and other seven untransformed variables and showed significant differences between males and females: F(7,230) = 2.09, p = 0.046; for the univariate follow up test, females and males differed on amotivation: F(1,236) = 10.13, p = 0.0017. Because the assumption of homogeneity of variance was violated (χ^2 (df = 28) = 114.57, p < 0.001) (Morrison, 1976), and the smaller sample size is associated with larger variance, the violation was not robust for the data. Therefore, n = 93 female students were randomly pulled out, together with the male students (n = 93), and MANOVA was rerun with the original variables and with the transformed variable (amotivation). The significant difference test results did not change. Therefore, it was safe to
conclude that the male and female students were different on a set of the seven motivation variables, and female students scored significantly lower on amotivation.

**Regarding sex difference based on AMS-Chemistry**

Tests of the multivariate normality assumption \( \{B_1p = 6.05, \chi^2 (df = 84, n = 208) = 213.39, p < 0.001; B_2p = 65.92, z_{upper} = 1.87, z_{lower} = 0.32\} \) suggested violation of the normality assumption. However, the deviation from multivariate normality has only a small effect on Type I error (Stevens, 2002), and given the sample size, MANOVA was expected to be robust to this violation (Stevens, 2002, p. 262). An outlier assessment test revealed one outlier with Mahalanobis distance of 20.87. The MANOVA was rerun without the outliers, but the significant difference test results did not change. Therefore the complete data set was used for analysis and interpretation. Since the Chi-Square value is not significant at the 0.1 level, \( (\chi^2 (df = 28, n = 208) = 29.22, p = 0.40) \) suggesting no violations to the homogeneity of variance (Morrison, 1976), a pooled covariance matrix was used in the test.

**Regarding attendance based on AMS-Chemistry.**

Tests of the multivariate normality assumption \( \{B_1p = 6.05, \chi^2 (df = 84, n = 208) = 213.43, p < 0.001; B_2p = 66.49, z_{upper} = 2.24, z_{lower} = 0.68\} \) suggested violation of the normality assumption. However, MANOVA was expected to be robust to this violation (Stevens, 2002, p. 262) given the sample size. An outlier assessment test revealed one outlier with Mahalanobis distance of 21.51. The MANOVA was rerun without the outliers, but the significant difference test results did not change. Therefore the complete data set was used for analysis and interpretation. Regarding the homogeneity of variance assumption, \( (\chi^2 (df = 28, n = 208) = 26.46, p = 0.55) \), suggesting the data did not violate this assumption (Morrison, 1976).
Appendix A8. Correlation studies

The correlations among the subscales are often examined to examine how well the instrument is aligned with SDT. Because the AMS-Chemistry is based on SDT, the intercorrelations between these subscales were expected to display a quasi-simplex pattern: the adjacent subscales would show stronger correlations than subscales that are farther away. At Time 1, the results showed that the adjacent subscales usually had stronger correlations, but with very few deviations as shown in Table A1. Regarding the three intrinsic motivation subscales, strong correlations are expected, and the results showed that the three intrinsic motivation subscales (*to know*, *to accomplish*, and *to experience*) were strongly correlated, $r = 0.84$ or $0.85$ at Time 1. At Time 1, amotivation showed negative correlation with the other subscales because amotivation suggests non-regulated and extrinsic motivation and intrinsic motivation subscales suggest positive regulation.

When AMS-Chemistry was administered at Time 2, the correlations (shown in Table A2) had similar trends but few were significant at an alpha level of 0.01. In general, the correlations suggested that the AMS-Chemistry scores were in accordance with the theory.

Table A1 Intercorrelations for the AMS - Chemistry subscales at Time 1, $n = 208$

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Amotivation</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. External regulation</td>
<td>-0.09</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Introjected regulation</td>
<td>-0.23&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Identified regulation</td>
<td>-0.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. To experience</td>
<td>-0.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.29&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.47&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. To accomplish</td>
<td>-0.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.78&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.53&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7. To know</td>
<td>-0.38&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.53&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.84&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
</tr>
</tbody>
</table>

<sup>a</sup> Correlation is significant at 0.01 level (two-tailed).
Table A2 Intercorrelations for the AMS - Chemistry subscales at Time 2, $n = 94$

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Amotivation</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. External regulation</td>
<td>0.06</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Introjected regulation</td>
<td>-0.22$^a$</td>
<td>0.10</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Identified regulation</td>
<td>-0.37$^a$</td>
<td>0.46$^a$</td>
<td>0.25$^a$</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. To experience</td>
<td>-0.25$^a$</td>
<td>0.08</td>
<td>0.50$^a$</td>
<td>0.37$^a$</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. To accomplish</td>
<td>-0.37$^a$</td>
<td>0.03</td>
<td>0.62$^a$</td>
<td>0.41$^a$</td>
<td>0.84$^a$</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7. To know</td>
<td>-0.42$^a$</td>
<td>0.15</td>
<td>0.48$^a$</td>
<td>0.46$^a$</td>
<td>0.81$^a$</td>
<td>0.85$^a$</td>
<td>1</td>
</tr>
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</table>

$^a$ Correlation is significant at 0.01 level (two-tailed).

References


Appendix B

Appendices for Chapter Four

Appendix B1. The demographics of students enrolled in the courses

<table>
<thead>
<tr>
<th></th>
<th>“Lecture-Based”</th>
<th>FLIP-PLTL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>n</strong></td>
<td>257</td>
<td>240</td>
</tr>
<tr>
<td>Females</td>
<td>158 (61.5%)</td>
<td>152 (63.3%)</td>
</tr>
<tr>
<td>Males</td>
<td>99 (38.5%)</td>
<td>88 (36.7%)</td>
</tr>
<tr>
<td>White</td>
<td>123 (47.9%)</td>
<td>109 (45.4%)</td>
</tr>
<tr>
<td>Hispanic or Latino</td>
<td>44 (17.1%)</td>
<td>54 (22.5%)</td>
</tr>
<tr>
<td>Asian</td>
<td>40 (15.6%)</td>
<td>47 (19.6%)</td>
</tr>
<tr>
<td>Black or African American</td>
<td>27 (10.5%)</td>
<td>14 (5.8%)</td>
</tr>
<tr>
<td>Senior</td>
<td>117 (45.5%)</td>
<td>120 (50%)</td>
</tr>
<tr>
<td>Junior</td>
<td>110 (42.8%)</td>
<td>90 (37.5%)</td>
</tr>
<tr>
<td>Sophomore</td>
<td>26 (10.1%)</td>
<td>29 (12.1%)</td>
</tr>
<tr>
<td>Post Bachelor</td>
<td>3 (1.2%)</td>
<td>1 (0.4%)</td>
</tr>
<tr>
<td>Freshman</td>
<td>1 (0.4%)</td>
<td>0</td>
</tr>
<tr>
<td>Biomedical Sciences</td>
<td>105 (40.9%)</td>
<td>125 (52.1%)</td>
</tr>
<tr>
<td>Cell and Molecular Biology</td>
<td>25 (9.7%)</td>
<td>22 (9.2%)</td>
</tr>
<tr>
<td>Integrative Animal Biology</td>
<td>18 (7.0%)</td>
<td>18 (7.5%)</td>
</tr>
<tr>
<td>Health Sciences</td>
<td>32 (12.5%)</td>
<td>16 (6.7%)</td>
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<tr>
<td>Chemistry/Chemical Engineering</td>
<td>11 (4.3%)</td>
<td>10 (4.2%)</td>
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</table>

Appendix B2. Examination of the academic background of all the students enrolled in two courses

<table>
<thead>
<tr>
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<th>Lecture-Based</th>
<th>Flip-PLTL</th>
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<tr>
<td></td>
<td>SAT_Q</td>
<td>SAT-V</td>
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<tr>
<td><strong>n</strong></td>
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<td>208</td>
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<tr>
<td>M</td>
<td>590.0</td>
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<tr>
<td>SD</td>
<td>74.4</td>
<td>79.5</td>
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### Appendix B3. Descriptive statistics of student motivation based on all students’ responses

<table>
<thead>
<tr>
<th>Data collection</th>
<th>Subscales</th>
<th>M</th>
<th>SD</th>
<th>Sk</th>
<th>Ku</th>
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<tbody>
<tr>
<td><strong>Pre1 n = 235</strong>&lt;br&gt;Amotivation</td>
<td>1.47</td>
<td>0.67</td>
<td>1.73</td>
<td>3.10</td>
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</tr>
<tr>
<td>External regulation</td>
<td>3.79</td>
<td>0.96</td>
<td>-0.79</td>
<td>0.00</td>
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</tr>
<tr>
<td>Introjected regulation</td>
<td>3.53</td>
<td>0.99</td>
<td>-0.43</td>
<td>-0.25</td>
<td></td>
</tr>
<tr>
<td>Identified regulation</td>
<td>4.05</td>
<td>0.75</td>
<td>-0.71</td>
<td>-0.19</td>
<td></td>
</tr>
<tr>
<td>To experience</td>
<td>2.65</td>
<td>1.11</td>
<td>0.24</td>
<td>-0.94</td>
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<tr>
<td>To accomplish</td>
<td>3.18</td>
<td>1.05</td>
<td>-0.07</td>
<td>-0.83</td>
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<tr>
<td>To know</td>
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<td>0.99</td>
<td>-0.11</td>
<td>-0.84</td>
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<tr>
<td><strong>Post1 n = 224</strong>&lt;br&gt;Amotivation</td>
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<td>1.00</td>
<td>1.19</td>
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<tr>
<td>External regulation</td>
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<td>-0.83</td>
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<td>Introjected regulation</td>
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<tr>
<td>To experience</td>
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<td>1.10</td>
<td>0.35</td>
<td>-0.83</td>
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<tr>
<td>To accomplish</td>
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<td>-0.14</td>
<td>-0.86</td>
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<tr>
<td>To know</td>
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<td>1.03</td>
<td>-0.08</td>
<td>-0.79</td>
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<td><strong>Pre2 n = 217</strong>&lt;br&gt;Amotivation</td>
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<td></td>
</tr>
<tr>
<td>External regulation</td>
<td>3.63</td>
<td>1.03</td>
<td>-0.65</td>
<td>-0.28</td>
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</tr>
<tr>
<td>Introjected regulation</td>
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<td>1.00</td>
<td>-0.4</td>
<td>-0.51</td>
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</tr>
<tr>
<td>Identified regulation</td>
<td>3.91</td>
<td>0.86</td>
<td>-0.82</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>To experience</td>
<td>2.65</td>
<td>0.96</td>
<td>0.33</td>
<td>-0.43</td>
<td></td>
</tr>
<tr>
<td>To accomplish</td>
<td>3.19</td>
<td>1.05</td>
<td>-0.06</td>
<td>-0.8</td>
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</tr>
<tr>
<td>To know</td>
<td>3.33</td>
<td>0.94</td>
<td>0.13</td>
<td>-0.64</td>
<td></td>
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<tr>
<td><strong>Post2 n = 190</strong>&lt;br&gt;Amotivation</td>
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<td>0.82</td>
<td>1.74</td>
<td>2.82</td>
<td></td>
</tr>
<tr>
<td>External regulation</td>
<td>3.42</td>
<td>1.05</td>
<td>-0.51</td>
<td>-0.25</td>
<td></td>
</tr>
<tr>
<td>Introjected regulation</td>
<td>3.25</td>
<td>1.05</td>
<td>-0.32</td>
<td>-0.45</td>
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<tr>
<td>Identified regulation</td>
<td>3.61</td>
<td>0.95</td>
<td>-0.53</td>
<td>-0.27</td>
<td></td>
</tr>
<tr>
<td>To experience</td>
<td>2.62</td>
<td>1.00</td>
<td>0.21</td>
<td>-0.67</td>
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</tr>
<tr>
<td>To accomplish</td>
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<td>-0.55</td>
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<tr>
<td>To know</td>
<td>3.09</td>
<td>0.98</td>
<td>-0.16</td>
<td>-0.64</td>
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</tr>
</tbody>
</table>

Note: Sk = skewness, Ku = kurtosis
Appendix C

Appendices for Chapter Five

Appendix C1. Learning Climate Questionnaire (LCQ) (Williams and Deci, 1996)

1. I feel that my instructor provides me choices and options

2. I feel understood by my instructor

3. I am able to be open with my instructor during class

4. My instructor conveyed confidence in my ability to do well in the course

5. I feel that my instructor accepts me

6. My instructor made sure I really understood the goals of the course and what I need to do

7. My instructor encouraged me to ask questions

Note:
8. I feel a lot of trust in my instructor
9. My instructor answers my questions fully and carefully
10. My instructor listens to how I would like to do things
11. My instructor handles people's emotions very well
12. I feel that my instructor cares about me as a person
13. I don't feel very good about the way my instructor talks to me
14. My instructor tries to understand how I see things before suggesting a new way to do things
15. I feel able to share my feelings with my instructor

Note: Items 11, 13, and 15 were not included in the shortened 12-Item LCQ

Appendix C2. Intrinsic Motivation Inventory (IMI) (McAuley, et al., 1989)
1. I would describe these activities as very interesting!
2. I don’t feel like I could really trust my group!
3. These were activities that I couldn’t do very well!
4. After working at these activities for awhile, I thought these activities were quite enjoyable!
5. I felt pretty competent!
6. I felt really distant to my group!
7. I think I am pretty good at these activities
8. It is likely that my group and I could become friends if we interacted a lot!
9. These activities were fun to do!
10. I am satisfied with my performance at these activities!
11. These activities did not hold my attention at all!
12. I feel close to my group!
13. While I was doing these activities, I was thinking about how much I enjoyed it!
14. I’d like a chance to interact with my group more often!
15. I think I did pretty well at these activities, compared to other students!
16. I felt like I could really trust my group!
17. I enjoyed doing these activities very much!
18. I really doubt that people in my group and I would ever be friends!
19. I was pretty skilled at these activities!
20. I thought these were boring activities!
21. I’d really prefer not to interact with my group in the future!

Note: Items 2, 6, 11, 18, and 19 were not included in the shortened 16-Item IMI

Appendix C3. Assumption tests

In Classes C and D, the assumption of multinormality was not violated based on the $p$ values. Since the Chi-square value was not significant at an alpha level of 0.1, as displayed in Table C1, $\chi^2 (df = 10) = 6.11, p = 0.81$, the assumption of homogeneity of variance was not violated for three comparisons (Morrison, 1976). Outlier assessment tests revealed one outlier in each comparison, the MANOVA was rerun without the outlier, but the significant difference test results did not change. Therefore the complete data set was used for MANOVA analysis and results interpretation.
**Table C1** Results from test of assumption of multinormality, homogeneity of variance, and outliers

<table>
<thead>
<tr>
<th>Test of assumption of multinormality</th>
<th>Class C and D</th>
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</thead>
<tbody>
<tr>
<td>$b_{1p}$</td>
<td>1.36</td>
</tr>
<tr>
<td>$\chi^2$ (df=20)</td>
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</tr>
<tr>
<td>$p$</td>
<td>0.43</td>
</tr>
<tr>
<td>$b_{2p}$</td>
<td>24.81</td>
</tr>
<tr>
<td>$z_{upper}$</td>
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</tr>
<tr>
<td>$z_{lower}$</td>
<td>-0.39</td>
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</table>

<table>
<thead>
<tr>
<th>Test of outlier</th>
<th>Mahalanobis Distance (max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi^2$ (df=10)</td>
<td>6.11</td>
</tr>
<tr>
<td>$p$</td>
<td>0.81</td>
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</table>