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

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Fundamentally concerned with motivation, self-determination theory (SDT) represents a framework of several mini-theories to explore how social context interacts with people's motivational types categorized by degree of regulation internalization. This paper aims to modify an existing theory-based instrument (Academic Motivation Scale, or AMS) and provide validity evidence for the modified instrument (Academic Motivation Scale-Chemistry) as a measure of seven types of student motivation toward chemistry. The paper explores how motivation as measured by AMS-Chemistry is related to student academic achievement and attendance. In a pilot study, the unmodified AMS showed good reliability, reasonable data fit, and the ability to detect motivational differences by sex in college chemistry courses. Based on the pilot study results, expert panel discussions, and cognitive interviews with students, the Academic Motivation Scale – Chemistry (AMS-Chemistry) was developed. AMS-Chemistry was administered to university students in a first semester general chemistry course twice within a semester. An examination of validity evidence suggested that the AMS-Chemistry data could be used to investigate student motivation toward chemistry. Results showed students were extrinsically motivated toward chemistry on average, and there was an overall motivational difference favoring males with a medium effect size. Correlation studies showed motivation was not associated with academic achievement at the beginning of the term, but intrinsic motivation subscales (*to know*, *to experience*, and *to accomplish*) were positively associated with academic achievement at the end of the term. Results also showed that students who persisted in class attendance scored higher on intrinsic motivation subscales than those who did not persist. The 28-item 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 the AMS-Chemistry to evaluate the impact of their efforts.

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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

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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 Fig. 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).

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;

Behavior	Nonself-Determined					Self-Determined
Types of Motivation	**Amotivation**	**Extrinsic Motivation**				**Intrinsic Motivation**
Types of Regulation	No Regulation	External Regulation	Introjected Regulation	Identified Regulation	Integrated Regulation	Intrinsic Regulation

Fig. 1 The self-determination continuum, showing types of motivation and associated types of regulation.

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 Fig. 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.

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

Behavior	Nonself-Determined				Self-Determined
Types of Motivation	**Amotivation**		**Extrinsic Motivation**		**Intrinsic Motivation**
Subscales	Amotivation	External Regulation	Introjected Regulation	Identified Regulation	To Know To Accomplish To Experience

Fig. 2 The seven types of motivation measured by AMS.

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' (Juriševič *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 1 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 $\frac{3}{4}$ (77.8%) were freshmen and sophomores, and 60.9% were females. About $\frac{3}{4}$ 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 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 14$^{\text{th}}$ 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 2–4), 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, χ^2 will not be large and significant; however, as χ^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 7.

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 5 and Table 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 confimatory 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), 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) 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 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.

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

Table 1 Internal consistency and characteristics of the seven factors of the AMS (n = 238)

	Amotivation	External regulation	Introjected regulation	Identified regulation	To experience	To accomplish	To know
Cronbach's α	0.90	0.83	0.87	0.77	0.89	0.89	0.89
M	1.40	5.80	5.38	6.10	3.74	5.06	5.57
SD	0.87	1.10	1.37	0.88	1.45	1.28	1.10
Sk	3.13	−1.29	−1.00	−1.47	0.09	−0.64	−0.78
Ku	10.90	1.54	0.57	2.86	−0.77	−0.04	0.37

Note: sk = skewness; ku = kurtosis.

Table 2 The mean, standard deviation, skewness, and kurtosis of the motivation variables in AMS by sex (F = females, M = males)

		Amotivation	External regulation	Introjected regulation	Identified regulation	To experience	To accomplish	To know
F (n = 145)	M	1.24	5.79	5.54	6.18	3.82	5.19	5.65
	SD	0.52	1.05	1.21	0.75	1.42	1.17	1.04
	Sk	3.12	−1.32	−1.02	−1.23	0.08	−0.69	−0.77
	Ku	11.40	2.09	0.78	1.66	−0.78	0.25	0.71
M (n = 93)	M	1.65	5.81	5.13	5.97	3.62	4.86	5.46
	SD	1.20	1.18	1.57	1.06	1.49	1.43	1.19
	Sk	2.23	−1.26	−0.81	−1.37	0.11	−0.48	−0.73
	Ku	4.58	1.00	−0.05	2.16	−0.76	−0.48	−0.08

Note: sk = skewness; ku = kurtosis.

subscale are given in Table 1 for the students in general and in Table 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 2, female students scored slightly higher on all subscales except for *amotivation* and *external regulation*.

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 small, 0.15 medium, 0.35 large) (Cohen, 1988). Univariate follow-up tests (Table 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).

Because the data were non-normal, the scores for *amotivation* were transformed (*log*(*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 for details.

Table 3 Results of univariate follow-up tests by sex based on AMS

Variables	$F(1,236)$	p
Amotivation[a]	12.55	0.0005
External regulation	0.01	0.9367
Introjected regulation	5.29	0.0223
Identified regulation	3.24	0.0729
To experience	1.08	0.3008
To accomplish	3.80	0.0525
To know	1.69	0.1954

[a] Significantly different at 0.0071 level.

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 4.

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 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 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 (χ^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.

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 χ^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 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.

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.

Table 4 Standardized loading from the confirmatory factor analysis of AMS-Chemistry (n = 208)

Item	Factor loading	Statement
Factor: amotivation		
Q5	0.868	Honestly, I don't know; I really feel that I am wasting my time taking chemistry courses.
Q12	0.430	I once had good reasons for taking chemistry courses; however, now I wonder whether I should continue.
Q19	0.652	I don't know why I take chemistry courses, I couldn't care less about them.
Q26	0.631	I don't know; I can't understand what I am doing taking chemistry courses.
Factor: external regulation		
Q1	0.683	Because without having taken chemistry I would not find a high-paying job later on.
Q8	0.867	In order to obtain a better job later on.
Q15	0.859	Because I want to have a well-paying career.
Q22	0.832	In order to have a better salary later on.
Factor: introjected regulation		
Q7	0.837	To prove to myself that I am capable of succeeding in chemistry.
Q14	0.867	Because when I succeed in chemistry I feel smart.
Q21	0.767	To show myself that I am an intelligent person.
Q28	0.883	Because I want to show myself that I can succeed in studying chemistry.
Factor: identified regulation		
Q3	0.745	Because I think that chemistry courses will help me better prepare for the career I have chosen.
Q10	0.625	Because taking chemistry will enable me to enter the job market in a field that I like.
Q17	0.636	Because taking chemistry courses will help me make more informed choices about my career options.
Q24	0.824	Because I believe that chemistry courses will improve my skills in my chosen career.
Factor: to experience		
Q4	0.807	For the feelings I experience when I am communicating chemistry ideas to others.
Q11	0.752	For the pleasure that I experience when I perform chemistry experiments.
Q18	0.725	For the enjoyment I experience when I think about the world in terms of atoms and molecules.
Q25	0.905	For the satisfaction I experience while learning about various chemistry topics.
Factor: to accomplish		
Q6	0.872	For the satisfaction I experience while improving my understanding of chemistry.
Q13	0.818	For the satisfaction I experience while succeeding in chemistry.
Q20	0.862	For the satisfaction I feel as I work toward an understanding of chemistry.
Q27	0.835	Because chemistry courses allow me to experience satisfaction in my quest for knowledge.
Factor: to know		
Q2	0.697	Because I experience pleasure and satisfaction while learning new things.
Q9	0.866	For the pleasure I experience when I learn new things about chemistry.
Q16	0.908	For the pleasure that I experience in broadening my knowledge about chemistry.
Q23	0.617	Because studying chemistry allows me to continue to learn about things that interest me.

Table 5 Fit indices of the confirmatory factor analysis of AMS-Chemistry (n = 208)

	χ^2	df	χ^2 change	Δdf	CFI	SRMR	RMSEA
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

Table 6 Internal consistency reliability for the seven factors of the AMS-Chemistry

	Cronbach's alpha	
	Time 1 (n = 208)	Time 2 (n = 94)
Amotivation	0.74	0.86
External regulation	0.88	0.90
Introjected regulation	0.90	0.83
Identified regulation	0.79	0.79
To experience	0.88	0.88
To accomplish	0.91	0.90
To know	0.86	0.84

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 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*

Table 7 The descriptive statistics for the subscales of AMS-Chemistry at Times 1 and 2

	Time 1 (n = 208)				Time 2 (n = 94)			
	M	SD	Sk	Ku	*M*	SD	Sk	Ku
Amotivation	1.64	0.74	1.30	1.51	1.81	0.93	0.95	−0.14
External regulation	3.81	0.94	−0.77	0.24	3.46	1.07	−0.59	−0.25
Introjected regulation	3.39	1.07	−0.37	−0.63	3.13	0.98	0.11	−0.45
Identified regulation	3.94	0.82	−0.88	0.63	3.68	0.95	−0.65	0.23
To experience	2.45	1.00	0.47	−0.26	2.56	1.05	0.40	−0.54
To accomplish	2.95	1.04	−0.04	−0.52	2.97	1.02	0.20	−0.46
To know	3.00	0.95	0.02	−0.49	3.08	0.97	0.10	−0.60

Note: sk = skewness; ku = kurtosis.

(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.

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 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 subscales (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 7 (see Table 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 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, Λ = 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 subscales at 0.007 alpha level. The effect sizes for differences between females and males, as shown by Cohen's d values in Table 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.

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 9.

The magnitudes of the correlations as shown in Table 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

Table 8 Female and male students' motivation structure at Time 1 based on AMS-Chemistry

	F, n = 129		M, n = 79		
	M	SD	*M*	SD	Cohen's d
1. Amotivation	1.64	0.72	1.64	0.79	0
2. External regulation	3.80	0.93	3.82	0.97	0.02
3. Introjected regulation	3.46	1.10	3.27	1.02	0.18
4. Identified regulation	3.99	0.80	3.85	0.85	0.17
5. To experience	2.33	0.99	2.64	0.99	0.31
6. To accomplish	2.92	1.08	3.00	0.97	0.08
7. To know	2.87	0.99	3.22	0.84	0.38

Table 9 Correlation of AMS-Chemistry subscales with Exam scores

	Exam 1, n = 208	Exam 3, n = 94
1. Amotivation	−0.08	−0.22[b]
2. External regulation	−0.03	0.07
3. Introjected regulation	−0.04	0.13
4. Identified regulation	0.03	0.16
5. To experience	0.02	0.34[a]
6. To accomplish	0.08	0.35[a]
7. To know	0.07	0.33[a]

[a] Correlation is significant at 0.01 level (two-tailed). [b] Correlation is significant at 0.05 level (two-tailed).

Table 10 The means and standard deviations of the subscales of AMS-Chemistry for students with both scores at Times 1 and 2

	Time 1			Time 2			
	M^a	SD	r_1^b	M^a	SD	r_2^c	Cohen's d^e
1. Amotivation	1.51	0.67	−0.04	1.72	0.78	−0.14	0.29
2. External regulation	3.62	0.94	−0.15	3.93	0.93	0.08	0.33
3. Introjected regulation	3.31	0.97	−0.09	3.44	1.13	0.06	0.12
4. Identified regulation	3.97	0.76	−0.02	3.91	0.86	0.19	0.07
5. To experience	2.53	0.98	0.07	2.39	1.01	0.36^d	0.14
6. To accomplish	3.02	1.00	0.13	2.90	1.06	0.30^d	0.12
7. To know	3.11	0.97	0.06	2.93	0.93	0.32^d	0.19

^{a} n = 76. ^{b} n = 75. ^{c} n = 74. ^{d} Correlation is significant at 0.01 level (two-tailed). ^{e} Effect size for the mean differences.

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 10. The correlations showed similar trends compared with Table 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.

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 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.

MANOVA conducted with ''attenders'' and ''absent'' groups showed that the difference in means on the set of seven subscales was statistically significant, Λ = 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.

Table 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

	Attenders, n = 83		Absent, n = 125		
Attendance	M	SD	M	SD	Cohen's d
1. Amotivation	1.51	0.67	1.72	0.78	0.29
2. External regulation	3.62	0.94	3.93	0.93	0.33
3. Introjected regulation	3.31	0.97	3.44	1.13	0.12
4. Identified regulation	3.97	0.76	3.91	0.86	0.07
5. To experience	2.53	0.98	2.39	1.01	0.14
6. To accomplish	3.02	1.00	2.90	1.06	0.12
7. To know	3.11	0.97	2.93	0.93	0.19

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) 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 (Juriševič *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.

Appendices

Appendix 1. 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.

Does not correspond at all	Corresponds a little		Corresponds moderately	Corresponds a lot		Corresponds exactly
1	2	3	4	5	6	7

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
3.	Because I think that a college education will help me better prepare for the career I have chosen.	1	2	3	4	5	6	7
4.	For the intense feelings I experience when I am communicating my own ideas to others.	1	2	3	4	5	6	7
5.	Honestly, I don't know; I really feel that I am wasting my time in school.	1	2	3	4	5	6	7
6.	For the pleasure I experience while surpassing myself in my studies.	1	2	3	4	5	6	7
7.	To prove to myself that I am capable of completing my college degree.	1	2	3	4	5	6	7
8.	In order to obtain a more prestigious job later on.	1	2	3	4	5	6	7
9.	For the pleasure I experience when I discover new things never seen before.	1	2	3	4	5	6	7
10.	Because eventually it will enable me to enter the job market in a field that I like.	1	2	3	4	5	6	7
11.	For the pleasure that I experience when I read interesting authors.	1	2	3	4	5	6	7
12.	I once had good reasons for going to college; however, now I wonder whether I should continue.	1	2	3	4	5	6	7
13.	For the pleasure that I experience while I am surpassing myself in one of my personal accomplishments.	1	2	3	4	5	6	7
14.	Because of the fact that when I succeed in college I feel important.	1	2	3	4	5	6	7
15.	Because I want to have "the good life" later on.	1	2	3	4	5	6	7
16.	For the pleasure that I experience in broadening my knowledge about subjects which appeal to me.	1	2	3	4	5	6	7
17.	Because this will help me make a better choice regarding my career orientation.	1	2	3	4	5	6	7
18.	For the pleasure that I experience when I feel completely absorbed by what certain authors have written.	1	2	3	4	5	6	7
19.	I can't see why I go to college and frankly, I couldn't care less.	1	2	3	4	5	6	7
20.	For the satisfaction I feel when I am in the process of accomplishing difficult academic activities.	1	2	3	4	5	6	7
21.	To show myself that I am an intelligent person.	1	2	3	4	5	6	7
22.	In order to have a better salary later on.	1	2	3	4	5	6	7
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 2. Demographics of participants compared with all the students enrolled (population) for AMS-Chemistry

	Participants at Time 1 (n = 208)	Participants at Time 2 (n = 94)	Population (n = 1039)
Female	62.0%	62.8%	60.4%
Male	38.0%	37.2%	39.6%
First-year	34.6%	31.9%	39.0%
Sophomore	43.8%	36.2%	32.4%
Junior	13.9%	19.1%	18.8%
Senior	5.8%	9.6%	6.4%
White	54.3%	54.3%	51.8%
Hispanic or Latina/o	19.2%	20.2%	20.1%
Black or African American	11.1%	7.4%	12.6%
Asian	11.1%	16.0%	12.2%
Biology	25.5%	23.4%	26.2%
Biomedical Sciences	33.7%	38.3%	25.9%

Appendix 3. Examination of the academic background of all the students enrolled in first semester general chemistry for AMS-Chemistry, n = 1039

	n	M	SD	Sk	Ku
SATV	800	544.89	76.09	0.17	0.57
SATM	800	548.81	67.86	−0.09	0.69
SATT	800	1093.70	125.01	−0.13	0.55

Note: Sk = skewness, Ku = kurtosis.

Appendix 4. Examination of the academic background of all the students with complete usable data for AMS-Chemistry at Time 1

	n	M	SD	Sk	Ku
SATV	179	549.61	72.07	−0.29	−0.22
SATM	179	554.08	72.08	−0.29	1.09
SATT	179	1103.69	127.30	−0.39	0.66

Note: Sk = skewness, Ku = kurtosis.

Appendix 5. Standardized loading from the confirmatory factor analysis for AMS (n = 238)

	Factor loading						
Item	Amotivation	External regulation	Introjected regulation	Identified regulation	To experience	To accomplish	To know
Q5	0.869						
Q12	0.878						
Q19	0.907						
Q26	0.825						
Q1		0.586					
Q8		0.772					
Q15		0.751					
Q22		0.892					
Q7			0.727				
Q14			0.792				
Q21			0.809				
Q28			0.845				
Q3				0.619			
Q10				0.616			
Q17				0.748			
Q24				0.726			
Q4					0.739		
Q11					0.784		
Q18					0.801		
Q25					0.845		
Q6						0.762	
Q13						0.811	
Q20						0.835	
Q27						0.869	
Q2							0.731
Q9							0.835
Q16							0.846
Q23							0.843

Note: there were correlated errors between q2 and q6, q8 and q10, q11 and q18, q12 and q19.

Appendix 6. Fit indices of alternative confirmatory factor analyses of AMS (n = 238)

	SBχ^2	df	CFI	SRMR	RMSEA
Five-factor	1073.81	340	0.80	0.075	0.095
One-factor	2095.31	350	0.52	0.134	0.145

Appendix 7. 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(*amotivation*)) 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, χ^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, (χ^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, χ^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, (χ^2 (df = 28, n = 208) = 26.46, p = 0.55), suggesting the data did not violate this assumption (Morrison, 1976).

Appendix 8. 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

	1	2	3	4	5	6	7
1. Amotivation	1						
2. External regulation	−0.09	1					
3. Introjected regulation	−0.23[a]	0.40[a]	1				
4. Identified regulation	−0.50[a]	0.58[a]	0.50[a]	1			
5. To experience	−0.28[a]	0.29[a]	0.63[a]	0.47[a]	1		
6. To accomplish	−0.33[a]	0.34[a]	0.78[a]	0.53[a]	0.85[a]	1	
7. To know	−0.38[a]	0.27[a]	0.63[a]	0.53[a]	0.84[a]	0.85[a]	1

[a] Correlation is significant at 0.01 level (two-tailed).

Table A2 Intercorrelations for the AMS-Chemistry subscales at Time 2, n = 94

	1	2	3	4	5	6	7
1. Amotivation	1						
2. External regulation	0.06	1					
3. Introjected regulation	−0.22[a]	0.10	1				
4. Identified regulation	−0.37[a]	0.46[a]	0.25[a]	1			
5. To experience	−0.25[a]	0.08	0.50[a]	0.37[a]	1		
6. To accomplish	−0.37[a]	0.03	0.62[a]	0.41[a]	0.84[a]	1	
7. To know	−0.42[a]	0.15	0.48[a]	0.46[a]	0.81[a]	0.85[a]	1

[a] Correlation is significant at 0.01 level (two-tailed).

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