2024

PROFILES OF SATISFACTION AND FRUSTRATION OF UNDERGRADUATE GENERAL CHEMISTRY STUDENTS' BASIC PSYCHOLOGICAL NEEDS AT THE BEGINNING AND END OF THE SEMESTER

Cara E. Worick
University of Kentucky, cara.worick@uky.edu
Author ORCID Identifier:
https://orcid.org/0000-0002-6567-5370
Digital Object Identifier: https://doi.org/10.13023/etd.2024.13

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Cara E. Worick, Student

Kenneth M. Tyler, Major Professor

Sharon S. Rostosky, Director of Graduate Studies

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DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Education
at the University of Kentucky

By

Cara Elizabeth Worick

Lexington, Kentucky

Co- Directors: Dr. Kenneth M. Tyler, Professor of Educational Psychology

and Dr. Peggy S. Keller, Associate Professor of Psychology

Lexington, Kentucky

2023

https://orcid.org/0000-0002-6567-5370

ABSTRACT OF DISSERTATION

PROFILES OF SATISFACTION AND FRUSTRATION OF UNDERGRADUATE GENERAL CHEMISTRY STUDENTS' BASIC PSYCHOLOGICAL NEEDS AT THE BEGINNING AND END OF THE SEMESTER

The early college years represent an adjustment period characterized by motivational destabilization and academic and career-related uncertainty for many STEM majors (Robinson et al., 2019). Although students who begin college less academically prepared than their peers are at greater risk of struggling in introductory STEM courses, many still struggle in these courses despite adequate academic preparation (Perez et al., 2014). Self-determination theory proposes that motivation, optimal functioning, and psychological well-being occur through the satisfaction, as opposed to the frustration, of three basic psychological needs for autonomy, competence, and relatedness (Ryan & Deci, 2020). Although many studies in educational settings demonstrate the positive outcomes associated with need satisfaction, little is known about need frustration and how it may be experienced simultaneously with need satisfaction within the same learning context. Therefore, this study aims to examine individual differences in basic psychological need satisfaction and frustration as possible mechanisms underlying variation in STEM student motivation, psychological adjustment, and intentions to persist.

Specifically, in these two studies, profiles are defined at both the beginning and end of the semester based on satisfaction and frustration of students' needs for autonomy, competence, and relatedness while simultaneously examining their associations with students' perceptions of the learning environment, motivation, psychological adjustment, and intentions to persist in STEM.

Three distinct profiles of students' satisfaction and frustration of basic psychological needs were identified at each time point in the academic semester. Profile characteristics were similar at each time point yet varied in size. One profile was characterized by need frustration prevailing over need satisfaction. A second characterized by need satisfaction prevailing over need frustration. The third profile was characterized by moderate levels of both satisfaction and frustration. The moderately satisfied and

frustrated profiles were the largest groups at both time points. Furthermore, perceptions of the learning environment predicted profile membership and need profile membership was associated with distinct motivational, psychological adjustment, and academic outcomes at each time point. Implications of these profiles in understanding variation in motivation, persistence, and student well-being for STEM students are discussed.

KEYWORDS: Self-Determination Theory, Basic Psychological Need Satisfaction and Frustration, Academic Motivation, Latent Profiles, Undergraduate Students, Persistence

Cara Elizabeth Worick

(Name of Student)

10/10/23

Date

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By
Cara Elizabeth Worick

Kenneth M. Tyler, Ph.D.
Co-Director of Dissertation

Peggy S. Keller, Ph.D.
Co-Director of Dissertation

Sharon S. Rostosky, Ph.D.
Director of Graduate Studies

10/10/23
Date

ACKNOWLEDGMENTS

The expression, “It takes a village,” has never been more fitting. And I would like to acknowledge the village of support that made this dissertation possible. First, I would like to extend my deepest gratitude to my primary mentors Dr. Peggy Keller and Dr. Kenneth Tyler for their mentorship, wisdom, care, and encouragement. Dr. Tyler, thank you for your invitation to explore my identity as a scholar, educator, and citizen. Your encouragement and wisdom expanded my thinking in immeasurable ways. Dr. Keller, thank you for your generosity, kindness, and for always encouraging me to continue making steady progress toward my goals. Not only did you make me excited about statistics but you made me believe in myself as a writer, statistician, and scholar.

Thank you to my dissertation committee for assisting with the planning and execution of this project, as well as for the professional guidance I received along the way.

Thank you to every one of my family and friends. Your support and encouragement were instrumental in helping me remain motivated. I would especially like express my sincerest thanks to Jason, Megan, Sharla, and Rich, for the hours spent listening to me talk endlessly about academic topics, keeping me grounded, and for making me laugh along the way. Each of you made me feel understood, loved, and supported on this journey.

And lastly, I would like to thank each of the informal mentors in my life both before and during my doctoral education. I am particularly thankful to my former colleagues, Kathryn, Bill, David, Chris, Ashely, and Kathi. Without each of you encouraging my ideas and believing in my capabilities, I would have never pursued this path.

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CHAPTER 1. INTRODUCTION

1.1 Introduction to the Problem

Improving student persistence in science, technology, engineering, and mathematics (STEM) degree programs has been a major focus of educational reform in the United States for decades (National Science Board, 2022). Focus on improving STEM education has remained a central issue because the number of STEM college graduates continues to lag behind the rapidly increasing need for qualified STEM professionals in the national workforce. In fact, the shortage of qualified STEM professionals has been projected to reach two million between 2015-2025 if successful interventions do not improve current graduation rates (Giffi et al., 2015). Furthermore, in 2012, former President Barack Obama's Council of Advisors on Science and Technology (PCAST) estimated that to meet national workforce demands, and to remain competitive in the global economy, colleges and universities need to increase the number of STEM degrees awarded annually by 34%. Unfortunately, many students motivated to pursue STEM pathways continue to abandon their original career goals at alarmingly high rates. To illustrate, national data shows that, on average, only 50% of incoming STEM majors graduate with a degree in their original program of study (National Sciene Foundation, 2019). Thus, the paradox between an increasing number of opportunities in lucrative, high status STEM careers and students' motivations to leave those career pathways is an issue that needs further examination.

1.1.1 Why Students Leave STEM

The reasons students abandon their STEM career goals is complex. For example, scholars have cited course-level factors such as instructors' pedagogical style and

institutional factors such as quality of academic advising and recommended course loads as barriers to persistence (Sithold et al., 2017). In addition, student-level factors such as variation in math preparedness and motivation (e.g., intrinsic motivation, extrinsic motivation, self-efficacy), and belonging uncertainty also predict persisting with or abandoning STEM (Chen et al., 2013). However, even students who are academically prepared and highly motivated still choose to leave STEM their majors, illustrating the need of a more comprehensive understanding of individual differences in students' experiences and decisions to persist.

One factor repeatedly found to predict the likelihood of remaining on a STEM trajectory is success in large-enrollment introductory STEM courses (Chen & Soldner, 2013). Withdrawing or failing one of these foundational STEM courses increases the probability that a STEM student will drop out of college altogether, whereas low grades increase the chance of them changing their major to social sciences, humanities, business, or professional programs (Ost, 2010; Sithole et al., 2017). These courses are often referred to as "gateway" courses since they reduce student motivation and become barriers to persisting in STEM. Specifically, introductory General Chemistry is a foundational science course that is often required for undergraduate STEM majors. Research has shown that introductory general chemistry courses are often quite challenging with students receiving grades of D or F more frequently than in other STEM courses (50% compared to 33.4%) (Cracolice, & Busby, *2015*). These findings suggest student experiences in introductory general chemistry courses may play an important role in reducing student motivation to remain in STEM fields.

1.2 Self-Determination Theory

The three primary assumptions of Self-Determination Theory are: (1) humans instinctively strive for growth and development, (2) self-determined motivation is essential for growth and human flourishing, and (3) the presence or absence of self-determination results from the satisfaction or frustration or three basic psychological needs for autonomy, competence, and relatedness (Deci & Ryan, 2000). Autonomy refers to feeling volition and ownership over choices and actions (satisfaction of need) opposed to feeling controlled or coerced by external pressures (frustration of need). Competence involves feeling capable and effective in the pursuit of desired outcomes (satisfaction of need) rather than feeling incompetent and lacking confidence in one's abilities (frustration of need). Relatedness refers to experiencing mutually caring and genuine bonds with other people (satisfaction of need) rather than feeling alone or rejected (frustration of need). The satisfaction of these three universal psychological needs is required for self-determined motivation, growth, and positive functioning. When needs are unsatisfied or actively frustrated people suffer, experiencing negative motivational, emotional, and behavioral outcomes (Ryan & Deci, 2017). Decades of research in a variety of domains, including education, support the assertion that the degree to which individuals experience self-determined motivation, and positive or negative outcomes is determined by the extent to which these basic psychological needs are satisfied or frustrated (Ryan & Deci, 2020).

Moreover, SDT asserts that motivations range from autonomous (higher quality, "want to" motives that are more self-determined) to more controlled (lower quality, "have to" motives that are less self-determined) (Ryan & Deci, 2017). Self-determination is fully autonomous among students with intrinsic motivation, and slightly decreases across three

sub-types of extrinsic motivation, including identified, introjected, and external regulations. When intrinsically motivated, the drive to learn and engage in academic activities comes from within because it is inherently enjoyable, interesting, and personally satisfying. In contrast, extrinsic motivations are driven by external factors with learning and engagement seen as necessary for a desired outcome or achievement. Identified regulation is an autonomous motivation, that is somewhat self-determined, with the student putting forth effort and engaging in academics because it is seem as valuable and useful for their academic and professional goals. Introjected regulation is a controlled motivation that is moderately self-determined and is driven by a desire to gain approval, live up to the standards or expectations of others, or to avoid feeling shame or guilt. External regulation the most controlled motivation, with low levels of self-determination, because academic engagement is motivated purely by obtaining external rewards (e.g., high grades) or avoiding punishment (e.g., academic probation). Amotivation is the final and least adaptive form of motivation because motivation and self-determination are absent resulting in students being unregulated and failing to put forth any effort toward academic work (Deci & Ryan, 2017).

Research has shown that the satisfaction of students' basic psychological needs creates the conditions for students to experience a number of positive outcomes, including more autonomous, self-determined motivations, persistence on academic tasks, improved performance, and greater well-being (Cheon et al., 2019; Reeve & CHeon, 2021). In contrast, students with low satisfaction of psychological needs is associated with negative outcomes including controlled motivations and amotivation, less resilience during times of difficulty, poorer performance, and greater intentions of dropping out of college (Gillet et

al., 2020). Moreover, when students feel instructor teaching style is autonomy supportive they experience need satisfaction across all three needs (Reeve & Cheon, 2021).

1.3 The Current Studies

Importantly, SDT researchers have recently suggested that low need satisfaction does not necessitate need frustration and is a unique construct with unique outcomes (Vansteenkiste et al., 2020). Since need frustration is hypothesized to be a distinct construct it should have different antecedents and consequences than low need satisfaction. Very little research has explored how need satisfaction and frustration of all three needs jointly operate as complex configurations of need-based experiences to explain individual differences in need-based experiences. Several studies outside of education have taken this approach using a person-centered approach and found that distinct need profiles explain differences in positive and negative outcomes including motivational differences, psychological well-being, and optimal functioning (Rouse et al., 2020; Warburton et al., 2020). However, no research to date has employed a person-centered approach to identify profiles of need satisfaction and frustration and the associations of those profiles with important educational variables in introductory STEM courses, such as General Chemistry. This dissertation aims to fill that gap by: (1) identifying profiles of students' satisfaction and frustration of their basic psychological needs for autonomy, competence, and relatedness in General Chemistry at both the beginning and end of the academic semester, (2) assess student perceptions of their both their learning and personal environments as predictors of need profile membership, and (3) to explore associations between need profile membership on relevant educational outcomes, including the quality of their academic

motivation (autonomous, controlled, amotivated), psychological adjustment in General Chemistry (e.g., resilience and stress), expected grades, and intentions to persist in their major.

CHAPTER 2. STUDY 1 - UNDERGRADUATE GENERAL CHEMISTRY STUDENTS' BASIC PSYCHOLOGICAL NEED PROFILES AT THE BEGINNING OF THE SEMESTER

2.1 Introduction

Self-determination theory (SDT; Deci & Ryan, 2000) proposes that autonomous motivation, goal-directed behavior, and optimal development emerges from satisfaction – as opposed to frustration – of the psychological needs for autonomy, competence, and relatedness. Recent theoretical and empirical advancements emphasize that satisfaction and frustration of a given need are not opposite poles on a spectrum, but instead can co-occur in the same setting (Bartholomew et al., 2011; Vansteenkiste & Ryan, 2013). However, although an extensive body of research has shown that satisfaction of the three basic psychological needs is associated with positive outcomes, including motivation, academic performance, and psychological adjustment (e.g., Corpus et al., 2020), very little is known about frustration of needs as a distinct construct. A critical open question is how satisfaction and frustration of each psychological need combine into different student profiles, and how these profiles relate to important educational variables. The current study addresses this gap by: (1) identifying within- person combinations of satisfaction and frustration of autonomy, competence, and relatedness (i.e., profiles) at the beginning of the academic semester in the context of undergraduate chemistry courses, (2) testing student perceptions of autonomy supportive learning environments as a predictor of profile membership, and (3) examining associations between psychological need profile membership with relevant educational variables including quality of motivation (e.g., intrinsic, amotivated), academic stress, resilience, and intentions to persist in current major.

2.1.1 Self-Determination Theory

According to self-determination theory (SDT; Deci & Ryan, 2000), individuals can be inquisitive, effective, proactive in their development, and can thrive as a result. They can also be disinterested, depleted, ineffective, languishing, and vulnerable to poor psychological health. The degree to which someone experiences optimal or non-optimal motivational, emotional, and behavioral outcomes depends upon the satisfaction or frustration of three basic psychological needs for autonomy, competence, and relatedness. Autonomy refers to feeling volition and ownership over choices and behaviors (satisfaction of need) rather than feeling controlled and coerced by external pressures (frustration of need). Competence refers to feeling effective and capable of successfully achieving desired outcomes (satisfaction) rather than feeling incompetent or lacking efficacy (frustration). Relatedness refers to feeling closeness and genuine connections with others (satisfaction) rather than feeling rejected or isolated (frustration). Furthermore, the satisfaction of each psychological need represents more than a desired or preferred psychological state; instead, satisfaction of these needs is a fundamental requirement for motivation, growth, and well-being (Ryan & Deci, 2017).

In educational settings, satisfaction of needs leads to student internalization of formerly external standards for performance, and higher autonomous motivation, engagement in academic work, persistence in academic tasks, and wellbeing (Cheon et al., 2019; Cheon et al., 2020; Reeve & Cheon, 2021). For example, if students in a large introductory science course experiences need satisfaction, they are more likely to see the value in learning course content and performing well on assignments and exams, be interested in the subject, have the desire to engage, and have the energy to put forth the

effort necessary to succeed, even when it is challenging. In contrast, low satisfaction of basic psychological needs yields poorer outcomes, including more controlled forms of motivation (i.e., doing something because it is expected or will allow them to obtain an external reward) and amotivation (Bureau et al., 2022), less resilience when faced with challenges (Neufeld et al., 2020), and greater intention to dropout of college (Gillet et al., 2020). For example, when students in large introductory science courses experience low need satisfaction, they may fail to see the value in learning about the subject or completing course assessments, only desire to complete the necessary assignments and requirements to pass the course, and engagement in course activities may feel effortful and draining. Importantly, all three of students' psychological needs are more likely to be satisfied when they view the learning environment as autonomy-supportive (Jang et al., 2016; Vansteenkiste, Niemiec, & Soenens, 2010). Autonomy supportive learning environments encourage students to view themselves rather than instructors as the primary agents in learning, help students develop the skills needed to monitor their learning and strategies they can use to achieve learning, and may empower students with decision-making opportunities such as choosing from a menu of assignments or offering feedback that affects the course (Reeve & Cheon, 2021).

However, low need satisfaction does not necessarily imply need frustration. Low need satisfaction suggests an absence of need satisfaction whereas need frustration requires that the basic psychological needs are under threat (Vansteenkiste et al., 2020). Importantly, as distinct constructs, the absence of need satisfaction should have different antecedents and consequences than experiences of need frustration. There has been very little research on how different experiences of need satisfaction and frustration are related

to psychological and educational outcomes. One possibility is that lower satisfaction without higher frustration of needs conveys less risk than the combination of lower satisfaction and higher frustration. The implication is that studying both need satisfaction and frustration may provide a greater understanding of the role of fundamental psychological needs. Bartholomew and colleagues' (2011) was the first to support the conceptualization by directly measure both need satisfaction and frustration as distinct constructs in a sample of athletes. Need satisfaction and frustration had only a moderate negative association, supporting the hypothesis of an asymmetrical relationship. In addition, need frustration was more predictive of maladjustment and ill-being (e.g., burnout, negative affect), explaining additional variance above that of low need satisfaction.

Need frustration has also been shown to predict ill-being and poorer everyday functioning in samples of university students, including associations with controlled forms of motivation (Neufeld et al., 2020), self-regulatory costs in career-related goal pursuits (Holding et al., 2020), and psychological distress (e.g., stress, anxiety, and depression) (Campbell et al., 2017; Gilbert et al., 2021; Vandenkerckhove et al., 2019). Thus, a student's growth and potential for success may be stunted by low need satisfaction, but experiencing need frustration can result in poor academic outcomes and come with an additional cost of deteriorating that student's psychological health and functioning. Frustration and satisfaction of needs may have different antecedents (e.g., features of the environment) and consequences (e.g., motivational, emotional, and behavioral). Therefore, SDT researchers have called for additional studies examining the unique effects of need satisfaction and need frustration on psychological growth, functioning and adverse

outcomes across domains, including education (Vansteenkiste & Ryan, 2013; Vansteenkiste et al., 2020).

2.1.2 Profiles of Need Satisfaction and Frustration

Answering this call involves further exploring how satisfaction and frustration of autonomy, competence, and relatedness combine within applied educational settings and predict outcomes. Although variable-centered methods are valuable for understanding the unique contribution of need satisfaction, frustration, and their interaction in predicting positive and negative outcomes, SDT proposes that optimal functioning will only occur when all three needs are satisfied, and that if some needs are not fully satisfied, or are actively frustrated, people become vulnerable to a host of negative outcomes (Vansteenkiste & Ryan, 2013). This dynamic, multidimensional conceptualization is better-suited for a person-centered approach where the independent, yet co-occurring, effects of satisfaction and frustration for each need can be modeled simultaneously within- and between-students who have diverse backgrounds and experiences rather than only examining the additive effects of satisfaction and frustration and their interaction (Rouse et al., 2020). According to Rouse et al. (2020), different profiles of need satisfaction and frustration were identified, supporting the proposition that satisfaction and frustration are distinct constructs, and each profile having unique associations with positive and negative outcomes.

The benefits of using a person-centered approach to describe individual differences in needs-based experiences and to identify sub-groups of students characterized by similar satisfaction-frustration experiences are theoretical and practical. First, this approach offers insight into how satisfaction and frustration constructs co-occur and relate to relevant

outcomes, advancing theoretical understanding. Second, exploring this co-occurrence among students in actual rather than experimental educational settings would allow for targeted interventions that support growth, positive development, and thriving (Vansteenkiste et al., 2020; Warburton et al., 2020). Despite these benefits, studies using person-centered methods for examining the dynamic co-occurence of need satisfaction and frustration (i.e., profiles) are limited.

One exception is a study within the domain of physical activity. Warburton et al. (2020) employed hierarchical cluster analysis to identify sub-groups based on need satisfaction and frustration and tested their simultaneous associations with motivation, well-being, and ill-being in two samples (high school Physical Education students and members of an athletic club participating in leisure sports). Among the high school students, analyses identified three distinct clusters: (1) a low satisfaction and high frustration cluster (35.7% of the sample), which had the highest controlled motivations (external regulation) and amotivation; (2) a high satisfaction and low frustration cluster (37.6% of the sample), which reported the highest levels of autonomous motivation (e.g., intrinsic and identified motivations); and (3) a moderate satisfaction and frustration cluster (27.7% of the sample) falling in between the two extreme groups in terms of their motivation. Although this study offers insight into qualitatively different experiences of need satisfaction and frustration and the varied associations with motivational outcomes, a limitation of this study is that measures of satisfaction and frustration assessed all three needs in combination rather than providing separate measures for each need. This leaves open questions about the unique contributions of each psychological need in defining profiles.

One study in the domain of work addressed this limitation, identifying profiles of need satisfaction and frustration among firefighters using latent profile analysis (Rouse et al., 2020). Five profiles emerged from the data: (1) a profile with higher overall need satisfaction and low frustration for all three needs (26% of the sample); (2) a profile with very high relatedness satisfaction, above average satisfaction for autonomy and competence and below average frustration on all needs (39% of the sample); (3) a profile with high competence satisfaction but higher than average autonomy and relatedness frustration (6% of the sample); (4) a profile with high competence frustration and below average satisfaction on all three needs (20% of the sample); and (5) a group with low overall satisfaction and the highest need frustration for all three needs (9% of the sample). Profiles characterized by higher need satisfaction than need frustration (profiles 1 and 2) experienced the best outcomes, including lower work-related stress, anxiety, and depression, and greater life satisfaction. In contrast, profiles with greater need frustration than satisfaction (profiles 4 and 5) had the poorest psychological functioning.

In the domain of education, one study examined profiles of changing need frustration and satisfaction from the beginning to the end of an academic semester among French university students (Chevrier & Lannegrand, 2021). Using latent class analysis, four profiles were identified: (1) high need satisfaction and low frustration of all three needs (40.65% of the sample), which remained stable across time; (2) high autonomy frustration with moderate levels of satisfaction of all needs and moderate frustration of competence and relatedness needs which experienced declines in autonomy frustration (25.61% of the sample); (3) moderate need satisfaction and frustration for all three needs at the beginning of the semester which transitioned to high frustration across all three needs

by the end of the semester (21.14% of the sample); and (4) low satisfaction and high frustration across all three needs at the beginning of the semester who transitioned to higher satisfaction and less frustration at the end of the semester. The first profile (high satisfaction and low frustration across all three needs) was associated with the highest autonomous motivation. The fourth profile (low satisfaction and high frustration at the beginning of the semester) was associated with the highest levels of amotivation.

Another education-based study used latent profiled analysis to examine need satisfaction profiles for autonomy, competence, and relatedness among a sample of first-year students at a French university (Gillet et al., 2020). Although this study did not include need frustration in their analysis, the identified profiles were similar to findings from Rouse et al. (2020). Five profiles emerged from the data: (1) a profile that was highly satisfied across all three needs (13.64% of the sample); (2) a profile that was moderately satisfied overall with scores for autonomy, competence, and relatedness being close to the average (21.69% of the sample); (3) a profile that was high in relatedness satisfaction but low in competence satisfaction (17.94% of the sample); (4) a profile that was globally dissatisfied but especially low in relatedness satisfaction (37.86% of the sample); and (5) a profile that was globally satisfied across the needs, but was especially high in relatedness satisfaction (8.87% of the sample). The best outcomes were associated with profiles 1 (highly satisfied) and 5 (highly satisfied with particularly high relatedness satisfaction). Students in these profiles had higher levels of interest in their studies, attended class more frequently, and reported the lowest levels of dropout intentions. The least desirable outcomes were associated with profile 3 (high relatedness satisfaction but competence deficient). Students

in this profile reported very little interest in their studies, attended class the least, and reported high intentions to drop out of college.

The aforementioned studies support the theoretical proposition that experiences of need satisfaction and frustration can be asymmetrical with low need satisfaction not being indicative of high need frustration. Importantly, the studies that assessed each need separately instead of combining them into a single satisfaction or frustration construct clearly demonstrated that psychological needs are not interchangeable and form unique profiles. In other words, profiles emerged that were characterized by one need being especially frustrated or satisfied compared to the other two. For example, there were separate profiles characterized by high competence frustration, autonomy frustration, and relatedness frustration (Chevrier et al., 2021; Rouse et al., 2020). These findings illustrate the benefits of using person-centered analytic procedures to identify and describe differences among unique subgroups in a particular context.

2.2 The Study Purpose

Taken together, existing evidence suggests that need satisfaction and frustration are, in fact, distinct constructs that exist in complex configurations associated with motivation and other outcomes. Additional studies, however, are needed in different educational contexts and assessing a broader range of antecedents and consequences of profile membership. Toward this goal, the present study will identify profiles of need satisfaction and frustration among university students at the beginning of the semester in large introductory chemistry courses to provide insight into the interplay within and between these distinct need-based constructs.

Applying a person-centered approach in samples of undergraduates enrolled in difficult STEM courses, such as introductory general chemistry courses, may offer novel insight into psychological needs as mechanisms influencing motivation, persistence, and overall functioning among this population. This is an important aim given the persistent difficulties with retention and disparities among historically underrepresented students in STEM fields (National Science Foundation, 2019; O'Brien et al., 2016). Students feeling confident in their ability to master skills and succeed in STEM (i.e., possessing and/or displaying a sense of competence) and feeling like they belong and are valued within the environment (i.e., a sense of relatedness) are both established predictors of motivation, resilience, and persistence in STEM disciplines (Rattan et al., 2018; Richardson et al., 2012). However, in a recent meta-analysis, competence emerged as the strongest predictor of student autonomous motivation (Bureau et al., 2022). It is therefore possible that profiles characterized by high competence satisfaction and low competence frustration will be associated with higher autonomous motivation among university students enrolled in introductory chemistry courses.

Moreover, student perceptions of the learning environment may determine their profile membership (Patall et al., 2017). Perceiving the learning environment as autonomy-supportive, rather than controlling, has been shown to satisfy students' basic psychological needs, increase autonomous motivations, persistence, and improve overall wellbeing (Howard et al., 2021; Reeve, 2012). Autonomy-supportive environments encourage students to take responsibility for their learning, train students in how to select and implement learning strategies, and allow students to have input or make choices about course content and structure (Ryan & Deci, 2020). These are malleable instructional

practices in which the instructors value and acknowledge students' perspectives and feelings, are transparent about expectations, provide structure while minimizing pressure and authoritative demands, and emphasize opportunities for students' to make choices regarding their learning (Reeve & Cheon, 2021). Therefore, research demonstrating that perceptions of an autonomy-supportive learning environment may help fulfill the fundamental psychological needs of students and promote their academic achievement and well-being would have important implications for interventions aimed at promoting need satisfaction and preventing need frustration.

The present study focuses on need profiles during the first few weeks of the course. Student need satisfaction and frustration profiles may change across a course in important ways (Chervrier et al., 2021), and therefore understanding psychological need profiles at different points in the course is important. Early course psychological need profiles have been demonstrated to be predictive of key academic outcomes (Chervrier et al., 2021; Gillet et al., 2020) and their investigation is an important first step for understanding the role of such profiles in this context. Specifically, findings will provide valuable information about how perceptions of the early course environment may influence student psychological needs, motivation, and psychological adjustment. Based on prior research (Gillet et al., 2020; Rouse et al., 2020), it is hypothesized that four to five profiles will best fit the data. It is expected that one profile will be characterized by high need satisfaction and low need frustration and have the best outcomes, including greater autonomous motivation, academic resilience, and intentions to persist in major. It is also expected that one profile will be characterized by low need satisfaction and high need frustration and have the worst outcomes, including greater controlled motivations and amotivation, higher academic

stress, and low intentions to persist in major. For the remaining profiles, an imbalance between need satisfaction and frustration is expected, with one need emerging as critically important in terms of satisfaction or frustration. In profiles where one need emerges as frustrated above the remaining needs, it is expected that motivation will be more controlled than autonomous and academic stress will be high. In profiles where one need emerges as highly satisfied above the remaining needs, it is expected that the satisfaction of this need will buffer against the negative outcomes otherwise associated with need frustration.

Lastly, perceptions of the learning environment as autonomy supportive should predict profile membership for all subgroups. Since no research to date has examined perceptions of the learning environment as a predictor of need satisfaction and frustration profile membership, the present study will not provide a priori hypotheses regarding the strength or direction of possible statistical associations. However, theory and research using variable-centered approaches suggest that perceiving the learning environment as autonomy supportive should have a strong positive association with profiles where need satisfaction exceeds need frustration.

2.3 Method

2.3.1 Participants and Procedure

Participants were undergraduate students enrolled across five general chemistry courses (An introductory chemistry course for health professionals; The first introductory chemistry course in a two-course sequence for students with advanced math preparation; The second introductory chemistry course of the two-course sequence for students with advanced math preparation who took the first of the two-course sequence; The first

introductory chemistry course in a two-course sequence for students with less math preparation; The second introductory chemistry course of the two-course sequence for students with less math preparation who took the first of the two-course sequence) at a large, public university in the Southeastern United States during the Spring 2022 semester. Students can enroll in only one of these courses per academic semester. Students were offered 1% extra credit on their overall course homework grade for completing the survey. Students who did not wish to participate in the study were given the option to complete an alternative assignment to earn equivalent extra credit. All students enrolled across the five introductory chemistry courses (N = 1505) were invited to participate in the study during the second and third week of the semester (n = 619, 40.9% response rate) via an announcement posted by their instructor in the course management system.

Most students in the sample were in their first year of college (80.6%), female (77.1%), White (73.7%), and STEM majors (percentage forthcoming once the variable for college major has been operationalized). Although students from all courses participated in the study, CHE 107 was the course with the most students (49.6% of participants) likely because the data were collected during the spring semester, and this course is the second in the typical course sequence required for many STEM students to progress in their majors. See Table 1 for full demographic details. This study was approved by the Institutional Review Board and informed consent was obtained.

2.3.2 Measures

Need Satisfaction and Frustration in Chemistry

Satisfaction and frustration of students' basic psychological needs were assessed using the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS; Chen et al., 2015). Items were adapted to reflect satisfaction and frustration of needs within the chemistry learning setting. The 24-item scale measures 6 factors (3 factors representing components of basic psychological need satisfaction and 3 factors representing need frustration) using six subscales: Autonomy Satisfaction (3 items; $\alpha = 0.73$; e.g., "In my chemistry class, I feel like my decisions reflect what I really want."; Competence Satisfaction (3 items; $\alpha = 0.87$; e.g., "In my chemistry class, I feel confident that I can do the coursework."; Relatedness Satisfaction (3 items; $\alpha = 0.81$; e.g., "In my chemistry class, I feel close and connected to the other students."; Autonomy Frustration (3 items; $\alpha = 0.78$; e.g., "In my chemistry class, I feel forced to do many things I wouldn't choose to do"; Competence Frustration (3 items; $\alpha = 0.85$; e.g., "In my chemistry class, I have serious doubts about whether I can do the work well."; and Relatedness Frustration (3 items; $\alpha = 0.71$; e.g., "In my chemistry class, I feel excluded from the other students.". Participants rated agreement for each item on a 5-point Likert-type scale from 1 (Never true) to 5 (Always true). Subscale scores were computed by averaging responses to the relevant items.

Autonomy-Supportive Learning Environment

Perceived autonomy-support were assessed using the 15-item Learning Climate Questionnaire (LCQ; Williams & Deci, 1996; $\alpha = 0.95$). Items were adapted for use in the

chemistry course setting (e.g., “My Chemistry instructor conveys confidence in my ability to do well in the course.”). Students responded to a 7-point Likert-type scale from 1 (Strongly disagree) to 7 (Strongly agree). Higher scores indicate students perceive the learning environment as autonomy supportive, whereas lower scores indicate students perceive the learning environment as more controlling.

Academic Motivation in Chemistry

Motivation in chemistry were assessed using items adapted from the Academic Self-Regulation Questionnaire (SRQ-A; Ryan & Connell, 1989) to assess different types of motivation in chemistry based on the SDT continuum ranging from autonomous motivations to controlled motivations to amotivated. This 25-item questionnaire measures 5 types of motivation: Intrinsic Motivation (5 items; autonomous; $\alpha = 0.88$; e.g., “I do my chemistry coursework…because I enjoy learning about it.”); Identified Regulation (5 items; autonomous; $\alpha = 0.80$; e.g., “I do my chemistry coursework…because it’s important to me to try to do well.”); Introjected Regulation (5 items; controlled; $\alpha = 0.74$; e.g., “I do my chemistry coursework…because I want others to think I am smart.”); External Regulation (5 items; controlled; $\alpha = 0.75$; e.g., “I do my chemistry coursework…because I need to for my major.”); Amotivation (5 items; $\alpha = 0.86$; e.g., “I do my chemistry coursework… I don’t know; I can’t understand what I am doing in this class.″).

Academic Resilience

For academic resilience, the 14-item Perseverance subscale from the Academic Resilience Scale (ARS) were used (Cassidy, 2016). Academic resilience is a multidimensional construct comprised of many components (Lee et al., 2013).

Perseverance is one component which captures student attitudes regarding remaining committed to academic goals after experiencing challenge rather than giving up (Tudor & Spray, 2017). Perseverance was selected as an indicator of academic resilience because validation studies have demonstrated that perseverance, as a factor of academic resilience, explains a larger proportion of variance in academic resilience than the remaining subscales (Cassidy, 2016). Furthermore, in a follow-up validation study of this scale, Hunsu and colleagues (2022) suggested that using individual subscale scores rather than a composite resilience score when using the ARS is more theoretically and methodologically valid because subscale scores more accurately depict academic resilience as a multidimensional construct whereas composite scores imply it is a unidimensional construct (Hunsu et al., 2022). When responding to items, participants were shown a vignette describing a failure experience in an academic setting and asked to imagine they had personally experienced the event. Participants then rated how likely they were to respond to the event through a set of items (e.g., "I would use the situation to motivate myself." "I would change my career plans.", "I would work harder.") on a 5-point Likert-type scale ranging from 1 (Very likely) to 5 (Very unlikely). The subscale had high internal consistency ($\alpha = 0.87$). Upon reverse scoring negatively phrased items, higher scores on this measure represent greater academic resilience.

Academic Stress

The 25-item Academic Stress in Secondary Education Questionnaire (QASSE; García-Ros et al., 2018) was adapted to measure academic stress among college students. Participants rated how stressful each item was for them in their academic lives on a 10-point slider scale ranging from 0 (Not at all stressful) to 10 (Extremely stressful). Items

corresponded to common sources of stress college students experience inside and outside of the classroom (e.g., “Managing time efficiently”; “Making friends in college”; “Preparing for exams”; $\alpha = 0.93$). Item responses were summed for all sources of stress so higher scores represent greater academic stress.

Persistence Intentions

Persistence intentions were measured with 6 items adapted from Banchefsky et al. (2019). The original items were developed to measure persistence intentions in STEM, but since students who take introductory chemistry courses have diverse majors beyond STEM, items were revised to assess intentions to persist in the student’s current program of study (e.g., “It is still my intention to stay in my same major after this year.”; $\alpha = .86$). Results from prior studies show that intentions are proximal predictors of actual behavior and are thus a reliable way to assess actual persistence (Ajzen, 1985, 2011). Studies in education have supported this proposition, finding strong correlations between persistence intentions in academics and actual persistence behaviors (Banchefsky et al., 2019; Davidson et al., 2009; Luke et al., 2015). Students indicated their agreement with items on a 5-point Likert-type scale ranging from 1 (Strongly disagree) to 5(Strongly agree), with higher scores representing greater intentions to persist in the student’s current major (i.e., chosen program of study).

Control Variables

The following variables will be included as covariates in the model, as each could be a possible confounding variable that could impact the validity of the findings. All educational and demographic background variables have been shown to be associated with

college student motivation, learning, and achievement in prior research (Allensworth & Clark, 2020).

Chemistry Course. First, chemistry course will be included to control for dependency among observations nested within each introductory chemistry course. Students in the sample could be enrolled in one of five general chemistry courses. Therefore, a categorical variable corresponding to the course each participant is enrolled in will be included in the primary analysis.

Prior Achievement. A prior achievement index with two to three indicators: self-reported high school GPA (HSGPA) and self-reported ACT scores, and self-reported SAT scores. The university from which the sample was recruited does not require both ACT and SAT scores be reported. Therefore, if one score was self-reported, the student will have two indicators (e.g., HSGPA and ACT) and if both were reported the student will have three indicators (e.g., HSGPA, ACT, and SAT).

Year in School. A single item was used to measure each student's year in school (e.g., "first year in college", "second year in college"). Participants were asked to indicate their year in school rather than their status as a freshman, sophomore, junior, or senior since many students begin their first year of college with college credits earned in high school so their class designation may not accurately represent their year in school.

College Major. Participants were asked to select their current major from a list of all college majors available at the institution where the sample was recruited. Students' college majors will be operationalized by creating a categorical variable representing broader fields of study in which the majors correspond (e.g., business, health and life

sciences, STEM (science, technology, engineering, and math), arts and humanities, social and behavioral sciences, and undecided).

Sex. Participants were asked to indicate if the sex they were assigned at birth was male (1) or female (0). Responses will be used as a single dichotomous variable.

Race. Participants were asked to indicate their racial or ethnic identity by selecting all options that apply (e.g., Hispanic or Latino, Black or African American, Native American or American Indian, Asian or Pacific Islander, White or Caucasian, A race other than the available options). Responses will be dichotomized as 1 (White) and 0 (non-White) to control for race as a confounding variable and given that there are not large enough numbers of minority students for each to be scored as a separate category.

First-Generation Status. Student participants' first-generation status was assessed using a single item in which students selected the option that best reflected their parents' or primary caregivers' educational attainment from two available options (e.g., "Yes, one or both of my parents or primary caregivers completed college", "No, my parents or primary caregivers did not complete college." This dichotomous variable will be dichotomized as 1 (First-Generation College Student) and 0 (Non-First-Generation College Student).

2.3.3 Analyses

Preliminary Analyses

All analyses were conducted in Mplus 8.8 (Muthén & Muthén, 2017). To begin, preliminary analyses verified that assumptions of latent profile analysis were satisfied before proceeding to the main analyses. Multivariate outliers were identified using the

Mahalanobis distance statistic, resulting in 25 cases being removed from the data. Following removal of outliers, assumptions of multivariate normality were evaluated for study variables by examining skewness and kurtosis statistics (Mardia, 1970). Due to multivariate non-normality being present in several study variables, maximum likelihood with robust standard errors (MLR), which is a sandwich estimation procedure that adjusts for non-normality (Schlomer, Bauman, & Card, 2010), was used for primary analyses.

Next, data were evaluated to identify patterns of missingness among study variables. Little's (1988) test statistic and a series of independent means t-tests comparing participants with complete and incomplete data on study variables suggested missing data were not missing completely at random. No missing data were present among latent profile indicators (satisfaction and frustration of each basic need). However, missing data were non-ignorable among predictors and outcomes associated with profile membership. Thus, Full Information Maximum Likelihood (FIML) was used to handle missingness, making it possible to include participants with responses on at least one predictor and one outcome of profile membership (Ferguson et al., 2020; Howard et al., 2015). FIML was selected to handle missingness since it has been shown to perform as well as multiple imputation in studies where large amounts of missing data are present (Baraldi & Enders, 2010; Larsen, 2011).

As a final step in the preliminary analysis, intra-class correlations (ICCs) were evaluated to determine if study variables were significantly influenced by nesting in the data due to participants being enrolled across several different introductory chemistry courses. ICCs for primary study variables all fell below .10 suggesting course nesting would not significantly impact the results of the latent profile analysis. Therefore, course

effects due to nesting were ignored in the primary analysis and highlighted in the limitations section of the discussion.

To examine variable means, standard deviations, correlations among constructs, and Cronbach's alpha's (α) for scale scores see Table 2.

Primary Analyses

The aim of the first research question is to identify and describe subgroups based on basic psychological need satisfaction and frustration among students enrolled in undergraduate general chemistry courses at the beginning of an academic semester. Latent profile analyses (LPA; Masyn et al., 2013) were conducted extracting 1 to 6 latent profiles using satisfaction and frustration variables for autonomy, competence, and relatedness as indicators of profile membership. The default Mplus settings for mixture modeling were utilized, allowing means for profile indicators to vary while constraining variances to be equal within profiles. To find the best global maximum solution and avoid local maxima, all LPAs were conducted using 1000 random sets of start values, 500 iterations, and retaining the 250 best solutions for the final stage of optimization (Hipp & Bauer, 2006).

To identify the solution with the optimal number of profiles in the data, multiple sources of information were evaluated including statistical criteria and interpretability and meaningfulness of the profiles (Bauer & Curran, 2003). Statistical indices used to support the decision regarding the optimal number of need profiles, include: (i) the Akaike's information criterion (AIC), (ii) the Bayesian information criteria (BIC), (iii) the sample-size adjusted BIC (aBIC), (iv) the standard and adjusted Lo-Mendell-Rubin's (2001) Likelihood Ratio Tests (LMR/aLMR), and (v) the Bootstrap Likelihood Ratio Test (BLRT)

(Geiser, 2013; Morin et al., 2016). Lower values indicate better model fit for AIC, BIC, and SABIC indices. For the LMR, aLMR and BLRT, significance testing is used to compare a k-profile model (additional profile) with a k-1-profile model (1 fewer profile). When statistically significant, the k-1-profile model (fewer profiles) should be rejected in favor of the k-profile model (Lo et al., 2001; Masyn, 2013). Results from simulation studies have demonstrated that the BIC, SABIC, and the BLRT are most effective when evaluating fit indices for LPA (Diallo et al., 2016; Nylund et al., 2007; Tofighi & Enders, 2008). Importantly, it should be noted that results from prior studies suggest that significance tests (LMR, aMLR, and BLRT) are heavily influenced by sample size, with fit indices continually suggesting improved model fit with additional profiles in large samples (Marsh et al., 2009). Consequently, this issue is circumvented by graphing information criteria using an "elbow plot" based on recommendations from Morin et al. (2011), and by interpreting the meaningfulness of adding the additional profile. When using the plot to assist in identifying the optimal number of profiles, the point at which the slope flattens out indicates the optimal profile solution. In addition, examining the nature of the profiles will illuminate whether each additional profile explains a homogenous group or is an artifact of varying levels of variables (e.g., higher or lower levels of need satisfaction or frustration) compared to the existing profiles. The final step involved in the identification of the optimal profiles will include evaluating posterior probabilities and entropy to determine how accurately individual participants fit within the profiles. There is currently no agreed upon cutoff criteria when evaluating probability values. Some researchers suggest values greater than .90 are appropriate (Muthén & Muthén, 2017), whereas others suggest that if the model is theoretically supported and other statistical criteria are satisfied,

values between .80 and .90 are acceptable (Weller et al., 2020). Entropy statistics will also be used to evaluate how well each LPA model partitions the data into homogenous profiles (Ferguson et al., 2020). Entropy can range from 0 to 1, with higher values (.70 or greater) suggesting that the model has classified individuals into profiles with greater certainty. Once the preferred model has been determined, the final step was to describe the within- and between-profile similarities and differences that characterize each need profile. Patterns of homogeneity for each profile were evaluated to determine how satisfaction and frustration of each basic psychological need defined each profile.

Associations Between Need Profiles and External Variables

Next, analyses aimed at assessing associations between theoretically supported predictors and outcome variables with need profiles was conducted. Analyzing associations between external variables (predictors or outcome variables) with profile membership is useful because it provides a more thorough understanding of subgroupings (latent groups) by identifying potential risks and consequences of profile membership, and it provides construct-validity for latent profile approaches. The Bolck-Croon-Hagenaars (BCH; Bolck, Croon, & Hagenaars, 2004) approach was used to investigate associations and compare differences across need profile groups for predictor and outcome variables via the BCH function in Mplus. The BCH approach is a three-step method that quantitative methodologists recommend over other approaches because it includes participants' individual class probabilities to determine the probability of individual's membership into each latent profile (Bakk et al., 2013; Nylund-Gibson & Masyn, 2016). In other words, this approach more efficiently corrects for uncertainty in profile membership at the level of the individual participant, reducing parameter estimate bias (Bolck et al., 2004). An additional

benefit is that allowing for uncertainty of profile assignment to be included in the model, the integrity of the latent profiles can be maintained once covariates or outcomes are added into the model (Ferguson et al., 2020). Lastly, researchers argue that when analyzing associations between latent profiles with multiple external variables (i.e., predictors or outcomes) one-step procedures may fail to converge (Bakk et al., 2013; Mulder et al., 2012).

The first step of the BCH approach is to estimate the final unconditional latent profile model using profile indicators (i.e., observed need satisfaction and frustration variables) without including covariates or outcomes in the model and save the BCH weights (Asparouhov & Muthén, 2021; Clark & Muthèn, 2009). This first step involves determining the optimal number of latent profiles based on statistical criteria, which was determined in the primary analysis above. In the second step, individuals are classified into their most likely need profile and errors associated with those probabilities are estimated. Specifically, posterior class probabilities are used to specify the probability of each individual participant's membership into each need profile, therefore allowing individual uncertainty of profile membership classification to be included in the analysis of associations with external variables (predictors or outcomes). In the third and final step, the class assignments from the step 2 model (i.e., a classification error variable used as a single indicator of latent class membership) were used to analyze relationships between need profile membership and external variables (i.e., predictor and outcome variables), thus maintaining integrity of the need profiles. In the third step of the BCH approach, regression procedures were used to estimate associations between latent profile variables (using classification errors) and external variables of interest.

To understand associations between the predictors of interest (perceptions of the learning environment and student demographics) and outcomes (types of academic motivation, resilience, stress, intentions to persist in major), a stepwise approach to the BCH analyses was taken. First, associations between perceptions of the learning environment (predictor of profile membership) and student demographic characteristics were evaluated to determine the degree to which need profile membership depends upon perceptions of the learning environment as autonomy supportive and demographic characteristics of students. Multinomial logistic regression models were assessed to determine if an autonomy supportive learning environment and demographic characteristics of students significantly predict most likely class membership. Next, mean differences between all outcomes and profile membership were evaluated to determine if students' need profile membership predicts type of academic motivation (e.g., intrinsic, identified, introjected, external, amotivation), academic resilience (well-being outcome), academic stress (ill-being outcome), and intentions to persist in current major. Specifically, equality of means omnibus testing using the Wald Chi-Square statistic will illuminate key differences in student outcomes dependent upon their most likely class membership.

2.4 Results

2.4.1 Research Question 1: Identification of need profiles at the beginning of the semester

The statistical indices associated with each estimated LPA are reported in Table 3. To begin, a solution with one profile was modeled, followed by estimation of consecutive models in which one additional profile was added up to five profiles. Values for the AIC, BIC and aBIC continued to decrease as each additional profile was added. Specifically, fit

indices improved substantially between the one and two profile models and improved again for the 3-profile solution. These results were further supported through evaluation of graphical elbow plots in which the slope flattens between the 2- and 3-profile solutions (see Figure 1). The BLRT significance tests suggested that each additional profile was supported over the *k*-1 model showing that it was not an effective test to identify the optimal number of profiles. The LMR and aLMR significance tests supported the 2-profile solution over the 1-profile solution, and the 3-profile solution over the 2-profile solution. The 4-profile solution did not support the *k* model over the *k*-1 model, suggesting that the 3-profile solution is the optimal solution. Lastly, entropy values remained high for the 3-profile solution (0.78 respectively). In sum, the model with three profiles was determined to be the optimal solution based on evaluation of model fit indices and the distinct and meaningful characteristics found between profiles.

The characteristics of each profile based on Chemistry students' experiences of satisfaction and frustration are illustrated statistically in Table 4 and graphically in Figure 2. Profile 1 (n = 338; 51% of the sample) is characterized by moderate satisfaction across all three needs, moderate frustration for autonomy and competence, and very low relatedness frustration. This Moderately Satisfied and Frustrated profile was the largest group in the sample and, on average, experienced slightly greater satisfaction than frustration. Profile 2 (n = 168; 25.3%) is characterized by slightly below average need satisfaction and high frustration in terms of their autonomy and competence. This Dissatisfied and Autonomy and Competence Frustrated profile was the second largest in the sample. Students in this profile were the least satisfied and most frustrated, reporting below average satisfaction across all three needs with relatedness being the most satisfied

and autonomy being the least satisfied. Of note, this group reported very high levels of autonomy and competence frustration with relatedness frustration being reported least frequently but still more frequently than the other two groups of students. Profile 3 (n = 156; 23.6%) is characterized by very high need satisfaction and very low levels of need frustration across all three needs. This Highly Satisfied with Little Frustration profile was the smallest group in the sample. These students reported greater satisfaction for all three needs than the other two profiles, with competence satisfaction reported most frequently, followed by autonomy satisfaction, and autonomy being their most frustrated need frustrated (albeit, still far below average compared to the full sample) and relatedness being their least frustrated need.

2.4.2 Research Question 2: Prediction of need profile membership by perceptions of the learning environment and student demographics

Probability of profile membership based on perceptions of the learning environment as autonomy supportive and student demographic characteristics was tested using multinomial logistic models in which odds of membership in one profile compared to a reference profile were estimated. See Table 5 for results.

Higher reports of an autonomy supportive learning climate was associated with lower odds of membership in Profile 1 (Moderately Satisfied and Frustrated) (OR = 0.311, $p < .001$) and Profile 2 (Dissatisfied and Autonomy and Competence Frustrated) (OR = 0.121, $p < .001$) compared to students in Profile 3 (Highly Satisfied with Little Frustration). In addition, higher reports of an autonomy supportive climate were associated with lower odds of membership in Profile 2 (Dissatisfied and Autonomy and Competence Frustrated) (OR = 0.389, $p < .001$) compared to Profile 1 (Moderately Satisfied and Frustrated). Mean

perceptions of learning climate were highest in Profile 3 ($M = 6.16$), lowest in Profile 2 ($M = 4.49$), and in between in Profile 1 ($M = 5.35$).

The odds of membership in Profile 1 (Moderately Satisfied and Frustrated) were lower for male students ($OR = 0.436$, $p < .05$) and higher for those in a health-related major ($OR = 2.053$, $p < .05$) compared to Profile 3 (Highly Satisfied with Little Frustration). Furthermore, the odds of membership in Profile 2 (Dissatisfied and Autonomy and Competence Frustrated) were lower for male students ($OR = .284$, $p < .01$). No other demographic variables were related to greater odds of belonging to Profile 2 compared to Profile 3. Lastly, demographic variables were unrelated to the odds of membership in Profile 1 (Moderately Satisfied and Frustrated) compared to Profile 2 (Dissatisfied and Autonomy and Competence Frustrated). The percentage of male students in Profile 1 (Moderately Satisfied and Frustrated) (47%) and 2 (Dissatisfied and Autonomy and Competence Frustrated) (50.4%) were similar, but higher in Profile 3 (Highly Satisfied with Little Frustration) (70.4%).

2.4.3 Research Question 3: Relationships between need profile membership and outcome variables

To examine mean differences in outcomes among need profiles, BCH and equality tests of means were performed. See Table 6 for results.

A consistent pattern emerged, in which more autonomous and less controlled motivations (e.g., intrinsic motivation and identified regulation) was characteristic of Profile 3. Less autonomous and more controlled motivations (introjected and external regulations) was characteristic of Profile 2. Profile 1 typically had mean values in between Profiles 2 and 3, although Profile 1 was similar to Profile 3 for introjected and external

regulation. Amotivation was highest in Profile 2 and lowest in Profile 3, with Profile 1 in between.

Consistent with findings for autonomous forms of academic motivation, resilience was highest in Profile 3, lowest in Profile 2, and in between for Profile 1. Similarly, academic stress was lowest for Profile 3, highest for Profile 2, and in between for Profile 1.

Intentions to persist in current major shared a similar pattern with more autonomous forms of motivation and resilience with intentions to persist being highest in Profile 3, lowest in Profile 2, and in between in Profile 1.

2.5 Discussion

Prior studies have shown that satisfaction of students' basic psychological needs for autonomy, competence, and relatedness is associated with positive academic outcomes (Bureau et al., 2022; Wang et al., 2016). However, in the context of undergraduate education, the simultaneous experience of basic psychological need frustration as a predictor of negative academic outcomes has been unexplored. Therefore, the primary aim of the present study was to identify profiles of satisfaction and frustration for the basic psychological needs for autonomy, competence, and relatedness among undergraduate students enrolled in General Chemistry courses at the beginning of the academic semester. A secondary aim was to determine how other relevant academic constructs related to need profile membership. Specifically, perceptions of the Chemistry learning environment as autonomy-supportive and student demographic characteristics were tested as predictors of need profile membership at the beginning of the semester. Then, unique relationships

between need profiles with educational outcomes including autonomous and controlled forms of academic motivation, resilience, academic stress, and students' intentions to persist in their current major were explored.

Three distinct profiles of students' satisfaction and frustration of basic psychological needs were identified: (1) A *Moderately Satisfied and Frustrated* profile characterized by students experiencing moderate satisfaction and frustration across all three needs; (2) A *Dissatisfied and Autonomy and Competence Frustrated* profile characterized by below average satisfaction across all three needs who were particularly frustrated in terms of their autonomy and competence; and (3) A *Highly Satisfied with Little Frustration* profile characterized by high levels of need satisfaction and low levels of need frustration across all three needs. Results contribute to a growing body of empirical evidence confirming that need satisfaction and need frustration are distinct, yet co-occurring constructs that should be considered jointly to fully understand individual differences within the context of introductory STEM courses like general Chemistry (Rouse et al., 2020; Vansteenkiste & Ryan, 2020; Warburton et al., 2020). Moreover, the present study is the first to show that at the beginning of the semester undergraduate Chemistry students' distinct experiences of need satisfaction and frustration have different antecedents and consequences, putting some students at an advantage and some at risk academically.

Prior research utilizing person-centered approaches to model the combined nature of need satisfaction and frustration have found four to five distinct need profiles within domains of work (Rouse et al., 2020) and education (Chevrier & Lannegrand, 2021). In addition, another study identified five unique need satisfaction profiles, omitting the inclusion of need frustration variables, in a sample of first-year French university students

(Gillet et al., 2019). In each of these studies, one profile was characterized by need satisfaction prevailing over need frustration, another profile with the reverse experience of need frustration prevailing over need satisfaction, a profile with moderate experiences of satisfaction and frustration, and the remaining profiles characterized by satisfaction or frustration of one need emerging as particularly important. Therefore, the identification of only three profiles, instead of four or five, within the current sample was fewer than expected. Although fewer profiles were identified in the current sample than anticipated, having one profile in which need satisfaction prevailed over need frustration, one in which need frustration prevailed over need satisfaction, and one with moderate levels of both satisfaction and frustration was expected. The number and nature of the profiles were similar to results of a hierarchical cluster analysis in a sample of high school physical education students with one profile having high need satisfaction with low frustration, one profile having high frustration and low satisfaction, and one with moderate levels for both satisfaction and frustration (Warburton et al., 2020). However, the current study extends Warburton and colleagues (2020) findings by including satisfaction and frustration of each need independently rather than exploring the co-occurrence satisfaction and frustration at the aggregate level. As a result, the present study provided more nuanced information, showing that frustration of autonomy and competence needs may contribute to student membership in a profile in which need frustration prevails over need satisfaction. This finding aligns with numerous variable-centered studies suggesting that competence emerges as the most central and salient need within educational domains, followed by autonomy (Bureau et al., 2021).

As hypothesized, perceiving the Chemistry learning environment as more or less autonomy-supportive predicted need profile membership. Students who viewed the Chemistry learning environment as more autonomy-supportive were most likely to be members of the *Highly Satisfied with Little Frustration* profile compared to the *Moderately Satisfied and Frustrated* or *Dissatisfied and Autonomy and Competence Frustrated* profiles. Following the same pattern, students who viewed the learning environment as more supportive of their autonomy were more likely to be members of the *Moderately Satisfied and Frustrated* profile than the *Dissatisfied and Autonomy and Competence Frustrated* profile. These findings are consistent with an established literature that has consistently shown that autonomy-supportive learning environments contribute positively to students' self-determined motivation and overall achievement through the satisfaction of their basic psychological needs (Reeve & Cheon, 2021; Ryan & Deci, 2017). Importantly, autonomy-supportive instructional practices are purported to satisfy all three of students' basic psychological needs (Ryan & Deci, 2020). The present findings make an important contribution to this literature by showing that autonomy-supportive learning environments increase the likelihood that university students will belong to a need profile experiencing higher levels of need satisfaction and moderate to low levels of need frustration within introductory STEM courses. This is noteworthy considering introductory STEM courses, like general Chemistry courses, have been cited as critically important courses for intervention to improve the ongoing retention issues in STEM degree programs (Chen & Soldner, 2013; Meaders et al., 2020).

Student demographic characteristics also demonstrated associations with need profile membership. Male students were more likely to be members of the *Highly Satisfied*

with Little Frustration profile than either of the other two profiles. Similarly, male students were also more likely to belong to the *Moderately Satisfied and Frustrated* profile than the *Dissatisfied and Autonomy and Competence Frustrated* profile. Thus, female students were more likely than male students to experience lower need satisfaction and higher need frustration at the beginning of the semester than their male peers. This finding makes a significant contribution to the literature seeking to understand and reduce underrepresentation of women in STEM by introducing the important role that basic psychological needs for autonomy, competence, and relatedness play in cultivating women's motivation to choose and remain in STEM degree programs. SDT proposes that self-determined motivation and overall well-being is a product of the extent to which the immediate environment satisfies or frustrates basic psychological needs (Ryan & Deci, 2017).

Studies have identified students' sense of belonging, which is similar to the need of relatedness, as a key factor influencing motivation to persist in STEM (Cheryan et al., 2017). Results from this study suggest that, in addition to satisfying female students' need for relatedness and belonging, satisfying their needs for autonomy and competence may also be important factors influencing their decisions to continue in or abandon majors requiring introductory STEM courses, like general Chemistry. This finding provides preliminary evidence of the role need satisfaction and frustration play for female students at the beginning of the semester. However, the results are limited to the general Chemistry context. Additional research is needed to examine satisfaction and frustration of students' basic psychological needs as potential mechanisms contributing to ongoing gender disparities in some STEM fields.

Regarding students' majors, students majoring in health sciences and health-related professional programs (e.g., Human Health Sciences, Dietetics, Nursing) were more likely to be members of the *Moderately Satisfied and Frustrated* profile than the *Dissatisfied and Autonomy and Competence Frustrated* profile. Although need satisfaction is typically associated with autonomous forms of motivation and other positive outcomes, and need frustration is associated with controlled forms of motivation, amotivation, and other negative outcomes, the relationship is likely much more complex since needs can be both satisfied and frustrated simultaneously. Prior research and findings from the present study demonstrate that increasing levels of need frustration prevent high need satisfaction from being experienced. However, some studies suggest that experiencing some need frustration with moderate levels of need satisfaction has a functional purpose for self-regulation and goal achievement because it signals to people that additional effort or changed behavior is required and supports the internalization of goals, increasing autonomous motivations (Rodrigues et al., 2021; Vansteenkiste & Ryan, 2013). Therefore, the results of this study may suggest that students in health-related majors—for whom General Chemistry is less central to their interests—are more likely to be in the *Moderately Satisfied and Frustrated* profile because they are more likely to require development of their self-determined motivation and positive functioning in this context. Future research may want to explore this possibility among specific student populations longitudinally.

Unique associations between profile membership and Chemistry students' academic functioning were consistent with study expectations. These findings highlight the importance of including both need satisfaction and frustration using a person-centered approach in the prediction of a variety of functional outcomes, including autonomous and

controlled motivations, amotivation, resilience, academic stress, and student intentions to persist in their academic major. Students in the profile characterized by higher levels of need satisfaction than need frustration had the best academic functioning. Specifically, students in the *Highly Satisfied with Little Frustration* profile had the highest autonomous motivations (e.g., intrinsic and identified regulation), the lowest levels of amotivation, were the most resilient, the least stressed academically, and had the greatest intentions to persist in their current major compared to the other two profiles experiencing increasing levels of need frustration. In contrast, students in the profile characterized by higher levels of need frustration than need satisfaction had the worst academic functioning. Students in the *Dissatisfied and Autonomy and Competence Frustrated* profile had the highest amotivation, the highest controlled motivations (e.g., introjected and external), the most academic stress, the lowest autonomous motivation, the lowest resilience, and the lowest intentions to persist in their major compared to the other two profiles. Students experiencing moderate levels of both need satisfaction and need frustration generally fell in between the other two extreme profiles on these variables, with the exception of controlled motivations. Specifically, students in the *Moderately Satisfied and Frustrated* profile experienced similarly low levels of introjected and external regulation in comparison to those in the *Highly Satisfied with Little Frustration* profile.

These results are consistent with an emergent line of research suggesting that need satisfaction and need frustration are, in fact, distinct constructs that should be considered simultaneously since they have different antecedents and consequences (Bartholomew et al., 2011). In addition, SDT proposes that the absence of need satisfaction does not necessitate need frustration but that need frustration results in an absence of need

satisfaction, suggesting an asymmetrical relationship (Rouse et al., 2020; Vansteenkiste et al., 2020). The present results are both theoretically and practically important since they are the first to confirm both theoretical assumptions using a person-centered approach within the educational domain of introductory undergraduate STEM courses. Importantly, it appears that students' psychological needs being frustrated to a greater extent than they are satisfied at the beginning of the semester not only reduces their ability to experience need satisfaction, but it also puts them at risk academically. In contrast, it appears that students' needs being satisfied serves as a protective buffer, reducing the chances that their needs will be highly frustrated, which positively influences their academic motivation, their ability to cope with academic challenges and setbacks, experience less stress related to their academic work, and persist. Thus, satisfying students' psychological needs at the beginning the academic semester may be an important determinant in how they progress over the remainder of the academic semester. Although understanding individual differences in student experiences of need satisfaction and frustration at the beginning of the semester—and associations with other academic factors—is a first step in understanding these psychological mechanisms, future research should consider how need-based experiences at the beginning of the semester influence academic functioning over the semester using longitudinal approaches.

2.5.1 Limitations and Future Directions

The present study makes an important contribution to the motivation and education literature by providing insight into how basic psychological need satisfaction and frustration are experienced among undergraduate students. However, there are several limitations that should be considered. First, the present results were limited to students

enrolled across introductory general Chemistry courses. These results may not apply to students across all academic domains. Future research should replicate these results in other relevant domains, such as other introductory STEM courses, to confirm their generalizability. In addition, the present study relied upon self-report measures for all study variables. Self-report is best suited for many motivational and affective variables, such as basic psychological need satisfaction and frustration, types of motivation, resilience, and stress, but may still be susceptible to socially desirable responses. However, future studies should explore actual persistence as a behavioral measure to determine if need-based experiences influence behavioral choices rather than mere intentions. Furthermore, results explore cross-sectional associations between variables based on theoretical assumptions but cannot confirm the directionality of such relationships. Additional longitudinal studies are needed to confirm how need satisfaction and frustration variables precede, follow, or are reciprocally reinforced with other relevant factors.

The present results did not account for multilevel effects of students being nested within five different general Chemistry courses. Considering that primary variables of interest were at the student level (Level 1) and there was an insufficient number of course clusters (Level 2) to conduct multilevel analyses, future studies should account for clustering effects when exploring the role of need satisfaction and frustration within educational settings (McNeish & Stapleton, 2014). Lastly, the BCH approach used to model associations with predictor and outcomes associations with profile membership uses listwise deletion to handle missing data for dependent variables (Wang & Wang, 2019). Future studies should consider alternative approaches to prevent the loss of potentially relevant data.

2.5.2 Theoretical and Practical Implications

Despite these limitations, findings from the current study have theoretical and practical implications within the context of large introductory STEM courses. From a theoretical perspective, the results suggest that need satisfaction and frustration constructs should be considered in tandem to understand their joint function in motivation, psychological adjustment, and functioning more accurately (Rouse et al., 2020; Vansteenkiste & Ryan, 2020; Warburton et al., 2020). Furthermore, SDT researchers have called for more person-centered approaches to understanding individual differences in need profiles and need trajectories (Vansteenkiste & Mouratidis, 2016). The present results answer that call by illustrating within-person combinations of need satisfaction and frustration within undergraduate Chemistry courses. Understanding need profiles in this manner has practical value for identifying potentially at-risk students and developing targeted interventions that will satisfy their psychological needs, in turn supporting their positive functioning and academic success in these historically challenging, gatekeeper courses (Chen & Soldner, 2013; Patall et al., 2018).

Results suggest that perceptions of autonomy-support within the learning environment may promote psychological need satisfaction and healthy academic functioning. Therefore, instructors of these courses could work toward incorporating autonomy support into their course structure and daily teaching practices (Bureau et al., 2020). Autonomy-supportive practices involve positive and empathetic interpersonal interactions with students, providing them with meaningful rationales for course learning goals, offering them choices that reflect their preferences and interests, and creating structure that transparently outlines expectations (Cheon et al., 2020). Supporting student

autonomy also involves minimizing controlling tactics and external regulation in an attempt to motivate or increase their effort, since these tactics tend to frustrate needs and reduce the more desirable autonomous forms of motivation (Howard et al., 2021).

2.5.3 Conclusion

In sum, the current study is the first to provide insight into need satisfaction and frustration jointly using a person-centered approach at the beginning of the academic semester within introductory general Chemistry courses. Findings confirmed individual differences in need-based experiences through the identification of three unique profiles, one in which need satisfaction prevails over need frustration, one in which need frustration prevails over need satisfaction, and one in which both need satisfaction and frustration are experienced at moderate levels. Importantly, membership in distinct need profiles was predicted by perception of the Chemistry learning environment as more or less autonomy supportive. In addition, findings suggest that experiencing need satisfaction buffered against potentially negative effects produced by need frustration. In contrast, students experiencing higher need frustration and dissatisfaction were at-risk academically. These findings emphasize the importance of jointly considering need satisfaction and frustration to fully understand differences in students' academic motivation and achievement outcomes.

Table 2.1 Demographic Information for General Chemistry Students at the Beginning of the Semester

Variable	*N*	Percentage of Sample
General Chemistry Course	686	100%
Course 1	87	12.7%
Course 2	154	22.4%
Course 3	338	49.3%
Course 4	43	6.3%
Course 5	64	9.3%
Year in School	618	90.1%
First Year	498	72.6%
Second Year	87	12.7%
Third Year	20	2.9%
Four or more Years	13	1.9%
Major	577	84.1%
pSTEM	111	16.2%
Agriculture & Biological Life Sciences	154	22.4%
Health Sciences & Professions	240	35%
Other	72	10.5%
First-Gen Status	612	89.2%
First-Gen	121	17.6%
Not First-Gen	491	71.6%
Sex	615	89.7%
Male	138	20.1%
Female	477	69.5%
Race/Ethnicity	659	96.1%
White	492	71.7%
Non-White	167	24.3%

Table 2.2 Means, Standard Deviations, Correlations, and Cronbach's Alpha of Primary Variables at the Beginning of the Semester

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Psychological Need Satisfaction															
1. Autonomy	–	.576**	.548**	-.593**	-.464**	-.357**	.464**	.574**	.417**	.280**	-.115**	-.310**	.350**	-.306**	.288**
2. Competence		–	.384**	-.466**	-.700**	-.339**	.357**	.491**	.338**	.205**	-.098*	-.348**	.294**	-.372**	.315**
3. Relatedness			–	-.397**	-.349**	-.534**	.415**	.355**	.354**	.249**	-.019	-.235**	.332**	-.280**	.245**
Psychological Need Frustration															
4. Autonomy				–	.609**	.476**	-.385**	-.446**	-.306**	-.150**	.255**	.375**	-.274**	.394**	-.190**
5. Competence					–	.454**	-.334**	-.398**	-.224**	.018	.210**	.389**	-.253**	.466**	-.273**
6. Relatedness						–	-.384**	-.234**	-.257**	-.085**	.047	.368**	-.258**	.330**	.250**
Covariates															
7. Learning Climate							–	.445**	.401**	.244**	-.007	-.345**	.237**	-.227**	.209**
8. Intrinsic Motivation								–	.600**	.497**	-.080*	-.284**	.337**	-.202**	.233**
9. Identified Regulation									–	.636**	.270**	-.464**	.343**	-.066	.298**
10. Introjected Regulation										–	.389**	-.144**	.214**	.095*	.159**
11. External Regulation											–	.033	.105**	.257**	.076
12. Amotivation												–	-.250**	.286**	-.281**
13. Academic Resilience													–	-.153**	.213**
14. Academic Stress														–	-.172**
15. Persistence Intentions															–
α	0.73	0.87	0.81	0.78	0.85	0.71	0.95	0.88	0.80	0.74	0.75	0.86	0.87	0.93	0.86
M	3.32	3.48	3.44	3.06	2.93	2.24	5.29	3.17	4.22	3.74	4.19	1.81	3.44	128.91	4.09
SD	.672	.698	.763	.782	.864	.645	1.128	.910	.744	.821	.707	.846	.340	44.99	.703

Note. ** $p < .01$, * $p < .05$.

Table 2.3 Latent Profile Fit Statistics for Models Based on Basic Psychological Need Satisfaction and Frustration Indicators at the Beginning of the Semester

Model	LL	Scaling	#FP	AIC	BIC	ABIC	*p* LMR	*p* aLMR	*p* BLRT	Smallest c	Entropy
1-Profile	-4292.08	0.992	12	8608.16	8662.10	8624.00	–	–	–	–	–
2-Profile	-3759.67	1.197	19	7557.34	7642.75	7582.43	0.000	<0.001	<0.001	49.6%	0.80
3-Profile	-3611.48	1.363	26	7274.95	7391.83	7309.28	0.032	0.034	<0.001	23.6%	0.78
4-Profile	-3552.41	1.605	33	7170.82	7319.16	7214.38	0.450	0.454	<0.001	10%	0.78
5-Profile	-3493.46	1.495	40	7077.91	7246.72	7119.72	0.125	0.128	<0.001	3.3%	0.81

Note. LL = LogLikelihood; Scaling = Scaling factor associated with the MLR log-likelihood estiamtes; #FP = number of free parameters; AIC = Akaïke Information Criteria; BIC = Bayesian Information Criteria; ABIC = Sample-Size Adjusted BIC; *p* LMR = *p*-value for the Lo-Mendell-Rubin likelihood ratio test for *k* versus *k*-1 profiles; *p* aLMR = *p*-value for the adjusted Lo-Mendell-Rubin likelihood ratio test for *k* versus *k*-1 profiles; *p* BLRT = *p*-value for the bootstrap likelihood ratio test for *k* versus *k*-1 profiles; Smallest c = the percentage of the smallest latent profile size relative to *n* = 662.

Table 2.4 Three-Profile Model Results for Chemistry Students at the Beginning of the Semester

Variable	Profile 1 Moderately Satisfied and Frustrated (n = 338; 51%)	Profile 2 Autonomy and Competence Frustrated (n = 168; 25.3%)	Profile 3 Highly Satisfied and Not Frustrated (n = 156; 23.6%)
Autonomy Satisfaction	3.33	2.68	**4.02**
Competence Satisfaction	3.52	2.80	**4.15**
Relatedness Satisfaction	3.42	2.88	**4.10**
Autonomy Frustration	3.01	**3.80**	2.25
Competence Frustration	2.90	**3.79**	2.02
Relatedness Frustration	2.24	**2.68**	1.71

Note. The highest responses for each psychological need are in boldface. Means and standard deviations for variables in the full sample: Autonomy Satisfaction M = 3.32 (SD = 0.67), Competence Satisfaction M = 3.48 (SD = 0.70), Relatedness Satisfaction M = 3.44 (SD = 0.76), Autonomy Frustration M = 3.06 (SD = 0.78), Competence Frustration M = 2.93 (SD = 0.86), Relatedness Frustration M = 2.24 (SD = 0.65).

Table 2.5 Results of the Multinomial Logistic Regressions for the Effects of Predictor and Demographics on Need Profile Membership at the Beginning of the Semester

	Profile 1 vs. 3[a]		Profile 2 vs. 3[a]		Profile 1[a] vs. 2	
Variable	Coef. (SE)	OR	Coef. (SE)	OR	Coef. (SE)	OR
Theoretical Predictor						
Learning Climate	-1.17*** (.202)	.311	-2.11*** (.248)	.121	-.945*** (.173)	.389
Student Demographics						
Year in School	-.169 (.305)	.844	-.021 (.331)	.979	.148 (.212)	1.16
Male	-.830* (.396)	.436	-1.26** (.489)	.284	-.429 (.386)	.651
White	.075 (.342)	1.08	.188 (.425)	1.21	.113 (.113)	1.12
HSGPA	-.370 (.629)	.691	-.858 (.691)	.424	-.488 (.523)	.614
Not FirstGen	-.233 (.377)	.792	.233 (.481)	1.26	-.466 (.382)	1.59
pSTEM Major	-.667 (.387)	.513	-.825 (.499)	.438	-.158 (.423)	.854
Health-Related Major	.719* (.308)	2.05	.345 (.368)	1.41	-.374 (.289)	.688

Note. Dummy coding (Male = 1 and Female = 0, White = 1 and Non-White = 0, 1 = Not First-Generation and 0 = First-Generation, 1 = pSTEM major and 0 = Not pSTEM major, 1 = Health-related major and 0 = Not Health-Related Major); SE = standard error of the coefficient (Coef); OR = odds ratio. Profile 1 = Moderately Satisfied and Frustrated; Profile 2 = Autonomy and Competence Frustrated; Profile 3 = Highly Satisfied and Not Frustrated.

[a] Reference group.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 2.6 Relationships between LPA Need Profile Membership and Outcome Variables at the Beginning of the Semester

Variable	Profile 1 (*A*) Mean (SE)	Profile 2 (*B*) Mean (SE)	Profile 3 (*C*) Mean (SE)	Differences between Profiles
Intrinsic Motivation	3.221 (.046) $^{B, C}$	2.434 (.071) $^{A, C}$	3.949 (.063) $^{A, B}$	3 > 1 > 2
Identified Regulation	4.232 (.042) $^{B, C}$	3.895 (.066) $^{A, C}$	4.711 (.038) $^{A, B}$	3 > 1 > 2
Introjected Regulation	3.869 (.046) ^{B}	3.513 (.079) $^{A, C}$	3.859 (.065) ^{B}	1 = 3 > 2
External Regulation	4.165 (.041) ^{B}	4.462 (.047) $^{A, C}$	4.033 (.068) ^{B}	2 > 1 = 3
Amotivation	1.865 (.051) $^{B, C}$	2.227 (.072) $^{A, C}$	1.171 (.034) $^{A, B}$	2 > 1 > 3
Resilience	3.429 (.020) $^{B, C}$	3.277 (.031) $^{A, C}$	3.653 (.024) $^{A, B}$	3 > 1 > 2
Academic Stress	129.221 (2.55) $^{B, C}$	159.579 (.3.735) $^{A, C}$	91.825 (3.252) $^{A, B}$	2 > 1 > 3
Persistence Intentions	4.044 (.044) $^{b, C}$	3.838 (.067) $^{a, c}$	4.470 (.053) $^{A, B}$	3 > 1 > 2

Note. Capitalized superscripts indicate profiles that are significantly different at $p < .001$; lower case superscripts indicate profiles that are significantly different at $p < .05$. Profile 1 = Moderately Satisfied and Frustrated; Profile 2 = Autonomy and Competence Frustrated; Profile 3 = Highly Satisfied and Not Frustrated.

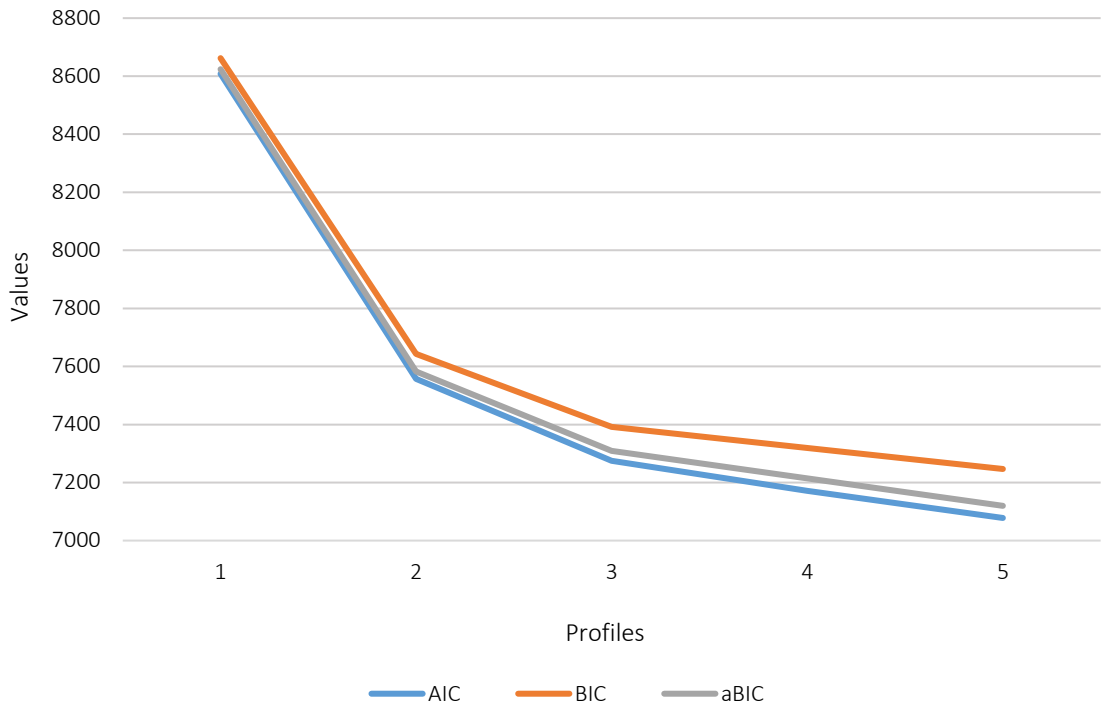

Figure 2.1 Elbow Plot Illustrating the AIC, BIC, aBIC Fit Statistics for Latent Profile Analysis Results at the Beginning of the Semester

Note. $n = 662$.

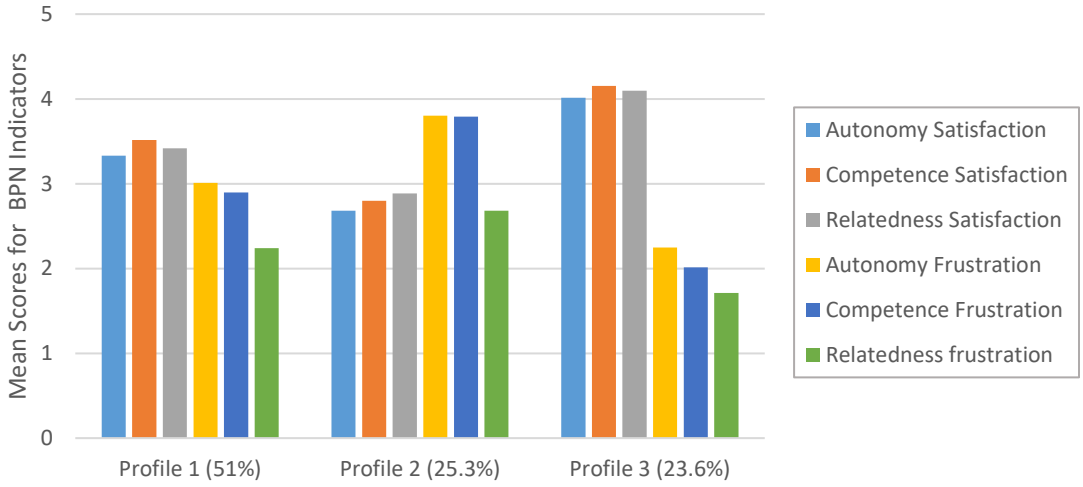

Figure 2.2 Final 3-Profile Solution for General Chemistry Students at the Beginning of the Semester

Note. $n = 662$; Profile 1: Moderately Satisfied and Frustrated ($n = 338$) ; Profile 2: Dissatisfied and Autonomy and Competence Frustrated ($n = 168$); Profile indicators are mean scale scores; Profile 3: Highly Satisfied with Little Frustration ($n = 156$).

CHAPTER 3. STUDY 2 – UNDERGRADUATE GENERAL CHEMISTRY STUDENTS' BASIC PSYCHOLOGICAL NEED PROFILES AT THE BEGINNING OF THE SEMESTER]

3.1 Introduction

The early years of college represent an adjustment period characterized by motivational destabilization and academic and career-related uncertainty for many STEM majors (Robinson et al., 2019). During this transition period, STEM students must adapt to new educational norms and navigate rigorous coursework more autonomously than in their prior years of schooling, while simultaneously identifying personal and academic social supports and exploring possible academic and career-related identities (Arnett & Tanner, 2006; Corpus et al., 2020). Some students adapt to the learning expectations in their STEM programs with ease, remain motivated and resilient despite challenges, perform well, and persist in their STEM majors. On the other hand, an alarmingly high number of students find it difficult to succeed in their STEM courses and abandon their original STEM career goals. National data shows that, on average, only 50% of incoming STEM majors earn a degree in their chosen program of study, with the remainder switching majors or leaving college altogether (National Science Foundation, 2019).

The reasons students leave STEM majors are complex and multifaceted. Prior math achievement and performance in large introductory STEM courses have been shown to be two of the most reliable predictors of persistence (Chen & Soldner, 2013; Ellis et al., 2016). Although students who begin college less academically prepared than their peers are at greater risk of struggling in introductory STEM courses, many students still struggle in these courses despite having adequate academic preparation (Perez et al., 2014; Robinson et al., 2019). In light of this, a more comprehensive understanding of individual differences

in the mechanisms that underlie motivation, psychological adjustment, and persistence in these courses is of critical importance.

Self-Determination Theory (SDT; Deci & Ryan, 2000) offers a theoretical framework for achieving this understanding. It proposes that optimal motivation, functioning, and psychological well-being occur through the satisfaction of three basic psychological needs for autonomy, competence, and relatedness. SDT is supported by many studies demonstrating that positive functioning is associated with psychological need satisfaction in educational settings (Bureau et al., 2022; Gillet et al., 2020; Ryan & Deci, 2020). However, research shows that needs can be satisfied and frustrated at the same time (Bartholomew et al., 2011; Vansteenkiste & Ryan, 2013), indicating that need satisfaction and need frustration are distinct constructs. Less is known about need frustration, including consideration of individual differences in how satisfaction and frustration of each basic psychological need may be experienced simultaneously within the same context (Vansteenkiste et al., 2020). Understanding how experiences of need satisfaction and need frustration at the end of the academic semester co-occur and vary within students in large introductory STEM courses may extend existing knowledge on the critical issues of STEM attrition by exploring potential psychological mechanisms that influence academic outcomes such as motivation, achievement, psychological adjustment, and persistence. Therefore, the present study aims to: (1) describe profiles of satisfaction and frustration of student basic psychological needs for autonomy, competence, and relatedness at the end of the academic semester in introductory chemistry courses using a person-centered approach (i.e., latent profile analysis) (2) assess perceived sacrifices of well-being to achieve academically and characteristics of the learning environment as predictors of psychological

need profiles, and (3) assess the impact of profile membership on educational outcomes, including quality of motivation (e.g., intrinsic, amotivated), academic stress, resilience, expected grade in chemistry, and intentions to persist in current major.

3.2 Self-Determination Theory

Self-determination theory (SDT; Deci & Ryan, 2000) proposes that peoples' quality of motivation, psychological well-being, and ability to adapt and flourish within the social environment depends upon the extent to which three basic psychological needs for autonomy, competence, and relatedness are satisfied or frustrated. Autonomy refers to experiences of willingness and volition. When satisfied, people feel a sense of ownership and identification with their actions which leads to initiative and engagement that feels authentic. When frustrated, people feel controlled by external forces and that they are being pressured to makes choices or behave in ways that do not align with their authentic desires. Competence refers to experiences of effectiveness when navigating the social environment. When satisfied, people have opportunities to successfully demonstrate skills and expertise as well as the support needed for expanding capabilities and improving mastery. When frustrated, people will feel incompetent, may feel like failures, and can even feel hopeless in effectively demonstrating or developing mastery toward their goals. Relatedness concerns feeling connection, closeness, and a sense of belonging with other people. When satisfied, people feel warmth, caring, and that others are responsive to and value them. When frustrated, people feel alienated from others, excluded, or lonely. Importantly, satisfaction of these needs are not preferences, but instead are essential for optimal functioning and psychological wellness.

In classroom settings, a student's need satisfaction facilitates the internalization of external performance standards which, in turn, increases the quality of academic motivation (i.e., autonomous forms of motivation including intrinsic or identified motivations), which is a strong predictor of educational achievement (Sheldon & Niemiec, 2006; Taylor et al., 2014) and persistence in the pursuit of academic and career-related goals (Gillet et al., 2020), Such increases in academic motivation also support psychological wellbeing and growth (Duineveld et al., 2017; Tian et al., 2014). On the other hand, studies have shown that low levels of need satisfaction are associated with negative outcomes, including lower quality academic motivations (i.e., controlled forms of motivation including introjected or external motivations) and amotivation (e.g., a lack of motivation) (Bureau et al., 2022), lower resilience on academic tasks (Neufeld et al., 2020), and higher intentions of dropping out of college (Gillet et al., 2020).

Moreover, considerable evidence highlights that students are more likely to experience higher need satisfaction when the classroom context engages in need-supportive practices (Vansteenkiste et al., 2020). Specifically, studies have shown instructors who have autonomy-supportive teaching styles tend to satisfy all three psychological needs in their students (Gilbert et al., 2021; Jang et al., 2016). This teaching style encourages students to take responsibility for their own learning rather than placing the responsibility solely on instructors, and facilitates the skills needed to do so, such as self-monitoring of learning, selecting appropriate learning strategies and seeking support when needed. It also permits students to have input into the course and make decisions about how their learning will be achieved.

Although most SDT research focuses on the satisfaction of psychological needs, evidence suggests that need frustration is a distinct construct that has unique associations with motivation, everyday functioning, and well-being (Bartholomew et al., 2011). To illustrate, the absence of need satisfaction may not involve experiences of need frustration but experiencing need frustration should imply the absence of need satisfaction. As hypothesized, a series of studies measuring both types of needs-based experiences supported the proposition of an asymmetrical relationship between satisfaction and frustration constructs, finding a moderate negative correlation between them (Bartholomew et al., 2011). Furthermore, in domains of work (Trépanier et al., 2016), physical activity (Teixeira et al., 2018), and romantic relationships (Kindt et al., 2016), need frustration has been shown to especially predictive of negative outcomes, including stress, anxiety, depression, and burnout (Vansteenkiste et al., 2020). Within the domain of physical education, Haerens et al. (2015) found that when students perceived the instructor as controlling (rather than autonomy supportive), they were more likely to experience need frustration, which was predictive of controlled motivations (i.e., introjected and external) and amotivation. Similar findings were observed in a sample of Korean high school students. Using a 3-wave longitudinal design, Jang et al. (2016) reported that increases in need frustration from the beginning of the school year to midway through the school year predicted increases in disengagement from academics. Therefore, SDT researchers have called for additional studies examining the unique antecedents (e.g., perceptions of the environment) and consequences (e.g., motivational, emotional, and behavioral outcomes) associated with need satisfaction and frustration.

3.2.1 A Person-Centered Approach

The proposed study answers this call using a person-centered approach to examining profiles of need satisfaction and frustration in relation to educational outcomes in large introductory chemistry courses. Variable-centered approaches fail to adequately characterize relations between variables and outcomes of interest among subpopulations of students. Person-centered analytic procedures resolve these issues by identifying qualitatively distinct subpopulations characterized by similar relations among key variables within the broader population (Bergman & Trost, 2006; Morin & Wang, 2016). Furthermore, person-centered approaches contribute to theoretical advancements by effectively modeling complex interactions between theoretical constructs that occur simultaneously, providing a more holistic view of the theoretical assumptions being tested (Magnusson, 1988). Although some studies grounded in SDT have used a person-centered approach (Howard et al., 2016; Lindwall et al., 2016), there are few that include both need satisfaction and need frustration, and none within the undergraduate STEM education literature.

One study of particular note used latent class analysis to identify profiles based on changes in need satisfaction and frustration from the beginning to the end of the academic semester in a sample of French university students (Chevrier & Lannegrand, 2021). Four profiles emerged from the data: (1) a profile with high need satisfaction and low frustration of all three needs (40.65% of the sample), which remained stable across time; (2) a profile with high autonomy frustration with moderate levels of satisfaction of all needs and moderate frustration of competence and relatedness needs which experienced declines in autonomy frustration (25.61% of the sample); (3) a profile with moderate need satisfaction

and frustration for all three needs at the beginning of the semester which transitioned to high frustration across all three needs by the end of the semester (21.14% of the sample); and (4) a profile with low satisfaction and high frustration across all three needs at the beginning of the semester who transitioned to higher satisfaction and less frustration be the end of the semester. The profile characterized by high satisfaction and low frustration across all three needs (profile 1) reported the highest autonomous motivation. In contrast, the profile characterized by low satisfaction and high frustration at the beginning of the semester who became more satisfied and less frustrated across all three needs by the end of the semester (profile 4) reported the highest levels of amotivation.

A study by Chevrier and Lannegrand (2021) supports the theoretical assumption that need satisfaction and frustration are distinct constructs, but it also introduces the importance of timing in the course (early vs. late in the semester). Three of the four profiles identified experienced changes across the semester. Thus, different combinations of satisfaction and frustration for each need were observed at each time point. Conclusions are somewhat restricted by using latent transition analysis rather than conducting two separate latent profile analyses. However, it may be the case that at the end of the semester there are only three profiles: one characterized by high satisfaction and low frustration, one characterized by moderate satisfaction and frustration, and one characterized by low satisfaction and high frustration. This set of profiles is similar to findings observed among a cross-sectional sample of participants in a work context (Rouse et al., 2020), and may indicate that initial variation among the three needs (i.e., some needs met more than others) may become more overlapped (i.e., all needs met to a similar degree) over time as course experiences accrue. If such a finding were to be replicated, it would have implications for

SDT. Specifically, it would suggest that over time the satisfaction or frustration of a given need influences perceptions about the satisfaction or frustration of other needs.

3.3 The Present Study

The present study aims to identify whether this increased overlap in need satisfaction and frustration will be observed at the end of the semester among general chemistry students. To date, no studies have explored need satisfaction and frustration within the context of large, introductory STEM courses at the university level. As a follow-up to the first proposed study, this study will provide valuable information about whether similar or different profiles are observed, and whether profile membership at the end of the semester is associated with other academic variables in similar or different ways as findings from Study 1 which identified need profiles and their unique associations with predictors and outcomes of profile membership at the beginning of the semester. The study also builds on the Chevrier and Lannegrand (2021) study by focusing just on the satisfaction and needs at the end of the semester. The latent transition model is a valuable technique for examining change in need satisfaction and frustration, but the profiles it derives are profiles of change rather than profiles at a given time point. As a result, the depiction of profiles at the end of the semester may be different from the change profiles and latent transition models benefit from additional within-time latent profile analyses.

Finally, this proposed study examines additional academic variables in relation to profile membership. As was the case for the first study, autonomy-supporting learning environment and academic motivation will be examined. It is again hypothesized that autonomy supporting learning environments will be associated with profiles that exhibit

greater need satisfaction and lower need frustration. Such profiles are also hypothesized to be associated with more autonomous motivation and less controlled motivation or amotivation. However, this study will also examine:

1. The extent to which students sacrificed other aspects of their well-being in order to succeed in the course,
2. Academic resilience,
3. Academic stress,
4. Expected course grade,
5. And intention to persist in current major.

SDT argues that students may experience psychological need satisfaction when they feel that prioritizing their well-being while pursuing valued academic goals is possible (Holding et al., 2020). Student sacrifices to well-being are emerging as an important factor in academic success and psychological health (Gilbert et al., 2021). It is therefore hypothesized that profiles in which needs are highly frustrated will be associated with greater student sacrifices to well-being. SDT also proposes that need-frustrating contexts diminish an individual's ability to cope and function within that environment and increases the likelihood of psychological dysfunction beyond the mere absence of need satisfaction (Deci & Ryan, 2000). Student perceptions that their needs are being actively thwarted by the learning environment undermine autonomous motivation and increase risk for psychological distress and maladjustment (Liu et al., 2017; Mabbe et al., 2018). Thus, profiles exhibiting high levels of need frustration may be related to higher levels of academic stress, while in contrast profiles exhibiting high levels of need satisfaction may be related to higher levels of academic resilience.

Academic success is often measured in terms of course grade, and passing or higher grades in a general chemistry course have important implications for whether students will be able to pursue their desired major and merit additional educational opportunities (e.g., research with a professor). STEM departments often struggle to retain their majors through such large introductory courses (Chen & Soldner, 2013; Ellis et al., 2016). Even when students earn acceptable grades, their course experiences may reduce enthusiasm and motivation to continue in their major (Perez et al., 2014; Robinson et al., 2019). An important question is whether SDT can shed light on these more final outcomes. Following the theory, it is proposed that students in profiles characterized by greater need satisfaction and lower need frustration will expect higher grades in the course and have greater intention to persist in their major.

3.4 Method

3.4.1 Participants and Procedure

Undergraduate students enrolled across five large-lecture general chemistry courses at a large, public land-grant university in the southeastern United States were invited to participate at the end of the Spring 2022 semester. Students had the option to earn 1% extra credit on their overall course homework grade by completing an end-of-semester online survey (distributed 2 weeks before final exams) or by completing an alternative assignment of equivalent time and effort. Most students majoring in STEM and health disciplines are required to complete a two-course chemistry sequence to advance in their majors. Students are placed in an appropriate two-course chemistry sequence based upon their major and math prior achievement as follows: An introductory chemistry course for health

professionals; The first introductory chemistry course in a two-course sequence for students with advanced math preparation; The second introductory chemistry course of the two-course sequence for students with advanced math preparation who took the first of the two-course sequence; The first introductory chemistry course in a two-course sequence for students with less math preparation; The second introductory chemistry course of the two-course sequence for students with less math preparation who took the first of the two-course sequence. Students were permitted to enroll in only one of these courses. This sampling procedure allowed for a representative sample of undergraduate chemistry students by including students who vary in terms of college readiness, math ability, and those who may not be following the typical Fall-Spring sequence (e.g., those who took the first course in the sequence in the spring instead of in the fall). Total enrollment across all five courses was 1505 students. Instructors were unaware of whether students chose to participate in the study or complete the alternative assignment. The study was approved by the university institutional review board and informed consent was obtained.

Of the 1505 students invited to participate, 828 elected to participate in the study and provided informed consent (55% response rate). Most students in the sample were enrolled in the second course of the two-course introductory chemistry sequence for students with advanced math preparation. This was expected since this course is the second course in the typical two-course sequence and has the highest enrollment. Most students in the sample are in their first year of college (69.6%), female (63.4%), White (65.5%), and are most likely to be STEM majors (% forthcoming). See Table 7 for full demographic details.

3.4.2 Measures

Need Satisfaction and Frustration in Chemistry

Items adapted from the Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS) were used to assess need satisfaction and need frustration within the domain of undergraduate general chemistry courses (Chen et al., 2015). The 24-item questionnaire contains six subscales, each containing three items, to assess participant satisfaction and frustration for each basic psychological need: Autonomy Satisfaction (α = 0.73; e.g., "In my chemistry class, I feel like my decisions reflect what I really want."; Competence Satisfaction (α = 0.89; e.g., "In my chemistry class, I feel confident that I can do the coursework."; Relatedness Satisfaction (α = 0.82; e.g., "In my chemistry class, I feel close and connected to the other students."; Autonomy Frustration (α = 0.79; e.g., "In my chemistry class, I feel forced to do many things I wouldn't choose to do."; Competence Frustration (α = 0.86; e.g., "In my chemistry class, I have serious doubts about whether I can do the work well."; and Relatedness Frustration (α = 0.72; e.g., "In my chemistry class, I feel excluded from the other students". Responses were scored using a 5-point Likert-type scale ranging from 1 (Never true) to 5 (Always true). Scores for each factor were computed by creating an average response for items from each subscale.

Autonomy Supportive Learning Environment

To assess student perceptions of an autonomy-supportive learning environment, items from the Learning Climate Questionnaire (LCQ; Williams & Deci, 1996) were adapted to fit the undergraduate general chemistry course context (α = 0.97; e.g., "My Chemistry instructor conveys confidence in my ability to do well in the course."). The 15-

item LCQ has been shown to have strong psychometric properties (internal consistency and predictive validity) in prior studies (Cheon et a., 2012; Jang et al., 2009). Internal consistency for this measure was consistent with psychometric properties reported in prior studies. Responses were scored on a 7-point Likert-type scale from 1 (Strongly disagree) to 7 (Strongly agree). Higher scores indicate that the learning environment is perceived as autonomy-supportive, while low scores indicate the learning environment is perceived as more controlling.

Well-Being Sacrifices for Academic Goal Pursuit

Sacrifices to well-being in the pursuit of academic goals were assessed using 8-items adapted from Holding and colleagues (2020) ($\alpha = .90$). On a 5-point Likert-type scale ranging from 1 (Never) to 5 (Very frequently), participants were asked to rate how frequently they had to make sacrifices during the semester related to their physical well-being (e.g., "So far this semester, I've had to sacrifice getting enough sleep."), social well-being (e.g., "So far this semester, I've had to sacrifice time with friends."), and academic well-being (e.g., "So far this semester, I've had to sacrifice study time in one class because of another class.") in order to pursue academic goals. Higher scores indicate more sacrifices made to student well-being in service of academic goals.

Academic Motivation in Chemistry

Items adapted from the Academic Self-Regulation Questionnaire (SRQ-A; Ryan & Connell, 1989) were used to assess five dimensions of academic motivation in chemistry. Each of the 25 items began with the sentence stem, "I do my chemistry coursework…" and asked student participants to rate their agreement on a 5-point Likert-type scale ranging

from 1 (Not at all true of me) to 5 (Always true of me). Dimensions of student motivation in chemistry included subscales for: Intrinsic Motivation (5 items; α = 0.86; e.g., "because I enjoy learning about it"); Identified Regulation (5 items; α = 0.81; e.g., "because it's important to me to try to do well."); Introjected Regulation (5 items; α = 0.73; e.g., "because I want others to think I am smart."); External Regulation (5 items; α = 0.74; e.g., "because I need to for my major."); Amotivation (5 items; α = 0.86; e.g., "I don't know; I can't understand what I am doing in this class."). Scores were calculated by creating an average response for subscale items corresponding with each type of motivation. Higher scores indicate greater motivation for the respective type of motivation.

Academic Resilience

Academic resilience was assessed using the 14-item Perseverance subscale (α = 0.85) from the Academic Resilience Scale (ARS; Cassidy, 2016). Perseverance is one dimension of academic resilience, which is a multidimensional construct (Lee et al., 2013; Tudor & Spray, 2017), that assesses students' attitudes toward sticking to academic goals after experiencing adversity rather than giving up. This subscale was selected to measure perseverance as a dimension of academic resilience because previous validation studies suggest that this factor accounts for substantially more proportion of the variance than the remaining subscales in measuring academic resilience (Cassidy, 2016). In addition, results from a follow-up validation study of this scale suggest that researchers should use individual subscale scores (representative of a multidimensional construct) rather than a composite (unidimensional) resilience score to ensure inferences are theoretically and methodologically valid (Hunsu et al., 2022). Student participants were shown a vignette describing an experience of failure and instructed to imagine they had experienced the

adverse event. Then they rated how likely they would respond in different ways (e.g., "I would use the situation to motivate myself.," "I would change my career plans", "I would work harder.") on a 5-point Likert-type scale ranging from 1 (Very likely) to 5 (Very unlikely). Positively phrased items were reverse scored so that higher scores indicate greater academic resilience.

Academic Stress

Academic stress was assessed using 25-items adapted from the Academic Stress in Secondary Education Questionnaire (QASSE; García-Ros et al., 2018). Students were asked to rate how stressful each item was for them on a 10-point slider scale ranging from 0 (Not at all stressful) to 10 (Extremely stressful). Each item represented a potential stressor associated with college life both within and outside of the classroom setting (e.g., "Managing time efficiently"; "Making friends in college"; "Preparing for exams"; $\alpha = 0.92$). Scores were calculated by summing responses to all stressors so that higher scores indicate greater academic stress.

Persistence Intentions in Major

Persistence intentions were assessed using six (6) items adapted from Banchefsky and colleagues (2019). The original scale was developed to assess persistence intentions in STEM programs of study, but items were rephrased to represent intentions to persist in each participant's current program of study (e.g., "It is still my intention to stay in my same major after this year."; $\alpha = 0.89$). Intentions have been shown to be proximal predictors of actual behavior (Ajzen, 1985, 2011). In the context of education, studies have shown strong correlations between intentions to persist in the academic settings and actual persistence

(Banchefsky et al., 2019; Davidson et al., 2009; Luke et al., 2015). Participants rated their agreement with each item on a 5-point Likert-type scale ranging from 1 (Strongly disagree) to 7 (Strongly agree). Higher scores indicate greater intentions to persist in the student's current program of study (i.e., academic major).

Expected Grade in Chemistry

Participants were asked to report their expected grade in chemistry (between 0 and 100) at the end of the academic semester. Self-reported grades have been found to be highly positively correlated with actual grades across academic subjects and grade levels, demonstrating they are reliable indicators of academic achievement (Sticca et al., 2017). Furthermore, one meta-analysis found that self-reported grades from college students are more reliable than those from high school students, and that self-reported grades in specific subject domains are more reliable than self-reported grade point averages (GPA) (Kuncel et al., 2005).

Control Variables

To control for potential confounding variables, the following variables will be included as covariates in the model. The first control variable accounts for student enrollment in one of the five general chemistry courses used to recruit participants and is intended to control for dependency among observations for students nested within each course. The remaining control variables include educational and demographic background variables that studies have found to be associated with college student success (Allensworth & Clark, 2020).

Chemistry Course. To control for dependency in individual observations among students enrolled in one of five different general chemistry courses, four dummy variables indicating which general chemistry course in which the student is taking will be included to control for potential nesting effects in the data.

Prior Achievement. Student participants were asked to self-report their high school GPA and standardized test scores for the ACT or SAT. The university that does not require scores for both the SAT and ACT so not all students will have both. Therefore, a prior achievement index using two or three indicators will be used to include prior achievement as a covariate in the analyses. Specifically, if one test score was reported, the student will have two indicators (e.g., HSGPA and ACT) and if both test scores were reported the student will have three indicators (e.g., HSGPA, ACT, and SAT).

Year in School. Student participants were asked, to consider their time in college and not credit hours earned, to indicate their year in school from six available options (e.g., "first year in college," "second year in college, "third year in college," "fourth year in college," "four or more years in college," "other"). Many students at this institution begin college with college credit hours earned in high school so their year in college more accurately depicts their time in college than their class designation (e.g, freshman, sophomore).

College Major. Student participants were asked to select their current college major from a list containing all available college majors at the institution. Responses will be operationalized as a categorical variable in which their major is categorized into broader fields of study (e.g., business, health and life sciences, STEM (science, technology,

engineering, and math), arts and humanities, social and behavioral sciences, and undecided).

Sex. Student participants were asked to indicate the sex they were assigned at birth from two options: 1 (male) and 0 (female). Responses will be included in analyses as a dichotomous variable.

Race. Student participants were asked to select all options that correspond to their racial or ethnic identity from a list of available options (e.g., Hispanic or Latino, Black or African American, Native American or American Indian, Asian or Pacific Islander, White or Caucasian, A race other than the available options). Due to the lack of racial diversity at the institution in which the sample was recruited, responses will be dichotomized as 1 (White) and 0 (non-White) for analysis.

First-Generation Status. Student participants were asked to indicate which option best reflected their parents' or primary caregivers' educational attainment (e.g., "Yes, one or both of my parents or primary caregivers completed college", "No, my parents or primary caregivers did not complete college." This dichotomous variable will be analyzed as 1 (First-Generation College Student) and 0 (Non-First-Generation College Student).

3.4.3 Analyses

Preliminary Analyses

All analyses in the present study were estimated using Mplus 8.8 (Muthén & Muthén, 2017). Preliminary analyses were conducted to verify that the assumptions of latent profile analysis were satisfied. First, data were screened to identify the presence of multivariate outliers using the Mahalanobis distance statistic. Second, distributions of

study variables were examined to determine if the assumption of multivariate normality was met (Mardia, 1970). Third, the data were evaluated to identify patterns of missing data using Little's (1988) test statistic and independent means t-tests comparing participants with complete and incomplete response data on study variables. Last, due to data being collected across five general chemistry courses, unconditional multi-level mean models will be used to obtain the intra-class correlations (ICCs) for study variables to evaluate nesting of data within courses. ICC values greater than .10 reflect significant nesting of variables within courses.

To review variable means, standard deviations, correlations among constructs, and Cronbach's alpha's (α) for scale scores see Table 8.

Primary Analyses

To identify if subgroups of psychological need satisfaction and frustration exist, latent profile analysis (LPA) was conducted (Masyn et al., 2013). The goal of LPA is to identify latent profiles or groups (k) of individuals who are a meaningful and interpretable pattern of responses on the measures of interest (Bergman et al., 2003; Marsh et al., 2009). Variables for satisfaction and frustration of each basic psychological need were included as profile indicators to evaluate the number, nature, and size of the latent need profiles. To begin, a baseline model with one profile was estimated, followed by additional models with increasing numbers of profiles for up to six profiles. To determine the optimal number of need profiles, multiple statistical criteria were used: consistent Akaike's information criterion (CAIC), Bayesian information criteria (BIC), sample-size adjusted BIC (SABIC), adjusted Lo-Mendell-Rubin likelihood ratio test (aLMR), and bootstrap likelihood ratio test (BLRT) (Geiser, 2013; Morin et al., 2016). Akaike's information criterion (AIC) is

reported but was not be used for model evaluation because this statistical indicator has been found to frequently overestimate the number of latent profiles (Henson et al., 2007). Results from simulation studies report that the CAIC, BIC, SABIC, and the BLRT are particularly effective with LPA (Diallo et al., 2016; Nyland et al., 2007; Tofighi & Enders, 2008). For CAIC, BIC, SABIC indices, lower values indicate better model fit. Both aLMR and BLRT compare a k-profile model with a k-1-profile model using significance testing. Statistical significance indicates that the k-1-profile model (fewer profiles) should be rejected in favor of the k-profile model (additional profiles) (Lo et al., 2001; Masyn, 2013). However, prior studies suggest that these tests are heavily influenced by sample-size resulting in indicators continuing to improve the model as additional latent profiles are added with large samples (Marsh et al., 2009). For this reason, information criteria were also graphically presented through "elbow plots" to illustrate gains in model fit associated with additional profiles (Morin et al., 2011). With this plot, the point at which the slope flattens will indicate the optimal number of profiles.

Next, posterior probability values and entropy were evaluated to determine how accurately individual cases define the profiles. There is no agreed upon cutoff criteria for probability values. Some studies suggest values greater than .90 are ideal (Muthén & Muthén, 2017), whereas others suggest that if other criteria are satisfied and the model is theoretically supported, values between .80 and .90 are tenable (Weller et al., 2020). Entropy relies on posterior probabilities to assess how well each LPA model partitions the data into homogenous profiles (Ferguson et al., 2019). Entropy can range from 0 to 1, with higher values (.80 or greater) offering evidence that the model has classified individuals into profiles with greater certainty. Finally, the preferred model was also determined based

on theoretical support, and interpretability and meaningfulness of the groups based on prior work and practical application in the undergraduate context. Furthermore, to thoroughly understand the nature of retained profiles, patterns of homogeneity within each profile and distinctions between the profiles were evaluated. To understand need satisfaction and frustration within each profile, associations between need satisfaction and frustration variables and the latent profile variable were estimated (Masyn, 2013). In addition, class separation and odds ratios were used to further understand the differences between profiles (Masyn, 2013). Mean differences in need satisfaction and frustration variables between the profiles were also examined.

Predictors and Outcomes of Need Profile Membership

To examine associations between predictors (autonomy supportive learning environment and sacrifices to wellbeing) and outcomes (resilience, academic stress, persistence intentions, and expected grades) of profile membership, additional LPAs were conducted using the three-step Bolck-Croon-Hagenaars (BCH; Bolck, Croon, & Hagenaars, 2004) approach via the BCH function in Mplus. The BCH approach is a robust, stepwise method recommended over other approaches because it includes uncertainty of profile membership for individuals into the model using weighted analysis of variance (ANOVA), with weights reflecting measurement error of each latent profile variable (Bakk et al., 2013; Nylund-Gibson & Masyn, 2016). An additional benefit of this approach is that it maintains the integrity of the profiles when including predictor and outcome variables into the models (Ferguson et al., 2020). The BCH approach was conducted hierarchically. First, associations between predictors (autonomy supportive learning environment and sacrifices to wellbeing) and profile membership were examined. Then, predictor variables

were added to the model as control variables and associations between profile membership and motivational, educational, and wellbeing outcomes were evaluated.

Upon determining the appropriate number of need profiles, which is the first step of the BCH approach, the final unconditional latent profile model using profile indicators (i.e., observed variables) was estimated and BCH weights were saved to use in the proceeding steps (Asparouhov & Muthén, 2014; Clark & Muthèn, 2009). Predictor and outcome variables were not included in this initial step. In the second step, posterior class probabilities estimated in the first step were used to determine each individual participant's probability of belonging to each need profile. The second step is necessary to classify participants into their most likely need profiles and determine the error associated with those probabilities. The third step involved using the class assignments from the step 2 model to analyze the associations between need profile membership and predictor and outcome variables. Latent profile variables were regressed onto predictors. Then, both predictors of profile membership (perceptions of the learning environment and sacrifices to wellbeing) were included in the final model as control variables by fixing the conditional response probabilities to their estimated values from the prior model, and then including all outcomes in the model.

3.5 Results

3.5.1 Research Question 1: Identification of need profiles at the end of the academic semester

Statistical indices for each model are reported in Table 9. Analyses to identify the optimal number of need profiles for the data began by modeling a solution with one profile

and subsequently estimating models with on additional profile up to six profiles. Models with additional profiles beyond six are not reported since model fit no longer improved and because the size of the smallest profile sizes for the 5- and 6-profile solutions were below 5% of the sample, which suggests the groups may be spurious at that point (Ferguson et al., 2020). Statistical indices for the aIC, BIC, and aBIC decreased with each additional profile. However, decreases in these values only suggests model improvement when the magnitude to which they decrease is substantial. Consequently, a graphical elbow plot of the AIC, BIC, and aBIC were examined to determine the point at which the slope flattens to determine when additional profiles do not substantially improve model fit to the data. Statistical indices and the corresponding elbow plot suggest that the optimal solution is between 3- and 4-profiles (see Figure 3). Furthermore, LMR, aLMR, and BLRT significance tests were examined to determine if the null hypothesis should be rejected for the *k*-1 model (solution with 1 fewer profile) in favor of the *k*-model (solution with 1 additional profile) as the better fitting solution. Of note, all *p*-values for BLRT tests were significant, making these results inconsequential when determining the optimal number of need profiles. For transparency, BLRT results are reported but were not considered in decisions regarding the final unconditional model. Hypothesis tests for the LMR and aLMR confirmed AIC, BIC, and aBIC results suggesting that the 3-profile solution was a better fit than the 2-profile solution and, similarly, that the 4-profile solution was a better solution than the 3-profile model. The LMR and aLMR produced a non-significant *p*-value at the 5-profile solution. In addition, entropy for both solutions remained high (3-profile = 0.85; 4-profile = 0.84). To aid in decision making between these two solutions, profiles were examined in terms of their unique characteristics, meaningfulness, and interpretability. The

4-profile solution revealed two groups within the sample that were identical in terms of their experiences of need satisfaction and frustration and only varied in terms of the degree to which those students were experiencing the needs. Therefore, the 3-profile solution was identified as the optimal model for the data.

Means for basic psychological need satisfaction and frustration indicators are reported in Table 10. An illustration of the profiles characteristics based on satisfaction and frustration means are provided in Figure 4. Students in Profile 1 (n = 252; 34.4% of the sample) are characterized by high satisfaction across all three needs with competence and relatedness being their most satisfied need. In addition, students in Profile 1 reported low frustration across all three needs. Despite not being frustrated with their learning overall, these Highly Satisfied and Not Frustrated students reported autonomy was their most frustrated need, followed by competence, and relatedness being their least frustrated need. Students in Profile 2 (n = 430; 58.8% of the sample) are characterized by moderate levels of need satisfaction on all three needs, with relatedness being their most satisfied need, followed by competence, and autonomy being their least satisfied need. In terms of their frustration, students in Profile 2 reported slightly higher than average autonomy and competence frustration, with competence being their most frustrated need and relatedness being their least frustrated need. This Moderately Satisfied, Slightly Autonomy and Competence Frustrated group was the largest in the sample. Lastly, students in Profile 3 (n = 50; 6.8% of the sample) are characterized by low autonomy and competence satisfaction, yet moderate levels of relatedness satisfaction. In addition, students in Profile 3 reported high levels of autonomy and competence frustration, with competence being their most

frustrated need, and reporting slightly below average relatedness frustration. This Autonomy and Competence Frustrated group is the smallest in the sample.

3.5.2 Research Question 2: Prediction of need profile membership

The BCH method was used to produce probability weights assigning students to their most likely latent profile, then multinomial logistic regression models were conducted to examine perceptions of the learning environment as autonomy supportive, sacrifices to well-being in the pursuit of academic goals, and student demographics as predictors of need profile membership compared to a reference profile. Results are reported in Table 11.

Autonomy-Supportive Learning Environment. Higher reports of the learning environment as autonomy supportive was associated with greater odds of membership in Profile 1 (Highly Satisfied and Not Frustrated) (OR = 7.872, $p < .001$) and Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) (OR = 2.778, $p < .001$) compared to students assigned to Profile 3 (Autonomy and Competence Frustrated). Furthermore, higher reports of the learning environment as autonomy-supportive was associated with lower odds of membership in Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) (OR = 0.353, $p < .001$) compared to Profile 1 (Highly Satisfied and Not Frustrated). Mean perceptions of the learning environment as autonomy supportive were highest in Profile 1 (M = 5.80), lowest in Profile 3 (M = 3.14), and in between in Profile 2 (M = 4.64).

Sacrifices to Well-Being. Reporting making more sacrifices to well-being in the pursuit of academic goals was associated with lower odds of membership in Profiles 1 (Highly Satisfied and Not Frustrated) (OR = 0.095, $p < .001$) and Profile 2 (Moderately

Satisfied, Slightly Autonomy and Competence Frustrated) (*OR* = 0.229, p < .001) compared to students assigned to Profile 3 (Autonomy and Competence Frustrated). Whereas reporting making more sacrifices to well-being in service of academic goals was associated with greater odds of students being in Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) (*OR* = 2.410, p < .001) compared to Profile 1 (Highly Satisfied and Not Frustrated). Profile means for students' sacrifices to well-being were highest in Profile 3 (*M* = 4.17), lowest in Profile 1 (*M* = 2.94), and in between in Profile 2 (*M* = 3.43).

Student Demographic Characteristics. Students' year in school, sex, race, self-reported high-school GPA, first-generation status, being a pSTEM major, nor being in a Health-related major were significantly associated with membership in Profile 1 (Highly Satisfied and Not Frustrated) or Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) compared to Profile 3 (Autonomy and Competence Frustrated). However, odds of membership in Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) were lower for male students (*OR* = 0.546, p < .05) and students who are not first-generation (*OR* = 0.529, p < .05) compared to Profile 1 (Highly Satisfied and Not Frustrated). The percentage of male students was highest in Profile 1 (Highly Satisfied and Not Frustrated) (29.2%), lowest in Profile 3 (12.8%), and Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) (23.0%) falling in between. Profile 2 contained the fewest first-generation students (15.7%), Profile 3 contained the most first-generation students (27.9%), and Profile 1 was in between (17.8%).

3.5.3 Research Question 3: Relationships between need profile membership and outcome variables

The BCH approach was conducted to assess differences in outcome variables among the need profiles. Results from equality tests of means across classes using the BCH for academic motivation, resilience, academic stress, intentions to persist in current major, and expected grade in Chemistry are reported in Table 12.

Academic Motivation. Autonomous forms of motivation (e.g., intrinsic motivation and identified regulation) were highest for students in Profile 1 (Highly Satisfied and Not Frustrated) and lowest for students in Profile 3 (Autonomy and Competence Frustrated), and in between for Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated). Introjected regulation, a more controlled type of extrinsic motivation, followed a similar pattern being highest for students in Profile 1 (Highly Satisfied and Not Frustrated), lowest for students in Profile 3 (Autonomy and Competence Frustrated), and in between for Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated. However, higher external regulation, the most controlled type of extrinsic motivation, was similar among students in Profiles 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) and 3 (Autonomy and Competence Frustrated) and lowest for students in Profile 1 (Highly Satisfied and Not Frustrated). Amotivation showed the opposite pattern found among autonomous forms of motivation (e.g., intrinsic and identified) and introjected regulation with students in Profile 3 reporting the highest amotivation, students in Profile 1 (Highly Satisfied and Not Frustrated) reporting the lowest, and students in Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) falling in between.

Resilience and Stress. Resilience was highest amongst students in Profile 1 (Highly Satisfied and Not Frustrated), but not significantly different between Profiles 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) and 3 (Autonomy and Competence Frustrated). On the other hand, academic stress was highest among students in Profile 3 (Autonomy and Competence Frustrated), lowest in Profile 1 (Highly Satisfied and Not Frustrated), and in between for members of Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated).

Persistence Intentions and Expected Course Grade. The highest intentions to persist in their current major and the highest expected course grades were characteristic of students in Profile 1 (Highly Satisfied and Not Frustrated). Intentions to persist in current major were similar between Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) and Profile 3 (Autonomy and Competence Frustrated). Students in Profile 2 (Moderately Satisfied, Slightly Autonomy and Competence Frustrated) expected to earn lower grades than students in Profile 1 (Highly Satisfied and Not Frustrated), however, students in Profile 3 (Autonomy and Competence Frustrated) expected to earn the lowest grades across the profiles. The average expected grade was 86.6% in Profile 1, 80.3% in Profile 2, and 73.2% in Profile 3.

3.6 Discussion

The first goal of this study was to identify profiles of satisfaction and frustration of the basic psychological needs of autonomy, competence, and relatedness among undergraduate Chemistry students at the end of the course. The second goal was to determine if students' perceptions of the learning environment as more or less autonomy

supportive, the frequency in which students report making sacrifices to their well-being in pursuit of their academic goals, and demographic characteristics predicted profile membership. The third and final goal was to determine associations between profile membership with academic outcomes, including autonomous and controlled forms of academic motivation, resilience, academic stress, intentions to persist in their current major, and their expected grade in Chemistry.

Results of this study were the first to reveal three distinct need profiles at the end of the university semester within the context of large introductory STEM courses, specifically, students enrolled in general Chemistry courses. The nature of the profiles was mostly consistent with the hypothesis that one profile would be characterized by high satisfaction and low frustration, one with high frustration and low satisfaction, and one with moderate satisfaction and frustration. Specifically, the *Highly Satisfied and Not Frustrated* profile was characterized by high satisfaction and low frustration across all three needs, with competence being their most satisfied need. In contrast, the *Autonomy and Competence Frustrated* profile was characterized by high autonomy and competence frustration, low satisfaction of these two needs, yet moderate relatedness satisfaction and frustration. Finally, the *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* profile was characterized by moderate satisfaction of all three needs, moderate relatedness frustration, yet slightly above average autonomy and competence frustration. The three observed profiles were similar in nature to profiles observed in other person-centered analyses of need profiles, including studies among first-year undergraduate students within the French university context (Chevier & Lannegrand, 2021; Gillet et al., 2020), apart from the number of observed profiles being fewer.

The number and nature of the profiles of the present study were most similar to results reported by Warburton and colleagues (2020) using a hierarchical cluster analytic approach among a sample of high school physical education students. However, in this study, each need was combined into two overall satisfaction and frustration composite variables with one cluster reporting high satisfaction and low frustration, one reporting low satisfaction and high frustration, and one reporting moderate satisfaction and frustration. It is noteworthy that the present findings highlight the importance of using a more precise approach of modeling each need independently since autonomy and competence needs emerged as important within and between the three profiles. This is conceptually and practically important since these two needs have repeatedly been shown to be critical in learning contexts, with competence being most important, in numerous variable-centered studies (Bureau et al., 2022).

Prediction of Need Profiles

Students' psychological needs are proposed by Self-Determination theory to be satisfied when they perceive the learning environment as autonomy supportive, as opposed to controlling (Ryan & Deci, 2020). As hypothesized, students who viewed the chemistry learning environment as supportive of their autonomy were most likely to be members of the *Highly Satisfied and Not Frustrated* profile relative to the *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* or the *Autonomy and Competence Frustrated* profiles. In addition, increased perceptions of the Chemistry learning environment as autonomy-supportive was more prevalent among students belonging to the *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* profile than the *Autonomy and Competence Frustrated* profile. These findings add further support for the theoretical

conceptualization that, for university STEM students, all three psychological needs are more likely to be satisfied when instructors use autonomy-supportive instructional practices, which foster a need-supportive learning culture (Ryan & Deci, 2020). Prior research has shown positive influence of autonomy-supportive instructional practices on academic outcomes, including but not limited to students' self-determined motivations, need satisfaction, and achievement (Bureau et al., 2022; Cheon et al., 2019; Howard et al., 2017; Vansteenkiste et al., 2009). However, most studies have focused on predicting satisfaction of psychological needs, leaving untested the theoretical proposition that frustration of needs is also a fundamental aspect of academic outcomes. Thus, the present study is the first to show the importance of supporting undergraduate STEM students' autonomy when predicting individual differences in student need satisfaction and frustration using a person-centered approach.

Results suggest that students vary in how much autonomy support they perceive in large introductory Chemistry courses, which in turn influences how satisfied or frustrated their needs are within the learning context. It is possible that some variation in perceptions of autonomy-support is due to course nesting, since students were enrolled across five general chemistry courses, each of which included multiple sections with different instructors. Inspection of intraclass correlations among students nested within courses on primary need satisfaction and frustration variables revealed ICCs ranging between .001 and .02, but the ICC for autonomy supportive learning environment was .178. Multilevel analyses were beyond the scope of this study since the primary focus was on the identification of subgroups of students based on their co-occurring experiences of need satisfaction and frustration. Future studies, however, should consider the influence of

nesting on perceptions of the learning environment when using it as a predictor of group membership into psychological need profiles.

Chemistry students who reported making more sacrifices to their well-being at the end of the semester, including maintenance activities such as eating healthy, getting enough sleep, exercise, and leisure activities including time with family, friends, and their communities, and academic sacrifices including study time and effort in other classes to do well in their Chemistry course, were more likely to be members of the *Autonomy and Competence Frustrated* profile compared to the *Highly Satisfied and Not Frustrated* profile or the *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* profile. In addition, students who felt they were making more sacrifices to their well-being at the end of the semester to succeed in Chemistry were more likely to belong to the *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* profile compared to the *Highly Satisfied and Not Frustrated* profile. These findings correspond with findings in domains of work (Mennino & Brayfield, 2002) and higher education (Holding et al., 2020) suggesting that when individuals make sacrifices to their well-being to pursue extrinsic career goals, it can backfire by frustrating basic psychological needs. Such can produce unintended negative consequences on motivation, self-regulation, goal attainment, and overall well-being.

These findings have theoretical implications for SDT and practical implications within STEM higher education. Goal Contents Theory (Ryan & Deci, 2017) one of six mini-theories within the SDT framework, suggests that prioritizing extrinsic aspirations (attaining wealth, status, grades, or socially valued achievements) above intrinsic aspirations (developing meaningful relationships, contributing to one's community or

society, having good mental and physical health, or developing as an individual) predicts poorer overall well-being, which is mediated by high need frustration. From a practical standpoint, students may learn in school, their families, and from the broader culture that placing their academic achievement and career aspirations above all else will lead to a good life down the road, but the unintentional consequences of this mindset may have harmful consequences on their lives and ability to achieve their academic goals. Students' intrinsic and extrinsic life aspirations were not directly measured in this study. However, future studies should directly assess if groups of students experiencing greater need frustration than satisfaction are more likely to have extrinsic opposed to intrinsic life aspirations.

Student demographic characteristics were included to control for their influence on the prediction of profile membership, and thus no explicit hypotheses involving demographic characteristics were proposed. Students' year in school, sex, race, self-reported high-school GPA, first-generation status, and being in a STEM or Health-related major were not significantly associated with membership in the *Highly Satisfied and Not Frustrated* or *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* profiles compared to the students in the *Autonomy and Competence Frustrated* profile. Nevertheless, it is worth noting that at the end of the semester, students in the *Highly Satisfied and Not Frustrated* profile had greater probability of being male and not first-generation (not the first in their families to attend college) than students in the *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* profile. These findings are interesting considering the persistent social challenge of encouraging student persistence in STEM fields, especially among females (National Science Foundation, 2019). If female students and first-generation college students are less likely to experience high satisfaction

and very little frustration of their psychological needs in large-enrollment introductory STEM courses, it may help explain why these groups more often choose to abandon their STEM majors (Chen & Soldner, 2013). It is possible that students whose needs are frustrated in these courses are seeking alternative contexts in which they feel their needs are better supported.

Outcomes of Students' Need Profile Membership

The final objective of this study was to determine the qualitatively distinct associations between profile membership with academic outcomes including types of motivation, markers of psychological adjustment including resilience and stress, intentions to persist in current major, and expected grade in Chemistry. As hypothesized, need profile membership had unique associations with each academic outcome. The profile in which need satisfaction outweighed need frustration (Profile 1 - *Highly Satisfied and Not Frustrated*) had the best academic outcomes. The profile in which need frustration dominated over satisfaction (Profile 3 – *Autonomy and Competence Frustrated*) was most at risk for negative outcomes, and the profile experiencing moderate levels of both satisfaction and frustration fell in the middle. These findings corroborate a growing body of evidence that need satisfaction and frustration are distinct constructs that have different antecedents and consequences (Bartholomew et al., 2011; Rouse et al., 2020; Vansteenkiste et al., 2020). In addition, results from this study offer are the first to model the unique associations of satisfaction and frustration of each basic psychological need with academic outcomes within undergraduate STEM context using a person-centered approach.

Specifically, results revealed that students in the *Highly Satisfied and Not Frustrated* profile reported the highest levels of autonomous motivations (intrinsic

motivation and identified regulation) and the lowest level of amotivation. Regarding controlled motivations, introjected regulation was also highest among this profile, with external regulation being the lowest. SDT proposes that motivation falls on a continuum from most- to least- autonomous with more autonomous forms of motivation being more self-determined, and thus higher in quality than more controlled forms of motivation. The findings that students in the *Highly Satisfied and Not Frustrated* profile still had the highest levels of introjected motivation is consistent with evidence that autonomous and controlled motivations can be experienced simultaneously within contexts in which high value is placed on external rewards such as grades (Pattall et al., 2018; Ryan & Deci, 2020). Since introjected is a controlled form of motivation that is more self-determined than other forms, it seems that students who are highly satisfied and not frustrated have the highest levels of motivations that are the most self-determined and lowest levels of those that are fully controlled or absent. In contrast, students in the *Autonomy and Competence Frustrated* profile showed the opposite pattern. These students had the highest levels of amotivation and the lowest levels of autonomous motivations (intrinsic and identified) and introjected regulation. Students in the *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* profile fell in between these two profiles apart from sharing similar levels of external regulation with the *Autonomy and Competence Frustrated* profile. The present results provide additional evidence of the motivational costs associated with need frustration within the context of introductory STEM courses.

In addition to having the most self-determined motivations, students in the *Highly Satisfied and Not Frustrated* profile were more resilient and less stressed than the profiles experiencing moderate to higher levels of need frustration. Although resilience was similar

among students in the *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* and *Autonomy and Competence Frustrated* profiles, students in the *Autonomy and Competence Frustrated* profile were the most stressed. These results advance propositions within SDT that need experiences have unique consequences on psychological functioning, namely that experiences of high need satisfaction predict well-being and healthy psychological functioning, whereas need frustration prevailing over need satisfaction comes at a cost of ill-being and psychological dysfunction (Vansteenkiste & Ryan, 2013). Findings from variable-centered studies within a clinical setting (Campbell et al., 2017) and within the context of romantic relationships (Weinstsein & Ryan, 2011) found that need frustration predicted stress. Using a person-centered approach, this study provides additional evidence that as students need frustration increases, their levels of stress increase. Not only did students in the profile in which need satisfaction prevailed over need frustration feel less academic stress overall, these students were also more resilient when faced with challenges and setbacks in their academic work than the other two profiles, putting them in the best position to cope with the challenging context of introductory STEM courses.

Students' intentions to persist in their current major and their expected course grades followed a similar pattern. Students in the *Highly Satisfied and Not Frustrated* profile had the greatest intentions to persist in their majors and had the highest expected course grades. Students in the *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* and the *Autonomy and Competence Frustrated* profiles had similar intentions to persist in their majors, but students in the moderate profile expected to earn higher grades than the profile in which need frustration prevailed over need satisfaction. Importantly,

students in both the *Moderately Satisfied, Slightly Autonomy and Competence Frustrated* and the *Autonomy and Competence Frustrated* profiles reported competence as their most frustrated need. Several theoretical frameworks including SDT (Niemiec & Ryan, 2000), Social Cognitive Theory (Zimmerman et al., 2017), and Expectancy-Value Theory (Eccles & Wigfield, 2002) suggest that student motivation is highly dependent on whether students believe they can succeed in the academic domain (Elliot et al., 2017). When students feel competent, and expect success, they feel motivated to put forth effort and persist, including in STEM fields (Perez et al., 2014; Wang & Degol, 2013). In the present study, expected course grades were tested as an outcome of psychological need profiles. However, this study is correlational in nature, making it impossible to infer the causal direction of association. It is possible that difficulties mastering the material and receiving lower grades led to reductions in perceptions of competence across the course. Future studies should conduct longitudinal analyses to determine if profiles of need satisfaction and frustration remain stable from the beginning through the end of the semester, or if some students begin college courses frustrated but become more satisfied, while others are more satisfied at course commencement and frustrated as the course progresses.

3.6.1 Limitations & Future Directions

Despite the original contributions of this research, several important limitations should be considered. First, all measures relied on self-report, including grades. Although self-report is appropriate for many motivational and affective variables such as experiences of need satisfaction and frustration, stress, and academic motivations, they are still susceptible to biases (e.g., socially desirable responses). In the future, researchers should consider including more objective measures, including behavioral measures that capture

students' actual persistence in their majors rather than their intentions to persist, actual grades rather than expected grades, and features of the learning environment such as instructional style, teacher language, or assessment structures, rather than exclusively relying on student perceptions of autonomy-support in the classroom. Second, because of the cross-sectional nature of the data, interpretation of directional relationships are based solely on theoretical assumptions and prior research. Using a cross-sectional design made it impossible to rule out reciprocal relationships between predictors, outcomes, and need-based experiences. Longitudinal studies are needed to directly test the direction, or bi-directional associations, of the proposed relationships.

A third limitation is due to the final, three-profile solution being selected from the full data set. To confirm the stability of the optimal profile solution, future research should recruit large enough samples to conduct LPA with a split dataset to more rigorously establish that the optimal solution has been selected for the data. Fourth, generalizability of the present results is limited by the fact that the participants were undergraduate students enrolled across five general Chemistry courses. Future studies should replicate these findings in other introductory STEM courses to confirm the generalizability of the results. In addition, participants were nested within five different general Chemistry courses, each containing multiple sections with different instructors. Each course within the sequence of general Chemistry courses is designed specifically for students based on their math aptitude scores. Due to a primary interest in Level 1 variables, insignificant intraclass correlations among primary study variables, and an inadequate sample size of Level 2 clusters (McNeish & Stapleton, 2014), accounting for cluster effects with multi-level modeling was not undertaken. However, ignoring cluster effects can result in underestimated standard

errors and inflation of the Type-I error rate. In the future, researchers may want to consider alternative analytic approaches that can account for hierarchical data with a small number of clusters and may consider collecting data using an adequately large number of clusters to justify a multilevel approach.

3.6.2 Practical Implications

The findings from the current study have several practical implications. For example, students experiencing need frustration at the end of the academic semester appear to be at greater risk in terms of their academic motivation, achievement, and ability to cope and adjust. Fostering an autonomy-supportive course climate may mitigate risk by increasing the likelihood that students exhibit a need profile with less need frustration and greater need satisfaction. Developing course structures and implementing pedagogical practices that support student autonomy may be effective for achieving this goal. There will inevitably be variation in students' preparedness and abilities for difficult coursework, but satisfying their psychological needs may buffer against such challenges (Patall et al., 2018).

Instructors can support student autonomy in several ways. In everyday classroom practices, instructors can welcome student opinions, perspectives, and course preferences (Cheon et al., 2020). This can sometimes be a challenge in large-enrollment courses, but use of in-class polls or periodic course surveys may help capture the voices of all students rather than the ones most comfortable with speaking up in a large course. Instructors should also consider providing rationales for how course content and requirements benefit students. This can be accomplished by explaining how content connects to real-world

scenarios and the skills being learning are relevant to their future courses and careers. Acknowledging and expressing understanding toward students' frustrations in understanding difficult material and performing as well as they would like can support autonomy by demonstrating to students that instructors are attuned to their experiences (Howard et al., 2021). Instructors can also support student-autonomy by designing courses that have a clear structure. This clarifies expectations for students, fostering a sense of control over how they will perform in the course. Instructors can provide structure by explicitly reminding students of the learning goals of the course, clarifying expectations, being transparent about how to succeed in the course, and providing regular feedback so students can adapt as needed. In large-enrollment STEM courses, instructors should consider providing students with structure and clarity in ways that extend beyond clear language in the course syllabus. Additional considerations include explicitly stating upcoming learning goals in online course management systems and in class. Lastly, making the learning behaviors required for success transparent to them in terms of the time things may take, offering guidance on how to approach studying and assignments, and scaffolding their learning can provide valuable structure.

3.6.3 Conclusion

In sum, this study was the first to use a person-centered approach to understand undergraduate general Chemistry students' simultaneous experiences of need satisfaction and need frustration. Findings confirm results from a growing body of SDT literature illustrating the importance of considering satisfaction and frustration of basic psychological needs for autonomy, competence, and relatedness as distinct constructs with unique antecedents and consequences within the domain of education. In addition, results

provide additional insight into the critical role of motivational and affective psychological processes within the undergraduate Chemistry classroom. At the end of the academic semester, basic psychological need frustration exceeds experiences of need satisfaction among a subset of students, which puts them at risk of decreased levels of self-determined motivation, increased amotivation, greater stress, less resilience, less likelihood of persistence in their majors, greater sacrifice of their well-being and lower grades. Conversely, students for whom need satisfaction prevails over need frustration have more autonomous academic motivation, better adjustment to undergraduate learning, and higher academic achievement.

Table 3.1 Demographic Information for General Chemistry Students at the End of the Semester

Variable	*N*	Percentage of Sample
General Chemistry Course	732	100%
Course 1	85	11.6%
Course 2	136	18.6%
Course 3	399	54.5%
Course 4	44	6%
Course 5	68	9.3%
Year in School	641	87.6%
First Year	558	76.2%
Second Year	97	13.3%
Third Year	22	3%
Four or more Years	10	1.4%
Major	641	87.6%
pSTEM	128	17.5%
Agriculture & Biological Life Sciences	165	22.5%
Health Sciences & Professions	276	37.7%
Other	72	9.8%
First-Gen Status	683	93.3%
First-Gen	118	16.1%
Not First-Gen	565	77.2%
Sex	686	93.7%
Male	172	23.5%
Female	514	70.2%
Race/Ethnicity	686	93.7%
White	535	73.1%
Non-White	151	20.6%

Table 3.2 Means, Standard Deviations, Correlations, and Cronbach's Alpha of Primary Variables at the End of the Semester

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
Psychological Need Satisfaction																	
1. Autonomy	–	.621**	.471**	-.588**	-.508**	-.262**	.479**	-.281**	.610**	.394**	.233**	-.189**	-.344**	.294**	-.314**	.195**	.275**
2. Competence		–	.400**	-.442**	-.731**	-.315**	.456**	-.357**	.493**	.325**	.153**	-.108**	-.418**	.264**	-.378**	.304**	.495**
3. Relatedness			–	-.330**	-.328**	-.536**	.320**	-.205**	.306**	.299**	.243**	.041	-.240**	.199**	-.258**	.132**	.179**
Psychological Need Frustration																	
4. Autonomy				–	.533**	.359**	-.390**	.393**	-.438**	-.295**	-.141**	.268**	.337**	-.176**	.328**	-.181**	-.180**
5. Competence					–	.374**	-.366**	.443**	-.381**	-.174**	-.002	.180**	.383**	-.176**	.455**	-.277**	-.497**
6. Relatedness						–	-.295**	.238**	-.178**	-.269**	-.126**	-.072	.327**	-.168**	.352**	-.239**	-.138**
Covariates																	
7. Learning Climate							–	-.130**	.436**	.332**	.241**	-.054	-.345**	.215**	-.197**	.132**	.233**
8. Sacrifices of Needs								–	-.154**	-.041	.088*	.185**	.206**	-.029	.472**	-.142**	-.209**
9. Intrinsic Motivation									–	.553**	.477**	-.111**	-.295**	.318**	-.222**	.174**	. 320**
10. Identified Regulation										–	.628**	.335**	-.477**	.331**	-.119**	.189**	.227**
11. Introjected Regulation											–	.404**	-.225**	.269**	.044	.102**	.191**
12. External Regulation												–	-.099**	.059	.156**	.097*	.007
13. Amotivation													–	-.207**	.246**	-.293**	-.338**
14. Academic Resilience														–	-.120**	.261**	.156**
15. Academic Stress															–	-.219**	-.262**
16. Persistence Intentions																–	.229**
17. Expected Grade																	–
α	0.73	0.89	0.82	0.79	0.86	0.72	0.97	0.90	0.86	0.81	0.73	0.74	0.86	0.85	0.92	0.89	–
M	3.19	3.36	3.46	3.14	3.12	2.25	4.95	3.32	3.03	4.02	3.61	4.12	2.01	3.44	127.63	4.00	82.01
SD	.666	0.741	0.728	0.775	0.882	0.652	1.341	0.863	0.914	0.793	0.794	0.699	0.898	0.326	41.80	0.782	9.01

Note. ** $p < .01$, * $p < .05$.

Table 3.3 Latent Profile Fit Statistics for Models Based on Basic Psychological Need Satisfaction and Frustration Indicators at the End of the Semester

Model	LL	Scaling	#FP	AIC	BIC	ABIC	*p* LMR	*p* aLMR	*p* BLRT	Smallest c	Entropy
1-Profile	-4888.96	1.009	12	9801.91	9857.06	9818.96	–	–	–	–	–
2-Profile	-4378.18	1.109	25	8806.36	8921.25	8841.87	<0.001	<0.001	<0.001	40.5%	0.81
3-Profile	-4221.17	1.120	38	8518.33	8692.97	8572.31	<0.001	<0.001	<0.001	6.8%	0.85
4-Profile	-4086.81	1.101	51	8275.62	8510.00	8348.06	<0.001	<0.001	<0.001	5.8%	0.87
5-Profile	-4023.91	1.078	64	8175.81	8469.94	8266.72	<0.05	<0.05	<0.001	4.8%	0.86
6-Profile	-3975.95	1.153	77	8105.89	8459.77	8215.27	0.243	0.248	<0.001	5.9%	0.81

Note. LL = LogLikelihood; Scaling = Scaling factor associated with the MLR log-likelihood estimates; #FP = number of free parameters; AIC = Akaïke Information Criteria; BIC = Bayesian Information Criteria; ABIC = Sample-Size Adjusted BIC; *p* LMR = *p*-value for the Lo-Mendell-Rubin likelihood ratio test for *k* versus *k*-1 profiles; *p* aLMR = *p*-value for the adjusted Lo-Mendell-Rubin likelihood ratio test for *k* versus *k*-1 profiles; *p* BLRT = *p*-value for the bootstrap likelihood ratio test for *k* versus *k*-1 profiles; Smallest c = the percentage of the smallest latent profile (class) size relative to $n = 732$.

Table 3.4 Three-Profile Model Results for Chemistry Students at the End of the Semester

Variable	Profile 1 Highly Satisfied and Not Frustrated (*n* = 252; 34.4%)	Profile 2 Moderately Satisfied, Slightly Autonomy and Competence Frustrated (*n* = 430; 58.8%)	Profile 3 Autonomy and Competence Frustrated (*n* = 50; 6.8%)
Autonomy Satisfaction	**3.74**	2.99	2.18
Competence Satisfaction	**4.03**	3.12	2.05
Relatedness Satisfaction	**3.93**	3.27	2.75
Autonomy Frustration	2.58	3.33	**4.35**
Competence Frustration	2.33	3.42	**4.56**
Relatedness Frustration	1.87	2.40	**2.83**

Note. The highest responses for each psychological need are in boldface. Means and standard deviations for variables in the full sample: Autonomy Satisfaction $M = 3.19$ ($SD = 0.67$), Competence Satisfaction $M = 3.36$ ($SD = 0.74$), Relatedness Satisfaction $M = 3.46$ ($SD = 0.73$), Autonomy Frustration $M = 3.14$ ($SD = 0.77$), Competence Frustration $M = 3.12$ ($SD = 0.88$), Relatedness Frustration $M = 2.25$ ($SD = 0.65$).

Table 3.5 Results of the Multinomial Logistic Regressions for the Effects of Predictors on Need Profile Membership at the End of the Semester

Variable	Profile 1 vs. 3[a]		Profile 2 vs. 3[a]		Profile 1[a] vs. 2	
	Coef. (SE)	OR	Coef. (SE)	OR	Coef. (SE)	OR
Theoretical Predictor						
Learning Climate	2.063*** (.263)	7.87	1.022*** (.227)	2.78	-1.042*** (.148)	.353
Sacrifices to Well- Being	-2.355*** (.391)	.095	-1.475*** (.370)	.229	0.880*** (.168)	2.41
Student Demographics						
Year in School	-0.667 (.408)	.513	-0.364 (.367)	.695	0.303 (.218)	1.35
Male	1.103 (.725)	3.01	0.612 (.685)	1.84	-0.606* (.291)	.546
White	0.771 (.660)	2.16	0.268 (.612)	1.31	-0.503 (.313)	.605
HSGPA	-0.557 (1.223)	.573	-1.807 (1.0176)	.164	-1.250 (.668)	.287
Not FirstGen	-0.049 (.606)	.952	-0.685 (.561)	.504	-0.636* (.318)	.529
pSTEM Major	-0.111 (.754)	.895	-0.475 (.714)	.622	-0.364 (.317)	.695
Health-Related Major	0.598 (.579)	1.82	0.551 (.533)	1.74	-0.046 (.266)	.955

Note. Dummy coding (Male = 1 and Female = 0, White = 1 and Non-White = 0, 1 = Not First-Generation and 0 = First-Generation, 1 = pSTEM major and 0 = Not pSTEM major, 1 = Health-related major and 0 = Not Health-Related Major); SE = standard error of the coefficient (Coef); OR = odds ratio. Profile 1 = Highly Satisfied and Not Frustrated; Profile 2 = Moderately Satisfied, Slightly Autonomy and Competence Frustrated; Profile 3 = Autonomy and Competence Frustrated.

[a] Reference group.

* $p < .05$. ** $p < .01$. *** $p < .001$.

Table 3.6 Relationships Between LPA Need Profile Membership and Outcome Variables at the End of the Semester

Variable	Profile 1 (*A*) Mean (SE)	Profile 2 (*B*) Mean (SE)	Profile 3 (*C*) Mean (SE)	Differences between Profiles
Intrinsic Motivation	3.657 (.053) **B, C**	2.785 (.043) **A, C**	2.007 (.142) **A, B**	1 > 2 > 3
Identified Regulation	4.388 (.047) **B, C**	3.903 (.039) **A, C**	3.214 (.166) **A, B**	1 > 2 > 3
Introjected Regulation	3.789 (.052) **B, C**	3.563 (.040) **A, c**	3.178 (.171) **A, B**	1 > 2 > 3
External Regulation	4.000 (.050) b, C	4.163 (.035) a	4.351 (.107) A	1 < 2 = 3
Amotivation	1.458 (.054) **B, C**	2.218 (.042) **A, C**	2.999 (.151) **A, B**	1 < 2 < 3
Resilience	3.560 (.020) **B, C**	3.381 (.017) **A**	3.357 (.062) A	1 > 2 = 3
Academic Stress	106.499 (2.789) **B, C**	136.090 (2.050) **A, C**	168.044 (6.698) **A, B**	1 < 2 < 3
Persistence Intentions	4.316 (.048) **B, C**	3.854 (.042) **A**	3.742 (.164) **A**	1 > 2 = 3
Expected Course Grade	86.642 (.510) **B, C**	80.250 (.472) **A, C**	73.172 (1.889) **A, B**	1 > 2 > 3

Note. Bold capitalized superscripts indicate profiles that are significantly different at $p < .001$; Upper case superscripts indicate profiles that are significantly different at $p < .01$; lower case superscripts indicate profiles that are significantly different at $p < .05$;. Profile 1 = Moderately Satisfied and Frustrated; Profile 2 = Autonomy and Competence Frustrated; Profile 3 = Highly Satisfied and Not Frustrated.

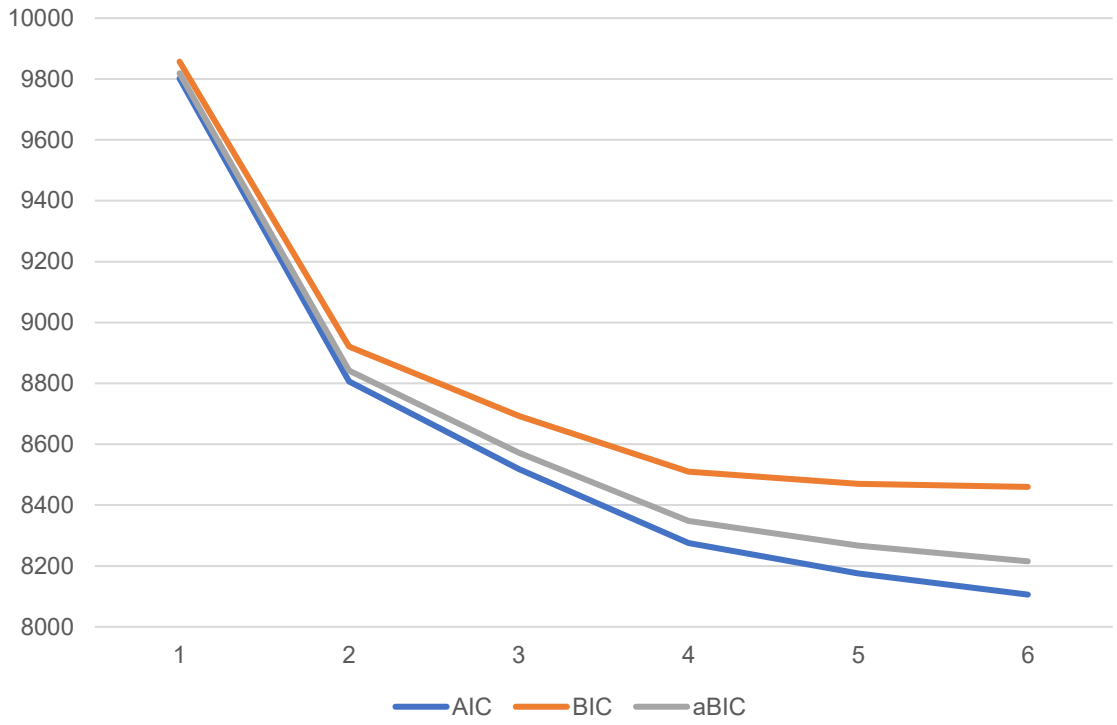

Figure 3.1 Elbow Plot Illustrating the AIC, BIC, aBIC Fit Statistics for Latent Profile Analysis Results at the End of the Semester

Note. $n = 732$.

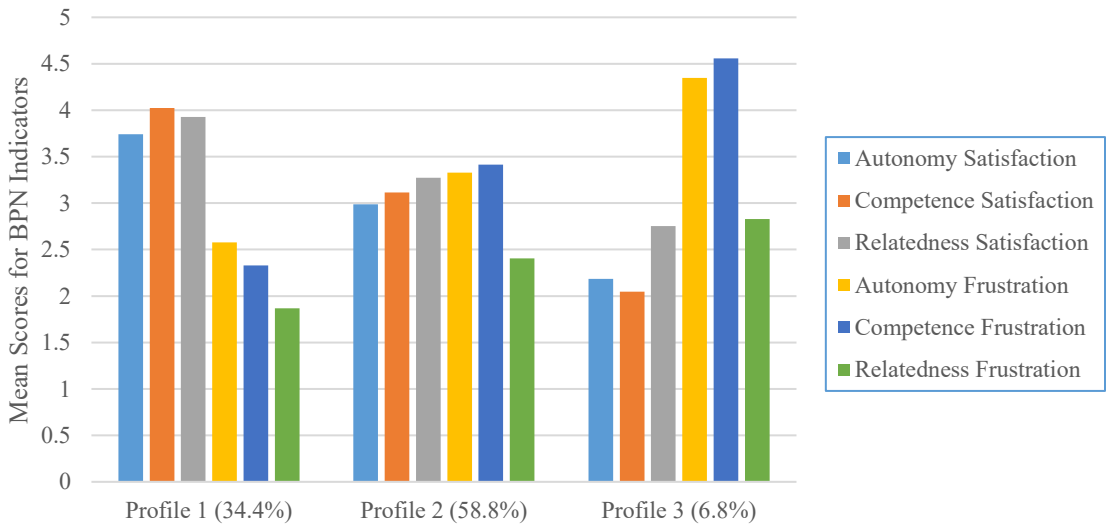

Figure 3.2 Final 3-profile solution for General Chemistry Students at the End of the Semester

Note. $n = 732$; Profile 1: Highly Satisfied and Not Frustrated ($n = 252$); Profile 2: Moderately Satisfied, Slightly Autonomy and Competence Frustrated ($n = 430$); Profile 3: Autonomy and Competence Frustrated ($n = 50$); Profile indicators are mean scale scores.

CHAPTER 4. GENERAL DISCUSSION

Recruiting and retaining students in STEM fields has remained a critical societal issue since students continue to abandon STEM fields at alarmingly high rates. Students place value on earning degrees in fields with available jobs and high earning potential upon graduation, which is possible and likely in many STEM fields, yet these programs have issues retaining student until graduation (Sithole et al., 2017). This perplexing paradox coupled with the national need to produce more qualified STEM professionals to remain competitive in the global economy has made this issue a priority among educators, researchers, administrators, and policymakers (National Science Foundation, 2019). While many factors interact to prevent students from pursuing and persisting in STEM, student experiences in large introductory STEM courses has been shown repeatedly to be an important barrier to motivation and persistence in STEM majors (Chen & Soldner, 2013). Introductory General Chemistry is an introductory STEM course is a required course for many STEM majors, yet students often struggle to pass this course more than they do in many of their other introductory STEM courses (Cracolice, & Busby, 2015). Therefore, the primary aim of this dissertation was to explore variations in academic motivation, persistence intentions, and psychological adjustment by understanding combined configurations of basic psychological need satisfaction and frustration in general chemistry courses at both the beginning and end of the semester using a person-centered approach.

4.1 Overall Conclusions About Need Profiles at the Beginning and End of the Semester

These studies were the first to identify three distinct profiles of both need satisfaction and frustration within introductory General Chemistry, a large-enrollment foundational STEM course, using a person-centered approach. At both the beginning and end of the semester, three unique profiles were identified that shared similar characteristics, yet varied in size. At each time point, one profile was characterized by high satisfaction and low frustration across all three needs (T1: n = 156; 23.6%; T2: n = 252; 34.4%). This profile was the smallest at the beginning of the semester and second largest at the end of the semester. One profile was characterized by need frustration, particularly autonomy and competence frustration, prevailing over need satisfaction (T1: n = 168; 25.3%; T2: n = 50; 6.8%) at each time point. This profile was the second largest at the beginning of the semester, yet the smallest at the end of the semester. A final profile experienced both moderate levels of both need satisfaction and need frustration at each time point (T1: n = 338; 51%; T2: n = 430; 58.8%). At the beginning of the semester, the moderate profile reported average levels of satisfaction and frustration across all three needs, with slightly more satisfaction than frustration. However, at the end of the semester, the more moderate profile reported moderate satisfaction across all three needs, and moderate relatedness frustration, but was slightly above average in terms of their autonomy and competence frustration. This suggests that need frustration was increasing slightly in this moderate profile at the end of the semester, compared to the beginning.

At first glance it seems promising that the number of students in the high satisfaction/low frustration profile increased from the beginning to the end of the semester,

and that the number of students in the high frustration/low satisfaction profile dramatically declined across the semester. However, these findings should be interpreted with caution. Although it is entirely possible that students became more satisfied and less frustrated over time, it is also possible that the most frustrated students withdrew from the courses and were not present in the end of the semester sample. Official academic records containing data about who withdrew and who persisted from the beginning to the end of the semester should be examined in future research. In addition, this study modeled person-centered configurations at each time point using cross-sectional data at each time point, therefore change in satisfaction and frustration over time cannot be determined from the present results. Future research should utilize longitudinal person-centered methods that can identify patterns of change across the semester.

4.2 Predicting Need Profile Membership at the Beginning and End of the Semester

Across educational contexts, autonomy-supportive teaching practices have been shown to satisfy all three of students' basic psychological needs (Bureau et al., 2022). Results from each study in this dissertation confirmed these findings using a person-centered approach. The present findings from both Study 1 and Study 2 add to this knowledge by demonstrating that perceptions of autonomy-support in General Chemistry predicts individual differences in satisfying or frustrating students' basic psychological needs. As expected, students who perceived higher autonomy-support were more likely to be members of the profiles in which need satisfaction prevailed over need frustration. Student demographic characteristics were also included in the prediction of profile membership to control for their influence. The key takeaway here, is that at both the

beginning and end of the semester, male students are more likely to be members of the most adaptive profile reporting high need satisfaction and low need frustration. At the end of the semester, students' perceptions that they were making sacrifices to their well-being to achieve academic goals was also found to predict profile membership. Results from the end of the semester revealed that when students feel they are making sacrifices to their personal well-being, they have greater odds of membership in profiles reporting higher need frustration.

4.3 Motivational and Educational Outcomes of Students' Need Profile Membership at the Beginning and End of the Semester

Self-Determination Theory research has clearly demonstrated the positive outcomes associated with need satisfaction (Ryan & Deci, 2017). However, in recent years, there has been a growing interest in need frustration as a distinct construct that increases vulnerability to maladjustment and non-optimal functioning. Findings from both studies in this dissertation found that students in the high satisfaction, low frustration profile had the best outcomes in terms of the quality of their academic motivations, were better adjusted psychologically, showing the most resilience and the least amount of stress, and were more likely to persist toward their academic goals by remaining in their current major. In contrast, the profiles reporting the lowest need satisfaction and highest need frustration struggling with their motivation, struggling to cope psychologically with their academic work, and being most likely to abandon their initial academic goals.

4.4 Overall Conclusions

Findings from this dissertation contribute to an urgent need to understand the motivational mechanisms underlying motivations and persistence intentions among students in introductory STEM courses using a person-centered approach. Basic psychological need satisfaction is known to predict positive educational outcomes, but much less is understood about the role of need frustration in students' motivational pathways in STEM courses. Importantly, this dissertation identified individual differences in students' motivational pathways. Two factors including students' perceptions of the learning environment as autonomy supportive and perceived sacrifices to personal well-being were predictive of individual differences in need profile membership. In addition, need profile membership predicted differences in the quality of students' academic motivations, the degree to which they were coping psychological with challenges in a challenging STEM course, and their intentions to persist in their chosen majors. Need profiles with greater need satisfaction and lower need frustration had the best outcomes reporting more self-determined motivations, more resilience, less stress, and greater intentions to persist. Need profiles with need frustration prevailing over need satisfaction had the worst outcomes, reporting more controlled motivations, more amotivation, less resilience, more stress, and lower intentions to persist. In sum, the results from this dissertation provide insight into how SDT concepts may explain variations in motivation and persistence among students enrolled in introductory STEM courses such as General Chemistry.

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VITA

EDUCATION

Ph.D., Educational Psychology, University of Kentucky *December 2023*
Research Concentration: Motivation, self-regulation, social-emotional development, and self-determination theory
Allied Area: Statistics & Quantitative Methods
Dissertation: *Profiles of Satisfaction and Frustration of Students' Basic Psychological Needs: Similarity and Change in Undergraduate General Chemistry*

M.S.Ed., Educational Psychology, University of Kentucky *May 2018*
Research Concentration: Motivation, self-regulation, and social-cognitive theory
Thesis: *Beliefs About Self-Control and Regulation: Do They Matter for College Performance?*

M.S., Instructional Design, Western Kentucky University *May 2016*

B.A., Media Arts and Studies, University of Kentucky *May 2008*

PROFESSIONAL & ACADEMIC APPOINTMENTS

Lecturer *August 1, 2023-present*
Psychology Department, University of Kentucky

Lab Instructor *Spring 2023*
Psychology Department, University of Kentucky
Course: Application of Statistics in Psychology
Format: Face-to-face; 4 credit hours

Primary Instructor *Spring 2022 – Fall 2022*
Psychology Department, University of Kentucky
Course: Introduction to Psychology
Format: Face-to-face & asynchronous online; 4 credit hours

Lab Instructor *Fall 2021*
Psychology Department, University of Kentucky
Course: Introduction to Psychology
Format: Face-to-face; 4 credit hours

Primary Instructor *Spring 2021*
Psychology Department, University of Kentucky
Course: Experimental Methods
Format: Face-to-face; 4 credit hours

Adjunt Faculty *Fall 2020*
Psychology Department, Centre College
Course: Introduction to Research Methods
Format: Hyflex; 3 credit hours

Graduate Assistant *August 2019 - May 2020*
First-Year Engineering Program, College of Engineering, University of Kentucky
Program Evaluation & Instructional Design

Instructional Designer *August 2018 – May 2019*
First-Year Engineering Program, College of Engineering, University of Kentucky

Primary Instructor *Fall 2018 – Spring 2019*
Educational, School, & Counseling Psychology Department, University of Kentucky
Course: Human Development & Learning
Format: Face-to-face; 3 credit hours

Faculty Instructional Consultant *July 2014 – July 2018*
Center for the Enhancement of Learning and Teaching (CELT), University of Kentucky
.
Co-Instructor *Fall 2017*
Graduate School, University of Kentucky
Course: Teaching in the 21st Century: Teaching and Engaging First-Year Students
Special Topics course for the Preparing Future Faculty Graduate Certificate
Format: Hybrid; 2 credit hours

Primary Instructor *Spring 2017*
Graduate School, University of Kentucky
Course: Instructional Technology
Format: Hybrid; 1 credit hour

Multimedia Specialist *November 2011 – July 2014*
Center for the Enhancement of Learning and Teaching (CELT), University of Kentucky

GRANTS, FELLOWSHIPS, & EXTERNAL FUNDING

National Academy of Education/Spencer Dissertation Fellowship. *Basic psychological needs in the learning environment: A person-centered approach for predicting academic motivation and psychological distress among students in STEM*. Unfunded, 2021.

Leslie Martin Endowed Fellowship Fund from the Department of Educational, School, & Counseling Psychology, College of Education, University of Kentucky. Awarded $4000, 2020.

Center for Equality and Social Justice Graduate Student Research Assistantship. *The Cost of Homogeneity: An Investigation of Belonging and Achievement in a First-Year Engineering Program*. Unfunded, 2019.

Professional & Organizational Development (POD) Network Grant Program. *How Teaching Centers Can Bridge Gaps in Teaching Assistant Development*. Principal Investigator. Funded, 2016. *Awarded* - $2000

MANUSCRIPTS

Worick, C. E., Usher, E. L., Osterhage, J., Love, A. M., & Keller, P. S. (2023). Self-Efficacy for Self-Regulated Learning Mediates Association between Implicit Theories of Willpower and Learning Strategies. *The Journal of Experimental Education*, 1-11.

Worick, C. E., Turner, T.A., Usher, E. L., Osterhage, J., & Keller, P. S. (in preparation). Unskilled and aware? Changes in accuracy and certainty of metacognitive judgements and associations with self-regulated strategy use and grades. In preparation for *Metacognition and Learning*. To be submitted December 2022.

Turner, T.A., **Worick, C. E.**, Usher, E. L., & Osterhage, J.L. (in preparation). Patterns of calibration and self-efficacy in undergraduate biology. In preparation for *Metacognition and Learning*. To be submitted December 2022.

Worick, C.E., & Keller, P.S. (in preparation). Satisfaction and frustration of basic psychological needs at the beginning and end of the semester: A latent profile analysis in undergraduate general chemistry. In preparation for *Motivation and Emotion*. To be submitted March 2023.