Differentiating Science Motivational Factors of Adolescent College Students by Career Orientation with a Self-Determination Theory Lens on Variables and Voices – an Explanatory Sequential Mixed Methods Study Utilizing the Academic Motivation Scale in Survey and Interviews

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Abstract

This study investigated how undergraduate college students with different STEM career orientations differ in their motivation toward science education. The purpose of this study was to surface differences in the quality of motivations between groups of students with different orientations toward STEM careers to support them in science education classrooms better. A more in-depth understanding of motivational quality would allow science course instructors to design learning more specific to the types of student motivational profiles. Specifically, five motivational sub-dimensions of the Self-Determination Theory were investigated using the Academic Motivation Scale: amotivation, external, introjected, identified, and intrinsic motivation. This explanatory sequential mixed methods study investigated the between-groups differences in each motivational sub-dimension quantitatively with a survey and qualitatively with interviews. The researcher conceptualized this study with a critical realist epistemology, applying self-determination theory as theoretical lens of the study.

Results show significant differences in intrinsic motivation between all three STEM career orientation groups investigated, those interested in STEM careers, those interested in STEM-related careers, including technical careers and health professions, and those not interested in STEM careers. For all other motivational sub-dimensions, students not interested in STEM careers were significantly different in their motivation from the other two groups. Interviews surfaced the following theme trends for motivational qualities: Students oriented toward STEM careers discussed the challenges of pulling apart dense science concepts to learn as part of their cognitive process to become competent. In contrast, students oriented toward STEM-related careers tended to view the science courses as an externally imposed *hurdle toward a career* that required learning of knowledge comprised of facts, often not seen as relevant to their career. Overall, the narratives were in line with the empirical results. These outcomes constitute tools for science educators to assess students' motivational profiles for science alongside authentic perspectives, allowing tangible insight into student views on education and their motivation to learn.

Keywords: explanatory sequential mixed methods, adolescence, motivation, undergraduate college, science education, STEM careers, Self-Determination Theory.

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Dedication

To my Mother.

This dissertation is dedicated to the many conversations throughout my youth on pedagogy and how to best support students, especially students from socio-economically and culturally diverse student populations. The many practical examples of curriculum that my mother employed in her elementary classroom have fueled my dedication to keep finding creative ways of designing curriculum that aligns with students' zone of proximal development and natural curiosity.

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Chapter 1: Introduction

Science education is currently not differentiated to fit student motivational profiles. It remains unclear how future career aspirations influence motivation toward learning in science classrooms and how students' motivations are supported in science courses. Considering the national need for increased science literacy and STEM career engagement, understanding how to provide motivation-supportive education in high school and in mandatory undergraduate science courses to both students interested in STEM careers as well as those not interested in STEM careers is crucial. While various factors are known to impact motivation, it is unclear if motivational mechanisms are oppositional to each other such that what motivates one student demotivates another. If not considered intentionally, learning designs supportive of the motivation of students with one kind of STEM career orientation may hurt the motivation of students with a different STEM career orientation. This dissertation study investigates how motivational factors differ for students with different STEM career orientations.

The role of science education in secondary and postsecondary public schools will be reviewed to understand the relevance of motivational science education for science engagement in society. Practitioner experiences will highlight possible impacts of conflating motivation to engage in science or STEM learning with motivation in order to advance toward a STEM career. A closer look at motivation as a construct that investigates levels and types of motivation gives an outlook at the tools available in educational research to view the motivational landscape of students.

The Need for Engagement in Science Education

Climate change and economical needs have made science education for all people important. The focus on science or STEM education is not new and has led to emphasizing science education with various formal and informal initiatives. However, these have not yet led to a society engaged in scientific learning as they may be in other core academic competencies such as reading and writing. Explained here is why engagement in science education by a motivated populace is crucially needed to face contemporary issues in the world for both individuals and society as a whole.

Science education has become foundational and thus there is a general need for all people to be science literate. Science often is seen as just relevant for scientists or STEM professionals, but science education has become essential in life in the 21st Century, just like reading and writing (Committee on the Call to Action for Science Education et al., 2021). People need to become prepared for science-related challenges in personal life (Kolstø, 2001; Murphy et al., 2019; U. S. Department of Education, n.d.). Science is also essential within STEM, given that scientific reasoning and questioning is the essential mechanism of understanding engineering and technology applications to human endeavors (Committee on the Call to Action for Science Education et al., 2021). However, there is a lack of STEM interest and literacy in the public (National Science Foundation, 2020; Osborne et al., 2003).

A scientifically literate society has become an urgent matter. The challenges arising out of climate change will require science-educated professionals to solve them. Science expertise is needed by both professionals and citizens to find ways to address the current climate change challenges we face. Internationally, science education is seen as an important factor to help with mitigation, adaptation, and the transition toward a low-carbon economy (Leal Filho & Hemstock, 2019). New Jersey, as a first state, took action accordingly and adopted climate change education standards in 2020 in which the subject of science has a central role in preparing people to be ready for the local effects of climate change (Madden, 2022). Also, since young people grow up in an environment influenced by climate change and science education, it is crucial to give the next generation the tools to face these impacts.

Engagement in science education is not representative of the general population. The focus on STEM education as a career pathway has led to targeting sub-groups of students by career interest for specific STEM educational opportunities, thus emphasis of science learning as linked to STEM career pathways to specific students is neglecting the concentration on science as core competency for all students (Committee on the Call to Action for Science Education et al., 2021). This creates inequity within groups of students of different STEM career interests.

Additionally, there is vast inequity between different genders and different ethnicity and races in their engagement and motivation to learn science. Despite more than a decade of presidential initiatives that have emphasized the need for equity in STEM education (President's Council of Advisors on Science and Technology Executive, 2012) and respective initiatives to decrease inequity in STEM, there remain many equity gaps (Fry et al., 2021). The persistence of these inequities have reinvigorated calls for equity in science education to be a national priority (Committee on the Call to Action for Science Education et al., 2021). Lack of diversity has been found to have led to a lack of motivation to learn science for underrepresented groups, especially when the instructional design does not consider cultural and local relevance and students' ability to experience science (Mansour & Wegerif, 2013; M.-T. Wang & Degol, 2017). Motivation thereby is an important indicator measure to understand the quality of science education for students.

Science education is crucial for economic interests of both individual employees and employers. There is a national demand and many opportunities to enter the STEM workforce (Modis, 2019; Xue

& Larson, 2015). The National Science Foundation (National Science Foundation, 2018) has identified a need for professionals skilled in science and its related subjects, technology, engineering, and mathematics (STEM). The shortage of people prepared for these STEM jobs is projected to increase, particularly in the technology sector, widening the gap in the number of youth entering the STEM workforce (National Science Foundation, 2018). This unmet need for professionals skilled in STEM jobs provides opportunities for employees to transfer mid-career (Randstad North America, 2017), provided they are open and interested in learning the respective STEM skill sets. Opportunities like these show that it is important for employees to be open to learning new technical skills, as the biggest gap in STEM professionals lies with being able to adjust to new technologies as they are developed (Deming & Noray, 2019). Thus, graduates motivated to engage in STEM, regardless of career interests, formally or informally, will be better prepared for a world and job market where technology applications and scientific thinking are required and ubiquitous (Randstad North America, 2017). The importance of education for STEM in the workplace will increase even more when STEM jobs soon outnumber non-STEM jobs (Fry et al., 2021). Thereby it is vital to understand why despite multiple decades of research and initiatives promoting youth to engage in STEM and to enter STEM careers, the STEM workforce gap is not closing and how students can retain and possibly even regain their motivation for STEM engagement (Hurk et al., 2019).

STEM Policies

Public STEM education strategy is slowly starting to shift from a STEM workforce-driven narrative back toward STEM as a core competency. The term STEM was coined by the National Science Foundation to address the national need for workforce in the cluster of science, technology, engineering, and math jobs (Hallinen, 2022). This provided a way to describe these subject fields and inter-disciplinary research and careers with one non-siloed term. For several decades, it has been the policy of the federal Department of Education to encourage students to enter into STEM careers to be part of the STEM *pipeline* (Metcalf, 2010). More recently, calls have changed to engaging in the STEM *pathway*, a slight but significant change from seeing STEM as a siloed linear career ladder starting with course choices in high school to viewing STEM as a career pathway toward STEM jobs or STEM career competencies on which people sometimes just travel a short while.

The STEM pathway perspective is much closer to the reality of STEM professional development trajectories (Lymn, 2016). Yet still, this perspective of STEM education is mostly workforce driven and gives little room for STEM education as basic life competency to be used in everyday life. Only in the last few years is the federal education policy narrative slightly shifting toward a vision where STEM education is basic and for all students regardless of career direction. Accordingly, the most recent update of the Federal STEM Education Strategic Plan states as one of three main goals to "Build Strong Foundations for STEM Literacy by ensuring that every American has the opportunity to master basic STEM concepts and to become digitally literate" (Office of Science and Technology Policy, 2021), page 8. This strategic plan outlines a vision that expects STEM education to build the motivation such that graduates of public education are likely to engage their STEM skills throughout their lives. Beyond spawning many initiatives and programs, the federal STEM education policy also sets the tone for the public science education standards in K-12.

Public science education standards became aligned with federal STEM education strategy a decade ago. Arising out of the call for STEM education associations of science educators, STEM employers, and states that collaborated to create a new standard more conducive to the interdisciplinary world of STEM and STEM careers. This effort created a new framework for science learning in public schools, resulting in the Next Generation Science Standards (National Research Council et al., 2012; NGSS Lead States, 2013). These standards substantially reworked the conceptualization for science by including more intentionally scientific thinking while also emphasizing career practical application of science in engineering and other STEM fields. This has put STEM into science, not only bringing a more inclusive applied aspect of scientific inquiry into the standards, but also the underlying narrative of education for the purpose of STEM career development. The two aspects of science education bear the potential to confuse the purpose of science education in students or instructors between foundational-building and STEM career-building.

Public Science Education Spans Adolescence Including Emerging Adulthood. As shown, a substantial number of students regularly participate in public science education classes from grade six on into college while having increasingly lower motivation to engage. This places the bulk of science education into an age where students are not only learning in public science courses, but also envision and develop their life and career as adults while biologically and cognitively forming their future selves. The span from secondary school to undergraduate college matches the developmental stage of adolescence, if considering a definition encompassing the biological development from the beginning of puberty to the end of major brain development around age twenty-six (Curtis, 2015; Sawyer et al., 2018). Social definitions define adolescence as ending at 18 years of age and more recently acknowledge the age range from 18 to 25 as extended youth development, the emerging adulthood (Arnett, 2000). For the purpose of this study adolescence will be defined as the age range from 13 to 26, to include the ages of emerging adulthood.

Following, the experience that students have in public science education classes through their adolescence–their level of engagement and motivation–substantially sets the tone of how the students think of science education and science itself in their future, ultimately becoming full members of society. As shown, science education is strongly influenced by STEM career perspectives while also being taught increasingly as a foundational interdisciplinary subject. It is important to understand how all these students experience motivation in their science education in college and how that relates to their career goals in the moment and long-term science engagement, a topic currently understudied in the literature. Given that public science education and STEM are so vital to society, it is unclear why there is such low engagement in science education. Thereby it is essential to investigate this phenomenon of low engagement in science education to be able to address it.

Public Science Education

A key venue of science education in the United States is public education. This section highlights that compulsory public education has a nexus function in society for science education with its charge to provide basic education to youth and the substantial number of students continuing education in public colleges. Crucially, there has been a shift in how science education in public schools is conceptualized in both policy and educational standards. It is important to explore the details of these conceptual changes as it has impacted how science learning is designed by instructors and will provide insight into the complexity of the science education research literature. The substantial portion of each generation enrolled in public science education courses for multiple years means significant exposure to science education and the opportunity for this to shape future science engagement of these students as they age to become full adults in society.

Public schools deliver science education to a majority of children in the United States. K-12 public education is charged with providing all people with a basic education, facilitating the creation of an educated society. While an increasing number of families opt out of assigned public education (National Center for Education Statistics, n.d., 2022b), still the overall percentage of all children going to both assigned and chosen public K-12 schools is steady since 1999 above 86% (National Center for Education Statistics, n.d., 2022a; U.S. Census Bureau QuickFacts, 2022). Chosen schools include public charter schools amongst others. Specifically, in 2021, 16.5% of the U.S. population were children between 5 and 18 years of age, nearly 55.8 million (U.S. Census Bureau QuickFacts, 2022) and K-12 public school enrollment, including public choice schools, was 49.5 million students in fall of 2021 (National Center for Education Statistics, 2022a), so most recent data show 89% of all children go to public schools.

The public school science curriculum in secondary schools includes several years of science courses. Starting in sixth grade in middle school, students generally take science classes such as earth science.

In U.S. high schools, students typically complete six semesters of science classes, at least two of which are usually biology, physics, or chemistry. However, details vary depending on individual state statutes. Idaho, for example, requires six-semester credits for high school graduation, two of which have to be laboratory science credits; choices include earth and space sciences, physical science, life sciences, computer science, biology, chemistry, environment, or approved applied sciences (Idaho State Department of Education (SDE), 2022). Similarly, Washington State requires three years of science credits, however double the amount–four years of laboratory science as part of those science credits (The Washington State Board of Education, n.d.).

Beyond secondary school, approximately half of all Americans take science courses in postsecondary school regardless of major. Colleges offer science education for all that continue their public education beyond high school. Science subjects taught in college include biology, chemistry, geography, geology, and physics. Almost half of the adult population in the United States (45%) holds an Associate's degree or higher (United States Census Bureau, 2022), and 62% percent of 18-year-olds enter colleges annually (U.S. Bureau of Labor Statistics, 2022). Following, every one in two Americans goes through an undergraduate college education. While college graduation requirements are regulated by various boards of education, colleges generally expect students to take two to three science courses as part of their general education requirements (Darrell B. Warner & Katie Koeppel, 2009).

Deficiencies in Science Engagement

Having reviewed the importance of engagement in science education, the following snapshot of the deficiencies of public science education motivation for different age groups highlights the complexity and severity thereof. Many science classrooms do not involve learners in active science inquiry learning, which has been shown as pivotal to in-depth and long-term motivation toward science learning (Banilower et al., 2013). Students lose interest in formal science and math education by the time they enter high school (Falk et al., 2016; Potvin & Hasni, 2014a). So, science students are not systematically supported in building long-term motivation toward science engagement, which is becoming visible as early as middle school.

In college, students have been found to have science literacy that is only minimally higher than the general public (Impey et al., 2011). And once having left public school, a quarter of Americans are not interested in current science and technology issues and half of Americans are not able to demonstrate an understanding of scientific inquiry thinking (National Science Foundation, 2020). Overall, this paints a picture of public science education serving students with science classes during their adolescence while not instructing students in a way that fosters long-term learning and engagement in science thinking. Considering that most of us find it natural to read and write on a daily basis, the lack of motivation to utilize science thinking to engage in daily issues as needed is staggering. Despite this bleak picture, when looking beyond public science education, informal science initiatives provide insight that many students are quite interested in science or STEM topics, while these students' motivation does not typically carry into the public science education classroom (Falk et al., 2016; Potvin & Hasni, 2014a).

Practitioner Experiences. This study is also inspired by the researcher's practitioner experience directing STEM educational outreach projects for adolescents. The researcher's outreach projects include the delivery of informal science activities and formal college science courses with overnight programs co-designed by the researcher. The feedback from high school participants, colleagues, and preliminary studies all indicate opportunities to improve science education for all learners who may still shift in their motivation, who may be more motivated to learn science that is presently known, and who may be often excluded from participating in projects that support their motivation to engage in science education.

In anonymous feedback surveys, high school participants regularly shared how they enjoyed learning science in the projects' courses. Often additional comments were made where students chose to contrast the courses to their experience in public school, reporting how the project's courses have shifted their motivation toward wanting to learn more science. Specifically, many students reported seeing themselves as capable of completing science courses successfully in the future, unlike before the program. Occasionally the participants would state that the project prompted them to consider a STEM career for their future, typically after completing the science college course. Regardless of the interest the students had in STEM careers, most program participants reported feeling motivated to engage in science in the future after completing project activities, which they may not have before. Comments on how their high school experiences do not provide in-depth and relevant engagement have especially made the researcher curious about what elements in public education are critical for students and what happens to motivation independent of the students' existing career aspirations. Considering the contrast between what students report about their public science education compared to the researcher's science education activities, it is of interest to understand these differences in more detail to be able to translate them into intentional instructional design.

The researcher also frequently encountered the attitude of other educators that out-of-school science education programs are for students interested in STEM careers, thereby inadvertently depriving other students of these opportunities of gaining science literacy. For example, when the researcher invited fellow educators to recruit for a funded out-of-school science education workshop, the resulting participants were those that were interested in science careers, and upon inquiry, it became clear that often only those had been invited. Contrary to these incidents, it has been the experience of the researcher's projects' team that when recruiting students directly and making relevant connections for them with the activity recruited for, often a lot of students not interested in STEM careers sign up for these science learning opportunities and find them beneficial or at least enjoyable. Even during recruitment for this dissertation research study, a faculty member commented that they thought that the study was intended only for STEM career track students, while the invitation clearly recruited instructors of any undergraduate science course without any limitations of students to STEM majors. The attitudes encountered by the researcher indicate a ubiquitous bias of science education being for STEM career geared students, even amongst science faculty.

These practitioner experiences highlight that a more intentional learning design of science education courses that is motivation-supportive has a substantial opportunity to improve engagement in science education for all learners. The personal insight of the researcher indicates that motivation is not a fixed construct but may shift as adolescents develop and may depend on the specifics of the science courses they are engaged in. Learning design, thereby, may need to be differentiated in the classroom for different learners depending on their motivational profiles. The pervasiveness of STEM pipeline thinking adds to the difficulty of understanding the motivation for science education engagement in all learners. While it is easy to conflate motivation to learn science with motivation to become a STEM professional, the researcher's experiences provide insight that many students not on a STEM career pathway are motivated to engage in science learning but possibly not motivated the same way. Given this potential to engage students in science learning in ways that they find enjoyable regardless of their career orientation, more information about the motivational landscape in adolescents is needed to then be able to identify specific learning design factors to support that motivation across the motivationally diverse and fluctuating landscape of learners.

Motivation Research in Science Education

Having reviewed the importance and need for engagement in science education, the complexity of what science education is, and its relation to STEM, and having gained insight based on practitioner experiences, a closer look at what determines engagement in science education is needed. Thus, the role of motivation will be scanned to situate this concept for the study at hand, with a short outlook of what is known for motivation for science education in adolescents, during which public science education classes are taught. Following, the framework of the study will clarify how specifically motivation will be used as a tool to get a differentiated view of students in science courses.

Motivation Theories

Motivation describes the direction and activation of behavior from psychological, biological, and pedagogical standpoints . Motivation operationalizes as a vector that shifts humans from not engaging in an activity toward engaging in it with varying strength and toward a specific activity to be engaged with. Additionally, motivation can differ in how it is conceptualized since different motivational theories have different views on where the motif, the origin of the motivational drive, is positioned. Applied to science education research, there are different types of motivation depending on the locale of the motif and the type of science education it is directed toward. Additionally, each of these specific motivation dimensions can vary from low to high motivation.

Several motivational theories can be found in educational research on motivation for STEM. Most prominent are Goal Orientation Theory, Expectancy-Value Theory, Social-Cognitive Theory, and Self-Determination Theory (Murphy et al., 2019; Rosenzweig & Wigfield, 2016). These theories differ in their view on what the motives for behavior are, such as goals or belief expectations (Cook & Artino, 2016; Petri & Govern, 2012). Internal basic needs are seen as driving motivation in Self-Determination Theory (Ryan & Deci, 2017) used as the theoretical lens in this study. While these theories approach motivation from different philosophical perspectives, the constructs are increasingly similar in the research studies published in the last decade (Cook & Artino, 2016). Hence, the literature review on motivation for science education was not limited to a specific theory. The following brief review of Self-Determination Theory explains its use as a theoretical frame for this study.

Self-Determination Theory (SDT). The Self-Determination Theory (E. Deci & Ryan, 1985; Ryan & Deci, 2017), seeks to explain the motivational processes that lead to engagement in activities. SDT postulates that humans have three basic innate psychological needs: competence, autonomy, and relatedness, which, if supported, enhance motivation and, if thwarted, decrease motivation (Ryan & Deci, 2000). According to Ryan and Deci, self-determination is maximized when intrinsic motivation is at its highest and all of the competence, autonomy, and relatedness needs are supported, going along with high interest and enjoyment; on the other hand, motivation becomes less self-determined and smaller as people perceive themselves as incompetent or not valued and external controls increase.

Research on Motivation for Science Learning in Adolescents

The body of literature on science motivation in adolescents is expansive and includes many studies specific to adolescents and will be presented in-depth in the second chapter (Murphy et al., 2019;

Potvin & Hasni, 2014b; Rosenzweig & Wigfield, 2016). This brief summary provides a general view on the range of findings on motivation for science in adolescents. Research has revealed that adolescent motivation for science is not fixed (Jensen & Sjaastad, 2013; Sadler et al., 2012), but rather can move up or down with age, semester to semester, or in even more fluid ways, which means while motivation toward science engagement seems to generally go down starting in middle school, this does not mean that the individual's motivation toward science engagement goes down. Motivation has been shown to be specific to the subject it is directed toward, which means that motivation toward biology does not operationalize the same way as toward chemistry or another science subject. However, the motivation toward science subjects as a whole, while not the same, seems to operate similarly. How adolescents relate to people in relation to their science courses has a major impact. Support by family or peers can strongly enhance existing motivation and similarly can also frustrate or hinder it. Similarly, diversity of people plays a role.

Research Methods

A range of methods investigate motivation toward science education in adolescents in the literature, the full range of which will be reviewed in the second chapter. Quantitative research is abundant with various surveys, many of which are not validated instruments (Potvin & Hasni, 2014b). Qualitative studies of motivation for science education are generally prevalent, and in relation to motivation specific to Black and Latinx students have been found to make up half of the respective publications (Starr et al., 2022). The range of validated instruments measuring motivation toward science education in adolescents is limited to a handful. One of these instruments is the Academic Motivation Scale based on Self-Determination Theory, which will be used for this research study. The second chapter will provide more insight as to why it is well suited to meet the methodological needs of this study and why that theoretical framework is most suited to enact the intended research aim. Qualitative research is not as common as quantitative research in science education motivation, yet has powerful insight as it provides an authentic narrative that allows us to not just look at levels but also quality of the motivational constructs (Wood, 2019). Mixed methods studies specifically have shown how interviews can enrich the quantitative findings in research on motivation toward science education in adolescents (Loukomies et al., 2013).

STEM Career Orientation

To research the role of STEM careers in motivation to engage in science learning, the specific variable used needs to be defined. This study investigates the influence of students' current stance toward STEM careers, applying specific career clusters defined by NSF as STEM. The term career orientation can also be found in the literature on career professional development, where it is defined similarly as a variable of present positioning toward careers that may influence or may be influenced by motivational factors (Hirschi & Koen, 2021; Li et al., 2019). This study will use a definition by the National Science Foundation for STEM careers that delineates non-STEM from STEM careers and sub-divides STEM into Science and Engineering and those related, the specifics are presented in the methods chapter.

Framing this Investigation

There is a clear need for increased motivation to engage in science education as a foundational subject as well as one path to prepare for STEM careers and respective skills for any career. At the same time motivation toward science education and pursuit of STEM careers are substantially different constructs (Roberts & Bybee, 2014; Sjöström & Eilks, 2018) and the relationship between them is still unclear. Thus, this research study aims to understand from an internal affective perspective how adolescents are motivated toward science education and how it relates to the careers the adolescents are aiming for. The researcher proposes that STEM career orientation influences the level and kind of motivation adolescents have toward science education while suggesting that the relationship is not a simple linear one where more orientation toward a STEM career translates into more motivation toward science education. Thus, the specific differences in the motivational continuum of students grouped by their present STEM career orientation are vital to understand.

Aim of the Study

The aim of this research study is to understand if and how motivational factors for science learning are impacted differently for students oriented toward STEM careers (STEM) versus students not currently interested in STEM careers (non-STEM), and to explain motivational factor levels with authentic voices. The overarching research question is: *How are SDT motivational dimensions toward undergraduate science education different for groups of adolescent college students with different STEM career orientations?*

Study Target Population

The target population for this study is adolescents, specifically undergraduate college students. The population was narrowed from the whole range of secondary and postsecondary adolescents to just undergraduate college students for practical reasons to be able to meet Institutional Review Board expectations. For students not yet 18 years of age both student and parent signatures would have been required for both survey and interview, which became time prohibitive. While the study itself thereby was limited to adolescent college students from age 18 to 26, currently enrolled in undergraduate science education courses, the literature review following is including the whole range from secondary to postsecondary adolescence.

Broader Impacts

This study improves the knowledge of how motivation operationalizes in science education in adolescents. Increased knowledge of the motivational diversity of science classes will allow instructors to design learning to be more supportive of the different students' motivations. Motivation-supportive learning design will help eliminate causes for motivation frustration that especially impact disadvantaged populations. The employed method will be available as a tool for instructors so they can identify the motivational profiles in relation to the group sizes of the STEM career orientations present in the classroom. This transparency on science then allows instructors to support their students' motivations in a differentiated or individualized way.

Most notably, the insight into motivation could shift advocacy for STEM engagement away from just asking for more numbers to enter a STEM career pathway toward a focus on science or STEM motivation-supportive education. Such a focus on science as foundation for all has the ability to buttress any students' interest in STEM careers instead of adding external pressure via lobbying or biases. The anticipated scholarly merit and potential impact of the study will be addressed after an in-depth view of the existing literature on motivation for science education in adolescents with a focus on Self-Determination Theory.

Study Methods

Self-Determination Theory will be used in this study as the theoretical framework because of its positioning of motif and the complexity of motivational factors it affords. This study investigates the inner motivational landscape of students in dependence on their current orientation toward STEM careers. This framing positions the study with theories that assume that motifs are internal drivers toward engagement. Self-Determination Theory is the one theory prominent in science education that encapsulates this assumption, as discussed in the section on motivation above. Self-Determination Theory also offers the ability to measure several distinct constructs of motivations which are organized on a continuum from extrinsic to intrinsic, thus allowing the assessment of multiple specific factors as well as the extrinsic-intrinsic dimension across the factors.

The current study is bounded by a focus on undergraduate college students with a Self-Determination Theory lens and the approach to research motivation with multiple methods. The limit to adolescent college students–emerging adults–is based on the age when students typically participate in required science education classes in college. The institutions participating are all public colleges to focus on public science courses. The theoretical lens of motivation with the Self-Determination Theory allows the researcher to investigate a continuum of motivational sub-dimensions of students. The organismic view of the cognitive mechanisms of motivation innate to Self-Determination Theory is supportive of pedagogical interpretation, in line with the researcher's critical realist stance, and has been applied in both quantitative and qualitative research. This is combined in this study in a mixed methods approach in order to explore the research question at more than one layer of the human experience and then be able to connect and relate levels of motivation with the quality the motivation holds for students. Mixed methods will be used as the methodological approach toward research as it allows a multi-layers view toward the complexity of motivation.

The hypothesis of this study is that motivation toward science education in adolescents is impacted by their positioning toward STEM careers in more complex ways than are currently known and leads to a substantial lack of motivation support for students. This study thereby focuses on prying apart different motivations with different methods to look at the specific levels and qualities while comparing different STEM career orientations. This approach provides insight into how motivations toward science education operationalize in relation to students positioning toward STEM careers. The findings of this study thereby will lead to a better understanding of the differences between students group by STEM career orientation. Increased awareness of how motivation operationalizes then can substantially change the approach instructors are able to take when designing learning in a way that sustainably supports motivation toward science education engagement and even avoids hindrance or frustration of motivations in students.

Glossary of Key Terms

This research investigation uses various key terms presented in this glossary section. Many terms are subject-specific and are shortened to acronyms, such as STEM, a combination of the first letters of science, technology, engineering, and math coined by the National Science Foundation. Other terms are included here to provide clarity on how the author in this research study used the terms. STEM Career Orientation, for example, was a key variable for this study as it was used to group students to then investigate differences between these groups. The specific definitions of how the author used these key terms thereby are critical to the understanding of this study.

Adolescence. Depending on the source, adolescence spans from 10 to 18 or from 9 to 26, the latter of which is more inclusive of the whole biological pubescent and brain development (Curtis, 2015;

Sawyer et al., 2018). This research study is using the term adolescence to be defined as the wider age range from 9 to 26 years of age, which also includes the developmental stage of emerging adulthood (Arnett, 2000). Since undergraduate students typically enter college at age eighteen, most students in undergraduate college education are still in the biological developmental phase of adolescence.

Construct. A construct is a term used in instrument development to define the specific concept measured by the questions of a survey.

Critical Realism (CR). Critical realism is an epistemological philosophy that views the world on a continuum from the natural realm to the world of social experience, which are described as strata. These provide a non-dualistic perspective of the world and knowledge thereof that also gives space to the potential of a spiritual realm as one of the strata (Bhaskar, 2017). Geographically, critical realism is more prominent in Europe, especially Great Britain, while it is still fairly unknown in the United States (Gorski, 2013). Critical realism provides an integrative philosophical frame that coherently connects ontology to epistemology to methodology and method, avoiding the pragmatist absence of an ontological and epistemological stance in methodology (Maxwell & Mittapalli, 2010).

Domain. Motivation is oriented toward a domain, often a specific subject like science. Domain is the specific action or subject field that motivation is activating.

Factor. In this dissertation, factors that influence motivation and factors that sub-dimensions of motivation are discussed. Factors represent theoretical constructs measured indirectly as latent variables (Brown, 2015). The concepts typically defined in theoretical frameworks are constructs. These constructs can be measured as latent variables, a variable that is not directly measurable, rather is assessed indirectly, for example via survey questions. The data allow for analysis and discussion of the factor, the expression of the construct in analysis or findings in form of data. In educational research, correlations between factors or causation of factors onto others may be investigated, for example with factor analysis.

Item. Questions in validated surveys that measure a specific construct are called items. Multiple items or item questions typically are used to assess one construct.

Motivation. Motivation describes activation and direction toward behavior at different level and of various types (Petri & Govern, 2012). The research field of motivation is complex. Each theory describes motivation differently with a multitude of psychological, biological, pedagogical, and personal perspectives.

Self-Determination Theory (SDT). The Self-Determination Theory, developed by Ryan and Deci (E. Deci & Ryan, 1985; Ryan & Deci, 2017) seeks to explain the motivational processes that lead to engagement in activities. According to Ryan and Deci, self-determination is maximized when intrinsic motivation is at its highest and all competence, autonomy, and relatedness needs are supported, going along with high interest and enjoyment; on the other hand, motivation becomes less self-determined and lower as people perceive themselves as incompetent or not valued and external controls increase (Ryan & Deci, 2000).

Science Literacy. Science literacy or scientific literacy describes the competencies in science knowledge, skills, and scientific problem-solving abilities (Roberts & Bybee, 2014).

STEM. The term STEM was created by the National Science Foundation to address the national need of workforce in the cluster of subjects science, technology, engineering, and math (STEM) and to emphasize the interdisciplinary quality of STEM in its practical applications (Hallinen, 2022).

STEM Career Orientation. This term is utilized by the researcher to capture the current positioning of a student when thinking of careers that a student may engage in in the future. This is intentionally different in concept from students' STEM career goals or motivation toward STEM careers. The study gages this orientation in a single-blind study design, meaning the students are not aware of STEM career orientation being the investigated dependent variable of the study, rather the study participants are asked in the section of demographic questions at the end of the survey/interview what careers they are currently thinking of for their future. The term career orientation has been used similarly in the literature (Hirschi & Koen, 2021; Li et al., 2019). The STEM career orientation groups in this dissertation are following the NSF organization of STEM careers into science and engineering (abbreviated in this dissertation as S) and STEM careers related to science and engineering (abbreviated as R) as a separate group (National Science Foundation, 2018).

Chapter 2: Literature Review

The current study uses a foundation of motivation for science learning among adolescents as it intersects with influencing factors and STEM-/non-STEM-career orientation. An overview of the prominent motivational theories in science educational research provides justification for the specification theory and measurement selected. Additionally, an exploration of the factors influencing motivation in adolescents for science education lays out the current understanding of the motivational landscape of adolescents toward science education and how it interfaces with orientation toward STEM careers. Lastly, future career interests provide insight into motivation influences for science learning. The conceptual framework for the study highlights the methodology applied, especially as it pertains to measuring motivation. Hence, a review of published instruments assessing science education motivation justifies using a modified scale with a mixed methods approach. In order for the reader to relate all the constructs across the different theories, this chapter first reviews the theories and secondly the findings by topic that present outcomes of the students for the various constructs in context.

Motivational Theories Applied in Science Education

This section looks closely at the research literature on motivation for science education, which utilizes a motivational theory. Focusing first on the motivational theories themselves will highlight the conceptual capacities of the different theories for providing insight into motivation specific to science education. Together, the theories provide a picture of people having a mix of internally driven motivators such as intrinsic motivation, interest value, and mastery goals influenced by externally driven motivators in form of rewards or performance goals. All these motivators vary in the levels the person feels in control of and thus has autonomy over, and most theories include social environment and anticipated outcomes as additional factors influencing motivation (Cook & Artino, 2016).

The motivational theories most commonly present in research on motivation for science education are three Achievement Goal theories, Social-Cognitive Theory, and Self-Determination Theory (Murphy et al., 2019; Rosenzweig & Wigfield, 2016). Both Expectancy-Value (Wigfield & Eccles, 2000) and Goal Orientation Theory (Kaplan & Maehr, 2007) are both achievement motivation theories that recognize outcomes humans anticipate as key motifs: the value of the task and the expectation of success or the desire to reach performance and mastery goals drive the motivation toward engagement in STEM education. Beliefs are the key motif for behavior in the Social-Cognitive Theory (Bandura, 2001), especially the expectation of how well one can do a behavior informed by past experiences, the self-efficacy for the behavior (Bandura, 2010). One additional theory, the ARCS theory (Keller,

1984) will be reviewed due to its contribution on motivation in education design specific to STEM education. These motivational theories all contribute to the body of literature on motivation for science education. Prior to the review of the other aforementioned motivational theories, the Self-Determination Theory (Ryan & Deci, 2017)–providing the theoretical lens of the study– will be reviewed more closely and then brought into context with the other theories as they are reviewed.

Self-Determination Theory

The selected theory, Self-Determination Theory (SDT), offers several constructs on a continuum from most extrinsic motivation to most intrinsic motivation. The self-determination theory (E. Deci & Ryan, 1985; Ryan & Deci, 2017) is a need-based theory. Basic human needs influencing motivation are autonomy, competence, and relatedness. It seeks to explain the motivational processes that lead to engagement in activities. SDT theory is grounded in the belief that humans have an inherent–intrinsic–desire to learn that can be encouraged through social influences (Koludrović & Ercegovac, 2015). Depending on the situation, the motivational status of humans may be fully intrinsic–thereby fully self-determined–or, on the other extreme, may feel a total loss of control and motivation, called amotivation. Between amotivation and intrinsic motivation is extrinsic motivation, where a person is motivated to do something because of external factors that have been internalized at varying degrees.

Self-determination is maximized when intrinsic motivation is at its highest and all the basic needs of competence, autonomy, and relatedness are fully supported, going along with high interest and enjoyment (E. Deci & Ryan, 1985). The needs, if supported, enhance motivation and, if thwarted, decrease motivation (Ryan & Deci, 2000). On the other hand, motivation becomes less self-determined and smaller as people perceive themselves as incompetent or not valued and external controls increase. When a person is motivated to do something because of external factors, the Self-Determination Theory views that as extrinsically. Humans are on this continuous spectrum from no motivation to total motivation, which is influenced by how much the basic human needs are met and how much and what kind of external influences are exerted onto the person. In order to boost somebody's motivation, self-regulated behaviors should be fostered, and intrinsic motivation supported (Lechuga, 2012; Seifert & Sutton, 2009).

In order to boost somebody's motivation, self-regulated behaviors should be fostered and intrinsic motivation supported (Lechuga, 2012; Seifert & Sutton, 2009). Self-Determination Theory investigates the factors that support or impede the human need for functional growth and integrity, building on research in psychology and biology on functional factors needed for the development of organisms while adding a focus on the social conditions and mechanisms (Ryan & Deci, 2017). Self-

Determination Theory is well suited for this study as it attempts to better understand the inner mechanisms of the students regardless of their self-efficacy beliefs, expectations, or goals.

Self-Determination Theory provides the opportunity to measure motivation with several constructs along a continuum from no motivation to externally driven motivations to fully self-determined intrinsic motivation. While Expectancy-Value Theory is more prominent in the research literature on STEM education (Murphy et al., 2019), there are a substantial number of publications utilizing Self-Determination Theory in science education (Dyrberg & Holmegaard, 2019; Lechuga, 2012; D. R. Williams et al., 2018). Also, this motivational theory is one of several major theories used in educational research in general (E. L. Deci et al., 1991; Howard et al., 2021; Reeve, 2002) and has led to an abundance of knowledge on how motivation operates for activities not considered a foundational subject such as physical education (Vasconcellos et al., 2020). Overall, this theory is best suited among the theories used in research for science education for the aspirations of this study, because it is not viewing motivation as driven by goals or expectations as a core premise, but gages the current inner motivations via the motivational constructs along the extrinsic-intrinsic continuum. This allows for differentiated view of motivational stance to be connected in relation to the career orientation as separate constructs. Using a theory that bases the motivation to learn science as driven by the goal or expectation toward a career would inherently limit the ability to view the inner motivational drive regardless of its relation to such an external career expectation.

Achievement Goal Orientation Theories

The Achievement Goal Orientation branch of motivational theory conceptualizes motivation around the perspective that motivation is driven by the goal to achieve, Expectancy-Value, Goal Orientation, and Achievement Goal Theory. Goal Orientation Theory (Ames, 1992; Dweck, 1986; Kaplan & Maehr, 2007) was developed in the 1980s. The Achievement Goal Theory (Ames, 1992; Covington, 2000; Maehr & Zusho, 2009) was developed based on the Goal Orientation Theory. Ames coined the terms *mastery* and *performance goal* for two types of achievement goals. The mastery achievement goal is also called *learning* or *task-involvement goal*. The second kind of achievement goal, the *performance achievement goal*, is sometimes called *ego-involvement goal* (Ames, 1992). The theory postulates that when being motivated by mastery goals, humans are working toward gaining competence and belief that the effort will lead to the desired outcome. To illustrate its practical application, Ames (1992) describes strategies that can be used to support students in their orientation toward mastery goals. In order to design education and interventions with mastery goals in mind, Ames suggests to organize the learning environment with salient structures in support of them; recognize how these relate to each other and are perceived by students; provide examples that are meaningful to students; include recognition of the student's efforts. More recently, this branch of goal-oriented theories has shifted toward viewing motivation with an intrinsic and extrinsic perspective. The mastery goal can be viewed as a simile to intrinsic motivation and has been shown to not only result in heightened interest of the students toward education but also continued choice expressed by enrolling in similar classes (Harackiewicz et al., 2002). The performance goal is the pursuit of ability and self-worth, also in comparison with others; hence the motivation is extrinsic in nature (Midgley et al., 2001).

Research with Achievement Goal Theory has linked performance goals to higher academic achievement (Harackiewicz et al., 2002), thereby this theory is often utilized to investigate motivation in relation to academic performance. However, viewing high performance motivation has become controversial. Other than students with high mastery achievement motivation, students with high performance goals have increased motivation short-term, but that has been linked to extrinsic pressure and negative motivation long-term (Midgley et al., 2001). Other scholars do not see performance goals in this light and emphasize positive effects. The performance goal has been sub-classified into performance-approach and performance-avoidance goals, which addresses the difference between motivation toward something that is viewed as positive, and thereby, approach is desired and when behavior is born from avoidance, for example, when avoiding looking bad in front of peers is the main motivation (Elliot & Church, 1997; Seifert & Sutton, 2009; T. Urdan, 2004). The tension in these perspectives is noticeable and shines a light on the damaging element of external pressures in their balance with students' goals toward performance.

Short-term increase in performance motivation in students results in higher GPA achievement for the semester. The typical measure of achievement in public education is one semester, so instructors design curriculum and learning experiences optimized for students to achieve high academically for that one semester, formally evaluated as GPAs. The literature on motivation for science education contains many short-term studies that show an increase in performance motivations (Murphy et al., 2019) as a positive outcome of interventions. However, as shown, high-performance motivation is also linked to lower long-term motivation means that interventions increasing performance motivation are likely to decrease the students' motivation to learn science long-term. Designing for high-performance motivation thus inadvertently also designs for less motivation to sustainably engage in science, likely leading to less science literacy engagement past graduation. Performance expectation operationalizes extrinsic with similar effects found for externally regulated motivation with Self-Determination Theory, one of the extrinsic motivational factors of the theory.

An addition acknowledging the impact relationships have on motivation is the expansion of goal theory into the personal context of students and how that context serves the motivational needs of the students. Social goals were introduced as a third goal to the Achievement Goal Theory (T. C. Urdan & Maehr, 1995) to acknowledge that social connection is often a goal that motivates behavior. Some goal motives are driven by the goal to avoid failure, which in this body of literature referred to as failure-avoidance goals. This expansion is making goal theories inclusive of the social-emotional needs of students by acknowledging them directly as a motivational dimension, and more recently, has spawned another goal theory, the Social Goal Theory (Jeanne Horst et al., 2007). This addition aligns the body of achievement goal theories more with other theories that include relatedness (Martin & Dowson, 2009). The SDT psychological need relatedness similarly captures the impact that relating to people has on motivation while positioning it as a foundational need drive underlying the SDT motivations. The extension into another theory exemplifies how goal theories have expanded over time. In contrast to that, the Self-Determination Theory research is organized by a center of researchers with the intention of integrating research back into the theory to improve it (CSDT, n.d.), more in line with the philosophical approach of this study.

Overall, the stance of the goal theories to see goals as the motif inherently elevates the visible measure of performance as an important motivation. Overall, the theories are not well positioned to assess the sustainable aspects of motivation, even though mastery goals are a compelling motivation as they capture competence and intrinsic motivation, which have more motivational longevity and relevance. The third achievement motivation theory, Expectancy-Value Theory provides a similar view; however, the focus on goal as motif changes to a focus on expectation as the motif. While one branch of the literature on motivation for science education links motivation to the various goal constructs of Achievement Goal and Goal Orientation Theory, another branch views motivation for science learning with the Expectancy-Value Theory (M.-T. Wang & Degol, 2013).

Expectancy-Value Theory

The Expectancy-Value Theory is a theory of achievement motivation developed by Eccles (Eccles, 1987; Wigfield, 1994; Wigfield & Eccles, 2000). This perspective on motivation sees the expectations and values that students attach to specific tasks as key motifs (M.-T. Wang & Degol, 2013). These are visible in task choice, persistence, engagement, effort, course enrollment decisions, intentions to attend postgraduate school, and achievement (Murphy et al., 2019). The expectation of success in relation to the value of the activity, the task, predicts the motivation level.

Task values are the values that individuals attach to an activity as to why they would do that activity (Pintrich & Schunk, 2002; Wigfield & Eccles, 2000). They are further sub-classified into attainment value, interest value, utility value, and cost. The value of attainment is the value connected to doing well; tasks central to the person's sense of self that confirm the valued parts of self-perception. Interest value describes the enjoyment a person gains when doing a task. The usefulness of an activity, especially in the long run, comprises the utility value. For example, specific math or science classes may hold utility value for a person for their education and career plan. Cost is the negative value that an activity is perceived to have such as needed effort that is anticipated. The overall task value is impacted by cost-benefit ratio of positive and negative task values that a person attaches to an activity. If the negative is dominant in the person's anticipation of doing a tasks it results in a lack of motivation for that task (Murphy et al., 2019).

The emphasis on expectancies by the Expectancy-Value theory in the context of motivation for science education makes this theory a lens that is focused on the conscious decision-making of students to learn science. Compared the Achievement Goal theories, viewing motivation as value-driven places the motif more internally into the space of conscious perception of motifs. The theory does not tend to consider contextual and emotional needs that afford motivation and has been critiqued for not providing clear definitions of its constructs. This theory was not employed for this study because of these limitations. However, many research studies on motivation for science education utilize an Expectancy-Value lens and contribute to the overall literature on motivation toward science education.

Social-Cognitive Theory

The Social Cognitive Theory of motivation, also called the Self-Efficacy Theory of motivation, (Bandura, 1986, 1997, 2001), presents a person's beliefs as the primary driver for motivation. Self-efficacy is the individual's perception of their ability to complete a specific task effectively (Bandura, 1997). The self-constructs of self-concept and self-efficacy (Andersen & Chen, 2016; Guo et al., 2017; Pintrich & Schunk, 2002) are also often connected to expectancy values. Self-concept is more broadly defined as the belief in a person's ability in regard to a specific domain, such as the ability to be good in science (Murphy et al., 2019). While the Expectancy-Value Theory focused on the outcome in terms of value, the Social-Cognitive Theory is a developmental theory that views the development of internal regulation and self-efficacy as core motivation (Cook & Artino, 2016).

One interesting aspect of the Social Cognitive Theory is that it has been connected to the Social Cognitive Career Theory (Brown & Lent, 2017). This career theory has been applied in science research (Beier et al., 2019; Hardin & Longhurst, 2016). The grounding of the research in STEM careers with the Social Cognitive Theory means that it views career orientation of adolescents from the perspective of beliefs and uses measures that assess the career aspiration that students have. Another aspect of this theory applied to the intersection of science education and STEM careers is that it measures the social cognitive motivation for careers–it does not investigate the impact of career orientation onto motivation to learn science. For the purpose of this research study this theory is not well positioned with its focus on belief in form of self-efficacy. A belief perspective on motivation does not consider internal cognitive mechanisms well. Also, this study attempts to view impact by career orientation onto science motivation and not the other way round.

ARCS Model for Motivational Design

One model of motivation, a motivational design theory directly derived from STEM education research, is the ARCS-V theory (Keller, 1984). First developed as ARCS motivation, the model in the context of technology education to be utilized as part of motivational design, a design-based approach to education. It organizes motivation constructs in four dimensions: attention (A), relevance (R), confidence (C), and satisfaction(S) (Keller, 1987, 2000). Thus, ARCS is not a motivational theory on its own, rather it is a synthesis of motivational theories. The first element of ARCS, attention, describes the interest level that a student has toward an activity. Relevance is the usefulness to the student. Confidence describes the student's perception of anticipated achievement success. Satisfaction is the overall level of feeling good about the activity and learning. An additional dimension, volition (V), was added recently to acknowledge the degree of commitment students have toward achieving the learning requirements and whether they will persist to the end (Keller, 2016). The ARCS model is used in STEM education contexts and the integration for design-based education is very attractive; however, the model has not been implemented in a lot of studies and is not as comprehensive as other theories.

Research on motivation in the context of the ARCS theory has mostly focused on instructional design for STEM learning. These studies show that active learning elements such as augmented reality, authentic real-world learning, or service learning increase motivation in adolescents in terms of attention, confidence, relevance, and satisfaction in a sustainable way such that it is still higher in following semesters (Estapa & Nadolny, 2015; Sevier et al., 2012; Stover et al., 2012). The theory is a great example where motivational theory can be used both to design instruction as well as assess the quality of instruction. It is well suited to assess the impact of learning design on students' motivation in science or STEM education. However, it is more a model than a theory and its strengths lie in practical application.

Motivation Toward Science Education in Adolescents

The literature on motivation for science education across secondary and postsecondary adolescents provides on overview of what is known on the motivational constructs across the theories.

Motivation Differences Between Subjects

Motivation is domain specific. The construct of motivation is directed toward the specific engagement, the domain (Petri & Govern, 2012). This study focuses on adolescent motivation toward engagement in science education. This specific focus on science education courses is important to note since the literature on research in science education presents research on motivation toward various versions of science or STEM education (Rosenzweig & Wigfield, 2016). This discussion on motivation toward science education maintains this clear focus while occasionally integrating related literature that addresses motivation for science education in public science courses. For example, research on motivation in informal STEM programs has much to contribute (D. R. Williams et al., 2018) to a better understanding of the factors that increase motivation toward science education as many of the instructional techniques applied there could be implemented in public science education.

In college, once students choose a science as their college major, the motivation for the specific subject area is higher, especially autonomous motivation (Dyrberg & Holmegaard, 2019). However, when students in a course are pushed to identify with a STEM subject it lowers their motivation (Starr et al., 2019), while a student with high STEM identity experiences an increase in their motivation. Specifically, students partook in a virtual reality experience of playing a future STEM professional with a related STEM curriculum in that study. In a separate study, identity was shown to be a mediator between stereotypes and expectancy-beliefs (Starr, 2018). STEM subjects and applications show that motivation toward STEM is specific to the STEM subject, while generally motivational mechanisms are similar. This shows also that pressure to engage in STEM tends to lead to a lowering of motivation.

Motivation Changes Over Time

While young people may still be interested in science, the motivation to engage in science education formally or informally drops off as students grow older, across secondary and undergraduate school (Cromley et al., 2016; Potvin & Hasni, 2014b; Rosenzweig & Wigfield, 2016). Studies show that motivation for STEM learning does not just stay constant over time, nor does it follow a linear path. For example, interest of high school students may remain high or can be regained when engaging students in science learning directly relevant to the students (Jensen & Sjaastad, 2013; Sadler et al., 2012). While the motivation for participation in science education is declining for adolescents, that is not necessarily true for engagement in science in general (Osborne et al., 2003; Potvin & Hasni, 2014b; Vedder-Weiss & Fortus, 2011). Studies have found that motivation may increase in early adolescence (Falk et al., 2016) and fluctuates significantly from week to week through the semester (Dillon & Stolk, 2012). Thus, while there are clear trends of lowering motivation toward science education throughout adolescents and emerging adulthood, in individual students and for science education in general, motivation may stay high or fluctuate significantly over time. The current study captured motivation at the time of the survey and interview and provides a snapshot of the motivations for that time. These findings emphasize that it is important to not type a student to a specific motivational profile since their motivation may increase or decrease with time. The evaluation of the data in this study was conducted with that in mind.

Science Motivation and STEM Career Orientation

There is also an indication of a difference in motivation for science learning between students oriented toward STEM careers versus those not, but the motivational factors are not well understood. Studies demonstrate that we cannot assume that the higher the motivation for STEM learning, the higher is motivation for STEM careers and vice versa (Falk et al., 2016; Osborne et al., 2003; Potvin & Hasni, 2014a; Vedder-Weiss & Fortus, 2011). A study investigating the relationship between motivation for STEM learning variables of the Social Cognitive Theory found that self-efficacy or interest is not correlated to STEM career orientation for middle school students (Nugent et al., 2015). This provides evidence that the motivation to learn science is not directly related to the STEM career orientation that students have. Given that it's appropriate to investigate them as separate variables in this research study, focusing this study on these two variables–motivation and career orientation–provides more insight into the relationship between them, and most importantly how they are separate. More clarity on how they are separate and how related will allow a more differentiated conversation on science motivation in relation STEM career pathways to create more space for a focus on science education regardless of STEM career interests.

External Factors Influencing Motivation for Science Education

During adolescence, students transition from middle school all the way to undergraduate college–where applicable–with increasing specialization and course selection such that there is no unified experience or exaptation of science courses at the end of high school or in college. As a result, external factors have been identified to influence motivation in students.

People and Relationships. Parents influence their children's STEM motivation positively when they emphasize the utility-value of STEM education positively (Rozek et al., 2017), which can counteract the loss of motivation as children age from middle to high school (Svoboda et al., 2016). At the same time, female college students in China were shown to be negatively impacted by their parents' low career expectations for STEM (Yang & Gao, 2019). Similarly, peer support positively correlates with STEM motivation, as shown for adolescent girls (Leaper et al., 2012). In general, personal support in STEM education itself has been shown to increase motivation (Aeschlimann et al., 2016; Jensen & Sjaastad, 2013). Thus, encouragement can buffer against negative motivational effects (Leaper & Starr, 2019).

Role of Diversity. For non-dominant populations, these impacts on motivation shown for women, relative to men, also play out. Negative impacts on motivation begin in elementary school for students with low socioeconomic status and earlier for girls than for boys (Isa & Chinen, 2016). Conversely, interventions that address the relevance of instruction positively impacted the non-dominant groups of low-income and racial minority (Harackiewicz et al., 2016) and, in another study, were shown to particularly foster underrepresented students' competence, relatedness, and autonomy (D. R. Williams et al., 2018). This motivation-supportive effect can thus be leveraged to address the achievement gap for these underrepresented populations.

Moreover, motivation is a diverse and complex concept across gender, socio-economic class, ethnic-racial groups, and regions. Males have been shown to receive more support for STEM education (Nugent et al., 2015; Tzu-Ling, 2019) and possess higher motivation for continuing STEM (Luo et al., 2019). Additionally, men exhibit high levels of academic self-concept and autonomous motivation related to higher academic achievement (Van Soom & Donche, 2014). For women–different from men–effort expenditure, the perception of how much effort it takes to succeed lowers women's motivation to engage in STEM education (Smith et al., 2013). Studies in Taiwan have shown that for women, autonomy motivation and self-concept do not predict their STEM achievement (Van Soom & Donche, 2014), nor does self-efficacy predict STEM career motivation; however, task value does (Tzu-Ling, 2019). The negative impact of these motivation threats, however, is buffered by self-efficacy (Simon et al., 2015), the perception that expending effort is normal, and an overall sense of belonging (Smith et al., 2013).

Awareness of these identified external factors and how they relate to motivation supported the interpretation of the study, especially for the qualitative phase with interviews. The influence of people was captured by a priori coding for the Self-Determination Theory basic need *relatedness*. The aspect of diversity was not specifically researched in relation to motivation. However, data were captured on gender and ethnic-racial identity and the demographic diversity of the sample was compared with the region in which the study took place to assess representativeness.

STEM Identity and Stereotype Threat

An increasing body of literature investigates science identity or STEM identity, seeing oneself as a future STEM professional. Identity combines the constructs of performance, competence, and recognition, the latter of which is an external component of being seen as a science person (Carlone & Johnson, 2007). Identity is of interest for this research study since identity includes how students are oriented toward STEM Careers and because the body of literature around STEM or science identity is rich in authentic qualitative research, providing glimpses into how STEM career orientation as a single factor impacts motivation.

In line with the concepts of motivation-frustration in Self-Determination Theory, research on identity has shown that negative external expectations of students' identity negatively affect their respective motivation toward the subject (Carlone & Johnson, 2007). The current study aims to isolate the element of career orientation in these effects and, rather than looking at a developed identity, look at the tentative career orientation at the moment.

There are also indications of the negative impact of forcing a STEM career perspective onto motivation. There are indications that being pushed to take on a career role without internal identification harms motivation. In an experiment (Starr et al., 2019), undergraduate women played successful scientists in virtual reality and the women without scientist identity experienced a decrease in their value expectancy of STEM education. This study is a rare publication where the impact of a forced STEM career orientation on motivation toward STEM education was investigated by imposing the experience of that identity for the time of the virtual reality experiment. It adds to the picture that external pressures have a negative impact–as shown in Self-Determination Theory–and that this extends to career orientation.

The author of this study found a lack of adolescent voice in relation to the empirical or quantitative results presented in the literature. Publications are mostly of quantitative nature, while some studies on motivation toward science education were qualitative (Lechuga, 2012; Lieu, 2022); both methods are highly valuable and contribute to the literature. However, in line with other literature reviews (Rosenzweig & Wigfield, 2016), the researcher of this study found that few publications tie to specific theoretical frameworks and clearly identify how constructs were defined and operationalized for research, thus making it difficult to understand how the perspectives presented in qualitative investigations tie to results in quantitative studies. This presents a gap in the literature on qualitative voices in relation to motivational factors for adolescents.

Impact of Learning Design

The learning design also has a major impact on the motivation for STEM education. College lecture classes lead to a decline in motivation from the beginning to the end of the semester (Young et al., 2018). Extrinsic reward systems such as grades negatively impact motivation (Lepper et al., 2005; Young et al., 2018). Instruction that makes learning relevant has improved motivation for adolescents across the STEM subjects (Aeschlimann et al., 2016; Dyrberg & Holmegaard, 2019; Jensen & Sjaastad, 2013; Kuo et al., 2019), for example through hands-on learning (Estapa & Nadolny, 2015; Julià & Antolí, 2019; D. R. Williams et al., 2018) or service-learning projects (Sevier et al., 2012). Authentic real-world learning was even shown to raise motivation long-term across semesters (Hernandez et al., 2013; Julià & Antolí, 2019; D. R. Williams et al., 2018). Project-based STEM education may protect against negative motivational effects (Hernandez et al., 2013). Out-of-school STEM learning programs where students have a higher level of autonomy over the pace and challenge level of their learning also have been correlated to increased motivation (Jensen & Sjaastad, 2013). As a result of increased motivation in relevant learning, students have been shown to have not necessarily gained higher grades but increased comprehension of the subject matter (Sevier et al., 2012) and improved performance (Harackiewicz et al., 2016).

The Career Orientation Impact Literature Gap

Motivation to engage in science learning and motivation toward STEM careers are not necessarily linked. While it would make sense to assume that students geared toward STEM careers are interested in and motivated to learn in science courses, many publications report that some students feel differently. Publications are reviewed here to understand the alignment of motivation and career interest in science. It is unclear how much adolescents are motivated to engage in science independent of their career interests (Thibaut et al., 2018). How much future scientists or STEM professionals are motivated to study in science courses, or reversely how students not interested in STEM careers may well be very interested and motivated to learn science in college is not well-known (Potvin & Hasni, 2014b). Students not oriented toward STEM careers often have interest and motivation to engage in science learning (Krapp & Prenzel, 2011). Interestingly, a report on the state of science education in Europe found that countries with higher STEM development have students liking science education less than students of other countries (Osborne & Dillon, 2008), potentially indicating a negative feedback mechanism of STEM career opportunities onto motivation to engage in science education.

In summary, very little is known about how the students' current career orientation influences motivation to engage in science education in the moment and indications of negative impacts. This research study views STEM career orientation as the current perspective of the student on the career they may choose. This will allow investigation of the influence that the immediate career orientation has on the motivational factors toward science education. The influence that STEM and related career aspirations play on the motivation to learn science in education courses is poorly understood and cannot be simplified to a linear relationship. The detailed understanding of how STEM career orientation impacts motivation toward science education is posing a gap in the literature.

Measuring Motivation for Science Education

A variety of methods have been used to research motivational constructs for motivation toward science learning, using surveys or instruments to assess motivational levels or using interviews or open-ended survey questions to add qualitative understanding (Potvin & Hasni, 2014b). However, the number of published research results that directly address motivational theories and inform their development is limited (Murphy et al., 2019; Potvin & Hasni, 2014b; Rosenzweig & Wigfield, 2016). Even fewer studies with quantitative results use a validated instrument (Potvin & Hasni, 2014b), so the number of instruments used multiple times or by multiple researchers is small.

For motivation toward science education, such validated instruments published in peer-reviewed academic journals include: the Academic Motivation Scale (Vallerand et al., 1989, 1993), the Intrinsic Motivation Inventory (Ryan, 1982), the Motivation for Learning and Doing Science (Porticella et al., 2017), the Motivated Strategies for Learning Questionnaire (Pintrich & De Groot, 1990), the Patterns of Adaptive Learning Survey (Midgley et al., 2000), and the Science Motivation Questionnaire II (Glynn et al., 2011). Amongst these, the instruments measuring motivational sub-dimensions based on SDT are the Academic Motivation Scale, the Intrinsic Motivation Inventory, and the Motivation for Learning and Doing Science. The latter two were developed to measure motivation toward a specific one-time activity or program. The Academic Motivation Scale has been developed to measure motivation toward education in general and, more recently, toward an educational subject. The Academic Motivation Scale is thus well suited to assess motivation toward science, the aim of this research study.

The Academic Motivation Scale

The Academic Motivation Scale (AMS) was developed by Vallerand to measure motivation sub-dimensions toward education following the Self-Determination Theory (Vallerand et al., 1989, 1992, 1993). AMS measures seven dimensions of motivation: amotivation, three orientations of intrinsic motivation (to know, to accomplish things, to experience stimulation), and three extrinsic motivational dimensions (external, introjected, identified regulation), each with four survey items (Vallerand et al., 1992). The three orientations of intrinsic motivation were established by Vallerand, based on Deci and Ryan's self-determination theory at the time. The instrument has been validated for use with high school students (Vallerand et al., 1992) for motivation toward education in general. More recent adaptations specific to STEM subject domains did not compromise the quality of the instrument: Lim and Chapman adapted AMS toward mathematics for high school students and Liu et al. for chemistry in college students (Lim & Chapman, 2015; Y. Liu et al., 2017).

Various adaptations of the scale have shown to have high reliability and validity across various populations and domain areas (Cokley, 2000), including high school student adaptations directed at education in general (Barkoukis et al., 2008; Núñez et al., 2010; Stover et al., 2012) and toward specific domain areas (Lim & Chapman, 2015; Y. Liu et al., 2017). Research on gender differences has shown that AMS can pick up differences between groups for the motivational factors measured in both univariate and multivariate statistical analysis (Caleon et al., 2015; Grouzet et al., 2006). Hence it can be expected that the AMS instrument can surface differences between the groups of student groups with different career orientations as they exist.

Both the instrument by Lim and Chapman and by Liu et al. are most applicable to measure motivation in adolescents toward science education (Lim & Chapman, 2015; Y. Liu et al., 2017). For the instrument, the prompt question of the original AMS statement, "Why do you go to school?" (Vallerand et al., 1992) was adjusted to "why do you spend time studying mathematics/chemistry?" (Lim & Chapman, 2015; Y. Liu et al., 2017). The instrument can be adapted to motivation toward science by replacing the word mathematics accordingly. The instrument by Lim and Chapman only measures five dimensions: amotivation, the three extrinsic motivations external regulation, introjection, and identification, and intrinsic motivation. The instrument contains less than seven dimensions since the intrinsic constructs collapsed in the factor analysis, meaning the that the intrinsic motivation sub-dimensions present as one factor and can not be statistically distinguished. The adaptation of AMS by Lim and Chapman hence has a smaller number of items of twenty-one items. The remainder of the proposal will refer to this version or the slightly modified version for this study when referring to AMS.

The AMS instrument by Lim and Chapman (2015) includes one combined intrinsic motivation factor, In the process of validating the instrument for adolescents in STEM subjects, Lim and Chapman (2015) found that the three sub-dimensions of IM included in the original AMS survey by Vallerand (Vallerand et al., 1989, 1993) collapse into a single IM factor. A collapse means that the statistical analysis was not able to show the sub-dimensions as different constructs in the factor analysis that Lim and Chapman conducted. The final validated instrument by Lim and Chapman thereby has twenty-one items.

The survey measures five motivational sub-dimensions of the SDT continuum. Amotivation (AMOT), the tree extrinsic motivations external regulation (EMER), introjected motivation (EMIN), identified motivation (EMID), and intrinsic motivation (IM), the latter being the most self-determined motivation. Intrinsic motivation in the AMS survey is comprised of several aspects of intrinsic motivation: IMTA, the intrinsic motivation to accomplish, IMTK, the intrinsic motivation to know, and IMTS, the intrinsic motivation to stimulate.

Variable STEM Career Orientation

Considering that the term STEM was first defined by the National Science Foundation, publications by NSF were scanned for available lists of STEM careers by occupation. One breakdown included both a narrow and a broadly defined list of STEM careers. The narrow definition of STEM careers included only science and engineering professions, while a broader definition included related careers, such as STEM medical, technical, and educational occupations (National Science Foundation, 2018). Using this definition provides the opportunity to group STEM careers into two sub-groups, the narrowly and the broadly defined sub-group of STEM professions. Practically, this allows the investigation to not just differentiate between groups of students interested in STEM careers and those not interested in STEM careers but further differentiate between those oriented toward STEM careers and STEM-related careers.

Table 2-1 shows an excerpt of the NSF career classification (National Science Foundation, 2018). Careers are categorized as *science & engineering*, those *related*, and the careers that are *neither*. For example careers such as health occupations, architects, actuaries, and teachers are considered related to *science & engineering*. In this study these categories are labeled with S (STEM), R (STEM-Related), and N (Not STEM).

Table 2-1
Careers Groups

S	Science & Engineering	Biological, agricultural, and environmental life scientists Computer and mathematical scientists Physical scientists Social scientists Engineers Science and engineering teachers

Table 2-1 Continued

R	Science & Engineering Related	Health-related occupations Science and engineering managers Science or engineering precollege teachers Science or engineering technicians and technologists Architects Actuaries Science or engineering related postsecondary teachers
N	None (Neither science & engineering nor related)	Non-science-and-engineering managers Management-related occupations Non-science-and-engineering precollege teachers Non-science-and-engineering postsecondary teachers Social services occupations Sales and marketing occupations Arts and humanities occupations Other occupations

The Conceptual Framework

This research study is conceptualized with a critical realist epistemology, the theoretical lens of Self-Determination Theory, the methodological approach of an explanatory sequential mixed methods research study, and the research methods of collecting data with a validated survey and interviews. This study will apply the lens of the Self-Determination Theory to the subject domain of science education in undergraduate college courses. The Self-Determination Theory is utilized in this study to view the motivation for groups of students with different career orientations for a handful of motivation constructs to provide a handful of data points to review for differences between these groups of different career interests. SDT is particularly well suited for this research study since it is developed to include a range of nuances on the type of internal motivation on a continuum of motivational sub-dimensions and thus can provide a differentiated picture of motivation for adolescents, providing a window into the motivational landscape of adolescents in relation to the STEM career orientation of the students at the moment of the research study. Self-Determination Theory also fits well with the researcher's critical realist stance toward knowledge acquisition. Self-Determination values basic science and is not a relativistic framework, rather it believes that there are universal principles within the social and cultural conditions that are necessities for all humans for healthy functioning (Ryan & Deci, 2017).

According to the Self-Determination Theory, motivation shifts on a continuum from the absence of motivation to full motivation in the form of intrinsic motivation, with different extrinsic motivational constructs in between. This research study will investigate these motivational constructs for the group of students that is STEM career-oriented (S), oriented toward STEM-Related careers (R), and the group of students not oriented toward STEM careers (N) at the time of the survey to identify between-group differences between the whole group of motivation constructs and the individual constructs.

Research Thesis

In summary, this research study aims to provide differentiated insight into the levels and mechanisms of motivation toward science education in relation to the students' STEM career orientation. The study actively questions the simplicity of the narrative that more motivation to learn science feeds directly into more interest in STEM careers in a linear fashion—the STEM pipeline narrative—to clarify the actual motivations of undergraduate students. Rather, *this research study hypothesizes that the motivational factors of Self-Determination Theory are different for groups of adolescent STEM career orientation such that the levels of SDT motivational dimension relative to how oriented a student is toward a STEM career cannot be reduced to a linear relationship*. The study intentionally investigates the interface between multiple levels of motivations and multiple STEM career orientation with multiple methods. This complex approach allowed for the researcher to surface details of the relationship between science education motivation and STEM career orientation that the literature shows is more complex than is currently understood. The overarching research question of this study is:

How much and how do self-determination motivational factors for science education differ based on STEM career orientation in adolescent undergraduate college students?

Chapter 3: Methods

This research study was designed to investigate SDT motivational factors for science education in undergraduate college courses relative to their STEM career orientation with an explanatory sequential mixed methods design. Motivational factors of the participants were assessed with the Academic Motivation Scale (AMS) survey and subsequently explained with open-ended questions in interviews. Undergraduate college students enrolled in science education courses in four different colleges in the Inland Northwest volunteered upon receiving an invitation from their undergraduate science course instructors. Out of the participants that took the survey, a sub-group further volunteered to be interviewed. The collected convenience sample comprised 235 survey datasets and 21 interviews. Participants of all three STEM career orientation groups volunteered for the survey yielding between fifty and one hundred surveys per group. For the interviews, only representatives of the STEM and STEM-related career orientation volunteered, 11 and 10. An integrative mixed methods approach leveraged a multi-level view of motivation to surface nuances of the relationships between the continuum of motivational dimensions for the three STEM career groupings.

In this chapter, the design of this study is presented. The research questions specific to the phases of the study arise from the overall research question of this dissertation. The variables that operationalize the investigated factors as dependent and independent variables are defined. Further, the target population and how the sample was recruited is explained. The specific explanatory design enacts the research questions with its procedures, which is explained in an overview of the design. Selected methodological needs are explored and how they were enacted is presented. Finally, this chapter presents a detailed chronological account of the data collection and analysis.

Research Questions

The overarching research question of the study was '*How much and how do self-determination motivational factors for science education differ based on STEM career orientation in adolescent undergraduate college students?*' Driven by the research question, the study was conducted in two research phases, a quantitative survey phase and a qualitative interview phase, followed by an additional integrative analysis. Specific to the research phases, the research question was narrowed into three phase-specific sub-questions.

Quantitative Phase Research Question. *How much do self-determination motivations for science education differ based on STEM career orientation in adolescent undergraduate college students?*

Qualitative Phase Research Question. *How do self-determination motivations for science education differ based on STEM career orientation in adolescent undergraduate college students?*

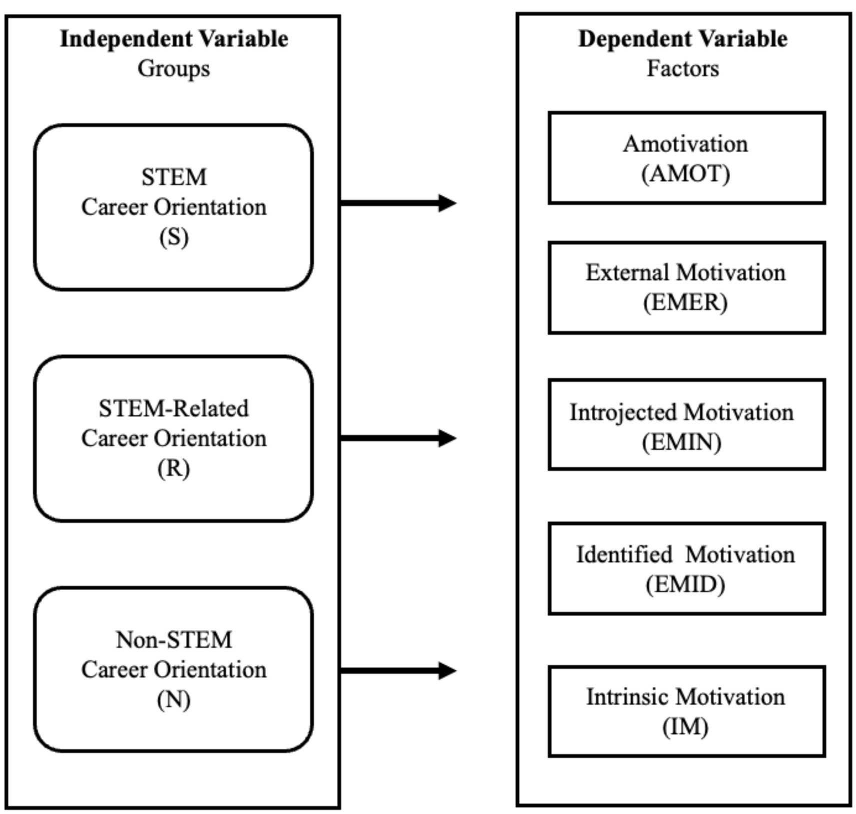
Integrative Analysis Question. *What is the relationship between how much and how self-determination motivations for science education differ based on STEM career orientation in adolescent undergraduate college students?*

Variables of the Study

The measures of the study were five dependent motivation variables and one independent variable (Figure 3-1), the STEM career orientation. All variables were employed in both the quantitative and qualitative phases of the study. In the quantitative phase, the motivations were measured as Likert-scale scores. In the qualitative phase interview, quotes were coded to the different motivational dimensions. The STEM career orientation was derived similarly from either typed or verbal responses in the survey and interview by identifying which STEM career group the careers students named belonged to. The following presents additional details of the enactment of the variables for the research procedures.

Figure 3-1

Independent and Dependent Variable

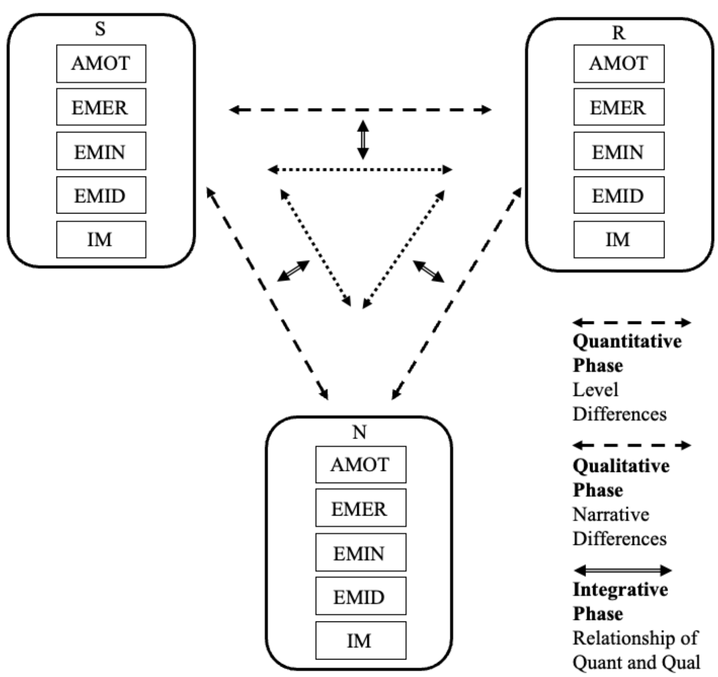


Each of the five motivation variables were assessed in both survey and interview. The AMS survey contains items on a five-point Likert scale, from one to five (see Appendix A). STEM career orientation is the independent variable in this study, specifically a quasi-independent variable. Quasi-independent variables are describing variables where the condition is not a result of manipulation but rather inherent to the individual or group of individuals is considered a quasi-independent variable (Privitera, 2017). The variable can have three values, the STEM career orientations, three categorical groups with independence of observation.

Multiple methods were employed to test between-group differences by comparing overall motivation as well as each of the individual motivation factors. Quantitative method tested how much there are between-group differences in motivation levels, the qualitative method reviewed how coded narrative differed between groups, and the integration viewed how any differences related between the methods (Figure 3-2). All methods checked for differences of overall motivation between groups of STEM career orientation as well as for how individual motivational factors may differ between groups (Figure 3-3).

Figure 3-2

Investigation of Differences with Multiple Methods

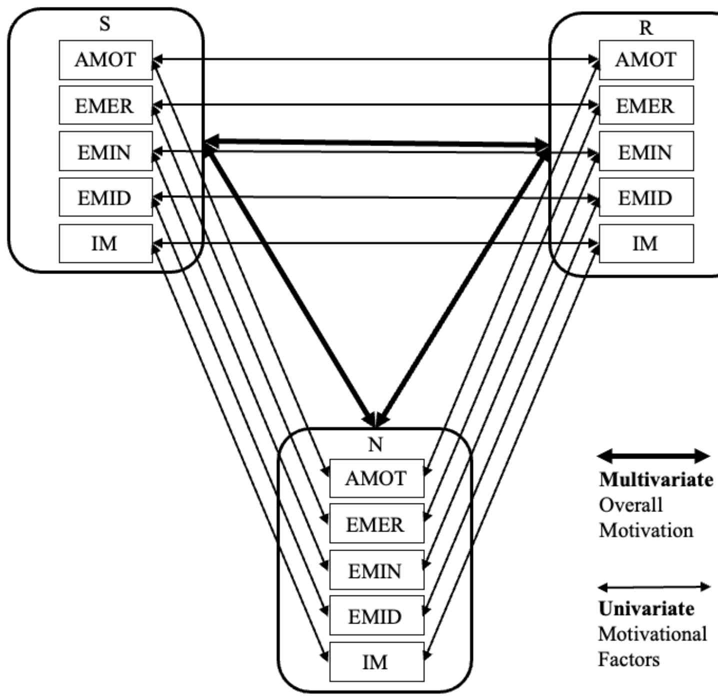


Note: The image Figure 3-2 illustrates the different methods employed to compare motivation between groups of STEM career orientations S (STEM), R (STEM-Related), and N (Non-STEM).

Test for differences with quantitative means and coding for differences with qualitative means are both depicted with dotted arrows. The review for how the results relate is depicted with a double line arrow.

Figure 3-3

Investigation of Differences of Overall Motivation and Individual Factors



Note: The figure illustrates that all comparisons in this research study are done for each individual motivational factors as well as for the overall motivation of the groups.

Target Population and Sample

Identification of Sample Sizes for Survey and Interviews

Prior to recruitment, target numbers were identified in order to have sufficient datasets for effective analysis of the data. Strategies to identify target numbers for recruitment were reviewed. In quantitative research, the key consideration for the size of the survey dataset is the ability to find significant differences between groups, if any. The target sample size was calculated with a priori power analysis. For qualitative research, interview numbers are of less concern as long as saturation is reached for codes and themes. Additionally, it was considered that recruitment typically only leads to a portion of the participants invited to take the survey, the actual response rates may be as low as half of the invited participants (Dillman et al., 2014). The specific identification of target numbers for each phase, quantitative and qualitative, was completed as follows.

For the survey, a target number of 300 survey participants were identified using a priori analysis. Power analysis for MANOVA with G*Power (Faul et al., 2009) shows that a sample size of 201 is recommended a priori for a Global Effects MANOVA with three groups and five dependent variables (Effect size $f^2 = 0.0625$, $\alpha = 0.05$, power = 0.95, three groups, five response variables), with each group at least one-third or 67. For univariate analysis of variance (ANOVA) a total sample size of 252 was determined with each group at a minimum size of one-third or 84 ($f = 0.25$, $\alpha = 0.05$, power = 0.95, 3 groups). The target survey sample size was rounded up to 300 to account for uneven distribution of groups, unusable data such as potential outliers, survey response rate and completion, or variation from the standard distribution of the data, to maximize the degree of confidence in the results.

An interview target of 18, while monitoring for coding saturation, was set based on best practice described in the literature as follows. While there is no broad consensus on the number of qualitative interviews necessary or typical, there are recommendations for numbers of interviews that can be planned prior to the begin of the interview phase and others that define a stop of the interview phase based on progress in the analysis. Target numbers of at least six interviews are recommended for phenomenological research per phenomenon (Marshall et al., 2013; Morse, 2000). In this research study, three phenomena, the motivations of the different STEM career orientations, were investigated. That translates into a total of 18 interviews. A different perspective recommends monitoring the coding redundancy during interview analysis and to stop at saturation. Saturation is considered to be reached when no new themes emerge and thus the research questions are all addressed (Trotter, 2012). The interviews were planned to be conducted in two batches of about nine interviews each, batch scheduled per one calendar week, since that allowed the researcher to then review the STEM career orientations included to assess the need for additional interviews for a potential third batch.

Participant Recruitment

The study was conducted in the Inland Northwest of the United States, an area comprised of Northern Idaho and Eastern Washington. Seven regional postsecondary institutions with existing relationships to the University of Idaho College of Education, Health and Human Sciences were invited to have faculty that instruct undergraduate science courses participate. Science Departments from four institutions participated in the study, two community colleges and two universities.

The researcher contacted faculty teaching undergraduate science courses via email. The email invited the faculty to inform their students of this voluntary research opportunity. Faculty that elected to participate in the present study subsequently shared an email invitation by the researcher with their science class. The email invitation by the researcher included a link to the research survey. In both email and survey, the consent to participate was clearly noted as voluntary and anonymous. The survey included a section at the end asking if students were interested in being interviewed. They were informed that the interview was a follow-up of the research survey to further investigate motivation in science education. At the end of the survey, students interested were able to then click on a separate survey form to submit their contact information. The researcher then followed up and arranged the date and time of the interviews. The survey was administered at the end of the fall semester of 2021.

A convenience sample of 21 interviews were conducted, resulting in 11 each for group S and R and none for group N. Interviews were scheduled in two rounds, each time scheduling students on a first-come first-serve basis to fill up available appointment times during a one-week period. Thus, interviewees were selected based on their timeliness in notifying the researcher of their willingness to be interviewed. This first round resulted in nine interviews. Upon completion of the first round of interviews, the distribution of the interviews was reviewed specifically for STEM career orientation. The completed interviews included six interviews of students with STEM (S) career orientation, three with STEM-related (R), and none with non-STEM (N) career orientation. A second round of interviews was scheduled with the same first-come-first-served approach. As a result, an additional five interviews of group S and eight of group R were conducted, while again, nobody from group N had volunteered. Again, STEM career orientation representation was reviewed, and coding saturation was monitored to assess the need for further interviews. After two batches, no new codes appeared while saturation was reached. In terms of grouping, the STEM and STEM-related groups were each represented evenly in the interviews, while no interviewee was in the non-STEM career orientation group. The two rounds of scheduling interviews exhausted the pool of survey participants that had volunteered to participate in interviews, and no additional students were responsive to email requests to schedule an interview to allow a third round. Further, one partial interview had to be purged since the student was currently not enrolled in a science course during the interview. The interview phase ended with 21 interviews total, above the target of six per phenomenon for S and R, and below the target for N.

Study Design - Explanatory Sequential Mixed Method

The study was designed as an explanatory sequential study, which is reviewed in this section. The section first provides an overview of the explanatory sequential design (Figure 3-4), followed by specific methodological aspects of the study design. The mixed methods research design of the study follows the explanatory sequential design pattern with quantitative research followed by qualitative to provide context to the quantitative data (Creswell & Creswell, 2003; Decuir-Gunby & Schutz, 2016; Ivankova et al., 2006). The objective of the first quantitative phase of the study was to investigate if and how the motivational factors differed quantitatively for the three STEM career orientation groups, students oriented toward STEM careers (S), STEM-related careers (R), and those that are not oriented toward either (N). The objective of the second qualitative research phase was to further investigate the findings from the first phase by adding authentic adolescent voices and perspectives with semi-structured interviews. The online survey consisted of the AMS instrument adjusted for science. A brief summary of the different steps of the explanatory sequential research process details how research questions are enacted in the quantitative and then qualitative phase and how points of interface lead to integrative analysis and joint results.

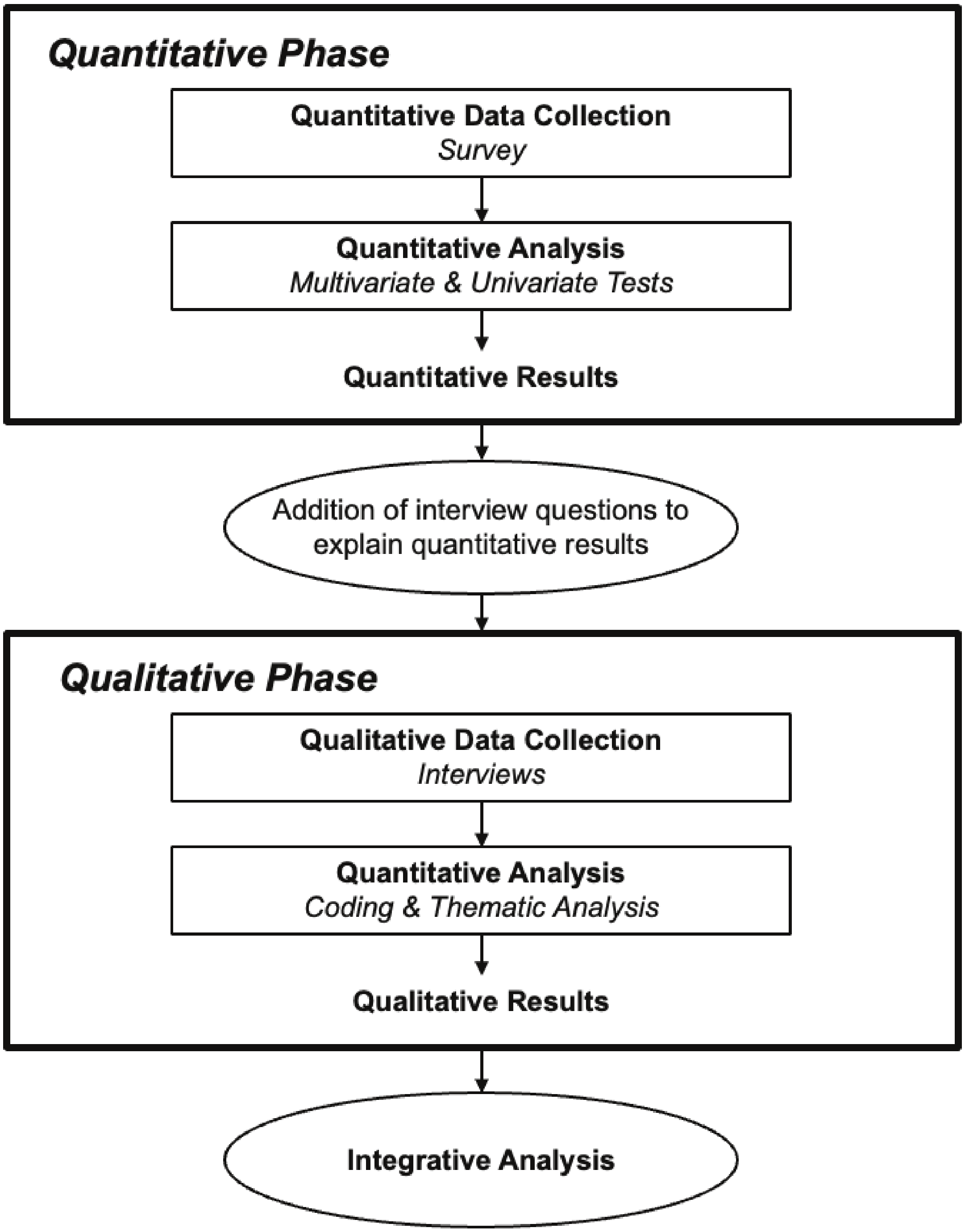
Enactment of the Research Questions. The study was driven by the research question of *how much and how do self-determination motivations for science education differ based on STEM career orientation in adolescent undergraduate college students?* The first part of the question, the investigation of how much they differ, was a numerical question that was investigated with quantitative means in the first phase of the study, the quantitative phase. The second phase of the study investigated how the motivations for science education differ in quality and how that subsequently explained the different levels found in the first phase, the qualitative phase. This way, this mixed methods approach constitutes an explanatory sequential design to research were multiple methods are engaged in sequence to shed light at the same question at different levels, which get integrated in the end. The driving research question thus is not simply two questions but two single question as well as the combination question.

Quantitative Phase Summary. During the quantitative first research phase, surveys were conducted and analyzed. A convenience sample of 235 surveys included complete datasets of career orientation and the motivations assessed by the AMS modified instrument. The dataset of 235 used for analysis consisted of 78 students oriented toward STEM careers (S), 100 students oriented toward STEM-related careers (R), and 57 students not oriented toward STEM careers (N). The statistical analysis of the dataset tested for differences between the three groups S, R, and N. The multivariate approach tested for differences for the combined numerical picture of all motivational levels to see if they differed between career groups. The univariate analysis tested one motivational factor at a time to identify the specific factors for differences between STEM career groups.

Qualitative Phase Summary. The qualitative second phase of the study was comprised of interviewing 21 participants with subsequent analysis. Eleven students with STEM career orientation

Figure 3-4

Explanatory Sequential Research Process Flow Chart



were interviewed, and 10 with STEM-related career orientation, no interviews with students not interested in STEM career orientation were interviewed. The interviews were structured to include specific scripted questions as well as follow-up prompts that were adapted based on the interviewees' narrative, considered a semi-structured interview protocol. The protocol included survey questions, explanatory questions, and prompt questions for each motivation as core elements of the interview. The AMS survey was conducted verbally in a simplified form with one question per construct to get a rough assessment of the interviewees' AMS motivation levels, not as a quantitative measurement. This allowed the researcher to customize the follow-up questions responsive to these survey motivation levels as well as the interviewees shared narrative on the motivations. The interviews were coded to the self-determination factors. The codes were then reviewed for differences between STEM career orientation groups to surface any themes that characterized one or multiple groups in relation to these factors.

Points of Interface. There were multiple points of interface between the two phases, the sampling, developing explanatory questions, the interpretation of an open-ended survey question, and the integrative analysis. During sampling, the participants for the qualitative phase were recruited from the pool of students participating in the quantitative phase, the survey and thereby constitute a sub-sample of the first phase. Upon statistical analysis in the quantitative phase, questions were generated to explain the results, which were added to the interview protocol of the qualitative phase. After coding the interview transcripts in the qualitative phase, it became apparent to the researcher that it would be beneficial to the study to also code the open-ended AMS question in the survey, which became a significant part of the findings. The final point of interface is the integrative analysis, where the results of both phases are integrated.

Integrative Analysis. During the integrative analysis, the datasets and results of the quantitative and qualitative phases were compared. The purpose of the explanatory sequential design is to explain the results of the first phase with the results of the second phase. Thus, the statistical differences of the survey with a relatively large sample size were compared to the qualitative differences of about two dozen interviews. Since no qualitative data were collected for the group not oriented in STEM career orientation (N), the researcher took advantage of having included an open-ended AMS text question in the survey. The majority of survey participants provided a short answer to the question, including those of the N group. The coding system used for the interview was then applied to these text responses.

Visual Joint Display. The overall results of this mixed methods study were summarized visually in a joint display, typically used to provide a visualization of the complex relationships revealed in mixed methods studies, especially those that go beyond just adding two methods in a summative way. The findings and joint display will be presented in the findings chapter. They include empirical findings, the thematic differences between STEM career orientation groups, the importance of motivations to participants revealed by the analysis of the open-ended survey question, and the relationships between these results.

Methodological Considerations

This section examines the methodological details of the study and explains the need based on which they were enacted. The researcher's philosophy is explored to explain methodological decision-making resulting in the choice of a mixed methods study. The fit of a mixed methods study with the specific intention of this study is laid out. The intention of the study was to investigate motivations toward science education thereby the questions participants answered did not focus on the career orientation of the students, while gathering the information at the end of both survey and interview.

Researcher Positionality Informing Methodological Integrity

This study was designed in line with the researchers' critical realist approach to research. Critical realism views the world on as a continuum of layers, from the natural realm to the world of social experience and beyond, described by Bhaskar as strata (Bhaskar, 2017). The non-dualistic perspective of critical realism also gives space to a potential spiritual realm as one of the strata of the human experience in this world. The integrative philosophical frame of critical realism coherently connects ontology to epistemology to methodology and method. Unlike other philosophical approaches more typical in the United States, such as pragmatism, it avoids the pragmatist absence from an ontological and epistemological stance in methodology (Maxwell & Mittapalli, 2010). Different epistemologies of authors have led to different conclusions in motivational research publications (Cook & Artino, 2016). Thereby, providing transparency of the philosophical stance of researcher is important to help clarify how conclusions are drawn and to allow the reader to integrate the gained understanding.

Geographically, critical realism is more prominent in Europe, especially Great Britain, while it is still fairly unknown in the United States (Gorski, 2013). The author of this study spent their youth in Europe, specifically Germany, and through public education and regional media, was regularly engaged in education in learning about various philosophers and spiritualities. This included philosophy following the Frankfurt School of critical thought, which was foundational in the philosophical approaches in post-war Germany. Especially many educators infused their teaching with critical philosophy to raise the next generation to be mindful and educated citizens aiming for a peaceful global society.

Investigating views based on career orientation is also informed by the researcher's personal background in both worlds of STEM and STEM-related professions, having earned separate academic degrees in both biology and education. The researcher has studied biology and has led both microbiology and physiology research projects in laboratories for multiple years. The diverse experience of studying a range of science subjects in college courses and both laboratory and field sites in two countries provides the researcher with in-depth knowledge of most undergraduate science courses, which allowed interviewees to share subject-specific examples of learning without a need to rephrase the details to be understood.

Critical Realist Approaches to Research. For the application of critical realism in research methods, there is only limited guidance available, and it has not traditionally been used in mixed methods; however, it is gaining momentum (Hoddy, 2019). Critical realism can add to a pragmatist approach and provides another alternative to constructivism and positivism as a philosophical frame for a study (Maxwell & Mittapalli, 2010; Zachariadis et al., 2013). Critical realism has been found to align well with a range of methods in general, from quantitative to qualitative and beyond. Hence, a mixed methods research design with more than one method of analysis is overall appropriate as methodology to shed light on motivational factors as outlined by SDT for a critical realist approach to research. The research question of how motivation for science education is influenced by STEM career orientation and is intentionally not limited to either empirical or qualitative research per se as both layers provide a contribution to the answer. This research study investigates both the quantity of motivations and then explores the qualities thereof to surface any disconnects and opportunities within these layers of what moves students to engage in science education.

Critical realism has been found to align well with empirical quantitative research (Scott, 2005). The founders of SDT, state that SDT values basic science and uses empirical non-relativist scientific methods to investigate functional factors and psychological growth in its biological, social, and cultural context (Ryan & Deci, 2017). A research design that investigates motivational factors with its contextual parameters hence fits both with critical realism and the philosophical positioning of SDT. This proposed research on better understanding motivational impact by career orientation is not limited to one specific plane of the strata, rather it extends to both the biological natural realm of human behavior as well as the social realm, hence aligning with the critical realism philosophy.

With a critical realist perspective, ontological, epistemological, and axiological values and implicit biases need to be considered transparently as part of the research design process (Maxwell & Mittapalli, 2010). Critical realism also mandates an intentional consciousness of the underlying assumptions for methods operating within and the contexts of the data derived, just as contemporary mixed methods researchers demand (Creswell & Clark, 2017; Johnson & Onwuegbuzie, 2004; Maxwell & Mittapalli, 2010). While some authors propose that methods should be driven by epistemology or theoretical framework, others suggest that methods may be selected based on the specific research question and context; for example, a thematic analysis may serve both as a method and approach in research driven by a realist approach to research (Braun & Clarke, 2006). In thematic analysis with a realist approach, themes may be selected to portray the individual experiences and their social context, all the while reflecting elements of reality (Braun & Clarke, 2006). Considering the researcher's critical realist perspective and the self-determination theory's focus on the organismic psychological context of motivation, thematic analysis as a methodology has been deemed appropriate for this research study, while not limited to this approach. The research results, analysis, and discussion are kept as transparent as possible to allow readers of any philosophical stance to glean their interpretation of the data and results, as is best practice in qualitative research.

Methodological integrity is important for a mixed methods study since it is not just a combination of two types of studies (Creamer, 2018). To address this, the study has been designed intentionally and reflexively, with the researcher's epistemological stance in mind, with full integration of the theoretical framework and its philosophical roots into the methodology, and with an analysis that capitalizes on the added value potential of a mixed methods study. Anchored in a critical realist view, this study intentionally shines a light onto motivation for science education at different layers, surfacing quantitative survey scores as well as qualitative interview narratives. Motivation is a human experience, and the interviews are designed to generate an understanding of that experience in relation to the research question. The mixed methods data allow for a comprehensive picture to be woven on how motivation to participate in science education is influenced by STEM career orientation for college students.

Contemporary Approaches to Mixed Methods Design

The field of mixed methods research has developed from studies that combine qualitative and quantitative methods in an additive way to intricate hybrid modes of research with integrative presentation of results. The author provides a contemporary look at publications on mixed methods methodology with a focus on sequential combinations. The chapter ends with the main aim of the study following this literature review. The field of mixed methods research is still fast evolving and arose out of the intention to do research with an approach that goes beyond the dichotomous world of quantitative research and qualitative research (Leech & Onwuegbuzie, 2009).

The topic at hand reaches from individual aspects of motivation linked to culture or gender to more general trends across whole populations. The researcher of this study was seeking to use a method that appropriately gathers and investigates both individual perspectives with the overall tendencies of students as a whole. The intentionality of choosing an appropriate method also is rooted in the philosophical perspective of the researchers, critical theory. Herein follows a brief review of methodology in educational research, providing context for the methodology chosen for this study as most appropriate for the topic and researcher's lens.

Educational research on dimensions of attitudes toward learning such as motivation draws on research methods established in psychological research. Traditionally that research was leaning on empirical methods that measured dimensions with surveys where participants rated their levels of attitude on numerical scales such as Likert scales. This research studied these attitudes quantitatively, often viewed from a researcher's positivist or post-positivist perspective attempting to get closer to the truth of how humans behave or feel. In the last century, educational and psychological researchers grounded in the constructivist perspective that each individual human has a different constructed reality have added qualitative research as a counterpoint, where the voice of individuals or groups are captured, for example via interviews. Research in this tradition attempts to provide insight into trends of human experience, often specific to groups of humans, for example underserved minorities. These two approaches have been combined in so-called mixed methods research.

In the last decades these approaches of combination have become more intentional and rather than just adding the two methods together, the field of mixed methods research has created integrative procedures and presentations that seek to connect the results gained via varying combinations of quantitative and qualitative methods into fabrics of human reality where the methods used to provide the context of relative representativeness. The first combinations in mixed methods were typically conducted with pragmatist approaches. More recently other philosophical approaches such as critical realism are used in integrated mixed methods research design and provoke additional layers of cohesiveness for mixed methods studies.

Thus, for this study, an integrated mixed methods approach is chosen. It will provide personal social perspectives to the quantitative understanding of the motivational factors collected with the AMS motivational instrument. It can be expected that the combination of the two methods into a mixed methods approach will enhance the overall results for research concerned with individual in-depth perspectives on issues that are sensitive (Creswell & Clark, 2017).

Mixed Methods Study to Reveal Multi-Layer Complexity

The present study investigates a lack of understanding of how adolescent motivation operationalizes and is experienced. Tying the adolescent voice directly to the quantitative results of specific motivational factors provides the opportunity to understand better the need for interventions in science education. The explanatory sequential mixed methods research design is well suited for this approach (Ivankova et al., 2006). Unlike many other approaches to mixed methods research, the epistemological approach toward research of critical realism provides an interconnected frame of the different layers, including the experimental quantitative approach to the unique human experience within our shared world. Both peer debriefing and member-checking (Teddlie & Tashakkori, 2009) were employed in this study to foster full integration of the results, including considering the philosophical aspects of the study. Resolving and integrating the incongruencies between the two types of research also fulfills the critical realist emphasis on integration.

Assessment of STEM Career Orientation

The independent variable STEM career orientation–as defined in the literature review–was assessed in both survey and interview by asking students to list the top one or two careers that they are currently interested in. This was asked in an open-ended question without any options or examples to not influence students' answers toward or against STEM careers. The independent variable STEM career orientation described and defined in the previous chapter was assessed in the survey and interview.

Masking the STEM Career Orientation Variable. The study was designed to keep the dependent variable and their groupings hidden from study participants until the end of survey and interview. Thereby, the participants were not aware that STEM career orientation was investigated. This limited any potential bias of how STEM career orientation influences motivation. Students were intentionally not asked for their career orientation until the end of either survey or interview. Specifically, the question about careers used to assess students' career orientation was included at the end as part of the demographic questions. A single-blind study (Ian Stuart-Hamilton, 2010) contains a masked variable (American Psychological Association, 2020). Specifically, the dependent variable groupings are not known by research participants in a masked or single-blind study. While study participants were informed that the research investigated motivation in science education courses, it did not reveal that the core focus of the study was the relationship of motivation to groups of STEM career orientation, the dependent variable.

This was fully accomplished for the survey phase, which was conducted as a true single-blind study. In the second research phase, however, partway through the interview–due to the natural flow of the interview in line with participant narrative– the scripted exploratory sequential questions were asked, including some relating to the STEM career orientation groups. The explanatory questions made visible to the interviewees that these career groupings were of interest to the researcher. However, for the remainder of the interview, the focus of the researcher remained on motivation in science education, and the interviewer did not ask to compare or comment on STEM career groups further. For all motivational factors and the thematic analysis, only the interviewee's comments on their own motivations were considered. Overall, the research focus on the dependent variable was mostly hidden from research participants. The interpretation of the narratives thereby takes into consideration that students were at times aware that STEM career orientation was also investigated by the researcher. As presented in the introduction, the bias introduced possibly is the perception that motivation to learn science is the same or directly related to motivation toward STEM careers. The intention of the analysis of the interviews was to investigate this relationship.

Modification of the Academic Motivation Scale

For this research study, the AMS survey by Lim and Chapman (Lim & Chapman, 2015) was adapted to have improved readability for the target population. Adjustments for clarity of language were made for most items. The changes were informed and reviewed by member-checking, a strategy recommended (Creswell & Clark, 2017) to improve validity of the survey. Members were a group of high school students who took the survey and subsequently provided editing feedback. The survey was then peer-examined by the researcher's peer research group, a group of education graduate students. The peer group reviewed the editing suggestions and made additional adaptations of the items for items where the peer-review group reached a quorum. While readability was tested, an attempt to bring the readability to a lower level was abandoned after a peer-review determined that these changes would have changed the item questions to be different in meaning from the constructs of the validated survey. The reviews by both high school and graduate college students overall affirmed that readability was anticipated to be good for undergraduate college students and that the item questions were expected to test the motivational factors that they target. The final shortened survey was member-tested to take under ten minutes and was overall considered reasonably short and readability to minimize survey-fatigue. The final modified survey (Table 3-1) consists of 21 items for the SDT motivational factors AMOT, EMER, EMIN, EMID, and IM. The IM construct is comprised of the subconstructs IMTK, IMTS, and IMTS as the IM item labels indicate. The Table 3-1 shows the adapted AMS items used in this study on the left with adaptations in bold. The number element of the factor acronyms indicate the positioning in the survey used. The original AMS instrument questions (Lim & Chapman, 2015) are shown on the right of Table 3-1, with the original item labels in parenthesis.

Table 3-1

Academic Motivation Scale Adapted for this Study

	Adaptation for this Study	**Lim & Chapman (2015)**
AMOT-1	Honestly, I don't know; I feel that it is a waste of time studying **science**.	Honestly, I don't know; I feel that it is a waste of time studying mathematics (AMOT1).
AMOT-4	I am not sure; I don't see how **science** is of value to me.	I am not sure; I don't see how mathematics is of value to me (AMOT4).
AMOT-17	I don't know; I can't understand what I am doing in **science**.	I don't know; I can't understand what I am doing in mathematics (AMOT3).
AMOT-19	I can't see why I study **science** and frankly, I couldn't care less.	I can't see why I study mathematics and frankly, I couldn't care less (AMOT2).
EMER-5	Because without a good grade in **science**, I will not be able to find a high-paying job later on.	Because without a good grade in mathematics, I will not be able to find a high-paying job later on (EMER1).
EMER-8	In order to obtain a more prestigious job later on.	In order to obtain a more prestigious job later on (EMER2)
EMER-10	In order to have a better salary later in life.	In order to have a better salary later on (EMER4).
EMER-16	Because I want to have "the good life" later on.	Because I want to have "the good life" later on (EMER3).
EMIN-2	**Because I want to show others (teachers, family, friends) that I can do science.**	Because I want to show to others (e.g., teachers, family, friends) that I can do mathematics (EMIN2).
EMIN-3	Because I want to show myself that I can do well in **science**.	Because I want to show myself that I can do well in mathematics (EMIN4).
EMIN-9	To show myself that I am an intelligent person.	To show myself that I am an intelligent person (EMIN3).
EMIN-20	Because of the fact that when I do well in science, I feel important.	Because of the fact that when I do well in mathematics, I feel important (EMIN1).
EMID-6	Because I believe that **science** will improve my work competence.	Because I believe that mathematics will improve my work competence (EMID3).
EMID-12	Because what I learn in **science** now will be useful for **college classes in the future.**	Because what I learn in mathematics now will be useful for the course of my choice in university (EMID4).
EMID-14	Because studying **science** will be useful for me in the future.	Because studying mathematics will be useful for me in the future (EMID2).
EMID-18	Because I think that **science** will help me better prepare for my future career.	Because I think that mathematics will help me better prepare for my future career (EMID1).

Table 3-1 Continued

	Adaptation for this Study	Lim & Chapman (2015)
IM-TK7	**I feel good discovering new things in science that I have never learned before.**	For the pleasure I experience when I discover new things in mathematics that I have never learnt before (IMTK2).
IM-TS11	**I feel good getting lost in science learning and discovery.**	For the pleasure that I experience when I feel completely absorbed by what mathematicians have come up with (IMTS3).
IM-TA13	Because I want to feel the personal satisfaction of understanding **science**.	Because I want to feel the personal satisfaction of understanding mathematics (IMTA4).
IM-TK15	**I feel good broadening my knowledge about science.**	For the pleasure that I experience in broadening my knowledge about mathematics (IMTK3).
IM-TS21	**I feel good when I learn how things in life work, because of science.**	For the pleasure that I experience when I learn how things in life work, because of mathematics (IMTS2).

Factor Modeling Strategy

The survey dataset, comprised of the 21 AMS items, was reviewed for fit with the five-factor model as well as a simpler three-factor model (Table 3-2). The three-factor model contains the construct EM, with the three factors AMOT, EM, and IM collapsed into one construct (Ryan & Deci, 2000). Lim and Chapman (2013) found that the five-factor structure fits most parsimonious for their survey, which is the survey adapted for this study. The construct of integrated regulation included in the SDT continuum (Ryan & Deci, 2000) is not part of the AMS survey used (Lim & Chapman, 2015) as it has been found to be highly correlated with IM and for the purpose of the AMS survey was found to not operate as a separate construct (J. C. K. Wang et al., 2009).

Table 3-2

AMS Factor Models

	Amotivation	Extrinsic Motivation				Intrinsic Motivation
SDT Continuum	Non-Regulation	External Regulation	Introjected Regulation	Identified Regulation	Integrated Regulation	Intrinsic Regulation
5-factor model	AMOT	EMER	EMIN	EMID	n/a	IM
3-factor model	AMOT	EM			n/a	IM

Quantitative Hypotheses

A one-way multivariate analysis of variance (MANOVA) test was used to check for a whole-group effect of difference in motivation due to STEM career orientation. The Kruskal-Wallis was used as non-parametric analogue. The main effect null and alternative hypotheses are:

Multivariate Null Hypothesis*: There are no statistically significant differences between adolescents with different STEM career orientations in regard to their overall perception of motivation (amotivation, extrinsic, introjected, internalized, and intrinsic motivation).*

H_{01}: $\mu_S = \mu_R = \mu_N$

Multivariate Alternative Hypothesis*: There are statistically significant differences between adolescents with different STEM career orientations in regard to their overall perception of motivation (amotivation, extrinsic, introjected, internalized, and intrinsic motivation): at least one of the groups' means is different from one of the other groups' means.*

H_{a1}: $\mu_S \neq \mu_R \vee \mu_R \neq \mu_N \vee \mu_S \neq \mu_N$

Criterium for Rejecting the Null Hypothesis: Alpha was set at 0.5 ($\alpha = .05$) for rejection of null hypothesis if $p \leq .05$.

Provided that a difference between STEM career orientations was indicated for motivational factors, univariate analysis was conducted.

Subsequently, univariate analysis was conducted to test for each motivational factor separately for a difference for each pair of the STEM career orientation sub-groups STEM (S), STEM-Related (R), and Non-STEM (N). The Bonferroni post-hoc t-test series was utilized for parametric analysis and Dunn's (Dinno, 2015; Dunn, 1961) for non-parametric. Results indicating differences between any two groups were addressed in the second phase of the study with corresponding questions added to the interview.

Univariate Null Hypotheses*: There are no differences for adolescents between two groups of STEM career orientation (STEM, STEM-related, or non-STEM) in regard to a motivational factor (amotivation, extrinsic, introjected, internalized, or intrinsic motivation):*

H_{01a}: $\mu_{S\text{-}AMOT} = \mu_{R\text{-}AMOT}$ H_{01b}: $\mu_{R\text{-}AMOT} = \mu_{N\text{-}AMOT}$ H_{01c}: $\mu_{N\text{-}AMOT} = \mu_{S\text{-}AMOT}$

H_{02a}: $\mu_{S\text{-}EMER} = \mu_{R\text{-}EMER}$ H_{02b}: $\mu_{R\text{-}EMER} = \mu_{N\text{-}EMER}$ H_{02c}: $\mu_{N\text{-}EMER} = \mu_{S\text{-}EMER}$

H_{03a}: $\mu_{S\text{-}EMIN} = \mu_{R\text{-}EMIN}$ H_{03b}: $\mu_{R\text{-}EMIN} = \mu_{N\text{-}EMIN}$ H_{03c}: $\mu_{N\text{-}EMIN} = \mu_{S\text{-}EMIN}$

H_{04a}: $\mu_{S-EMID} = \mu_{R-EMID}$ H_{04b}: $\mu_{R-EMID} = \mu_{N-EMID}$ H_{04c}: $\mu_{N-EMID} = \mu_{S-EMID}$

H_{05a}: $\mu_{S-IM} = \mu_{R-IM}$ H_{05b}: $\mu_{R-IM} = \mu_{N-IM}$ H_{05c}: $\mu_{N-IM} = \mu_{S-IM}$

Univariate Alternative Hypotheses*: There are significant statistical differences for adolescents between two groups of STEM career orientation (STEM, STEM-related, or non-STEM) in regard to a motivational factor (amotivation, extrinsic, introjected, internalized, or intrinsic motivation):*

H_{01a}: $\mu_{S-AMOT} \neq \mu_{R-AMOT}$ H_{01b}: $\mu_{R-AMOT} \neq \mu_{N-AMOT}$ H_{01c}: $\mu_{N-AMOT} \neq \mu_{S-AMOT}$

H_{02a}: $\mu_{S-EMER} \neq \mu_{R-EMER}$ H_{02b}: $\mu_{R-EMER} \neq \mu_{N-EMER}$ H_{02c}: $\mu_{N-EMER} \neq \mu_{S-EMER}$

H_{03a}: $\mu_{S-EMIN} \neq \mu_{R-EMIN}$ H_{03b}: $\mu_{R-EMIN} \neq \mu_{N-EMIN}$ H_{03c}: $\mu_{N-EMIN} \neq \mu_{S-EMIN}$

H_{04a}: $\mu_{S-EMID} \neq \mu_{R-EMID}$ H_{04b}: $\mu_{R-EMID} \neq \mu_{N-EMID}$ H_{04c}: $\mu_{N-EMID} \neq \mu_{S-EMID}$

H_{05a}: $\mu_{S-IM} \neq \mu_{R-IM}$ H_{05b}: $\mu_{R-IM} \neq \mu_{N-IM}$ H_{05c}: $\mu_{N-IM} \neq \mu_{S-IM}$

Criterium for Rejecting the Null Hypothesis: Alpha was set at 0.5 ($\alpha = .05$). H_0 will be rejected if $p \leq .05$.

The Statistical Aspects of the Variables in the Survey

The AMS motivation dimensions are the dependent variables, treated as interval data. While some propose that Likert scale data are ordinal data based on the argument that it is unclear if the space between the answers is equally distributed (Bishop & Herron, 2015), most argue that since Likert scales yield normally distributed data, treating Likert scale data as parametric for the purpose of statistical analysis is appropriate (Carifio & Perla, 2008, 2008; Mircioiu & Atkinson, 2017; Murray, 2013). The AMS survey contains items on a five-point Likert scale from one to five (see Appendix A). With the Likert scale data treated as interval data, parametric methods of analysis were be used as applicable after testing for normality of the data. An adequate sample was determined by the a priori sample size determination.

STEM career orientation is treated as an independent variable with three categorical groups, with independence of observation. Specifically, STEM career orientation is a quasi-independent variable, a variable where the condition is not a result of manipulation but rather inherent to the individual or group of individuals (Privitera, 2017). The dependent variables in this analysis are the 21 motivation item scores, later comprised into the AMS factors for final analysis of differences. The plausible range and missing values were reviewed by inspecting all data manually to catch any unlikely answers or unanswered survey questions. Additionally, screening of data was conducted to confirm assumptions of normality, homogeneity of variance, pairwise linearity, and univariate and multivariate outliers, presented in the results section.

Coding Method with A Priori Codes

In the first phase of coding, the transcripts were reviewed in vivo, allocating codes to the motivation a priori codes or emerging codes. The analysis method of in vivo coding has been found to be especially appropriate for coding adolescent voices (Saldaña, 2016) and thereby was used to in the first phase of analysis to capture the participants' authentic language. The motivational factors of the Self-Determination Theory were applied as a priori codes; additional topics were captured as emerging codes. The qualitative analysis of the transcript thereby consisted of a combination of inductive and deductive coding, specific to the research question. Codes were categorized to provide transparency of the types of topics that the researcher noted. Coding for the five AMS factors followed the language of the AMS survey probing for the respective factors.

A priori codes (Table 3-3) are both the SDT motivations assessed by the AMS survey and the three SDT psychological needs autonomy, relatedness, and competence. The AMS motivation survey inherently limits the assessment of the five motivation constructs measured to the item questions asked in the survey. So the coding was done to the general description presented in the Table 3-3, taking the items into consideration. Each SDT motivation construct in line with the respective definitions of the SDT motivations. The a priori codes thereby are a more simplified version of the SDT motivation constructs. This alignment to the AMS survey was done in order to be able to integrate the findings of quantitative and qualitative phase per each same motivational factor.

Table 3-3
A Priori Motivation Codes

Motivation	**Description with Example Statements (AMS Survey Items)**
Autonomy	Being in charge of decision making and having flexibility to find an approach fitting with one's person.
Relatedness	Being in relation to other people, viewed for its connection to the motivated actions.
Competence	Mastering knowledge and skills, thus being able to enact them in experiences and express it to oneself and others.

Table 3-3 Continued

Motivation	Description with Example Statements (AMS Survey Items)
AMOT Amotivation	Student does not perceive any motivation. **Example Statements** • Honestly, I don't know; I feel that it is a waste of time studying science. • I am not sure; I don't see how science is of value to me. • I don't know; I can't understand what I am doing in science. • I can't see why I study science and frankly, I couldn't care less.
EMER External motivation	Motivation is driven by external demand or reward. *Example: grades or job prospective* **Example Statements** • Because without a good grade in science, I will not be able to find a high-paying job later on. • In order to obtain a more prestigious job later on. • In order to have a better salary later in life. • Because I want to have "the good life" later on.
EMIN Introjected motivation	Internal motivation is seen as caused by factors outside of the person. *Example: family expectations or peer encouragement* **Example Statements** • Because I want to show others (teachers, family, friends) that I can do science. • Because I want to show myself that I can do well in science. • To show myself that I am an intelligent person. • Because of the fact that when I do well in science, I feel important.
EMID Identified motivation	Being motivated by goals that the person fully identifies with as inherently important to thrive for. *Example: competence* **Example Statements** • Because I believe that science will improve my work competence. • Because what I learn in science now will be useful for college classes in the future. • Because studying science will be useful for me in the future. • Because I think that science will help me better prepare for my future career.
IM Intrinsic motivation	Internal drive and feeling joy or satisfaction for the doing itself regardless of outcome drives motivation. **Example Statements** • I feel good discovering new things in science that I have never learned before. • I feel good getting lost in science learning and discovery. • Because I want to feel the personal satisfaction of understanding science. • I feel good broadening my knowledge about science. • I feel good when I learn how things in life work, because of science.

Thematic analysis was conducted after coding. Thematic analysis (Nowell et al., 2017) has been identified as fitting for most qualitative research, especially when personal and psychological perspectives are investigated, which is the case in this study (Saldaña, 2016). Prolonged engagement with the interview transcripts and coded text were conducted until the emerging themes reached saturation for groups or portions of groups, as per (Haney et al., 1998).

Coding of STEM Career Orientation. The career responses were coded as STEM career-oriented (S) if at least one of the two careers listed fell into the STEM classification used for this study. If this was not the case, the listed careers were viewed to see if at least one fits the definition of STEM-related careers (R). If neither was the case, the career orientation was categorized as not STEM career-oriented (N). The grouping of the data was conducted to create the independent variable of STEM career orientation, with ordinal values of S, R, or N. The STEM career response was coded to one of three STEM career orientations. The career responses were coded as STEM career-oriented (S) if at least one of the two careers listed fell into the STEM classification used for this study (National Science Foundation, 2018). If this was not the case, the listed careers were viewed to see if at least one fits the definition of STEM-related careers (R). If neither was the case, the career orientation was categorized as not STEM career-oriented (N). Data were analyzed to look at S versus R versus N for differences in motivation between these three groups.

Chronology of Data Collection and Procedures

Survey Data Collection

The data were viewed for accuracy by viewing plausibility of entry and missing data by reviewing age, completion level of critical fields, and missing or invalid entries. First, the dataset was reviewed for age range. As part of the consent-agreement question, participants less than 18 years of age opted out at the beginning of the survey. As one of the demographic questions, students were asked to select their age range and participants identifying their age at above 26 were removed from the dataset. Completeness was reviewed for responses critical to the study, the AMS items and the STEM career orientation question. Datasets that were mostly incomplete for the AMS variables or that did not provide an answer to the STEM career question were removed. The data set was further screened for missing or invalid data. For example, the course subject that students entered and completed the motivation survey for was confirmed to be a science subject. Also, responses were reviewed in the context of all other responses the participant provided to check their overall validity. The remaining dataset was used for statistical analysis.

Quantitative Procedures

Determinations for the appropriateness of analytic methods were made after consulting texts on statistical methods (Abu-Bader, 2010; Finch et al., 2016; Tabachnick & Fidell, 2018). The data were analyzed using the statistical analysis software SPSS 28 (IBM Corp., 2021) and additionally for factor modeling SPSS Amos 25 was used (Arbuckle, 2019).

The quantitative analysis of the survey data consisted of multiple steps: screening of ungrouped data, factor modeling, screening of grouped data, and statistical analysis with multi- and univariate analysis. The screening of ungrouped data assures fit of the mathematical application of factor modeling to the dataset and includes checking plausible range, normality, and outliers. Factor modeling is an application of confirmatory factor analysis to test how well the individual items fit with the factors they are hypothesized to represent. In other words, it is testing if the item questions for each AMS factor can be averaged into their respective motivational dimension to then have a numerical value for that factor that can be used for analysis. Then followed a screen specific to three dataset sub-groups, consisting of the datasets of the participants grouped into S, R, and N. This screen of grouped data tested the statistical assumptions required to conduct the multi- and univariate statistical analysis that follows. That last step then tests for differences of motivation levels between groups of STEM career orientation.

Quantitative Screening Procedures. Data were screened for both ungrouped and grouped data as recommended (Tabachnick & Fidell, 2018) to assure all statistical assumptions (Table 3-4) are met. Assumptions per each respective analysis were reviewed for appropriateness of methods (Abu-Bader, 2010; Tabachnick & Fidell, 2018). Following is a brief review of assumptions and the respective analytic strategy applied in the screening process. The plausible range and missing values were reviewed by inspecting all data manually to catch any unlikely answers or unanswered survey questions. Additionally, the plausible ranges were checked by reviewing minimum, maximum, mean value, and standard deviation of the descriptive statistics. Screening of data was conducted for assumption of normality, homogeneity of variance, pairwise linearity, and univariate and multivariate outliers, presented in the results section. Factor modeling evaluated ungrouped data, while the multi- and univariate analysis processed the data grouped by STEM Career orientation.

Table 3-4

Statistical Assumptions

Factor Modeling	Multivariate Analysis	Univariate Analysis
Basic Assumptions • Dependent variables are interval or ratio data: interval data • Adequate Sample Size: a priori determined sample size of 252		
Ungrouped data screening	**Grouped data screening** • Independent variables are categorical, independent groups • There is independence of Observation	
• Plausible range • Missing values	• Plausible range • Missing values	
• Normality • Outliers • Homogeneity of Variance • Pairwise Linearity	• Normality • Outliers • Homogeneity of Covariance Matrices • Pairwise Linearity	

Initial Scan for Quality of Data. As first step of the survey data analysis, the dataset's distribution of demographics and career orientation was reviewed. Secondly, the model fit of the data with published AMS motivation models was assessed to determine the number of factors to be utilized. Finally, the resulting factor scores were evaluated with multi- and univariate to identify differences between groups of STEM career orientation overall and for each factor. Prior to data analysis the dataset was viewed for quality such as plausible range and missing data.

The survey demographics of age, gender, ethnicity, and race were reviewed to check representativeness of the sample against the regional anticipated demographic distribution for those values. For ethnicity and race multiple choice options were provided for all standard categories. In addition, a text-entry options were provided. Participants selected all choices they felt applied to ethnicity and race. Similarly, for gender multiple choice options included multiple options as well as a text-entry field for participants to self-identify their gender. Text entries were reviewed and could be coded to the categories provided, some participants declined to respond to these questions or provided a response that did not fit any of them and was coded to the *declined to respond* category.

The distribution of the dataset to the independent STEM career orientation values, S, R, and N, was reviewed to assess the similarity of the group sizes to each other. For statistical analysis the groups ideally are equally distributed since the sample size of the smallest group strongly influences the validity of the statistical result. Depending on the group sizes, it could have been appropriate to combine two groups to compare against the third, for example to combine S and R into one STEM career group, which however was not the case.

Screening Ungrouped Data Prior to Model Fit Analysis. Prior to the factor modeling, the ungrouped dataset was screened for plausible range, normality, and outliers. For each variable, the descriptive statistics of minimum, maximum, and mean values as well as standard deviation, were inspected for plausibility and reasonableness and found appropriate.

Further, the dataset was reviewed for the assumptions of normality of the dependent variables. To check for normality skewness and kurtosis was reviewed. Recommended are ranges of skew within ±1.96 (Abu-Bader, 2010; Tabachnick & Fidell, 2018) or for the skew to be within ±3 and kurtosis within ±10 (Kline, 2010; Lim & Chapman, 2015). Variables not fitting the assumptions were transformed. Normality of all variables was further visually inspected by reviewing histograms with normality curves and Q-Q plots, both normal and detrended.

Screening for univariate and multivariate outliers was conducted using with Z-score and Mahalanobis distance calculations. To identify univariate outliers, Z-scores for all raw AMS scores were created, and the minimum and maximum scores per variable were identified. Several considerations were taken into account when the Z-scores reviewed to assess the univariate outliers for exclusion from the dataset. High raw scores may lead to the respective raw scores having a large effect size in the factor analysis (Knekta et al., 2019), which is why scores greater than +-3 can be considered an outlier (Abu-Bader, 2010). On the other hand, outliers may be left in the dataset if not assessed as error entries (Tabachnick & Fidell, 2018). Multivariate outliers were identified with Mahalanobis distance calculation (Abu-Bader, 2010). Mahalanobis distance was assessed with a chi-square using the number of variables as degrees of freedom (Tabachnick & Fidell, 2018). The critical chi-square value with an alpha of .001 used was 46.79 at 21 degrees of freedom.

Model Fit Analysis. The survey dataset was viewed for factor model fit with the theoretical AMS survey structure. The goodness of fit for factor models for 21 dependent variables were evaluated for fit with the AMS factor models to confirm construct validity. The survey for this study was tested for fit with a five-factor model (AMOT, EMER, EMIN, EMID, IM) and with a simpler three-factor model (AMOT, EM, IM). Regression weights were fixed at one for one variable per factor as required for calculation in SPSS Amos. To gauge how well the dataset fit the AMS factor models several indicators were reviewed ($\chi 2$ chi-square, $\chi 2/df$ chi-square divided by degrees of freedom, SRMR standardized root mean square residual, RMSEA root square mean error of approximation, CFI comparative fit index, TLI Tucker-Lewis index). Factor modeling was conducted with SPSS Amos 25 (Arbuckle, 2019).

Data Reliability. To test the reliability of the survey the Cronbach Alpha was determined for the overall survey and also per each factor of the final factor model. Additionally for all items and factors the means, standard deviations, and inter-item correlations were reviewed for plausible range.

Interview Conduct

The interviews were held in a semi-structured format to elicit responses to all five motivational dimensions while providing space for the interviewees' authentic perspectives. The interview protocol (Appendix D) commenced with pre-written and follow-up questions that were designed to elicit a narrative on all motivational constructs. Other questions where asked to explain findings in the survey from the previous quantitative phase of the study. Additionally, the researcher followed up on other content that they identified as being relevant to the research questions of the study. Interviews were each one hour long. Interviews were held by online audio or video meeting, depending on the interviewees' preference. This was to ensure that the interviewees felt comfortable and safe while being interviewed. Topical probes (Hennink et al., 2010) were used to elicit additional answers to gain a comprehensive understanding of the participants' perspectives. The researcher followed best practice recommended: when interviewing includes that researchers strive to derive balance in the meaning conveyed between the interviews (Louise Barriball & While, 1994) and questions be added or dropped interview questions accordingly (Gray, 2018). Additionally, interviewees were asked one AMS survey question per construct to gain a numerical score for each motivational dimension per interviewee. The numerical score provided insight into the quantitative motivational profile of the interviewee to allow for comparison with the survey results and to be able to understand the specific levels of motivational factors of the interviewee in their relationship to the codes found in qualitative analysis. Lastly, demographic questions were asked at the end of the interview and included the same question on possible careers that was included in the survey, used to categorize students into the groups of STEM career orientation. Interviewees were then asked to rate their motivation toward their science course for all five factors. At the end of the interview were asked to share their age, gender, and ethnic-racial identity.

The interviewer intentionally used the interviewees' own phrasing for follow-up questions whenever possible to limit the introduction of bias, such as "you previously mentioned <interviewee phrasing>, can you tell me more about that?" The researcher took hand-written notes throughout the interview to capture key words and phrases used by the interviewee as well as their survey ratings on AMS factors. This allowed the researcher to direct the flow throughout the interview with follow-up questions specific to the interviewee's responses while following the protocol to remain consistent with other interviews.

Transcription was completed in a way to keeps the authentic language of the interview participant intact as much as possible by only removing a minimal amount of language. During the transcription process words were first recorded verbatim, other than omission of fill words and simple repetitions. Fill words were ‘like’ or ‘um,’ used in many sentences by interviewees. Simple repetitions were one or two words that the interviewee repeated or self-corrected themselves were shortened to represent the interviewees intended words; however, any phrases of more than two words were kept. For example, the verbatim transcription of “So I definitely, I'm definitely not, I don't consider myself a computer person and I wow I definitely, like um, I consider myself like computer illiterate though um.” was shortened to “So I’m definitely not, I don’t consider myself a computer person and I wow, I definitely consider myself computer illiterate though. Both the original audio and the full transcripts are kept by the researcher. These details are captured to provide transparency on the actual transcribing that occurred that limited the adjustment from verbal to written language to a minimum to retain maximum authenticity.

Qualitative Analysis Plan with A Priori Codes

Twenty-one interviews were transcribed and coded. Quirkos Software was utilized for initial interview analysis. Interviews were viewed and coded to a priori and emerging codes, following the in vivo coding method. For each of the a priori codes of the five motivational factors and three psychological needs, autonomy, relatedness, and competence quotes were present in the interviews (Table 3-5). Additional codes that addressed motivation were coded to a list of emergent codes. All emergent codes were reviewed to find categories that appropriately organize them. The researcher limited coding to the parts of the transcript sections where the interviewees talked about their experiences in their own words to capture the authentic motivational voice of the interviewees themselves for this main qualitative analysis. Exception were the responses to the explanatory questions, which were coded with the same method, however separately from the main qualitative analysis.

Table 3-5

A Priori Motivation Codes with Samples

	Description	**Sample Quote**
AMOT	Amotivation: student does not perceive any motivation	“I would stop going to class and at one point I kind of stopped doing everything for the course” (Carmen R.)
EMER	External motivation: motivation is driven by external demand or reward of grades or job prospective	“I mean things that improve my grade I'm motivated by” (Lucas R.)

Table 3-5 Continued

	Description	Sample Quote
EMIN	Introjected motivation: internal motivation is seen as caused by factors outside of the person. Example: family expectations or peer encouragement	"just kind of having some camaraderie with other people who are going through the same thing that I was, I would say, helped me realize that I could do it and I'd be fine and that kind of gave me a little boost of motivation to power through it" (Josie R.)
EMID	Identified motivation: being motivated by goals that the person fully identifies with as inherently important to thrive for. Example competence	"you know chemistry is a really important thing, because if you don't understand chemistry, you don't really understand the chemical components of the body and like everything, you know. So that motivates me" (Carmen R.)
IM	Intrinsic motivation: having internal drive and feeling joy or satisfaction by the doing itself regardless of outcome.	"at the beginning of the semester, it was mentioned like that we should get a 3D modeling kit, for you know for modeling molecules and stuff so I picked up one of those, which I think was a lot of fun with it [sic] and I definitely enjoy like, learning about all of these different reactions and their, you know, their significance" (Olev S.)
Auto-nomy	being in charge of decision making and having flexibility to find an approach fitting with one's person	"being able to, we do some practice examples in class and then go home or go back wherever you go, you know into your dorm or apartment or whatever it is, and put pen to paper and start to do some on your own and when you're able to, you know, succeed in that, and find that you're able to, you know, carry on what you did in lecture and do it on your own. I think that's very rewarding and very important." (Ben S.)
Related-ness	Being in relation to other people, viewed for its connection to the motivated actions	"I think it's a lot easier to feel motivated to do something when you're surrounded by people who are also motivated to do that" (Zelda R.)
Compe-tence	mastering knowledge and skills, thus being able to enact them in experiences and express it to oneself and others	"I feel like learning as much as I can about as many different animal groups as possible is going to be what helps me the most down the line to be competent in my field" (Josie S.)

Note. The quotes are examples from the transcripts when students with relatively high motivation for the specific factor addressed this motivation in relation to their science courses.

In Vivo Coding. During thematic analysis, all codes were analyzed for differences between STEM career orientation groups. Specifically, the coded text sections were reviewed in light of the research questions at hand: *how do self-determination motivations for science education differ based on STEM career orientation in adolescent undergraduate college students*. Guided by the research question of differences between the groups S and R in Motivation toward learning science in science courses, the data were inductively coded for any passages of the text that spoke to the research question as described in the methods section. The coded passages identified with this inductive method were labeled as emergent codes (Saldaña, 2013) in this study, since they emerged from the data, in contrast to the a priori codes deducted from the theoretical framework of the study, the Self-Determination Theory. Additionally, a priori codes were applied to the text passages depending on which a priori motivation codes was discussed by the interviewee. Once initial coding to a priori codes and emergent codes was completed the codes were reviewed for differences between the groups S and R via mapping of factor codes to other codes.

Mapping of Factor Codes to Surface Differences. The factor codes were mapped onto the other codes to create a map of cross-codes and the split by STEM career orientation group as follows. The map of cross-coded narrative was then reviewed. For each motivational factor AMOT, EMER, EMIN, EMID, and IM the cross-codes then were reviewed for interviewees of group S and group R. When more than two occurrences of the same cross-code were found for either S or R, the coded text sections were reviewed for the specific content. Occurrence of two cross-codes means that two or more interviewees of one of the groups S or R spoke to an emergent code relative to one of the motivational factors. Reviewing the narrative specific for how the motivations are connected to one of the other coded aspect then revealed the differences by factor between the groups S and R. Codes were grouped by S and R and text coded as relating to at least one motivational factor was viewed one factor at a time to see which emergent codes mapped onto which factor and if themes emerged with a focus on any differences between groups for any of the codes per factor.

Chapter 4: Findings

The following chapter presents the findings of this study after initial dataset screening and analysis. Quantitative phase results include the statistical results for differences between groups of career orientation. In the qualitative phase, the perspectives of students on motivational factors, emerging codes and themes will be presented. Finally, in the integrative phase results from the second phase will be applied to data of the first phase and as a result will illuminate how important the motivational factors are for the different groups of students in their motivation to learn science.

Quantitative Analysis

The median time to take the survey was 5.7 minutes. Seventeen participants' surveys were completed at more than 15 minutes. Given that the surveys were completed online, it is likely that the participants were interrupted and then continued to complete the survey. All other participants completed the survey between 1.3 and 13.3 minutes, with duration time normally distributed. Thus, the information provided to survey participants that the survey takes approximately seven minutes to complete was appropriate.

Responses from 299 college student participants had been collected, one short of the number determined in the a priori power analysis. Out of these 299, 242 of the respondents identified their age as between 18 to 26. Screening removed missing and invalid data such as four students that identified math as the subject they completed the survey for. The remaining dataset included 235 responses considered valid.

Survey Dataset Initial Screen

The datasets of 235 cases for statistical analysis had complete sets of responses for all 21 AMS items and STEM career orientation without any obvious errors. The cases were from participants age 18 to 26 who completed the survey toward an undergraduate science course. Student responses were coded for S, R, and N, which created roughly similar group sizes. 33.2% (78 respondents) identified a STEM career, 42.6% (100 respondents) identified a career in the category of STEM-related, and 24.3% (57 respondents) named a career that is neither STEM nor STEM-related. The demographics of the dataset were reviewed as well as the distribution of science subjects that the students took the survey for (Table 4-1). Percentages shown in the table are rounded and add up to 100% between S, R, and N.

Table 4-1

Survey Frequencies of STEM Career Orientation and Demographic Breakdown

	S	%	R	%	N	%	total
	78	33%	100	43%	57	24%	235
18 or 19 years of age	28[a]	27%	36	35%	38	37%	102
20 to 26 years of age	50	38%	64[b]	48%	19	14%	133
Female, Trans female, or Trans woman	43	27%	81[b]	50%	38	23%	162
Male, Trans male, or Trans man	26[a]	46%	16	29%	14	25%	56
Nonbinary, Genderqueer, or non-conforming	6	46%	3	23%	4	31%	13
Declined to respond	3	75%	0	0%	1	25%	4
American Indian or Alaska Native	1	20%	2	40%	2	40%	5
Asian	3	18%	10	59%	4	24%	17
Black or African American	0	0%	3	100%	0	0%	3
Hispanic or Latino or Spanish Origin of any race	6	32%	7	37%	6	32%	19
American Indian or Alaska Native	1	20%	2	40%	2	40%	5
Native Hawaiian or Other Pacific Islander	0	0%	2	100%	0	0%	2
White or 'Caucasian' (1 entry)	69[a]	35%	84[b]	42%	47	24%	200
Declined to respond or 'Human' (1 entry)	3	75%	0	0%	1	25%	4
selected two choices							*15*
Biology	33	43%	39[b]	51%	5	6%	77
Chemistry	9[a]	33%	15	56%	3	11%	27
Physics	14	19%	18	24%	42	57%	74
Geology	1	13%	4	50%	3	38%	8
other	21	43%	24	49%	4	8%	49

Note: [a, b] Grouped screening for outliers removed the two cases after Factor Modeling.

As illustrated in (Table 4-1), fewer than half of the students selected 18 or 19 (43%) as their age, and just above 50% identified their age as 20 to 26 as age (57%). The majority of the participants (70%) were female, males made up one-quarter of the responses (24%), 13 (6%) of the participants identified as nonbinary, gender-queer, or gender non-conforming, and lastly, only four participants declined to identify their gender. The distribution of the demographics roughly matched the diversity in undergraduate enrollment in the Inland Northwest.

Quantitative Data Analysis

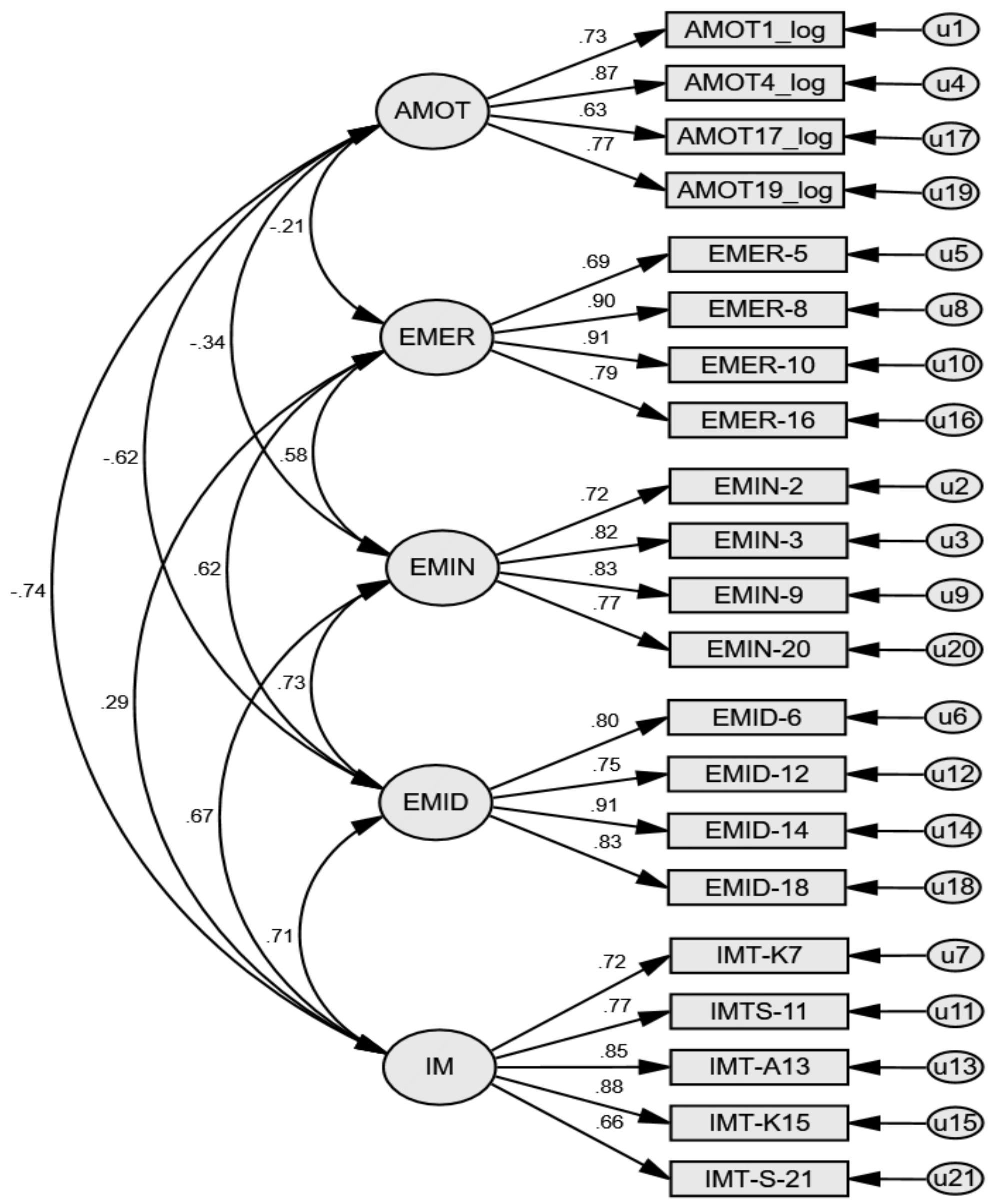
Screening of ungrouped data for normality was conducted and AMOT was log transformed as a result (see Appendix B). Normality screen revealed all AMOT variables as severely positively skewed with significance values above eight or greater. Several other variables also fell outside of the skewness range of ±1.96 while they were within the limits of ±3 for skewness and ±10 for kurtosis applied by the authors of the instrument (Lim & Chapman, 2015). By transforming AMOT with log10, all AMOT variables were transformed, resulting in AMOT_log variables. Log transformation was found appropriate, given that the AMOT variables had positive skew and all values were above zero. While the skew for AMOT_log variables was still somewhat high with between four and as high as 11, it was significantly improved for the untransformed variable. Alternate and additional transformations were tested, none of which led to a better result, and AMOT_log variables were adopted as alternatives for AMOT variables for the following multivariate analyses. The histograms with normality curves (see Appendix B, Figure B-1) and the Q-Q plots (see Appendix B, Figure B-2) were found to be reasonably normal in their distribution and appropriate for factor modeling of ungrouped data.

Ungrouped data were screened for outliers and non were removed from the dataset. Five univariate and five multivariate outliers were identified with Z-score and Mahalanobis distance calculations, respectively, and upon review of raw scores, were found to be plausible and reasonable, thus left in the dataset. The transformed AMOT-19 variable (AMOT 19_log) had five cases with z-scores at just slightly above three at 3.29. No other variable had raw scores above that threshold. For the five outlier cases, all raw scores and text responses were reviewed for validity and considered plausible. Since the five outliers were found not likely to contain errors and the Z-score had a value of just above 3, the outliers were considered acceptable and left in the dataset. Five multivariate outliers were identified. The raw scores of the respective cases were reviewed, considered valid, and left in the dataset. For further details on Z scores, see Appendix B: Screening of Ungrouped Data.

The five-factor model (Figure 4-1) had acceptable fit and provided a much better fit than the three-factor model (Figure C-3, Appendix C) on all fit indices tested (Table C-3, Appendix C). Correlations between the 21 items and their respective factors were high at values of around .8 for most items. The fit of the five-factor model is shown in Figure 4-1. The correlations between factors and between factor and item are shown are shown on the arrow lines. The correlations between the five factors of AMOT, EMER, EMIN, EMID, and IM had an overall good fit with the predicted model. To model the AMOT factor, AMOT_log items were used instead of AMOT items. Error variables (u1 to u21) for each of the 21 items were employed. All items loaded with significance onto their predicted latent factors.

Figure 4-1

AMS Five-Factor Model with Correlations



Reliability and Correlation for the Five Factor Scale. The survey statistics for the 21 items showed overall good reliability of the survey data. The overall reliability of the survey based on scores for all 21 AMS of the 235 cases was assessed by determining the overall survey Cronbach Alpha, found to be .87, which is considered good reliability as per Cohen. Item mean and standard deviation (Table

4-2), as well as inter-item correlations (Appendix C, Table C-0-4), were reviewed, and no unusual results were noticed. The mean scores depicted item have values between 1 to 5 since the survey AMS scores were assessed on a 5-point Likert scale.

Table 4-2

Item Statistics

	Mean	Std. Deviation	N
AMOT-1	1.59	.898	235
AMOT-4	1.48	.884	235
AMOT-17	1.70	.973	235
AMOT-19	1.40	.834	235
EMER-5	2.66	1.234	235
EMER-8	2.94	1.244	235
EMER-10	2.74	1.280	235
EMER-16	2.68	1.239	235
EMIN-2	2.56	1.244	235
EMIN-3	3.26	1.246	235
EMIN-9	3.07	1.243	235
EMIN-20	2.68	1.146	235
EMID-6	3.26	1.239	235
EMID-12	3.13	1.271	235
EMID-14	3.52	1.360	235
EMID-18	3.34	1.325	235
IMT-K7	3.74	1.112	235
IMTS-11	3.22	1.258	235
IMT-A13	3.26	1.225	235
IMT-K15	3.62	1.179	235
IMT-S-21	3.20	1.228	235

With the factor model confirming that items appropriately load onto their anticipated factors, AMS factors scores were calculated by averaging the respective items. Per each factor, Cronbach's alpha was determined and found to be above 0.8, indicating good reliability per each factor, just like for the whole scale (Table 4-3). The means and standard deviations for the five factors were calculated to confirm data to be of plausible range. Cronbach Alpha was calculated per each construct based on the sub-item scores in the survey for 235 cases.

Table 4-3

Cronbach Alpha for Each Factor Scale

	Cronbach Alpha	Mean	Standard Deviation
AMOT	.84	1.54	.74
EMER	.89	2.76	1.09
EMIN	.87	2.89	1.03
EMID	.89	3.31	1.13
IM	.88	3.41	.99

Inter-factor correlations were calculated for all five factors based on item averages (Table 4-4). Correlations between factors were lower than .8, indicating separate constructs, with some correlations as low as .15, indicating a minimal correlation between the respective constructs. AMOT relates to all other factors negatively since it is a reverse motivation question, asking for a lack of motivation rather than presence of motivation. The correlations between all factors but AMOT are above .5, showing a clear positive correlation below .8, indicating distinct constructs measured. Correlations between AMOT and EMER, AMOT and EMIN, as well as EMER and IM are very low at around .2, indicating a low correlation between these factors, respectively. EMER is the most extrinsic factor of the continuum while intrinsic motivation is found to be on the other end, thus low correlation is anticipated.

Table 4-4

Inter-Factor Correlations

	AMOT	EMER	EMIN	EMID
AMOT	1.000			
EMER	-.150	1.000		
EMIN	-.255	.517	1.000	
EMID	-.481	.572	.653	1.000
IM	-.619	.234	.575	.604

Screening Grouped Data for Statistical Analysis for Differences between Groups

Normality Test of the Grouped Data. The dataset grouped by STEM career orientation was screened for statistical assumptions for MANOVA and ANOVA testing. Descriptive statistics of factors by STEM career orientation group were reviewed, including skewness and kurtosis (Table 4-5), to check for normality of the factor scores by group. The significance of skew or kurtosis scores is recommended to be within the +-1.95 margin (Abu-Bader, 2010; Tabachnick & Fidell, 2007), which was used to evaluate the homogeneity of variance. AMOT showed significant skewness in both groups S and R. AMOT was transformed with log10, given that variables were only positively skewed and did not contain negative scores or zeros, and the resulting skewness and kurtosis for AMOT_log were much reduced (significance of skewness for S: 5.17 and R: 4.34). AMOT and AMOT_log thus failed the homogeneity of variance assumption and AMOT was chosen to be analyzed with nonparametric tests.

Table 4-5

Statistics for AMS Factors by STEM Career Orientation

	Mean	Std. Deviation	Variance	Minimum	Maximum	Sig. of Skewness	Sig. of Kurtosis
				STEM (S)			
AMOT	1.33	0.55	0.30	1.00	3.50	**7.45**	**7.36**
AMOTlog	0.10	0.14	0.02	0.00	0.54	**5.17**	**1.96**
EMER	2.94	1.00	1.00	1.00	5.00	0.70	-1.19
EMIN	3.09	0.95	0.91	1.00	5.00	-0.19	-1.25
EMID	3.71	0.84	0.70	1.75	5.00	**-2.12**	-0.58
IM	3.83	0.84	0.70	1.60	5.00	**-2.90**	-0.39
				RELATED (R)			
AMOT	1.52	0.74	0.55	1.00	5.00	**8.95**	**12.37**
AMOTlog	0.14	0.17	0.03	0.00	0.70	**4.34**	0.96
EMER	2.99	1.14	1.30	1.00	5.00	-0.09	**-2.08**
EMIN	3.06	1.00	1.01	1.00	5.00	-1.08	-1.26
EMID	3.57	1.11	1.23	1.00	5.00	-3.51	-0.50
IM	3.38	0.98	0.96	1.00	5.00	-1.51	-0.37
				NONE (N)			
AMOT	1.87	0.84	0.70	1.00	5.00	**4.26**	**3.83**
AMOTlog	0.23	0.18	0.03	0.00	0.70	1.09	-0.90
EMER	2.11	0.83	0.69	1.00	4.00	0.73	-1.48
EMIN	2.34	1.00	1.01	1.00	4.00	0.57	-2.16
EMID	2.32	0.91	0.83	1.00	4.50	1.21	-1.23
IM	2.87	0.95	0.90	1.00	5.00	-0.06	-0.28

EMER and EMIN only showed slight kurtosis in one group each (significance of kurtosis EMER for R group at -2.08, EMIN in N group at -2.16). EMER and EMIN were overall considered to meet the homogeneity of variance with all significance of skewness values below the threshold of absolute 1.95 and kurtosis below or just slightly above the threshold (significance of kurtosis for EMER in R group at -2.08, and EMIN in N group at -2.16). Both EMER and EMIN were analyzed with parametric tests. EMID had some skew in one group and kurtosis in another (significance of skew for

S: -2.12, for R: -3.51), and IM had slight skew in one group (significance of skew for S: -2.90). EMID and IM were thus tested with non-parametric analysis.

Normality was also viewed visually with histograms overlayed by normal curve (Figure 4-2), Q-Q, and bivariate plots (not shown) and found to be in line with the findings based on skewness and kurtosis. The pairwise linearity assumption of the factors was checked by visually reviewing bivariate plots (not shown) of AMOT, AMOT_log, EMIN, EMID, and IM against the factor most normality distributed, EMER, and subsequently found acceptable.

The histograms shown in (Figure 4-2) for the three STEM Career Orientations STEM, STEM-Related, and Non-STEM are displayed for all the five motivational AMS variables AMOT, EMER, EMIN, EMID, and IM, as well as the log-transformed variable, AMOT_log. The x-axis of the figure shows the distribution of scores from 1 *does not correspond* at all to 5 *corresponds totally* for the five non-transformed variables the x-axis and the respective distribution of log scores for transformed AMOT_log. The y-axis shows the frequencies of the respective scores.

Figure 4-2

Histograms for AMS Factors by Career Orientation

S (STEM)	**R (STEM-Related)**	**N (None)**

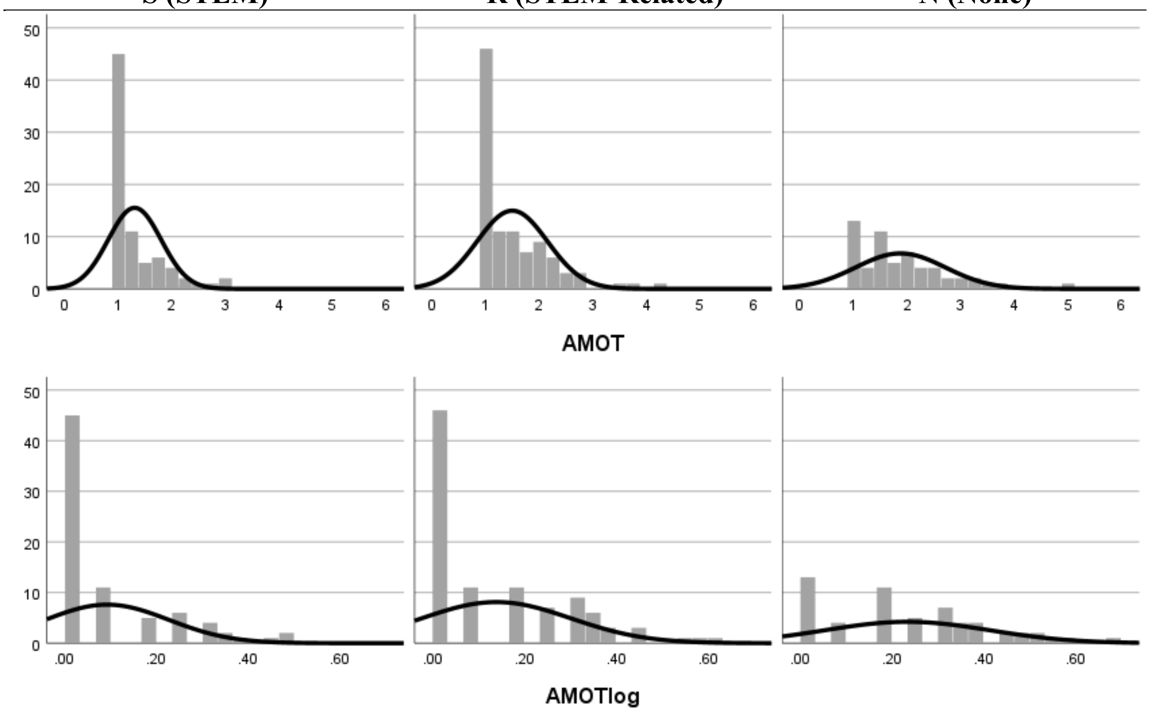
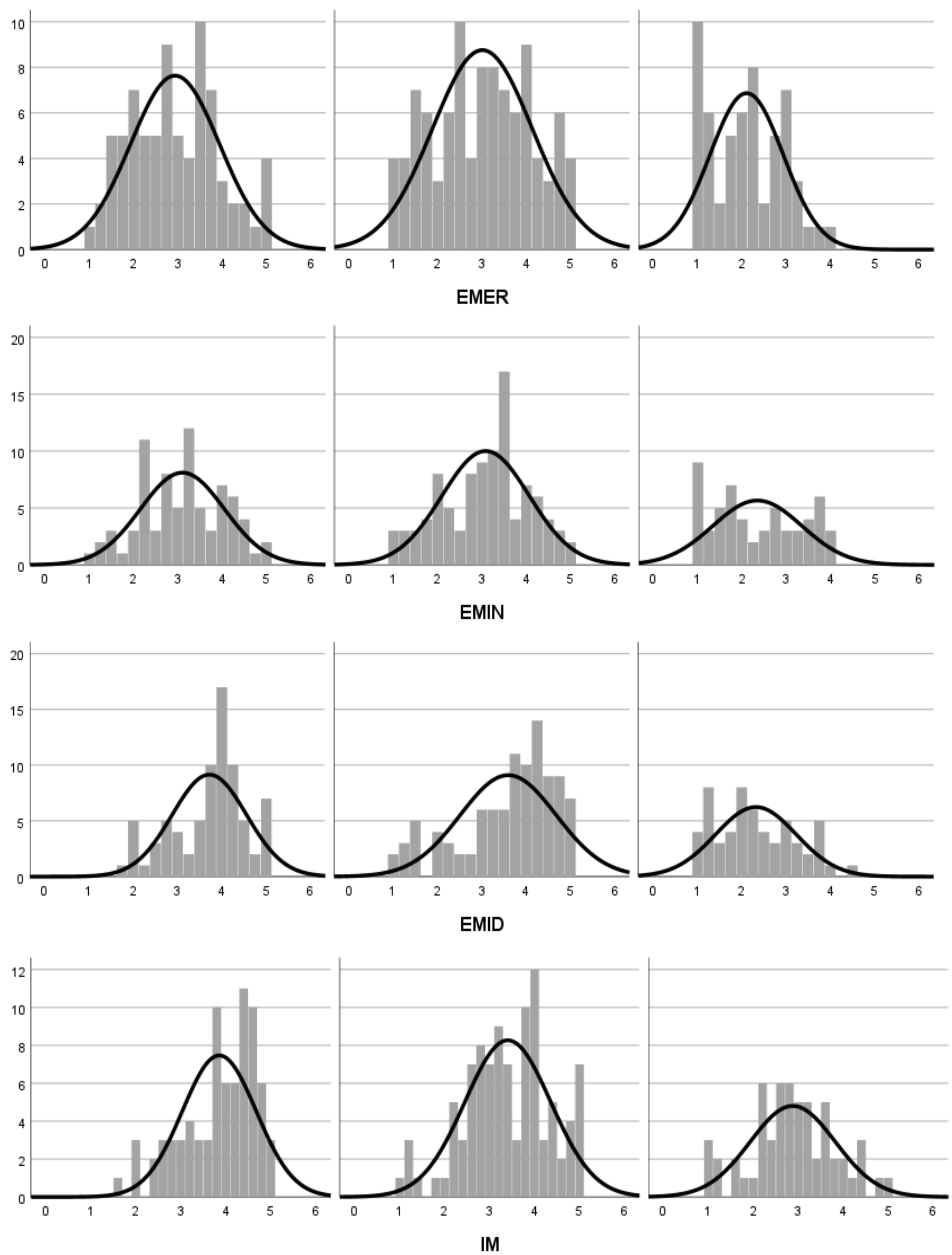


Figure 4-2 Continued

S (STEM) R (STEM-Related) N (None)



In summary, two of the motivational factors (EMER, EMIN) were found to be sufficiently normally distributed to be analyzed with parametric statistical methods, while the others (AMOT, EMID, IM) were analyzed with non-parametric means (Table 4-6).

Table 4-6

Method of Analysis per Factor

AMOT	EMER	EMIN	EMID	IM
Non-parametric	Parametric	Parametric	Non-parametric	Non-parametric

Univariate and Multivariate Outliers. The AMS factor scores were checked for univariate and then multivariate outliers. First Z-scores were reviewed to identify univariate outliers. Z-scores beyond the threshold of three (Abu-Bader, 2010) were found in the transformed AMOT factor for the groups S and R, with one case each. For the two outlier cases, the student's respective answers were inspected in detail. One student is planning on a career in equine management (R) and responded to the AMS text question for their motivation that they study for their science course:

> "because my college requires me to take the courses even though they have no correlation to my major or career choice. I don't learn anything, it's all forced on me which makes me hate it even more. I don't feel like I have the mental capacity to understand anything of the sciences."

The student scored all four amotivation questions at the highest score and all others at the lowest. The second student noted that they were geared toward a STEM career in computer or electrical engineering (S) and had differentiated answers as their AMS responses. They responded in the open-ended survey question, "I spend time studying chemistry because it's required for the degree I'm going for. Quite frankly, i [sic] don't really have even a sliver of interest in the topic and it just seems like a waste of time." Both cases were removed from the dataset to control for the inflated effect of the respective scores, leaving 233 cases (77 S, 99 R, and 57 N) for the following analysis. One case was part of group S, 18 or 19 years of age, male, White, and took Chemistry and the other case was part of group R, 20 to 26 years of age, female, White, and enrolled in Biology as marked in the demographics overview (Table 4-1). The Mahalanobis distances were calculated for all remaining groups to check for multivariate outliers, and no cases were found for which the chi-square value was below 0.001, a value used as the cut-off for multivariate outlier acceptability (Abu-Bader, 2010, p. 54). Hence, no multivariate outliers were identified for either of the STEM career orientation groups.

The groups of STEM career orientation were of similar size, with no group double the size of another or greater. The group of STEM-career-oriented students (S) made up 33% of the data sample, the group of students geared toward STEM-related careers (R) was the biggest group with 43% of the sample, and students not interested in STEM careers (non-STEM, N) were the smallest group with 24%. The consideration of combining STEM and STEM-related groups into a combined extended STEM group was discarded due to the small effect size of the relatively small group of non-STEM students, which would be relatively smaller with the other two groups combining to more than three-quarters of the sample (76%). Thus, sub-categories of STEM and STEM-Related were left separate, so all three groups of STEM, STEM-related, and Non-STEM were tested for differences.

Multi- and Univariate Testing for Quantitative Differences

A one-way MANOVA was performed with parametric and nonparametric methods to examine the effects of STEM career orientation on the overall motivation toward studying science for the dataset of 233 adolescent college students (Table 4-7). Motivation for this purpose is comprised of the perceived motivational factors of amotivation (AMOT), extrinsic motivation (EMER), introjected motivation (EMIN), identified motivation (EMID), and intrinsic motivation (IM) as measured by the AMS instrument based on Self-Determination Theory. The 233 cases are comprised of 77 group S, 99 group R, and 57 group N cases.

Table 4-7

Descriptive Statistics for All Variable Combinations

		Mean	Std. Error of Mean	Median	Standard Deviation
S	AMOT	1.31	0.06	1.00	0.49
	EMER	2.93	0.11	2.75	1.01
	EMIN	3.10	0.11	3.25	0.95
	EMID	3.72	0.10	4.00	0.84
	IM	3.85	0.09	4.00	0.83
R	AMOT	1.49	0.07	1.25	0.66
	EMER	3.01	0.11	3.00	1.13
	EMIN	3.08	0.10	3.25	0.99
	EMID	3.60	0.11	3.75	1.08
	IM	3.40	0.10	3.40	0.96
N	AMOT	1.87	0.11	1.75	0.84
	EMER	2.11	0.11	2.00	0.83
	EMIN	2.34	0.13	2.25	1.00
	EMID	2.32	0.12	2.25	0.91
	IM	2.87	0.13	2.80	0.95

Assumptions for MANOVA were tested (Table 4-8). Only EMER and EMIN were found to be meeting parametric assumptions for MANOVA; however, Pillai, Hotelling's, and Roy's Largest root (not shown in the table) all indicated clear significance for effect with $p \leq 0.000$, well below $p < 0.05$ requirement of significance. Bartlett's test for sphericity showed pairwise linearity between motivational factors ($p \leq 0.001$, $p < .005$). Box's test showed homogeneity of variance-covariance matrices across groups ($p = .182$, $p > 0.05$). Thus, Wilk's lambda was reported for MANOVA. The residual SSCP matrix showed no multicollinearity between dependent factors with correlation values between .14 to .60. Levene's test showed homogeneity of variance for EMIN, EMID, and IM ($p > .05$). However, failed for AMOT ($p = .00$, $p > .05$) and EMER ($p = .03$). Levene's is relevant to univariate testing, which will be done with non-parametric methods for AMOT. For EMER, non-parametric results will be viewed to confirm the parametric outcomes, given that the violation is not severe, and the variable was considered overall acceptable for assumptions. Specific to Kruskal-Wallis, the assumption that the distribution of scores for each factor is of similar shape between the three groups was visually confirmed by viewing respective boxplots.

Table 4-8

MANOVA Whole Groups Effect Indicated

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Wilks' Lambda	0.685	9.413	10	452.000	$p \leq 0.000$	0.172

The results of the MANOVA test indicated an overall difference between groups of STEM career orientation in their motivation (Wilk's lambda = .69, $F_{452} = 9.41$, $p < .05$, with STEM career orientation tentatively accounting for about one-fifth (17%) of the variance in the overall student motivation ($\eta^2 = .172$). However, interpretation is limited since three out of five factors were not found to meet the parametric assumptions. Univariate ANOVA and post-hoc t-test and their nonparametric analogs were used to further investigate differences between groups.

Univariate tests of all dependent variables inspected differences in groups of career orientation S, R, and N. Significant between-subjects effects within STEM career orientation groups for all motivational factors resulted (Table 4-9). The parametric MANOVA showed significant univariate effects for EMER ($F = 15.67$, $df = 2$, $p < .001$) and EMIN ($F = 12.59$, $df = 2$, $p < .001$). The non-parametric Kruskal-Wallis test showed a significant difference in median motivation scores for AMOT ($H = 23.42$, $df = 2$, $p < .001$), EMID ($H = 58.40$, $df = 2$, $p < .001$), and IM ($H = 33.62$, $df = 2$,

$p < .001$), with H being the non-parametric analogue of the F statistic. Nonparametric results also substantiated the significance of the result for EMIN ($H = 20.18$, $df = 2$, $p < .001$) for which interpretation of the univariate parametric results was limited.

Additionally displayed in Table 4-9 are the sum of squares (SS), degrees of freedom (df), mean squares (MS), F ratio, and level of significance (p) output of the MANOVA. For the p value of EMER and EMIN the Kruskal-Wallis output is shown and for AMOT, EMID, and IM, the asymptotic significance was calculated. The value was s significant for all factors ($p < 0.001$).

Table 4-9

Univariate Analyses of Differences

	SS	MS	F	H	df	p	Partial Eta Squared
AMOT				23.42	2	< 0.001*	
EMER	32.65	16.33	15.67		2	< 0.001	0.12
EMIN	24.08	12.04	12.59		2	< 0.001	0.10
EMID				58.40	2	< 0.001*	
IM				33.62	2	< 0.001*	

Note: *asymptotic significance

Univariate pairwise post hoc tests for differences were conducted to identify specific pairs of groups with significant difference from each other. Bonferroni post-hoc tests were used for EMER and EMIN while AMOT, EMID, and IM were tested with the nonparametric post hoc Dunn's test (Table 4-10). The conservative Bonferroni correction of 15 was applied to account for this being a multivariate investigation into differences between five AMS factors with three groups to limit type I error. The pairwise comparison of dependent variables showed significant differences for all motivational factors of N and the respective groups S and R, so students, not STEM career oriented have significantly different motivation in science courses than students with either STEM or STEM-related career orientation. For intrinsic motivation, there was also a significant difference between S and R, so students oriented toward STEM careers have different intrinsic motivation than students oriented toward STEM-related careers. (AMOTlog: $p = 0.155$, EMER: $p = 1$, EMIN: $p = 1$, EMID: $p = 1$). Group N was significantly different in all motivational factors from both the STEM group as well as the STEM-related career orientation group at $p \leq 0.001$ for all) and IM R to N at $p = 0.002$.

Table 4-10

Univariate Pairwise Comparison for Differences

		Standard Error	p
AMOT (1)	S to R (a)	9.75	.184
	R to N (b)	10.67	.002*
	N to S (c)	11.22	< 0.001*
EMER (2)	S to R (a)	0.16	1.000
	R to N (b)	0.17	< 0.001*
	N to S (c)	0.18	< 0.001*
EMIN (3)	S to R (a)	0.15	1.000
	R to N (b)	0.16	< 0.001*
	N to S (c)	0.17	< 0.001*
EMID (4)	S to R (a)	10.21	1.000
	R to N (b)	11.17	< 0.001*
	N to S (c)	11.74	< 0.001*
IM (5)	S to R (a)	10.22	0.0049*
	R to N (b)	11.18	0.004*
	N to S (c)	11.75	< 0.001*

Note. *Significance level was set at $p \leq 0.05$.

In summary, the a significant difference was found for comparisons of group N to either S or R on all factors. A difference was also found for all between group comparisons on IM, also all with significance. For EMID, significance of difference between N and S as well as N and R were confirmed with parametric methods. Significant differences found with non-parametric means were substantiated with Bonferroni adjustment for all. Visually, the differences between the groups for each of the motivational factors can be seen on the estimated means plots (Table 4-11). Groups are plotted next to each other from STEM (1), to STEM-Related (2), and None-STEM (3) in both line and bar graph format. The estimated means bar graphs show error bars for the 95% confidence interval.

Table 4-11

Estimated Means Plots of STEM Career Orientations Groups

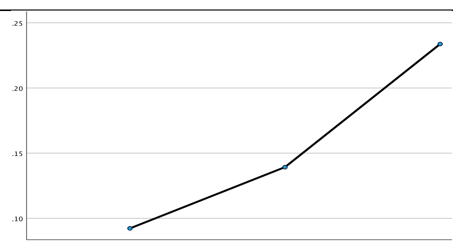
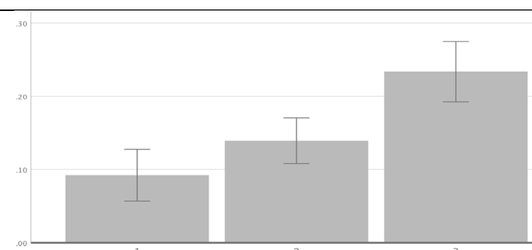
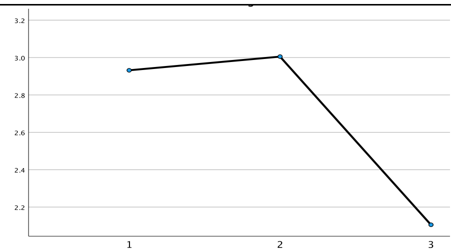
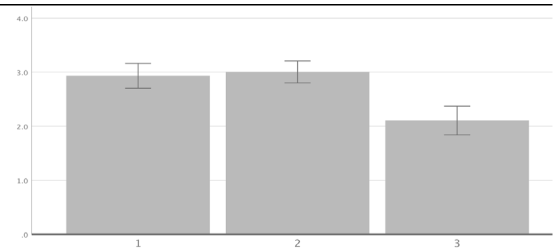
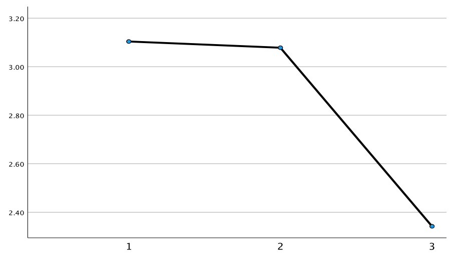
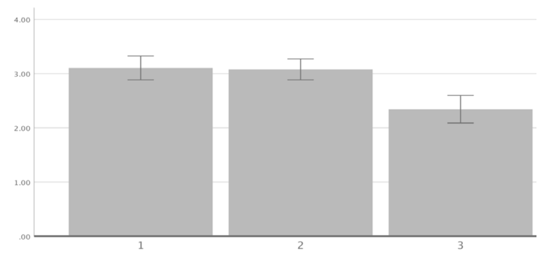
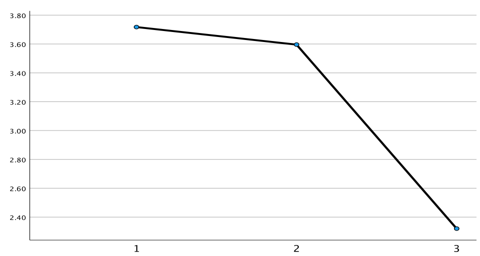
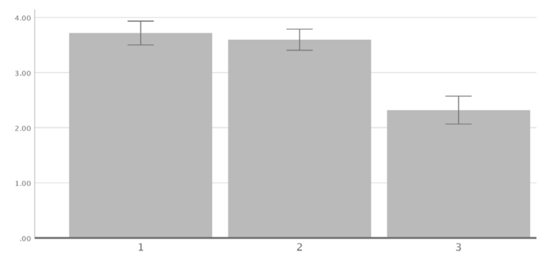
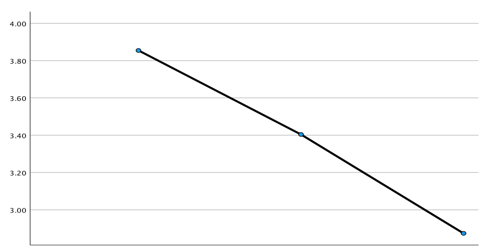
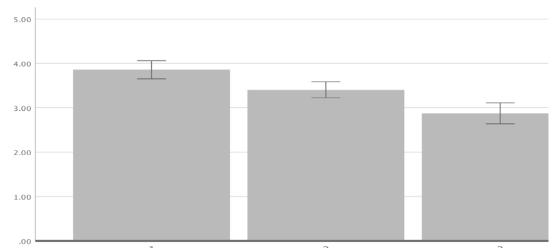
	Profile Plots	Bar Graphs
AMOT log		

Table 4-11 Continued

	Profile Plots	Bar Graphs
EMER		
EMIN		
EMID		
IM		

Note. Estimated Mean Levels of Motivations STEM (1), STEM-Related (2), Non-STEM (3). Y-axis shows estimated marginal means.

Quantitative Hypotheses Testing

The univariate tests confirmed that for each group of motivational factors at least two of the groups of STEM career orientation were found to be significantly different, confirming that the alternative multivariate hypothesis can be accepted.

$H_{a1:}$ *There are statistically significant differences between adolescents with different STEM career orientations in regards to their overall perception of motivation (amotivation, extrinsic,* *introjected, internalized, and intrinsic motivation): at least one of the groups means is different from one of the other groups means ($\alpha = .05$, $p < 0.05$):*

$\mu_S \neq \mu_R \vee \mu_R \neq \mu_N \vee \mu_S \neq \mu_N$

Further, the results of the univariate tests allow for the following univariate hypotheses to be accepted (Table 4-12):

Null Hypotheses*: There are no differences for adolescents between the two groups of STEM and STEM-Related orientation in regards to amotivation, extrinsic, introjected, and internalized.*

Alternative Hypotheses*: There are significant statistical differences for adolescents between the group of students not oriented toward STEM careers to students oriented toward STEM or STEM-related careers and there are significant statistical differences for adolescents between the three groups of STEM career orientation in intrinsic motivation ($\alpha = .05$, $p < 0.05$). Differences for all factors but EMID were confirmed with parametric methods, while all other significances were substantiated with non-parametric methods.*

Table 4-12

Quantitative Univariate Differences

S to R	R to N	N to S
H_{01a}: $\mu_{S\text{-AMOT}} = \mu_{R\text{-AMOT}}$	H_{01b}: $\mu_{R\text{-AMOT}} \neq \mu_{N\text{-AMOT}}$	H_{01c}: $\mu_{N\text{-AMOT}} \neq \mu_{S\text{-AMOT}}$
H_{02a}: $\mu_{S\text{- EMER}} = \mu_{R\text{- EMER}}$	H_{02b}: $\mu_{R\text{- EMER}} \neq \mu_{N\text{- EMER}}$	H_{02c}: $\mu_{N\text{- EMER}} \neq \mu_{S\text{- EMER}}$
H_{03a}: $\mu_{S\text{- EMIN}} = \mu_{R\text{- EMIN}}$	H_{03b}: $\mu_{R\text{- EMIN}} \neq \mu_{N\text{- EMIN}}$	H_{03c}: $\mu_{N\text{- EMIN}} \neq \mu_{S\text{- EMIN}}$
H_{04a}: $\mu_{S\text{- EMID}} = \mu_{R\text{- EMID}}$	H_{04b}: $\mu_{R\text{- EMID}} \neq^{*} \mu_{N\text{- EMID}}$	H_{04c}: $\mu_{N\text{- EMID}} \neq^{*} \mu_{S\text{- EMID}}$
H_{05a}: $\mu_{S\text{- IM}} \neq \mu_{R\text{- IM}}$	H_{05b}: $\mu_{R\text{- IM}} \neq \mu_{N\text{- IM}}$	H_{05c}: $\mu_{N\text{- IM}} \neq \mu_{S\text{- IM}}$

Note. *Significant difference established with parametric methods.

Identification of Explanatory Follow-Up

The results were reviewed to identify which results warrant follow-up and respective research questions were added to address these. The qualitative research procedure was adjusted by adding questions to the interview protocol (Table 4-13). All additions have the goal to prompt narratives rich in description for the motivations toward undergraduate science courses. This adds the explanatory follow-up to the quantitative results in this sequentially designed study as described in the literature review on mixed methods explanatory sequential research. The three questions added further investigated intrinsic motivation differences, the AMOT outliers, and career fields responses.

Table 4-13

Interview Questions Identified for Follow-Up Based on Quantitative Results

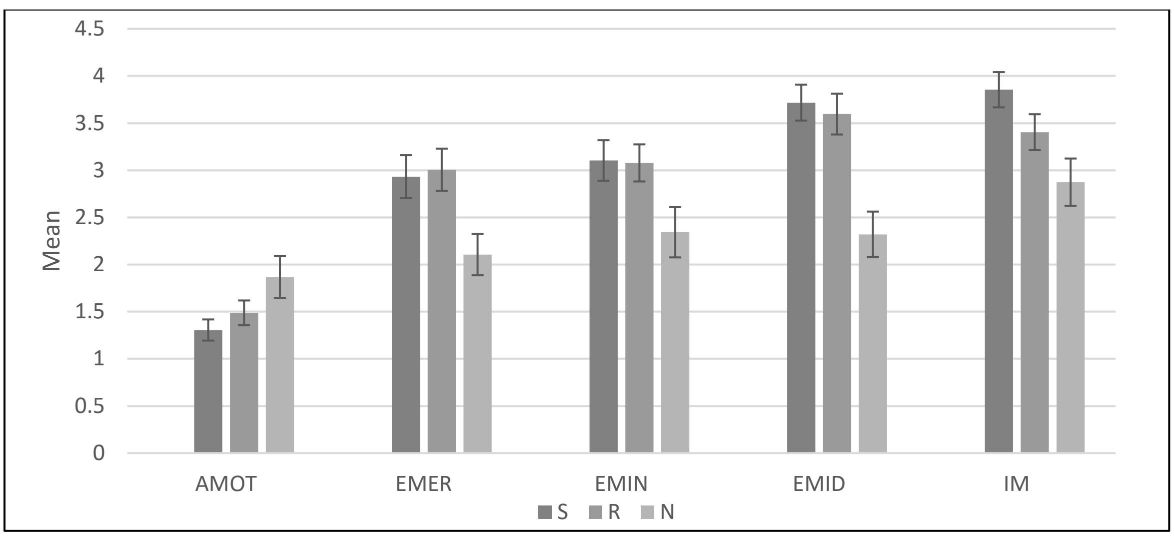
Variable	Quantitative Results Warranting Follow-Up	Qualitative Interview Question
IM	Differences between S to R	When comparing students planning on a job in science or engineering with students wanting a career in health, survey results suggest that being motivated by discovering new things is higher for students planning the science or engineering job. Can you tell me more about that?
AMOT	Occurrence of High Number of Outliers	A few students rated their amotivation very high, so don't have motivation to learn for the course at all. What do you think about that?
Career Orientation	Career Field Answers	When asked for which career students are currently interested in, a lot of students naming a subject area as career goal and not an occupation or job. Can you tell me more about that?

Addition of Intrinsic Motivation Question

Intrinsic motivation was the only factor where quantitative differences were found between the two STEM career orientations, students with STEM and STEM-related career orientation. Intrinsic motivation for students with STEM career orientation is significantly higher than for students with career orientation toward STEM-related careers. Figure 4-3 shows bar graphs for the factors for the

Figure 4-3

Clustered Bar Means for Five AMS Factors



Note: The bar graph shows three bars per motivation: S on the left, then R, then N on the right.

all groups S, R, N, with 95 percent confidence error bars. Hence, a question to elicit student perspectives on these found differences between two STEM orientations was added: *When comparing students planning on a job in science or engineering with students wanting a career in health, survey results suggest that being motivated by discovering new things is higher for students planning the science or engineering job. Can you tell me more about that?*

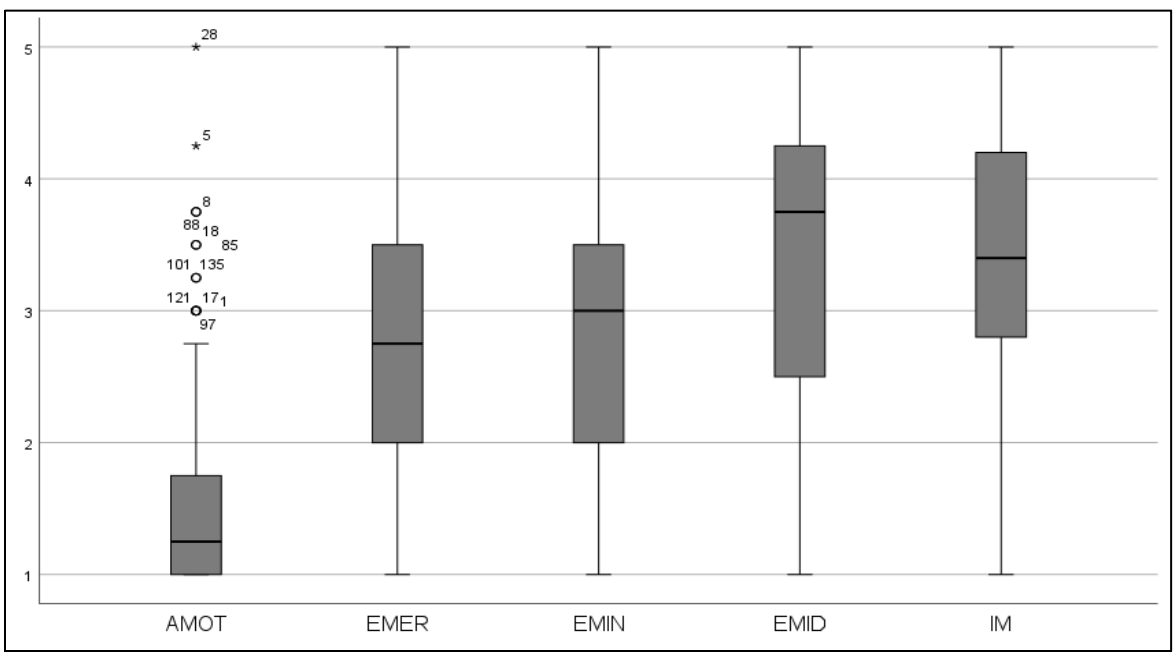
Addition of Question on Amotivation

The AMOT variable contained a substantial number of outliers, unlike the other factors. In other words, a group of students had amotivation of a noteworthy amount unlike the rest of the students. This indicated that amotivation operates differently from the other factors. The survey questions for amotivation are different from the other factors in that it is asking for levels of negative motivation rather than levels of positive motivation.

Figure 4-4 shows box plots for the five AMS Variables EMER, EMIN, EMID, and IM are displayed, with the substantial number of outliers for AMOT. In the box plot figure the middle two quartiles of the data are displayed as box with a line at the median, minimum and maximum mark the end of outside quartiles. A question eliciting perspectives on students with significant lack of motivation was added: *A few students rated their amotivation very high, so don't have motivation to learn for the course at all. What do you think about that?*

Figure 4-4

Boxplots for AMS Factors with Outliers



Addition of Subject Field for Career Question

Student responses to the career orientation question provided answers that are career occupations and subject areas, the latter of which does not constitute a career, but a career field. For example, one student provided “Wildlife Biologist” as possible career while another student only provided the subject area “biochemistry” as a response to the career question (Table 4-14). Overall, for all three groups S, R, and N, most responses provided were career occupations (Figure 4-5). Because the independent variable of this study, career orientation, was based on the answers to this question, the researcher considered it important to better understand these two types of answers. A follow-up question was designed accordingly: *When asked for which career students are currently interested in, a lot of students naming a subject area as career goal and not an occupation or job. Can you tell me more about that?*

Table 4-14

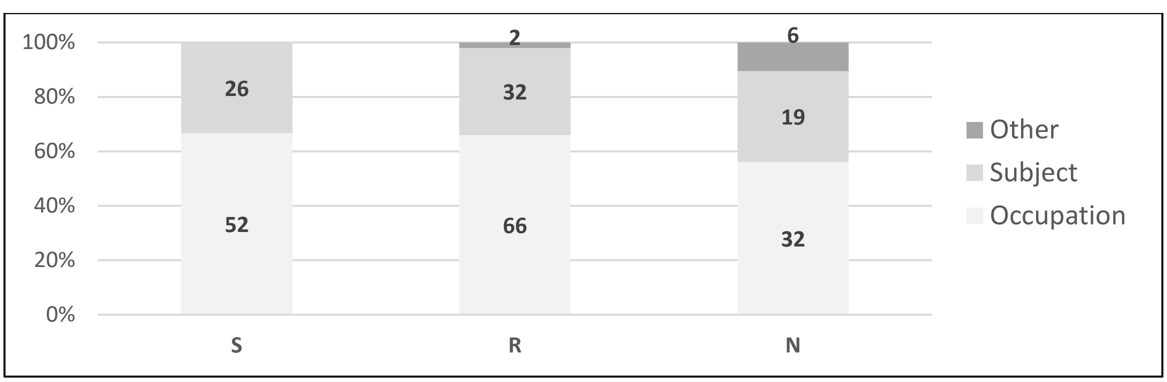
Representative Career Entries Including Subject Fields and Occupations

	STEM	**STEM-Related**	**Non-STEM**
Occupation	“Wildlife Biologist” “Geologist”	“Greenhouse Technician” “Doctor, Physician's Assistant”	“Teacher or Social Worker” “Lawyer”
Subject Field	Biochemistry” “Automotive engineering”	“Dental hygiene” “Environmental education”	“Education” “Law and Criminology”
Other	n/a	“I’m not sure, but something that works with animals in a caretaking capacity.”	“I haven’t quite thought of it.”

Note: Complete entries are presented, with capitalization as originally entered by the participant.

Figure 4-5

Career Field Answers



Interview Demographics and Interviewee Motivational Profiles

Distribution of demographics and motivational profiles were reviewed and found to be representative (Table 4-15). The survey sample included female and male genders approximately equally, and one non-binary participant. Considering the size of the sample, ethnicity and race was roughly representative sample of the Inland Northwest, containing mostly participants of White identity, three of Hispanic and one of Asian identity. Lastly, the motivational profiles aligned with the motivational distributions of STEM career orientation in the survey. Interviewee pseudonyms were assigned a last name initial indicating their career orientation group S or R. The scores for the motivational factors displayed in Table 4-15 were gathered in the interview as verbal rating of the AMS factors.

Table 4-15

Interview Participants with Ratings for AMS Factors

	Age	**Gender**	**Ethnic-Racial Identity**	**AMOT**	**EMER**	**EMIN**	**EMID**	**IM**
Ben S.	18	male	White	1	4	5	4	5
Charlotte S.	20	female	White	1	3	5	5	5
Hazel S.	21	female	White	1	5	4	5	5
Jolene S.	21	female	White	1	4	4	5	5
Josie S.	22	female	White	1	4	2	5	5
Maro S.	21	male	White	1	2	4	5	5
Milo S.	22	male	Hispanic	1	3	5	4	5
Olev S.	19	non-binary	White	1	4	5	5	5
Piper S.	18	female	White	2	1	3	5	4
Susan S.	21	female	White	3	5	5	4	4
Willow S.	22	female	White	2	5	4	4	5
Ada R.	21	female	White	1	3	3	4	5
Carmen R.	20	female	Hispanic	3	3	4	4	4
Emma R.	21	female	White	2	4	5	4	4
Kylie R.	21	female	White	1	5	5	5	5
Lian R.	21	female	Asian	1	4	5	5	5
Lucas R.	18	male	White	1	4	4	2	2
Maia R.	20	female	Hispanic	5	1	1	2	5
Olivia R.	22	female	White	1	5	3	5	5
Sierra R.	20	female	White	2	3	5	2	4
Zelda R.	25	female	White	1	5	3	4	4

Qualitative Analysis and Codes

Analysis of the qualitative dataset–the coded transcripts–was conducted in two steps. First, the transcripts were coded to the a priori and emergent codes to answer the qualitative phase research question: *How do self-determination motivations for science education differ based on STEM career orientation in adolescent undergraduate college students?* This question on qualitative differences was analyzed first for between-group differences per factor and then for between-group differences across motivations. Second, the explanatory questions were viewed for findings specific to the specific explanatory questions asked and occurrence with a priori and emergent codes related to those.

The a priori codes—presented in the methods section (Table 3-3)—identified the parts of the narrative where interviewees spoke about a motivational factor explicitly or their narrative described the respective motivational construct, both of which included authentic narrative enriching the understanding about the motivations investigated. The emergent codes (Table 4-16) related to motivation and provided context to the factors. By mapping the emergent codes onto the a priori factor codes, the emergent codes related to the specific motivational constructs were surfaced and differences could be investigated between the STEM career orientation groups S and R.

Emergent Codes

After in vivo coding, all emerging codes were reviewed and viewed to identify categories they fit into. Emerging were three categories that the emergent codes could be fitted in: course-related narrative on motivation, personal circumstances relating to motivation, and the quality of motivation (Table 4-16). Course-related codes included anything related to the science courses discussed by the interviewees. Personal circumstance codes note various elements outside of the science courses in college such as family background or youth school experiences mentioned as influencing motivation. The third category included various quality aspects of motivation not fitting the a priori codes. The categories themselves were not used further for analysis but are provided here as organizing element for the emergent codes as the researcher viewed them. The emergent codes were used in a following step to investigate differences between S and R within the respective emergent codes per factor and overall. The course-related emergent code *struggle with volume of learning* (Table 4-16, first code) surfaced differences between groups S and R during the qualitative analysis.

Table 4-16

List of Emergent Codes with Definitions

Code	Definition
	Course-Related Codes
Struggle with volume of learning	Reference to high amount of learning expected in course while experiencing time pressure.
Scientific engagement	Description of scientific thinking or science hands-on learning.
Long-term or in-depth learning	Description of learning that refers to the depth or longevity of learning.
Communication to peers or instructor	Refers to communication with peers or instructor.
Curriculum methods	Relates to learning design methods in course.
Experiential learning methods	Relates to learning design methods that engage students in experiential learning.
Relevant learning	Relates the relevance of learning to the students.
Intentional learning	Describes aspects of the curriculum that are designed to intentionally deliver learning.
Sequencing of curriculum	Describes aspects of instructional design that sequences the learning intentionally.
Group learning	Refers to learning in groups of students.
Support by peers or instructor	Describes support by peers or the instructor.
Teacher attitude	Addresses the attitude of the teacher or instructor.
Alignment of curriculum with course	Addresses how curriculum is aligned within the course.
	Personal Circumstance
Gender	Addresses gender.
Past	Refers to the past, for example experiences of their youth.
Age	Addresses age.
Cost	Refers to a cost.
Career or Major Subject	Refers to a career or college major.
Future	Refers to the future.
	Motivational Quality
Supports motivation	Description something supporting motivation.
Motivational strategy	Describes a strategic method that manages motivation.
Challenges motivation	Description of something as non-supportive of motivation.
Frustrates motivation	Description of something as frustrating motivation.
Motivation threat	Description of something threatening motivation.
Motivational shift	Description of a shift in motivation, such as from one type to another or from feeling frustrated to supported.
Suggestion for motivation	Code describes a recommendation the student voices to support motivation.

Findings for Explanatory Follow-Up

Arising out of the quantitative results, questions were designed to better understand the differences for intrinsic motivation, the outliers for amotivation, and the type of answers provided as career considered. Due to the nature of the explanatory questions, the interviewees provided a combination of their experience as well as opinions about groups of students for these explanatory questions:

1. **Intrinsic Motivation**. *When comparing students planning on a job in science or engineering with students wanting a career in health, survey results suggest that being motivated by discovering new things is higher for students planning the science or engineering job. Can you tell me more about that?*
2. **Amotivation**. *A few students rated their amotivation very high, so don't have motivation to learn for the course at all. What do you think about that?*
3. **Career Orientation**. *When asked for which career students are currently interested in, a lot of students name a subject area as career goal and not an occupation or job. Can you tell me more about that?*

Explanation For Intrinsic Motivation Differences

The answers explaining differences between groups S and R for intrinsic motivation were diverse and extensive. Students talked about S students being more motivated to learn science because that is their main focus, while R students were presented as being more motivated to complete the courses driven by various extrinsic motivations. The specific responses covered the whole spectrum of codes and no saturation was reached for a specific explanation.

Explanation For Amotivation Outlier Occurrence

Amotivation did not receive many responses that could be coded as describing the motivational factor amotivation, and none described high amotivation while not having other motivation at all. All interviewees were from groups S and R, all of which reported extrinsic or intrinsic motivation. No explanation for the high occurrence of outliers for amotivation could be derived from the interview responses to this question.

Explanation For Career Orientation Field Answers

The group typically identifying a subject field as a career were the S students. Responses to this question reflected that. Students that identified a subject as their career in the interview commented that they were motivated to learn the subject and within the field of STEM. They expanded that they often were not clear what occupations may await them after graduation. Students of group S also explained the difference by having been encouraged to go to college as a path to a career instead of directly going into a career without college. R students also contributed to the response that S students were not aware of specific careers or even had the freedom to not yet specify a career while in college.

Qualitative Findings of Differences in Motivation Factors

Findings of the interview analysis per each individual motivation factor are presented in this section to answer the qualitative research question: *How do self-determination motivations for science education differ based on STEM career orientation in adolescent undergraduate college students?*

As presented in the methods section, the interviews were analyzed with the saturation method. Coded narratives were systematically reviewed across all transcripts. Due to the open-ended nature of the interviews, the topics covered by the individual students were individual narratives responding to a range of questions about the motivational factors. Thus, the findings presented are only the themes that reached saturation and the rich descriptions of the motivation factors themselves. The motivational factors were coded, reviewed, and presented based on the a priori code definitions (, presented in methods in Table 3-3. These are simplified versions of the factors of Self-Determination Theory. This approach was taken to compare the results from the interviews with the survey results. The latter limited the motivational constructs inherently to the AMS item statements and hence are not as expansive as the actual constructs. The qualitative findings reflect this simplification of the factors.

Findings for Amotivation

None of the students spoke of being totally amotivated at the time of the interview and data revealed no differences between groups S and R. The findings on amotivation thereby are descriptive only. At the same time, interviewees described having experienced amotivation in the past. In those instances, they describe amotivation in science courses in contrast to other times when they do not experience amotivation to that level and rather were motivated. Some amotivation narratives include descriptions of the external factors that they feel lead to amotivation. No between-group differences existed for amotivation or any of the other codes. Saturation was only reached for the way students described amotivation overall, not for a specific other code. The following quotes describe amotivation for both students S and R.

Piper S. described the past, during her first year of school in a new town: “one thing that like especially this year starting around spring break that really like hindered my motivation to like discover things by science was actually a burnout. … Burnout and just being tired of trying to figure everything out actually really reduces my energy to want to learn things to try to figure things out because I'm already doing enough of that in my own life." One additional student, Sierra, reported high level of amotivation due to extreme depression: "I'm in a science class, but I hate it here, I don't feel like I'm learning anything, I don't feel motivated at all, sometimes I don't want to go to class or sometimes I will skip classes, cause I'm just like 'what am I even doing?'" (Sierra R.).

Similarly, Carmen S. shared that the beginning of the semester,

> "I started out kind of rough- not going to lie. Because the course moves so fast and the professor herself–she talks so fast. And I have like issues really focusing when things are moving so fast, so I would stop going to class and at one point I kind of stopped doing everything for the course." (Carmen R.)

Carmen's description illustrates how external factors like time pressure can be demotivating, which increased her amotivation. At the end amotivation was very high so that she "stopped doing everything for the course," an example of a student feeling high amotivation and no self-determinate motivation, neither extrinsic nor intrinsic motivation.

Lian R. describes the feeling of *waste of time* that some of her peers and she feels on occasion with a lack of control.

> "A lot of the frustration that me and I know a lot of what my other classmates felt, like just doing things because we're told to be doing it, but not really knowing why. ... for those it's just like, we don't know why we're doing anything, and it was just like you're learning it and that's it and that just, I know that frustrates a lot of students, because like we're putting all time and effort into this one class, because we need our GPAs to be up, we need to have this class for our major, but it feels like a waste of time for a lot of us." (Lian R.)

While the description includes elements of external regulation, given the descriptions of *being told to do* to gain a good GPA, the re-emphasis of not *knowing why* leads to her summary of *waste of time* as a contrasting motivation as separate construct.

Maia R. said about classes in her science course, "I did not really feel motivated, because I never once got to, like, like he did not really show experiments in class, it was all these videos." While the AMOT statement of the AMS survey matched how she felt about her motivation, she was not without motivation. She had rated amotivation very high (5) in the interview (Maia R., refer back to Table 4-15 above). Maia's rating fits the outlier group in the survey; however, it is unclear how representative her narrative is for AMOT outliers given that she also rated IM very high (5). Rather, she in the remainder of the interview discussed that she liked to learn science, just not in parts of the class that included video. Thereby, her narrative fits with the remainder of the AMOT descriptions by either group in the interviews, not adding understanding to the outlier behavior of AMOT.

While SDT amotivation is defined as not perceiving any motivation, the AMS survey allows for ratings from 1 to 5 on the item statements for amotivation. Thus, it invites ratings of a partial amotivation by students when students felt they agree somewhat with the amotivation statements, also while possibly feeling positively motivated. The descriptions in the narrative were coded in line with the AMS survey thus resulting in descriptions of partial or full amotivation, at times parallel to students feeling some form of extrinsic or even intrinsic motivation. This then has amotivation function as hindering or working against a positive motivation. This opposite direction that amotivation (negative) has to the other motivations makes amotivation different from the other motivations (positive). This possibly contributes to the presence of outliers, further reviewed in the discussion. Overall, the descriptions of amotivation are matching the quantitative results of no difference between the groups S and R. Additionally, other than the following descriptions for the remaining factors, amotivation is described often by contrasting it with other motivations, which highlights the lack of regulation that amotivation is expected to have. This volatile nature of amotivation of not being a regulated motivation visible in the interviews fits with the occurrence of the high number of outliers, even though that was not exemplified directly by the interviewees.

Findings for External Motivation

Both groups of students, S and R, report some level of external motivation (EMER). External motivation is motivation driven by external demand or reward, for example, motivation to learn pressured by the external demand of grades to pass the class on the way to the career. Comparing the narratives of S and R revealed one theme of difference between the groups. In students with STEM-Related career orientation (R), external motivation occurred in connection with the *struggle with volume of learning* emergent code in descriptions of external pressure of learning high amounts in order to pass the class with a good grade as motivation. The theme for this between-group difference for EMER was named *struggle over hurdle toward career* and was specific to students in group R. Similar to a hurdle on a race-track that an athlete has to jump to get to the finish, completion of the course with a good GPA was seen as hurdle, a barrier to finishing the college program. The theme was described in connection with a high demand of learning. A *struggle with volume of learning* was an emergent code that cross-mapped with EMER for R students and surfaced the theme *struggle over hurdle toward career.*

For example, students talked about needing to pass the course to get to veterinary or medical school while commenting on how the content of the course was not relevant to their future profession even though at times interesting, leaving the grade as core motivation to study in the course. Olivia R. stated, “Veterinary medicine is the only thing I've ever wanted to do and because I have to complete all of the schooling for that, that is my main motivation right there, I want to get the good grades.” Olivia R. utilizes the pressure of grades toward her career goal like a propellant. “I think I definitely work harder in the exams-only course because there is no wiggle room …., so I definitely focus more on the courses that are exams-only because they stress me out a lot more.” She talked about this external pressure quite positively, explaining how this focus allowed her to have clear prioritization of what to learn and when.

Differently and not coded to EMER, students of group S did not see grades as the external motivation to learn. An example of a non-R student talking about grades is Josie S., en route to be a scientist.

> “I definitely want to do well in the class because that reflects on my transcript and I'm trying to get into Grad school. So that part I would say is definitely a big motivator but not the biggest motivator for me to do well.” (Josie S.)

So, while Josie S. describes grades as important, she describes them not as her main motivator nor external pressure. More than half, six of the interviewed students of group R were oriented toward a medical career.

Findings for Introjected Motivation

Introjected motivation (EMIN) is motivation seen as caused by factors outside of the person, such as family expectations or peer encouragement. Students across the groups talked about how people were a contributor to motivation in their science courses, either to please or confirm their positive expectations of doing well in the course or to avoid disappointing their expectations. No between-group differences were noted in relation to introjected motivation. The following are descriptions of EMIN from the interviews.

One example of introjected motivation was students that wanted to please their parents. Hazel S. said that she liked to share “all the good test scores and the good grades” with her parents. Ada R. described how people help her stay motivated to complete her pre-medical degree program, highlighting the internal locus of regulation of EMIN motivation.

> "I always thought about the end goal, so I was actively, I was employed at a hospital so, probably every weekend I would interact with patients and healthcare, and I think that honestly helped because I would always see that end goal" (Ada R.).

The outside cause seen internally as motivation can also be peers. Josie S. describes not wanting to disappoint other students in her course:

> "My motivation to study in herpetology did come from some of the people in my class, ... that class centered quite a bit on group work, we would do like a miniature group project every single week and so that definitely played into it, because I didn't want to let my group down ... so that definitely was also a motivator to do well in the course." (Josie S.)

Overall, introjected motivation occurred across the groups S and R and did not occur differently between the groups, in line with the quantitative results of no difference between the groups for that motivational factor.

Identified Motivation and Intrinsic Motivation

Students described being motivated by important internal goals they fully identify with, the definition of identified motivation (EMID). Typically this was the motivation to become competent. In context with the emergent code of *struggle with volume of learning*, students of group S described the science they wanted to become competent in as *dense*, identified motivation. The vivid descriptions of their struggle through the *dense* material students also described pure joy of learning, intrinsic motivation (IM). Included were descriptions of great satisfaction or joy from the feeling of resolution once the concepts are understood, after struggling through great effort of conceptual learning, when the learning shifted them from trying to learn the concepts to full comprehension of the concepts. Reaching full comprehension of scientific knowledge and mechanisms is narrated as a personally deep and satisfying experience by these students of group S. Since this theme was not specific to one factor in the descriptions but was found to be straddling two factors. This section thereby presents findings for both identified as well as intrinsic motivation. No other differences between S and R were found.

Jolene describes the motivation of being drawn to complexity (IM) and the additional motivation of wanting to know it well (EMIN).

> “A big thing with science sometimes is that it seems really dense. And sometimes it almost seems unapproachable if you don't explain it correctly and so there's definitely a lot of drive to you know not only just be good at the science but communicate it well because that's how

> you get other people engaged, that's how you kind of expand your research more ... I always was really drawn into how complex things can get and how deep in the weeds we can get with things, but I have definitely run into that with other people, where I interact with them and try and explain the thing I do and they're like wow that's a lot." (Jolene S.)

Similarly visual is Ben S.'s description of hitting a roadblock of new concepts. This illustrates the quality of intrinsic motivation to be driven by learning something new and overcoming a challenge.

> "The frustration of hitting like roadblocks with it [new concepts]. Sometimes you're thrown some ideas that click really easily and then you have some that are … I think of examples like spontaneity [chemistry example, spontaneous reaction] … it is kind of non-intuitive. And when those ideas don't click as well as some of the others do, it can be frustrating, and I think that comes with new concepts, especially when it's really easy to pick up on things that you've kind of heard before. But when something is new, that challenge, like, being able to overcome those challenges can definitely be a struggle" (Ben S.)

The description of conceptual learning driven intrinsically (IM) is described by Ben after he takes a break from learning. "When you sit back down all of a sudden, things start to kind of click" (Ben S.). Conceptual learning driven by IM was also described by Susan S. "When you get a concept, like a really hard concept, it makes you feel good and now it kind of makes you proud of yourself."

Milo, who has been committed to work with fish from a young age, talks himself toward wanting to be competent (EMID) in the knowledge outside of the field of fish, ending with wanting to learn about the world for its own sake (IM) with a bigger picture view than before. He starts with a scenario when he thought he had to let go of a career working with fish, yet tried to persist.

> "In terms of studying. It definitely made me study harder. Because of the fact that, even though I'm demoralized, it doesn't mean I should [n't] just brush off the information that's given to me. It definitely made me go 'I need to understand this, if i'm going to keep pushing forward, whether or not I'm motivated or not'. I need to at least have understanding, I guess. And in that case I guess ... I would say I pushed aside my motivation for a career [ichthyologist] and instead my motivation swapped to a motivation of gaining knowledge, to be more like 'listen, I know that you're sad about this being this way, but you need to put aside that sadness that maybe this isn't what you want and look at the uniqueness of what you're learning here. You are now learning about how the world works.' And so, it definitely pushed me to understand the knowledge more, to really push me to be like 'okay so this phylum [group of organisms] is like this... You need to broaden your scope a lot and making

> me go 'okay, so I focus on fish, now it's time to look at the other organisms that are around,' because fish are not the only thing on this planet clearly. (Milo S.)

Overall, in the thick descriptions of this theme, S students mostly talked about learning as concept learning, the creation of space or unlearning to reorganize the cognitive building blocks, with a reward of feeling joy after the struggle. While some details of the descriptions could be seen in interviews with R students, they did not fit the theme of *struggle through conceptual learning*.

Summary of Qualitative Findings

The analytic reflection of emergent codes for differences between career orientation groups—one factor at a time—surfaced two themes that reached saturation for the respective factor. The following is a summary of the qualitative findings in relation to the respective research question:

How do self-determination motivations for science education differ based on STEM career orientation in adolescent undergraduate college students?

Students of both groups provided genuine descriptions for all motivational dimensions in line with Self-Determination theory. Differences between groups of career orientation were noted in the two themes surfaced by the emergent code *volume of learning* with students describing how they deal with needing to learn a high amount of content with the time pressures of a college course. The descriptions surfaced two themes in dependence of the STEM career orientation group. Students oriented toward STEM careers (S) described a *struggle through conceptual learning* as the motivation, while students working toward STEM-related careers (R) explained the motivation to learn a high amount with striving to pass the course as the *struggle over hurdle toward career*. The two themes occurred in different factors. This quality of motivation was linked for S students to EMID and IM for R students to EMER. Thus, career orientation plays a role in the way students operationalize motivation as a response to volume of learning. The type of language used by students showed a different level of engagement with the learning material in science classes. S students tended to engage in conceptual learning, while R students talked about engaging to learn facts. Themes also were connected with comments about long-term learning for S and short-term learning to pass the course for R. The qualitative findings are summarized in Table 4-17.

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Table 4-17

Trends of Qualitative Difference

Themes Surfaced by Emergent Code *Volume of Learning*	Related Factor	Description	Trends of Motivation Directionality	
			S	R
Struggle over Hurdle Toward Career	EMER	Studying for the science course toward sufficient grades is seen as external requirement on the path to career and requires pushing through		Focusses motivation to push learning for grades
Struggle Through Conceptual Learning	EMID & IM	Volume of learning is seen as 'dense,' challenging the learner to struggle toward comprehension	Focusses motivation toward active struggle through concepts to gain competency and joy	

Integrated Research Outcomes

The chapter so far presented the quantitative survey phase and the qualitative interview phase. The remainder of this chapter will provide an integrative view of the study considering the data and findings of the first two phases. To begin, the participant sample is reviewed to evaluate consistency and representativeness. Then the resulting data sets are summarized revealing opportunities for integrative analysis, followed by said analysis. At the end of the chapter all results are reviewed jointly to summarize the findings. The overall quality of this research study is also considered.

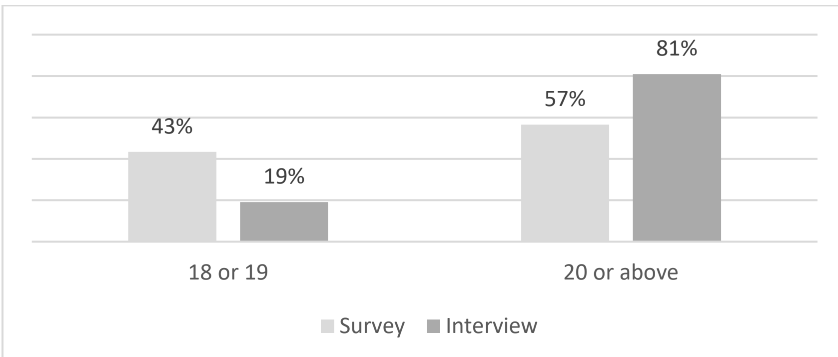
To be conducive to reading the remainder of the dissertation, the different motivational factors may be presented with contractions, drawn from the prompts in the survey and interview questions: grade motivation for EMER (extrinsic motivation), people motivation for EMIN (introjected motivation), and competence motivation for EMID (identified motivation). Amotivation and intrinsic motivation will not be contracted as it is assumed that the reader is familiar with these concepts without a need for cognitive translation. It is hereby noted that these are simplistic expressions of the motivational factors of the Self-Determination Theory. The topical contexts of motivation by grades, people, and competence were presented by the a priori factor codes used in this study.

Review of Participants

Age, gender, and ethnic-racial distributions were reviewed between survey and interviews. The age of the interviewees was overall higher than in the survey. Age groups measured were the group of eighteen- and nineteen-year-old students and the group of students twenty to twenty-six years of age. Only one quarter of the interviewees were eighteen or nineteen (Figure 4-6).

Figure 4-6

Age Distribution Survey and Interviews



Note. Percentages for age groups are displayed for the survey (on the left) and interviews (on the right).

Gender distribution for survey and interviews were found to be similar to the public data (Figure 4-7). Four colleges participated and since neither survey nor interviews gathered information on which college students were enrolled in, the public data (College Navigator - National Center for Education Statistics, n.d.) were averaged to have each of the four colleges equally contributing to the comparative data, not adjusted for enrollment. Considering gender, female students are overrepresented in the study, especially in the interviews with three-quarter of participants (surveys 69%, interviews 76%, colleges 58%). Accordingly male students were relatively underrepresented (surveys 24%, interviews 19%, colleges 42%). The study assessed also third gender identification, not available in public data. Both survey and study included non-binary students at around one twentieth of overall students (surveys 6%, interviews 5%), which for the interviews was one participant. The greatest difference between research study and public data was the presence of non-binary participants in both survey and interviews and the underrepresentation of males.

Figure 4-7

Gender Distribution for Survey and Interviews Compared to Colleges

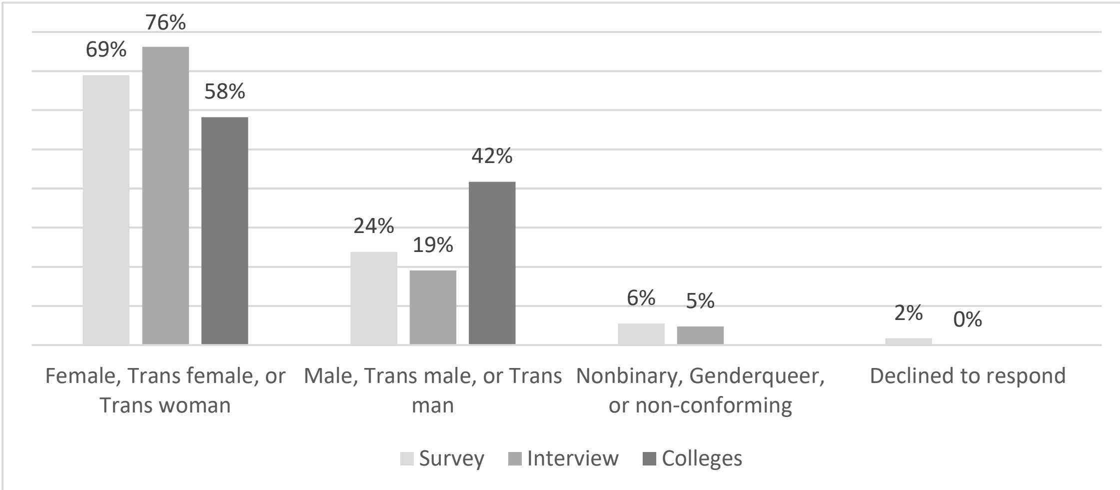
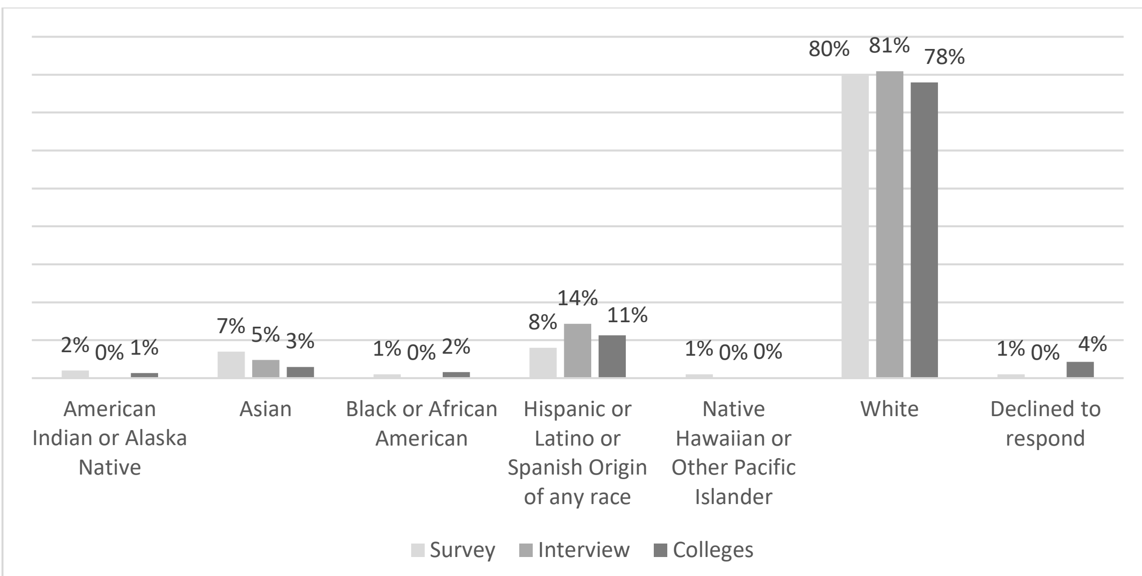


Figure 4-8

Ethnic-Racial Distribution for Survey and Interviews Compared to Colleges



The ethnic-racial identity (Figure 4-8) for both survey and interviews was roughly similar to public data (*College Navigator - National Center for Education Statistics*, n.d.). White was the majority, with four-fifth of the participant population for both survey (80%) and interviews (81%), slightly higher than public college enrollment in participating colleges (78%). Hispanic students participated at about one tenth of total survey (8%) and interview (14%), similar to college enrollment (11%).

Asian students provide around one twentieth of the participants, similar to the college population and also survey and interviews (surveys 7%, interviews 5%, colleges 3%) Minorities with minimal representation in the colleges were represented in the survey and interviews at overall similar levels while not be present in all groups (Native American: survey 2%, interview 0%, colleges 1%; Black or African American: surveys 1%, interviews 0%, colleges 2%; Native Pacific Islander: surveys 1%, interviews 0%, colleges 0%; Declined to respond: surveys 1%, interviews 0%, colleges 4%).

Resulting Datasets

There are two main datasets resulting from this study, all describing the motivational factors for groups of career orientation of undergraduate students (Figure 4-9). The AMS survey dataset for all three groups S, R, and N comprised of 233 Likert scores for the five motivational factors with no missing fields and the open-ended AMS text responses. The second dataset are the interviews for groups S and R, not including N, including the codes for motivational factors and the derived themes. This provided the opportunity to use the codes and themes resulting from the qualitative phase and apply them to the dataset of the first phase of the study, specifically the AMS text responses. Additionally, careers and demographic information is included in each dataset.

Figure 4-9

Datasets Overview

		Survey	Interviews
Quantitative Phase	S, R, N	AMS factor scores **AMS text response** Careers, Demographics	
Qualitative Phase	S, R		**Coded and themed Transcripts** Careers, Demographics
Integrative Phase	S, R, N	**Coded and Themed AMS text responses**	

Note. quantitative data are underlined, qualitative datasets bolded.

Integrative Analysis for Motivation Text-Entry in Survey

The data were reviewed to answer the integrative analysis research question: *What is the relationship between how much and how self-determination motivations for science education differ based on STEM career orientation in adolescent undergraduate college students?*

To inspect if the whole group of survey participants contributed to the qualitative findings, the open-ended survey question on motivation of the interview was further investigated. The survey question had asked survey participants to add in their “own words” the answer to the survey prompt “Why do you spend time studying <science>?," with the word science being auto-populated with the subject they answered with in the survey. 225 out of 233 students had entered a response, a high response rate of 97%. The motivational factor codes and the themes derived in the qualitative analysis were applied to the 233 survey text responses as a priori codes. This also added the voice of Non-STEM students–not represented in the interviews–to the qualitative results. The quotes coded to the motivational factors (Table 4-18) were similar to the quotes found in the interviews.

Table 4-18

Representative Quotes for Motivational Factors in Survey

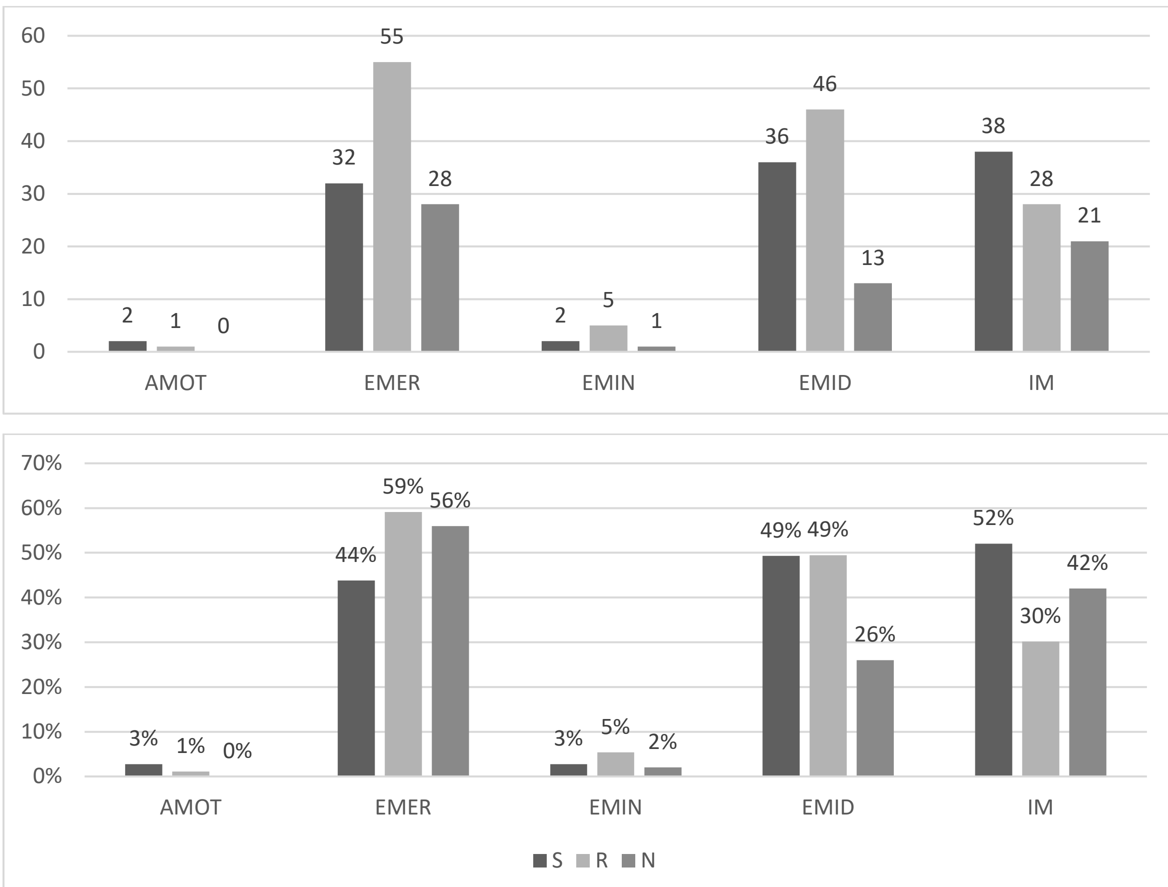
	AMOT
S	"I have a great love for animals and was excited to find there was a major I could study that revolved around them. But as I continue my time in college, I find it hard to stay passionate about my studies."
R	"I don't have time or motivation anymore."
N	N/A
	EMER
S	"Not only is it part of my major requirements, but understanding chemistry will help me with my future job and career goals"
R	"I spend time studying wildlife ecology because I need a degree in a wildlife or natural resources field in order to pursue my future career of being a game warden."
N	"I am fascinated in space, but it's mostly just because I have to finish my generals and get a good grade."
	EMIN
S	"I feel a great sense of satisfaction when I am able to explain why something works or why it is fact."
R	"Honestly I just thought it was cool and I get to talk about some of the stuff I'm learning about with my sister since all [sic] lot of this space stuff is part of her job."
N	"I love doing the experiments every week with my group."
	EMID
S	"I think it is important to understand how our natural systems work and function."
R	"There's so much complexity, and I love the satisfaction of understanding it."
N	"I study because the material interests me."
	IM
S	"Understanding life and interrelatedness of all living things gives meaning to my life."
R	"I enjoy studying the stars, and i [sic] enjoy learning about planets and what caused said planets to form"
N	"I enjoy learning about science, and I love learning more about our solar system and the entities in it."

Note. Survey responses to AMS prompt were coded for the a priori factors. Representative quotes per group are provided.

The relative occurrence of the motivational factors mentioned in this short answer was reviewed. Figure 4-10 displays the numbers and percentage of occurrence for the motivational factors in the open-ended question. The question “Why do you spend time studying science?” was answered as part of the survey by 225 out of 233 participants. The total number of 225 responses is a fairly large dataset to evaluate the relative importance that students gave qualitatively to the factors in the text response. Amotivation (AMOT) was not mentioned often, with two in the S group, one for R, and none in N. Introjected motivation (EMIN) also was rarely mentioned, twice for S, five times in R, and once for N students.

Figure 4-10

Survey Open-Ended Question Coded for AMS Factors



Motivational factors mostly noted in the short answers were EMER, EMID, and IM. R students mentioned externally regulated motivation (EMER) most often (59% of group R), N students slightly less (56% of group N), while S students mentioned EMER the least (44% of S students). Identified motivation (EMID) occurred nearly as frequent with 49% of both S and R students mentioning it, while only about have that many N students (26%) mentioned it. Intrinsic motivation (IM) was mentioned most by S students (52%), less by N (42%), and the least by R (30%). Noteworthy is that many students–at least one third of each group–commented on being motivated by joy or enjoyment, fitting within intrinsic motivation (IM). Given the high response rate of 97% the results were considered representative for the survey participants.

Findings for Themes. The occurrence of the two themes found in the qualitative findings as difference between S and R was investigated in the open-ended survey responses. While the open-ended answers contained the emergent code of *volume of* learning, neither of the two themes surfaced from that emergent code: *struggle over hurdle toward career* and *struggle through conceptual learning* were not visible in the short answers (Table 4-19). Students had answered the AMS prompt question "In your own words, please tell me why you spend time studying <Science Course Subject>?" following 21 AMS 5-point Likert items in the survey.

Table 4-19

Open-Ended Survey Statements coded to Volume of Learning

STEM
"I feel all I have is science and the only thing I can do is push on and get my Biology Associates at NIC and expand my knowledge of our world through the scope of science. I don't mind expanding my scope of knowledge along the way as I have learned so many fascinating things I never would have thought of before.
"I study to be able to do well in my classes but I do enjoy learning difficult topics and pushing myself to do better."
"Because it's a hard class and the satisfaction of doing well in it means a lot to me"
"I want to challenge my intellect"
"I need to spend time studying to find success in the course, and learn the content that doesn't come as easy as just listening to lecture."
STEM-Related
"I suck at studying and learning and I loathe school. I want to get the f... [spelled out] out of this hell hole. Anything is better than school."
"challenges me to see the world differently"
Non-STEM
"interesting and worthwhile, even if it's difficult."
"I did not think it would be as difficult as it is."
"Certain topics are really hard for me to grasp, particularly in chem but regardless I enjoy learning at my own pace."

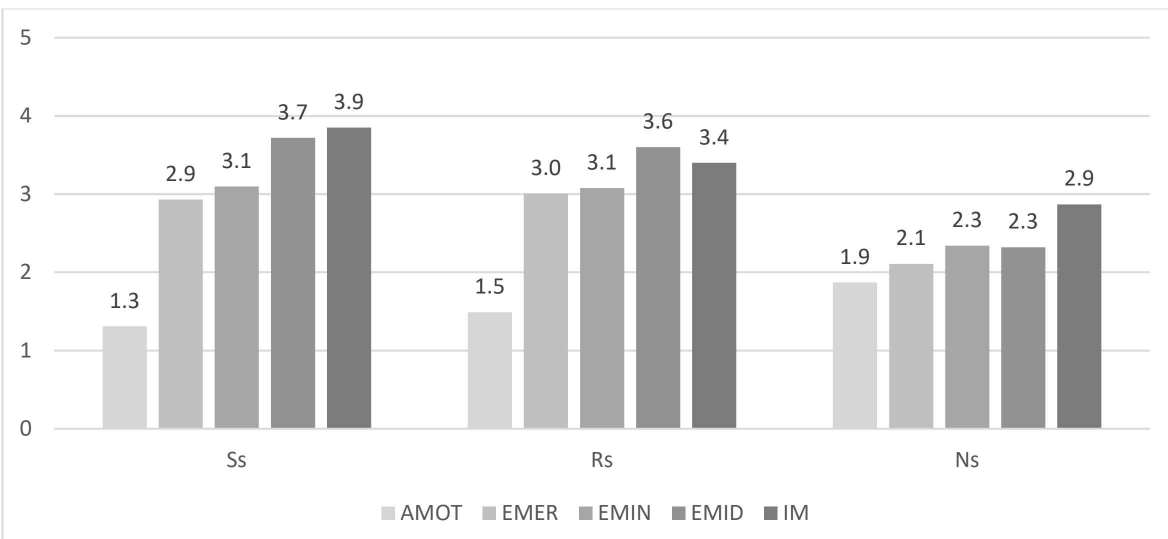
Considering the qualitative findings for both interviews and survey, the themes of S-R differences were not further substantiated, however also not rejected. In the interviews, the themes were derived from passages that were multiple sentences long, thus a short-answer text box may have not provided sufficient space to elicit them.

Integrative Review of Level and Occurrence for Motivational Factors

The results on occurrence of motivational factor codes in the text question was compared with the mean levels of the group. Since both sets of results are derived from the same sample of participants these lend themselves to integrative analysis. The kind of data is different, however. The levels for the AMS factors (Figure 4-11) consider all participants in how they rated the respective factor. The occurrences of the motivational factors (Figure 4-12) represent how many students mentioned them. In combination, they provide insight into the importance of the motivational factors in the students' motivation, since they combine the quantitative level of how much they are perceived to motivate students and the qualitative level of how much they are seen as main motivation for the students.

Figure 4-11

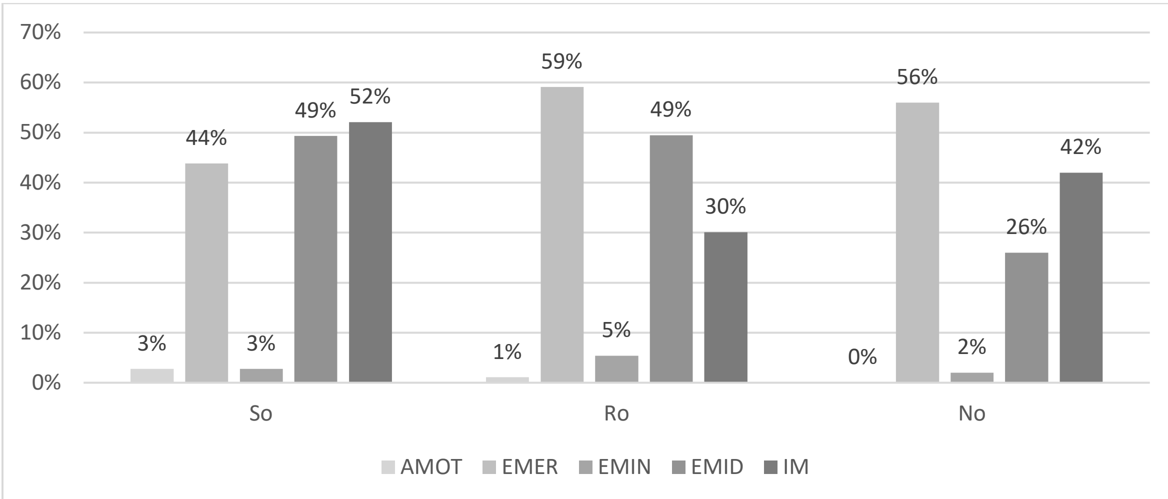
Means for Five AMS Factor Levels, By Groups



Note. The bar graph shows the survey score means of the motivational factors. For example, the mean rating of IM in the AMS survey (s) was 3.9 for the S group. Mean levels for N were slightly higher for EMIN (2.34) than EMID (2.32), not displayed, for reference see Table 4-5, page 68.

Figure 4-12

Percentage for Factors Named in AMS Text Response, By Group



Note. The bar graph depicts the percentage of total survey text responses per group S, R, and N coded to the respective factor. For example, 52% of S students mentioned IM in the open-ended survey question (o). For S, AMOT and EMIN were at the exact same level of 3% of population. Considering both quantitative and qualitative importance, the motivational factors revealing themselves as most important are discussed in the following, beginning with the S group.

For S students, EMER, EMID, and IM are most important from their perspective, intrinsic motivation (IM) most important, competence (EMID) nearly as important, and then external motivation to pass the class (EMER). While people (EMIN) played a role greater than passing the class in the quantitative data, it was barely noted in the text question as what motivated the student. Amotivation played nearly no role for the S students in either data set.

For R students, this looks quite different. The data include more disparities between quantitative and qualitative patterns. Dominating qualitatively is the motivation to pass the class (EMER), even though that factor is rated quantitatively less than the other external motivations and intrinsic motivation. High in both types of data for R students is competence (EMID), which has the highest rating in the quantitative and second-highest in the qualitative data. Intrinsic motivation, which received the second highest rating for the R group–just after competence (EMID)–in the survey, received much less often a mention in the open-ended question, less than both passing (EMER) and competence (EMID). So, while it was rated higher than passing the class quantitatively, it only was half as important qualitatively. Similar to the S group, R students rated people (EMIN) high in the Likert survey but barely mentioned them in the text question. Also, like S, amotivation is not important for R students in either dataset of the survey.

For N students, grades, competence, and intrinsic motivation are most important. Intrinsic motivation is rated highest quantitatively and has the second-most mentions in the open-ended question. Extrinsic motivation of grades was most important qualitatively, while rated second-lowest–just above amotivation–in the quantitative survey. Competence motivation was consistently second most important for both types of data. Again, both amotivation and people motivation was not important qualitatively. However, quantitatively amotivation was rated higher than in the other two groups even though lowest within the group N and people motivation was third highest, so more important than grades. So, while grades and people play a role for level of motivation they overall are not seen as a main motivation compared to the others.

Joint Display of Mixed Methods Study Results

All results of the three phases, quantitative, qualitative, and integrative, are summarized in a joint display (Table 4-20). The survey data—both quantitative and qualitative— were simplified into ranking of importance and presented alongside the themes found in the interviews. Specifically, for the survey data (quant) of each group the motivation with the lowest level rating was ranked 1 while the motivation of the same group with the highest rating was ranked 5. For example, in group S AMOT was lowest (quant 1) and IM was ranked as highest motivation (quant 5). For the survey open-ended question that was analyzed in the integrative phase with qualitative means (qual), the importance rankings from 1 to 5 were kept as presented. The simplifications allow Table 4-20 to effectively show the differences found in this research study between the STEM career orientations S and R and N. Both AMOT and EMIN occurred at the same lowest percentage in the qualitative survey question for group S they were both ranked 1.

The integrated results show that amotivation (AMOT) was not important as motivation for either of the groups, with quantitative differences between N and the other two groups S and R. Grades (EMER) was of highest importance qualitatively for the R group, showing itself in the *struggle over hurdle toward career* theme. It was ranked quantitatively second for all groups, however statistically different in level between N and the other two. People (EMIN) were qualitatively not very important even though level ratings were third highest and even second highest for the group N, matching the statistical difference in level from N to the other two groups. Competence (EMID) was ranked quantitatively and qualitative very high for both S and R, and only ranked medium for both types of data in N, matching the statistical differences from N to the other two groups.

Table 4-20

Joint Display of Differences Between Groups of Career Orientation

	S	**S-to-R**	R	**R-to-N**	N	**N-to-S**
AMOT *amotivation*	Quant 1, qual 1	=	Quant 1, qual 1	≠	Quant 1, qual 1	≠
EMER *grades*	Quant 2, qual 3	=	Quant 2, qual 5 **Theme** *struggle over hurdle toward career*	≠	Quant 2, qual 5	≠
EMIN *people*	Quant 3, qual 1	=	Quant 3, qual 2	≠	Quant 4, qual 2	≠
EMID *competence*	Quant 4, qual 4	=	Quant 5, qual 4	≠	Quant 3, qual 3	≠
EMID & IM	**Theme** *struggle through conceptual learning*					
IM *intrinsic*	Quant 5, qual 5	≠	Quant 4, qual 3	≠	Quant 5, qual 4	≠

Specific to S, competence was linked to the theme of *Struggle Through Conceptual Learning* for S together with intrinsic motivation (IM). For intrinsic motivation there were stark differences in ranking between S and R, with highest rankings for group S, while R ranked it quantitatively second and qualitatively third. This difference matches the statistical difference between S and R for intrinsic motivation, the only significant difference found between two groups.

Notably, the ranking of N students is nearly identical to the S group, with it quantitatively being highest and qualitatively second highest. However, the absolute level of the quantitative mean for the N group is much lower, in line with N being statistically different from S and R for this factor as well. It is to be noted that interviews were not conducted with any students in group N and thus no themes could be derived. It is possible that N contains either or none of the themes found for the other two groups. Overall, statistical differences were found between all three groups and indications and trends of differences were found in the qualitative data and integrative analysis.

Chapter 5: Conclusion

This investigation researched how much and how self-determination motivational factors for science education differ based on STEM career orientation in adolescent undergraduate college students. The results showed differences in levels of motivational factors and the qualitative results added context on how motivations are different for all three groups of STEM career orientation, STEM, STEM-Related, and Non-STEM. This chapter provides discussion and summary of the findings with their relevance for literature and practitioners.

Limitations

This study was designed to gain a basic understanding of if and how groups of students with different STEM career orientations are different in their motivation toward science courses in undergraduate college and was limited due to various factors. The transferability of the participant sample to undergraduate college students necessitated several external validity considerations. The sample population was not randomly selected and is specific to one region in the Inland Northwest. There were multiple layers of non-random participant selection: faculty volunteering to invite students, those students, in turn, volunteered to participate, and out of these participants, a sub-group volunteered to interview. Students invited were enrolled in various types of science subjects and considered a range of STEM careers, creating a complex composition of participants.

While that approach is more likely to be representative of the overall population, it creates complexity and may skew the data in unknown ways. A control population of similar makeup was not considered for this research study. To assess representativeness of the sample, some basic demographic data, including age, gender, and ethnic-racial identification, were collected. As presented in the findings, the gender and ethnic-racial make-up of survey and interview participants was similar to the overall regional population of undergraduate college students. Limitations of the study planned for in methods and limitations that arose during the research investigation were examined in detail. The following sections present the limitations for each study phase beginning with validity and reliability of survey, followed by credibility and trustworthiness of interview, and then inference quality and transferability of the integration.

Validity and Reliability of the Survey Results

The validity of the STEM career orientation group assigned to students was checked with a peer group familiar with STEM occupations. Readability of the adapted survey was tested with high school students in fall of 2021. It took the high school students the predicted estimated time of seven minutes to take the survey. Improvements were made to the language and visual design of the survey directly in response to the feedback by the high school students to maximize response validity.

Confirmatory factor analysis (CFA) was performed to test the reliability of the survey instrument (Jöreskog, 1969) to determine if the items assigned to the same motivational sub-dimension load together and thereby indeed measure the same latent variable, thus providing construct validity. To review internal consistency and reliability of the AMS instrument, Cronbach's alpha (Cronbach, 1951) was calculated for the survey results. The internal consistency index Cronbach alpha was shown to be .87 for the overall scale of 21 items, and for each factor score the Cronbach alpha was above .8, which is considered good reliability as per Cohen, thus confirming the reliability of the AMS instrument for the sample in this study.

To control for that Type I validity error, both multivariate analysis and univariate testing for differences was applied. Multivariate MANOVA and their non-parametric equivalents were used to test for difference between the STEM career orientation groups S, R, and N for the combined motivational factors. MANOVA analyzes results with the assumption that the variables may be related and influence each other (Tabachnick & Fidell, 2018). Where a significant difference between groups was found, post-hoc tests confirmed which factor contributed to in the univariate tests. The conservative Bonferroni correction and its non-parametric equivalent was applied to the post-hoc univariate results of significance. The Bonferroni correction adjusts significance found in the univariate tests based on the number of groups and factors in the multivariate test to minimize Type I error.

Normality of the dataset of each of the motivational factors per each STEM career orientation group is another concern for the validity of the found significance of difference. Significance found in surveys with a validated instruments are not considered strictly valid when the variable behaves non-normal (Tabachnick & Fidell, 2018). Thereby, investigation of normality in this study was conducted with several methods and presented fully to provide transparency. Three out of five variables did not meet the normality of variance assumption in terms of skewness and kurtosis, the reason for which may lie in the relatively small dataset of 235 cases. Histograms with normal curve, bar graphs, and sample plots added visual insight into the level of normality to provide insight into the significance and distribution of differences to the reader. The results thereby are presented with a note detailing if they were derived with parametric or non-parametric means.

Interview Credibility and Trustworthiness of the Interview Findings

Establishing the quality of the interview phase meant addressing the credibility of the data and the trustworthiness of the findings (DeCuir-Gunby & Schutz, 2017). To manage quality of findings this study implemented several strategies recommended (Creswell & Clark, 2017), peer-examination, saturation, and triangulation. Member-checking with participants—also recommended—was not conducted due to time constraints. Peer-examination was conducted for codes and the overall findings by viewing of transcripts and discussing respective findings with a peer researcher in multiple sessions as analysis progressed. Only findings of codes and themes that reached saturation within their respective STEM career orientation groups are presented as outcomes assuring credibility of data that lead to findings. The transparent presentation of the detailed methods and analysis in combination with triangulation of the data in the integrative phase provides trustworthiness. Additionally considered was that especially for qualitative methods, philosophy is important to consider as influencing factor (Patton, 1999). The researcher's epistemology of Critical Realism values both empirical and qualitative methods and thus no bias toward one method over the other was present. Rather, the belief for a need of integration between the strata and findings where possible drove the recursive integrative analysis manifesting substantial triangulation as part of the investigative process.

The interview text used for coding was authentic and comprehensive in its content due to the following credibility considerations. All interviewees were engaged in the interview for the whole hour, and all reflected at the end that it was a positive or at least not negative experience. Most interviewees commented that they had learned something about themselves in the interview that was meaningful for them. Some students reflected that it was much more enjoyable than they had expected. The researcher noted that the regular mirroring of the student's own words and phrases with a request for follow-up lead at times to the interviewees adding additional depth and reflection, while other times the interviewees repeated themselves and conveyed a sense of not being sure what to add, thus demonstrating that what they had said was all they could think of to add. The latter also showed that interviewees felt sufficiently comfortable to express their feelings of being unsure as they were very outspoken about not knowing more and or feeling unsure.

Prolonged engagement added credibility to the findings. Several themes were considered by the researcher in the last phase of analysis but dropped due to only being genuine to one or two students. Final themes were representative of multiple students of the respective groups, and patterns of its elements could be seen across the group while it was not visible as a theme in the other group. The researcher spent extended time on coding and theming, reviewing the data set at least two times for coding and multiple times for theming.

Only codes and themes reflective of a group with saturation were included in the final findings. Since only a sub-group of students contributed to most codes and themes in significant ways, the findings are described as themes per group. This limits the noteworthiness of the findings. On the other hand, the extensive number of interviews, with more than ten per group S and R substantiates the likelihood of the themes to be findable in the general undergraduate college student population enrolled in science courses.

Inference Quality and Transferability

In addition to considerations of validity and reliability in the study's methods and analysis of the quantitative and qualitative phase, this mixed method study was conducted with concern for inference quality and transferability of the whole study. Inference quality describes the overall internal validity and trustworthiness of a mixed methods research study and its results, while inference transferability addresses the ability to transfer the study's results to people or circumstances outside of the study (Teddlie & Tashakkori, 2009). Internal validity is assured by the various steps to maximize validity and credibility taken in the quantitative and then qualitative phase of the research study. Consistency of research process provides legitimation to mixed methods studies (Onwuegbuzie & Johnson, 2006). Consideration of trustworthiness and reliability of the findings indicate transferability. These considerations were taken into account throughout design and conduct of this mixed methods study.

The researcher considered that the investigation *may have been potentially influenced* by the impacts of the COVID-19 epidemic due to the timing of the study; however, no specific indications were found by the researcher. Surveys were conducted in Fall 2021, and the interviews were concluded in Spring 2022. No findings of the study were found to be linked to the COVID-19 pandemic, and no responses in the survey or interview indicated limiting the generalizability of the findings due to the timing of the study.

Multiple integrative analysis steps contributed and explored the transferability of the study. This research study was written with intentional transparency to allow the reader to follow the phases and reasoning throughout, providing high inference quality. The methods, analysis, and results were kept with high consistency to the same research question–differences between groups for five specific motivational factors of the Self-Determination Theory–while the type of analysis was varied in alignment with the type of data and how they were gathered, constituting a high level of legitimation. The integrative analysis of the open-ended AMS text question in the survey revealed an aspect of the motivational factors, the relative importance. The importance of the motivational factors for students substantiated several of the quantitative results and qualitative findings. It provided interpretative connection between the two datasets. Overall, the interconnection between the different types of findings increases the likelihood that the findings are transferable to other undergraduate students of the Inland Northwest enrolled in science courses in general.

Discussion of Survey Results

The survey generally behaved in line with the instrument used by Lim and Chapman (2015) as the following details matching that instrument show. The Academic Motivation Scale (AMS) dataset fit best with the five-factor model of the instrument. AMOT correlated negatively with all other factors, understandable by the nature of the question asking for lack of motivation rather than for presence as did the remainder of the items in the survey. The intrinsic motivation items consisting of item questions adapted from the sub-constructs to accomplish, to know, and to stimulate (Vallerand et al., 1992) correlated highly and behaved as one factor. This was predicted based on these intrinsic items collapsing into a single factor in multiple previous studies (Cokley, 2000; Lim & Chapman, 2015). Factor loadings of the items on their respective construct also was in line with the instrument (Table 5-1).

Table 5-1

Factor Loading Comparison to Instrument

Factors	AMOT	EMER	EMIN	EMID	IM
Survey Factor Loadings	.63 - .87	.69 - .91	.72 - .83	.75 - .91	.66 - .88
Instrument Factor Loadings	.78 - .84	.73 - .86	.72 - .79	.71 - .81	.77 - .87

Note. The range of correlations for factors to their items are displayed for both the survey used in the present study and the instrument (Lim & Chapman, 2015), which the survey was based on.

Amotivation Outliers and Simplex Pattern

Unlike the instrument, AMOT scores had a significant amount of outliers and did not fit the normal distribution well. This may be due to the relatively small number of participants. There are different perspectives on how to view normality and outliers and when parametric methods are appropriate. While some authors suggest considering numerical cut-offs (Abu-Bader, 2010), other authors encourage visual inspection and suggest that outliers can be left in the dataset if shown to be plausible data entries (Tabachnick & Fidell, 2018). This research study took these considerations into account and provided transparency on respective decisions. The outlier data considered true outliers were all in the AMOT variable. One consideration for non-normality—or outlier behavior—in behavioral science is the concern that the items belonging to their respective factors may not have been sufficiently adapted to assure that the participants interpret items of the same factor as statements of the same conceptual construct. Only when Likert-scale statements are understand as the same construct is the respective factor dataset expected to be normally distributed. The non-normal distribution of AMOT with the substantial amount of outliers indicates that it needs to be reviewed if the statements are part of one AMOT construct.

The simplex pattern of the continuum of the Self-Determination Theory was visible in the factor analysis, as proposed (Lim & Chapman, 2015). The simplex pattern predicts that factors next to each other are expected to be highly correlated, which was found to be true in other studies applying the Academic Motivation Scale for science subjects In the present study, this pattern is generally visible for all but AMOT, other than a slight deviation for EMER. EMER is correlated higher to EMID (r = .62) than its continuum neighbor EMIN (r = .58). For the other non-AMOT factors the simplex pattern holds true in this study. While factors close to each other are expected to be highly correlated, they are not expected to be so extremely correlated that they collapse into one combined factor. While EMID is correlated at the highest value of correlations amongst the factors with EMIN at .73 and IM at .71, they are still below the threshold of .8. For AMOT, the opposite of the simplex pattern is the case. The further away the other factors on the continuum, the higher is the absolute value of the correlation, explainable by AMOT assessing motivation reversely. This simplex pattern review confirms that all factor—other than Amotivation—are related while separate constructs as expected. So, the motivational constructs of the Self-Determination Theory are appropriately considered sub-constructs of a bigger overall construct, motivation. AMOT is inversely correlated to the other motivational factors, thereby it can be considered part of the overall construct motivation while it is a reverse sub-construct in line with the items being of reverse nature.

The behavior of the factors in this study fits with related publications. Amotivation (AMOT) plays a unique role in the AMS survey. It had the most outliers, was most non-normal, did not show the simplex pattern, and was negatively correlated with the other factors. Similar studies have found this for AMOT as well (Lim & Chapman, 2015; Y. Liu et al., 2017), even though the bigger the dataset the less non-normal the factor behaved. Vallerand, who created the AMS survey (Vallerand et al., 1989) intended for the AMS scores to be summed into a total score of self-determination per survey participant. So possibly, the fact that AMOT typically is not reverse coded is a historical artefact. Typically, questions formulated reversely in surveys are also coded reversely (Dillman et al., 2014). The results of this study in context with related studies indicate that Amotivation may need to be reverse-coded when factor modeling. Further investigation of AMOT in the context of Academic Motivation Scale analysis is needed to test alternative methods such as reverse coding.

Motivation Differences Between Groups

Significant differences were found in intrinsic motivation between students geared toward science and engineering careers (STEM) compared to other STEM careers (STEM-related), not investigated by previous publications. Also different between the two groups STEM and STEM-related, the most relevant motivation for students geared toward STEM-Related careers was the motivation to be competent (EMID), highest in level and second-highest in relative importance after the motivation to complete the class. In contrast to that, STEM students' motivations were higher and more important for the group, the more self-determined the motivation is on the continuum, with the exception of motivation by people (EMIN) barely mentioned in the open-ended survey. Thus, motivation-supportive learning design for STEM students needs to consider that the group of students interested in STEM careers contains these two groups with their very different motivational disposition (STEM and STEM-Related).

In the literature, differences in motivation have been found between students of STEM majors compared to the ones enrolled in non-STEM majors (Dyrberg & Holmegaard, 2019), however the difference within students enrolled in STEM majors, those geared toward STEM and those geared toward STEM-Related careers has not been shown before to the best knowledge of the author of this study. It is to be noted that science major is not the same as science career orientation. Several interviewees enrolled in a biology major were not interested in a career in biology (STEM), but medicine (STEM-Related). Also, enrollment in a STEM major and STEM career orientation are not the same construct. Career orientation captures the current students' disposition while the major is only an approximate career goal at time of enrollment in the semester. Several interviewees reported being enrolled in a science major while having changed their career orientation away from science or a related career and the other way round. Thereby, the variable of STEM career orientation established in this study provides a timely insight into the students' career trajectory in line with the nature of the motivational constructs used in this study. Research studies on motivation in undergraduate students—including those using Self-Determination Theory—use typically less timely measures of career trajectory disposition such as majors.

Non-STEM students have distinctly different motivation from the other two groups, even though they share some profile similarity with science and engineering geared students (STEM). Significant differences were found for all motivational factors between non-STEM students and other students

(STEM and STEM-Related) in terms of level. Students not interested in STEM careers at all (non-STEM) had a motivational profile similar to students geared toward science and engineering careers (STEM), in terms of relative levels of motivations. While their overall levels of motivations were not as high, the relative levels were similar, with intrinsic motivation being the highest motivation. The more extrinsic the motivational factor on the Self-Determination Theory continuum, the lower the level of motivation for both groups (STEM and Non-STEM). While the absolute level of intrinsic motivation for non-STEM students was at a medium at just under three on the five-point Likert scale, intrinsic motivation (IM) was at the highest level of all motivational factors for the group and the second most important just after completing the course. Joy of learning science was clearly the highest motivation overall for non-STEM students, a possibly surprising result, given that typically in the literature students not interested in STEM careers are discussed as not being motivated to learn STEM.

There are no qualitative studies of big groups that the researcher could find that show how important intrinsic motivation is to the students not interested in STEM careers in comparison with other groups. While the literature showed that motivation fluctuated and may remain high for some students not interested in STEM careers, this clear evidence of interest in a compulsory science course in college is surprising and bears further investigation. This can likely be attributed to most studies researching motivation toward science education with the view that motivation to learn science is in line with being interested in STEM careers, only looking to understand how a loss of motivation leads to the loss of students in STEM career pathways. The closer look provided in this study reveals that while their motivation may be lower compared to other students, their motivation to learn is driven by the joy of learning science. Further studies are needed to understand what the combination of low level while high importance of intrinsic science motivation means for the opportunity to engage these students in building STEM proficiency for non-STEM careers and life-long science citizen literacy.

Open-Ended Question Adds Methodological Value of Motivational Importance

Voice of the adolescent undergraduate students for motivational factors of the Self-Determination Theory was added into the survey with an open-ended question. The original intent of the researcher was to provide validation to individual survey responses as needed, for example used in the ungroups scan for outliers. Given the plan to apply thematic coding of the motivational factors to interviews, the researcher also applied that method to the open-ended survey question, yielding findings on relative importance of motivation to participants of the study. While many studies, when developing instruments, first interview students in order to elicit the questions to ask in the surveys, few of those qualitative findings are published. This present study—utilizing an instrument prompt as open-ended question—contributes to the qualitative understanding of SDT motivational factors in science education for college undergraduate students.

The author only found one published study, where a thematic analysis of an open-ended question was utilized to add meaning to a survey of self-determination motivation (Dyrberg & Holmegaard, 2019). The respective publication surveyed the constructs of autonomous and controlled motivation—intrinsic motivation versus extrinsic motivation—however unlike this study, the open-ended question was formulated to invite comments and not a repetition of the survey prompt. Similar to the present study, the authors found that adding a short open-ended question to a motivational survey that is thematically analyzed substantially contributed to their findings, one of which was that STEM undergraduate college course are not sufficiently relevant to students.

Motivational Importance. Coding the open-ended question yielded one or two motivations that participants noted as their motivation toward science in the short text response box. This led the researcher to categorize these as motivational importance, in contrast to motivational levels in the AMS Likert scale responses. The author of this study has not found publications doing similar interpretation of short open-ended survey questions. Given that the respondents mention of AMS codes in open-ended question of the survey did not mirror the levels they scored in the survey surfaces how numerical survey questions do not measure the same as a qualitative question. When doing side-by-side comparison between numerical and qualitative responses to the AMS prompt, it became clear to the author that the open-ended question does not simply capture the one or two motivations that the respondent felt were highest in a qualitative sense. Rather, the respondents seemed to elevate what they felt was most important to say. This resulted in describing the results of this analysis as motivational importance.

Discussion of Interview Results

The study found that students *struggle with volume of learning* differently, depending on their career orientation. The two themes found include several aspects of difference. Students oriented toward STEM careers (S) described the difficulty of motivating to in-depth concept learning, while students interested in STEM-Related (R) careers described learning of facts to pass the class. This evidences different levels of cognitive engagement, as described by Bloom's taxonomy. Students of group R recounted learning at the knowledge level and S students described learning at the conceptual synthesis level (Bloom, 1956; Krathwohl, 2002). Hofer found two different epistemological ways of seeing the nature of knowledge (Hofer, 2000). In their research, first year college students viewed knowledge in natural science as fluid body of concepts while they saw social science with as a fixed set of facts. While the grouping for this research was a bit different, it contains the same two nature of knowledge descriptions for science found in this research study.

Struggle Through Conceptual Learning Theme Describes Systemizing

The descriptions of the theme *volume of learning struggle through conceptual learning* describe learning by pulling apart concepts and assembling. Concepts were described as "building blocks" that make up science knowledge, alongside a strong internal drive to understand how the natural world works. The drive to understand could also be described as systemizing. Studies have found a link between systemizing and motivation when learning science (Focquaert et al., 2007; Zeyer & Wolf, 2010). Systemizing describes the drive to analyze the natural world systems to comprehend how they operate. It is unclear how the strand of literature on systemizing and empathizing cognitive types that arose out of autism research (Baron-Cohen, 2009) is linked to the present study. The descriptions of the *systemizing cognitive type* of students matches the findings of this study for the theme *volume of learning struggle through conceptual learning.*

Systemizing has been found to be more prevalent in males while empathizing cognitive traits are more often dominant in women (Focquaert et al., 2007). Interestingly, in a study on Social-Cognitive Theory motivation factors, systemizing was found to directly influence motivation while gender only had an indirect impact on motivation (Zeyer, 2018). This suggests that differences between groups in how student are motivated to learn science may also be linked to differences in cognitive processing; possibly more directly than gender. Some authors caution that this research on cognitive types is not based in neurobiological research (C.-J. Liu & Chiang, 2014), which emphasizes that the cognitive types described here are social science constructs and not biological phenotypes of the brain. Overall, the theme found specific to S, *struggle through conceptual learning* further contributes to the literature on cognitive trait differences in science motivation. Research is needed to clarify the link between cognitive types and their neurobiology to the Self-Determination Theory motivational factors, not yet specifically investigated in this context.

Hurdle Toward Career Theme Explicates STEM-Related Group

The qualitative them of *volume of learning struggle over hurdle toward career* adds explanation to the differences found in the survey. The narratives on completing the courses to get to the next step in the career explains both the overall high motivation compared to the students oriented toward science and engineering careers (STEM) and most importantly it explicates the high extrinsic motivation and significant different of intrinsic motivation to the STEM students. Curious is that the highest level of motivation of the students geared toward STEM-Related careers was the motivation to be competent

(EMID). Competence (EMID) also was second highest motivation after external extrinsic motivation in the open-ended question. This is in line with the narratives of the students emphasizing how they are motivated to learn for their career.

The drive to learn to be competent for the career being extremely high is in stark contrast with the narratives that STEM-Related students do not see the science course as very relevant to their career even though for medical students these courses are required as critical learning for their career. Reviewing the literature, the author of this study was not able to find research on motivation toward undergraduate science courses specific to students interested in STEM-related careers or specific to medical students. While there are recent publications on motivation for medical students (Holland, 2016; Pelaccia & Viau, 2017; G. C. Williams et al., 1999), no studies specific to motivation toward science courses for medical students were found. Generally, the literature on motivation of medical students grounded in theory is limited (Kusurkar, 2012). Further research is needed to better understand how STEM-Related students are motivated and how science education can support these students in their high motivation toward becoming competent for their careers.

Students with Science Subject Orientation Show Protean Career Orientation

Many students listed subjects as a career and several students commented that they do not know what occupations are available other than going into academia or becoming a researcher. This is surprising given the many initiatives to get students into the STEM workforce. It is also a reminder that colleges may need to offer more opportunities to their students to understand the job market with its many careers. Interviewees in this study often expressed that they wished to know more about what careers await them after completing their college degrees. Interestingly, less than half of the students completing a STEM degree enter a STEM career and vice versa (US Census Bureau, 2014), evidencing high fluctuation onto and off the STEM career pathway. It is unclear if that change in career trajectory is related to declined motivation toward science education at completion of a STEM degree or students' lack of career information. The present study found indications for both.

First, low motivation toward science education was visible in survey and interview. The STEM oriented groups (STEM and STEM-Related) included amotivation outliers, students with no motivation toward engaging in science education. Also in interviews students from these groups expressed a high level of frustration with their motivation to engage in science learning. Second, many interviewees of the science and engineering oriented group (STEM) talked about not having sufficient information about STEM careers or intentionally not committing to a specific career yet. Future research is needed to investigate how level of career information informs motivation to engage in science for the different STEM career orientation groups of students. Similar to secondary education, colleges are degree-driven and career-education is not a core goal, voiced as a contributing factor by interviewees as to why students did not list a specific career, but rather a degree subject when asked about a career. Thus, the system of college itself may not sufficiently inform about career outcomes for their degree programs. Inadvertently, this also lowers career relevance, impacting career competency motivation (EMID) shown in this study as one of the key motivations for all groups in level and importance.

Addressing the main research question, if career orientation impacts science motivation, the current study found a link between motivation and students' career orientation. Several interviews included commentary of students shifting in their thoughts on future career. Additionally, a substantial number of students identified a subject area and not wanting to commit to a specific career occupation or were not aware of options. This evidences that more information for potential careers could be of interest to college students. On the other hand, some students were very committed to the subject and trusting that careers will arise for them. This is a stance considered a protean view of career orientation, a perspective more recently found in the literature and found especially in college students. The science subject orientation fits with this protean description of career orientation.

Provision of any career information provided to adolescents thereby would need to be aligned with this protean stance in order to be motivational. Considering the high need of employees especially in the technical STEM workforce, it is important to not assume that students want to be educated about available careers nor are they driven by the need of the workforce market or setting career goals. Many students in the STEM group talked about their connection to earth, nature, and their interest in protecting the natural environment. Any workforce recruitment effort would need to consider these interests of students currently in college. One systematic investigation of the research literature on career orientation and career attitudes showed that most studies view career orientation and motivational factors as precedent to career development and self-management, which is comprised of behaviors and attitudes that ultimately may lead to career outcomes (Hirschi & Koen, 2021). Figure 5-1 (adapted from Hirschi & Koen, 2021) shows career orientation in response to motivational factors. In this model it is defied as the current view a person has toward career, possibly leading into career self-management and related outcomes. This model may be useful when considering motivation to learn science since it depicts STEM career orientation as influencing motivation while motivation also influences the STEM career orientation.

Figure 5-1

Career Orientation Relative to Career Attitudes and Outcomes

Discussion of Integrated Analysis Outcomes

The integrative analysis, including the analysis of the survey text question discussed as part of the survey results in this chapter, provided substantial results by adding qualitative outcomes for all three STEM career orientation groups. Integration in mixed methods can be conducted in the integration stage after the two research phases are completed (Ivankova et al., 2006; Onwuegbuzie & Teddlie, 2003). While the author considered the integrative analysis as a final stage of integrating the results of the previous phases, this particular study applied coding method from the second phase to text contained in the first phase. This added not just integration, but a third dataset to the study. This integrative stage can be viewed as phase in its own right since it involved a complete research step of applying a method to data to reveal findings that could not be seen prior. Retrospectively viewed, an integrative phase where the method as outcome of the second phase is applied to data of the first could contributed to the mixed methods literature, providing a publication example for this type of explanatory sequential mixed methods study with a recursive integration phase.

Double-Mixed Methods Design

The study was a double-mixed methods explanatory design with integrative stage. The interview phase similarly to the survey phase included mixed methods, combining a verbal assessment of the ASM motivational factors on a five-point Likert scale with the remaining interview questions. The researcher included the verbal rating of motivations to be able to follow up appropriately with questions on the motivational factors of the interview participants. It was further used to validate the interview responses. The integration stage has been described in the literature as one of many appropriate ways of adding value to a mixed methods study (Ivankova et al., 2006; Onwuegbuzie & Teddlie, 2003), it followed the interview phase. Due to the complex design of this explanatory sequential design, the integration stage was substantial. The combination of the survey that included mixed methods, the a mixed methods interview phase, and the final extensive integrative stage, the overall study was an explanatory sequential mixed methods study that sequenced two mixed methods phases in mixed sequence.

The complex design provided substantial insight into the complexity of motivation while highlighting specific mechanisms. The ability of the researcher to gain insight into specific motivations with all methods applied for one specific sample population added substantial value to the research. For example, intrinsic motivation for students geared toward science and engineering careers (STEM) was highest in level as well as importance and showed up in the interviews as patient narrative on being driven to learn even in situations during which they struggled with the amount of learning that was expected. This is an example where the multi-method design provided cross-validation between the methods while highlighting the different methodologies involved. The quantitative survey provided numerical level, the survey text question added ranking of importance, the AMS interview rating assessed individuals numerically, and the interview narratives contextualized all these data with rich authentic descriptions.

Philosophy-Driven Analysis

Overall, the complexity of the design was in line with the epistemological philosophy. The integration of all findings from the different phases focused on three sets of data, the quantitative and qualitative findings of the survey phase and the qualitative findings of the interview phase. The integration was partially driven by the researcher's view that the different methods reveal information at different levels about reality, from individual accounts of perception to empirical representation of quantified feedback of whole groups. Critical realism describes these layers as different strata, the real, the actual, and the empirical (de Souza, 2014). The empirical layer describes what we observe and where experimental research allows us to draw theoretical conclusions. The actual layer encompasses our lived experiences of what actually happens in relation to us as individuals regardless of our observation. The real is the combined totally of structures or mechanisms that make up the world, the reality. Thus, the outcomes of the different research methods were seen as different layers of insight into the same phenomenon of the real, the motivation to engage in science in undergraduate college courses as a real mechanism for humans while also being an experienced actuality for individual humans. The dedication to transparency and giving each method equal value in this research study in combination with the belief that only the integration of results can allow us to get a multidimensional view onto motivation led to a very complex, while illustrative study.

Implications for Literature and Future Research

The findings in this study suggest that the three STEM career orientations investigated have distinctly different motivation toward science education, both quantitatively and qualitatively. While motivation has been researched for different science majors, the approach to differentiate motivation by STEM career orientation for two STEM career clusters, a narrow (STEM) and a broad (STEM-Related) definition, is novel and has surfaced differences not previously found. The methodology employed provided insights into difference of levels of motivation between groups, relative levels of SDT motivations within groups, motivational importance, and thick narratives on motivation. The combination of these different layers of viewing motivation added substantial value to how the specific motivations of the Self-Determination Theory operationalize in the three groups of STEM career orientation.

The two STEM Groups Operationalize Motivation Significantly Different

STEM-Related Students appear to be unique in their motivation. The results indicate a clear difference between STEM and STEM-Related students in their motivation toward science education in level of intrinsic motivation and in how they are motivated. STEM students are motivated to learn scientific concepts while students with STEM-Related career orientation were motivated to complete the courses. Also, the motivational profiles in how self-determined these students are in their motivation sub-constructs relative to each other were very different. This research study's portrait of these two types of STEM students enrolled in STEM majors is noteworthy. The presence of two distinct types of students in science courses is relevant both for research on motivation for students on STEM pathways as well as for instructional design for science classes. Included in the STEM-Related group were students geared toward medical careers, aspiring future physicians and veterinarians. Future research will need to further investigate the motivational differences within students interested in STEM careers (STEM and STEM-Related). Also, how specific the findings are to medical students versus other students needs to be clarified.

Career orientation and major are not the same construct. The difference in intrinsic motivation between students geared toward science and engineering careers and those completing an undergraduate degree in science to prepare for medical school to become a physician or veterinarian or other STEM-related careers shows clearly that major and career orientation are not the same construct. While all STEM majors are preparing for STEM careers, the two STEM career orientation groups investigated in this study with both survey and interview have substantially different motivational profiles, a grouping difference not visible when just viewing the major. Future studies need to consider this difference when investigating motivation toward science education.

Not Interested in STEM Career Does not Equal Not Motivated to Learn Science

Students not interested in STEM careers are mostly motivated intrinsically. Even though more non-STEM students named external motivation as motivation to learn science in the open-ended question, the second most named motivation was intrinsic motivation. Most importantly, in the AMS survey intrinsic motivation was the highest for the group. Together, this clearly indicates that students not interested in STEM careers are interested in learning science and that at the highest level of self-determination, intrinsic motivation. The total levels of motivation were lower than for the other groups, which is in line with the group not geared toward respective careers. Yet, when considering science courses in undergraduate college classes as contributing to science becoming a foundational subject, it is remarkable that this group of students is mostly motivated to learn science by that being a joyful experience. Self-Determination Research with its continuum of motivational factors provides a mechanism that allow for these types of findings, relative type of motivation. These findings of students not oriented toward STEM careers being mostly intrinsically motivated need to be further substantiated and explored.

Expanding, Investigating, and Mining the Resulting Datasets

Additional statistical analyses are possible and may be of interest to perform in the future. The dataset of 233 complete AMS survey items provides the opportunity to look for differences in the motivational factors between gender. Several of the quantitative differences between groups were established with non-parametric methods. Extension of the dataset by asking the participating faculty to invite this year’s science course students to take the survey would add numbers to the data sample that are likely leading to produce a total dataset with more normal motivational factors. This would allow for validation or discard of the present findings. Future interviews with students not interested in STEM careers could gather qualitative explanation how their motivation toward science learning is different from other student groups. Additionally, reverse coding AMOT may provide more useful data than the current practice of leaving AMOT negatively correlated to the other factors. Since the dataset gathered the responses to what students thought of as careers, the data can also be analyzed using different STEM categorizations. The present interview transcripts comprised of 110 hours of interview recording per group S and R were rich in descriptions with practical recommendations for learning design in relation to the specific motivational factors. These voices can be organized into a practical guide for instructors.

Cluster Analysis to View Motivational Profiles. Cluster analysis (Dillon & Stolk, 2012; Osborne et al., 2003; Potvin & Hasni, 2014b; Vedder-Weiss & Fortus, 2011) can be used with datasets of motivational factors to identify how many and what motivational profiles exist. To date, there are no studies applying cluster analysis to SDT motivational factors for postsecondary students in science courses. While this approach to viewing motivation via motivational profiles has been applied in physical education (Ullrich-French & Cox, 2009), only a few studies in STEM education investigated motivational profiles via cluster analysis (Dillon & Stolk, 2012; Ng et al., 2016). In both fields, cluster analysis has yielded useful results to better understand how motivation operationalizes in the classroom and provided tools for instructors to gauge the motivational levels of their students. The resulting profiles could also be related to career orientation to provide validity of the motivational constructs and relationships found in this study.

Survey Method Assessing Motivational Levels and Importance

This research study modified the AMS survey to assess motivation toward science education in undergraduate college students and added an assessment of qualitative importance. The combination of a survey measuring multiple sub-constructs of motivation quantitively while gathering qualitative data on motivation via text response utilizing the same prompt question is a novel method. The author of this research study was not able to find other studies that utilized this approach. The specific interpretation of motivational importance, numerically evaluating the frequencies of the same motivational factors assessed in the Likert-scale survey also was a new approach, for which the author did not find a precedent. This method was possible due to the Self-Determination Theory containing multiple sub-constructs. The arrangement of these sub-constructs on a continuum made it possible to visualize the results as bar graphs along this continuum for both levels of the motivation sub-constructs and their motivational importance. This specific survey method is a convergent mixed methods design (Creswell & Clark, 2017; Teddlie & Tashakkori, 2009) that combines both data intake phases within one survey. The method can be applied to investigate differences of motivation based on any independent variable, such as STEM career orientation in this study. Future research applying this method will provide more insight into the concept of motivational importance defined in this study specific to this method.

Amotivation Deviates From the Norm

The AMS instrument is adapted in various countries and some inconsistencies have been noted between the countries possibly due to translation of words but not concepts. When applying factor analysis to the AMS instrument it may be more appropriate to reverse code the amotivation (AMOT) items. Since amotivation (AMOT) assesses lack of motivation, the construct may simply represent the inverse of positive motivation assessed by the other motivations in this study (EMER, EMIN, EMID, IM). Future research with the AMS instrument could assess this numerically. Within Self-Determination Theory research, scales are available to assess negative and positive motivations for each of the motivation sub-constructs. A combination of those scales that include motivation-frustration and motivation-support with the AMS instrument would clarify the role of amotivation and how much it is just the equivalent of motivation-frustrations. The assessment of amotivation due to its non-normal behavior did not add much to the understanding of motivation in the present study. Since amotivation is defined as complete absence of motivation (E. Deci & Ryan, 1985), assessment via Likert scale of motivation needs to be considered as possibly inappropriate for the construct amotivation. Limiting a possible response in a survey for amotivation items to yes or no may be more appropriate. Future survey research is needed to investigate these suggested changes in AMS survey practice.

In summary, this study, for the first time, provides a nuanced view into the relative importance of different motivations at play for science undergraduate courses of three STEM career orientations by combining quantitative levels with qualitative relevance and descriptions. This study provides a new look into the complex cognitive process of how motivation operationalizes for students. It also contributes to mixed methods research by providing an example of the multi-layered mixed methods design and the integration of results becoming an extended stage after completion of the second stage research phase, where qualitative results of the second phase are woven back into the first phase to produce additional outcomes.

Recommendations

Application for SDT Motivation Survey Assessing Both Levels and Importance

Science instructors can assess the motivational make-up of their course to be able to strengthen how motivation-supportive it is for the students. The survey utilized in this study, taking only seven minutes to complete, provided significant insight on the motivational make-up of the participants in this study. While this study conducted extended statistical analysis of the survey, this is not necessary to gain transparent insight into the motivational composition of a science classroom. The quantitative survey results can be evaluated by the instructor by averaging all data per motivational factor. Additionally, the instructor then can review the short text responses to note which of the constructs the responses fit with by using the survey items, organized by factor, as a priori codes. Two bar graphs showing a) the quantitative average levels and b) the percentage that participants selected a motivation for all five SDT motivations as the five bars of the two graphs will provide a clear visual of the course participants' motivational make-up.

An added question for students to identify a tentative career or additional questions would allow the instructor to split the dataset to gain motivational insight into the respective sub-groups and provide motivation-differentiated instruction. When doing this step, it is important to not label students to the groups but rather think of the groupings as current course composition with students that may well change the group they are in without the instructor knowing. Applying the insights and recommendations of this thesis and motivation literature, the survey results then can be utilized to more intentionally support students' motivation.

Students with STEM-Related Career Goals Need More Motivation-Support

The relative lack of intrinsic motivation by the students with STEM-Related career orientation is noteworthy. Included in the group of STEM-Related students were a substantial number of students planning on medical school. Especially when considering that medical students are future physicians providing health care in society, the lack of joy when learning science is concerning. Science courses are foundational to understanding medicine. For example, the two subjects chemistry and biology provide scientific understanding for the biochemistry of humans, the chemistry of medications, the physiology of organs, while providing an evolutionary context for the development of the human body relative to other organism used abundantly in medical research. In-depth engagement in specific basic science concepts without practical application—while relevant to students geared toward STEM careers—may not be appropriate as a core focus for the STEM-Related students that are motivated to relate those concepts.

Instructors of undergraduate science courses that include medical students have a consequential opportunity to support their self-determined motivation by making their courses more directly relevant to medical students. For example, the assessment of learning could be adjusted to the strong focus on passing tests shown in the interviews of this study. Combining exams to test the required learning that is graded with pass/fail mandatory assignments for which students choose their science engagement that focus on applications relevant to their future career could be more adequate to these students. A minor shift in how the learning material is assessed and integration of career-relevant engagement individuated by the student would be substantially more motivation-supportive to all learners in a science course. Similar suggestions were voiced in the interviews.

A Call to Motivation-Differentiated Action

A brief survey assessment at the beginning of a course would allow instructors to link learning engagement to the students' career interests and personally relevant topics. The survey should collect motivational levels and careers students have in mind, the survey presented in this study. Additionally, questions could elicit topics that students find personally interesting, hobbies students have, or their cultural and regional backgrounds to gather information for relevance-making. Alternatively, instructors can glean relevance key words from online discussions to then add to their lectures, which was described by several interviewees as an example as instructional design that they noted as substantially motivation-supportive instruction. These adjustments facilitate motivation-differentiated instruction while not posing a major shift in instructional design for the instructor. It could be reasonable to set the goal that students leave the course with a least a few concrete examples of in-depth learning that are relevant to their future career and that provide positive memories for future engagement in scientific thinking once graduated into the adult workforce.

Motivation-differentiated learning design is paramount to making the undergraduate years of learning meaningful to all students, but especially to students geared toward STEM-Related jobs, including future physicians, and students not interested in STEM careers at all. The findings of this study elucidate the importance of designing science courses with the relevance to the student in mind. It is of concern if students graduate from their undergraduate students without having been supported in their motivation. Intrinsic motivation and motivation to be competent in relation to their career was clearly visible in all participants of this study. These students will be future professionals influencing policy and practice in society and as voting citizens. The impact of motivational design in science education onto our world deserves more attention—it is at the root of education to provide learning—research on motivation provides practitioners with the tools to be more impactful in facilitating sustainable learning in their students.

Concluding Practical Guidance

Instructors of undergraduate science courses are encouraged to design for motivation-differentiated learning to support the complex motivational make-up of their classes. Utilizing the survey with open-ended text question with the question which one or two careers students currently consider would allow instructors to gage the motivation of their science courses. Since the survey assesses motivation toward science learning in the course it should be applied two or three weeks into the course or anytime after that. Instructors then can adjust their learning design according to the motivational diversity of their students. This section provide a few concrete recommendations to 1) support the conceptual learning of students oriented toward careers in the science and engineering subject field (labeled STEM in this study), 2) catalyze relevance-making for all students, 3) provide specific information of learning expected to students geared toward medical or technical STEM careers (STEM-Related group), and 4) encourage the intrinsic motivation of students not interested in STEM careers (Non-STEM student group). These differentiations are crucial to acknowledge the very different sub-groups of a typical science course as shown in this study. The basis for these differences lies in the group of STEM students not being a homogenous group of students.

STEM students split into two sub-groups with very different motivational need. Students interested in any kind of STEM career have higher motivation to learn science than students not interested in STEM careers. However, their motivation and perspective of science and careers are quite different. STEM students (science and engineering careers) need to be motivated differently than STEM-Related (medical, technical STEM careers). For science and engineering students, intrinsic and overall motivation was higher than for students planning on other STEM careers, which in turn had higher motivation than students not interested in STEM careers as generally anticipated. Considering the responses of subject versus science occupation, the students geared toward STEM-related careers listed occupations more often than students interested in science and engineering careers who preferred for the career path to remain flexible. So, while motivation toward science learning was higher for science and engineering-geared students (STEM), specific STEM occupation goals were more prevalent in students geared toward medical careers or other STEM-related jobs. Both groups are oriented toward STEM careers, but with different motivation, different perspective toward jobs, and different epistemological view of science. Practically, instructors of undergraduate science courses are encouraged to take these differences into consideration and to design for both STEM-geared groups as well as the students not interested in STEM careers described in the remainder of the section and visually summarized in Table 5-2.

1) Support Struggle Through Conceptual Learning in Science and Engineering Students. Students of this group talked in the interviews about their process of learning concepts as an individual endeavor in their personal time. Instructors are encouraged to make the challenge of reconciling known concepts with new information a part of their teaching and learning expectation. Instructors could encourage group conversation between students to talk through the new concepts learned without a productive outcome that needs to be submitted, but rather in-class dedicated time of wrestling with concepts and through learning to become the culture of scientific engagement.

Table 5-2

Practical Recommendations

<table>
<tr><th></th><th colspan="2">Extrinsic External
Grade Motivation</th><th>Extrinsic
Introjected
People-Inspired Motivation</th><th>Extrinsic
Identified
Competence Motivation</th><th>**Intrinsic Motivation**</th></tr>
<tr><td>**Science & Engineering** (STEM group)</td><td rowspan="3">Support student time management and limit extrinsic pressure: space tests throughout course; provide transparency on grading; allow for make-up or extra credit at the end: supports extrinsic motivation of all students while minimizing motivational threat by too much pressure.</td><td></td><td rowspan="3">Support students' ability to connect to their peers by adding interaction time related to course, ideally without performance pressure. Support students' relatedness to science learning by supporting reflection on how learning connects to their family and culture.</td><td colspan="2">Wants to be supported in learning concepts to become competent to be able to reach joy of learning when connecting existing to new science learning:
1) support process of conceptual learning struggle
2) support relevance-making</td></tr>
<tr><td>**Medical and technical STEM** (STEM-Related group)</td><td>Wants to know what facts to learn:
3) provide fixed list of knowledge expected at begin of course</td><td>Competence is highest drive for learning and currently not supported:
2) include activities that provide career relevance-making</td><td></td></tr>
<tr><td>**Not interested in STEM careers** (Non-STEM group)</td><td></td><td></td><td>Enjoys engaging in science learning
4) support engagement without STEM career pressure,
2) allow for relevance-making to non-STEM career</td></tr>
</table>

Graduate student teaching assistants could shadow and support these conversations while role modeling and sharing their experience of that type of science learning. This explicit engagement in conceptual struggle may also encourage students that perceive science as fixed set of facts (many of the STEM-Related group) to understanding science more as an ever-expanding and self-updating field of expertise and knowledge. Long-term scientific literacy in society depends on the majority of the population to be willing to engage in continuous science learning throughout life. Students not interested in STEM careers expressed joy in discovering new information and concepts well fitting with this active science learning struggle to gain new conceptual knowledge. Practically, this type of active learning engagement can be effectively built into laboratory and field activities.

2) Relevance-Making most wanted by STEM-Related group is important for all students. For all students, and especially for students geared toward STEM careers (both STEM and STEM-Related groups) the relevance of learning to their careers is crucial. The sub-group of students interested in medical or technical STEM careers (STEM-Related) expressed in interviews that their science classes were not relevant to their careers, which is a missed motivational opportunity. In general, all groups of students voiced being motivated when learning is relevant to their life and careers. So how to make learning relevant for students? It is unrealistic to include learning relevant to each individual student in science courses. However, there are many ways to engage students in open-ended assignments such that students are creating relevance for their learning. Active learning assignments such as personal reflection on connection between course and personal life has been shown to increase motivation. Leveraging the opportunities of the internet, students could be asked to add key words into a browser search bar; specifically key words from both the topic taught and the students' personal interests. By combining key words from both the browser will produce search results that combine both, creating relevance.

Key words for the topic could be provided by the instructor for the lesson taught. Key words that are connected to the student's life and career interests could be produced by the student based on a set of prompts given by the instructor. Prompts such as *describe a possible career future of yours* and *write a summary of your childhood or culture* creates language and students could copy their answers as a whole or highlight main words to copy then as key words. The combination of at least one key word from topic and one personal key word into the search bar surfaces sources that connect those. Specifying search bars of literature search sites will surface articles that provide relevance. A pass/fail assignment that asks students to report on what they found would encourage students to engage in relevance-making of their science course and learning. Dedicated time in the science course for students to exchange what they found in group conversations (in person or in breakout rooms in video meetings) would add relatedness and further reinforce relevancy found by the group.

3) Provide Specific List of Learning Expected for Students in Medical and STEM-Technical Career Pathways. Students geared toward medical and STEM technical careers (STEM-Related) reported severe time pressures and a high amount of combined knowledge learning expected between all their courses. While ideally, the motivation of students is supported such that they have high self-determined motivation that is strongly intrinsic. The reality of many students enrolled in a science course is that the extrinsic pressure to pass the class dominates their motivation. One pre-med student specifically talked about wishing that instructors would provide the list of facts needing to be learned and open tests in the online course interface early on to be taken as soon as the student has learned the content. While creating a course that only consists of content learning and tests is extreme, instructors are encouraged to recognize that simplifying the letter-graded part of the course for these students may be a good choice to design for learning. Additionally, engagement in active concept learning, relevance-making, and/or hands-on experiential science learning in laboratory and field site could be a required part of the course. Pass/fail grading of such activities encourage engagement regardless of the specific learning outcome as long as it meets a basic threshold of engagement. This approach is an autonomy-supportive motivational approach to learning design.

4) Support Engagement Regardless of STEM Career Path. While many initiatives encourage students to enter the STEM career *pipeline*, it is important to foster motivation to engage in science learning in all students. Science faculty *must* design learning for all groups of career orientation without a bias for one over the other. Students reported in the interview that their generation was encouraged to go to college and many students reported to have chosen science majors, because their K-12 schools and their families believed that to be one of the best career choices available. At the same time many students are not on STEM career pathways, but may well be interested later in life to enter a STEM career or apply learning from their science courses in their jobs. Students not interested in STEM careers deserve to be supported in their intrinsic motivation to learn science, which was clearly visible in the present study.

Creating motivation-supportive learning design that keeps the three groups investigated in this study in mind will benefit both scientific literacy in society and students on STEM career pathways. Instructors are encouraged to utilize the published survey to get an overview over the motivational diversity of their class and integrate the provided suggestions. It is important to remember that motivation is not a fixed construct, but rather a cognitive-behavioral dimension that sometimes shifts from day to day and for others may be very stable. Thus, instructors should view their class as a group of learners with diverse motivational and career orientation make-up that shifts and changes over time. Providing motivation-supportive rather than motivation-frustrating curriculum is crucial to build a science-knowledgeable society with sufficient STEM workforce and expertise.

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Appendix A: Survey

Welcome to this research survey
I am Kirsten LaPaglia, a doctoral candidate in the College of Education, Health, and Human Sciences, and I am interested in understanding what helps students succeed in science education. The purpose of this research is to understand students' motivation towards science better. You are invited to participate in this study because you are currently taking a science course in college. It is important for educators and researchers to hear the voice of students on this topic.

Your participation in this survey will take approximately 7 minutes and involves answering questions about science learning motivation, such as "Why do you spend time studying science?" Your involvement in the study is voluntary, and you may choose not to participate. You can refuse to answer any of the questions at any time. There are no names or identifying information associated with your response. There are no known risks in this study, but some individuals may experience discomfort or loss of privacy when answering questions. Study data will be saved on secure servers of the University of Idaho.

The findings from this project will provide information on motivations for science learning in school. If published, results will be presented in summary form only, anonymous quotes from the survey may be included.

If you have any questions about this research project or would like to receive a report of the research results, please contact doctoral candidate Kirsten LaPaglia at <email> [1]or <phone>, or the dissertation advisor, <name>, at <email>. If you have questions regarding your rights as a research subject, or about what you should do in case of any harm to you, or if you want to obtain information or offer input, you may call the Office of Research Assurances at <phone> or <email>.

By clicking the button below, you certify that you are at least 18 years of age and agree to participate in the above-described research study.

- I consent, begin the study.
- I am not yet 18 years of age.
- I do not consent, I do not wish to participate.

[forced response, allowed one answer]

[page break]

Great, here is part 1 of 2.

For each of the statements, please select the best response indicating why you spend time studying science in college. When answering these questions, think about the course of the teacher who sent you this survey.
Please tell me, which **Science** subject are you currently taking?
(for example Biology, Chemistry, Geography, Geology, Physics)
____ *[text box]*

*[The answer to this question was auto-added as piped text to the following question as <**Science Choice Text Entry Value**>]*

[page break]

There are 21 questions. Some statements may ask for the same thing, but we just want to make sure we get your perspective right. Please select the answer that best corresponds with the reasons **why do you spend time studying <Science Choice Text Entry Value>**.

---

[1] *Text in italics are comments by the researcher not included in the survey; < and > brackets indicate the content that was displayed within not shown here.*

[The following 21 AMS questions were presented as matrix table with checkbox, with 3 questions per page. Each page repeated display of the prompt at the top and column headers; response requested, allows one answer per question item]

Why do you spend time studying <**Science Choice Text Entry Value**>? *[prompt]*

	Does not correspond at all (1)	Corres-ponds a little (2)	Corres-ponds moderately (3)	Corres-ponds a lot (4)	Corres-ponds exactly (5)
1. Honestly, I don't know; I feel that it is a waste of time studying science.					
2. Because I want to show others (teachers, family, friends) that I can do science.					
3. Because I want to show myself that I can do well in science.					
4. I am not sure; I don't see how science is of value to me.					
5. Because without a good grade in science, I will not be able to find a high-paying job later on.					
6. Because I believe that science will improve my work competence.					
7. I feel good discovering new things in science that I have never learned before.					
8. In order to obtain a more prestigious job later on.					
9. To show myself that I am an intelligent person.					
10. In order to have a better salary later in life.					
11. I feel good getting lost in science learning and discovery.					
12. Because what I learn in science now will be useful for college classes in the future.					
13. Because I want to feel the personal satisfaction of understanding science.					
14. Because studying science will be useful for me in the future.					
15. I feel good broadening my knowledge about science.					
16. Because I want to have "the good life" later on.					
17. I don't know; I can't understand what I am doing in science.					
18. Because I think that science will help me better prepare for my future career.					
19. I can't see why I study science and frankly, I couldn't care less. (AMOT-19)					
20. Because of the fact that when I do well in science, I feel important. (EMIN-20)					
21. I feel good when I learn how things in life work, because of biology. (IMT-S-21)					

[page break]

In your own words, please tell me why you spend time studying <**Science Choice Text Entry Value**>?
____ *[text box]*
____

Great. You are almost done. Now to Part 2 of the survey.

[page break]

Just a few more questions to understand a bit more about what influences the success of students in science education. Rest assured that your answers will remain anonymous.

What are the top one or two careers you currently are considering?
____ *[text box; forced response]*

How long you have thought of the careers you listed? Please select the best answer.
I have changed my mind about careers ... *[allowed one answer]*

- ... multiple times in the last year.
- ... at least once in the last year.
- ... not at all in the last year.

What major are you currently in in college? *[allowed one answer]*
- My major: _______ *[text box]*
- I have not picked a major yet.

Please tell us about your <**Science Choice Text Entry Value**> class. Select all that applies.
[allowed one answer]
- I attend this class in person on campus.
- I take this class online.

What type of paid or unpaid experiences have you had in the last six months that relate to your major or potential career? *[allowed one answer]*
- paid or unpaid experiences, internships, practicum, jobs
- none, but planning on it in the next year
- none, and not planning on it in the next year

What is your gender? *[allowed one answer]*
- Female, Trans female, or Trans woman
- Male, Trans male, or Trans man
- Genderqueer/gender non-conforming
- Self-Identify: ______ *[text box]*
- Decline to respond

What is your age? *[allowed one answer]*

- age 18 or 19
- age 20 to 26
- age 27 or older

What do you consider your ethnicity and race? Please check all that apply. *[allowed multiple answers]*

- Hispanic or Latino or Spanish Origin of any race
- Black or African American
- Asian
- American Indian or Alaska Native
- Native Hawaiian or Other Pacific Islander
- Whit
- Self-Identify ____
- Decline to respond

[redirect to a separate online questionnaire]

[Separate survey was set up so that survey answers are not connected to personal information.]

We thank you for your time spent taking this survey.

Would you be interested in being interviewed?
Your answers to the survey can help us quantify student motivation toward science. However, we'd really like to chat with some of you about these motivations to understand what the contributing factors are, like the motivation to learn in order to get a good job or the motivation to study for the satisfaction of understanding the subject. Would you be interested in being interviewed? The interview takes approximately one hour and if you choose to be interviewed you earn $20 for your time.

- Yes, I am interested in an interview.
- No, I am not yet 18 years of age.
- No, I am not interested.

[skip logic implemented: if 'yes, I am interested in an interview' is not selected, survey skips to end of survey]

Great, please provide your information below so we can contact you. Your contact information is not connected to the survey you just completed.

Here is a bit more information about the interview: The interview conducted on zoom will take about thirty minutes to an hour to complete. The interview includes questions such as "Can you tell me about why you spend time studying science?" Your involvement in the study is voluntary. If you have any questions about this research project, please feel free to call the researcher Kirsten LaPaglia at <phone> or the principal investigator <name> at <phone>.
You can still opt out anytime without consequences. We delete your contact information upon completion of the study or when you opt out.

Your name: ______ *[text box]*
Your Email: ______ *[text box]*
Your Mobile Phone: ______ *[text box]*
We look forward to contacting you!

[End of survey:]
We appreciate all your responses and feedback.
Thank you so much for your time.

Appendix B: Screening of Ungrouped Data

Table B-0-1

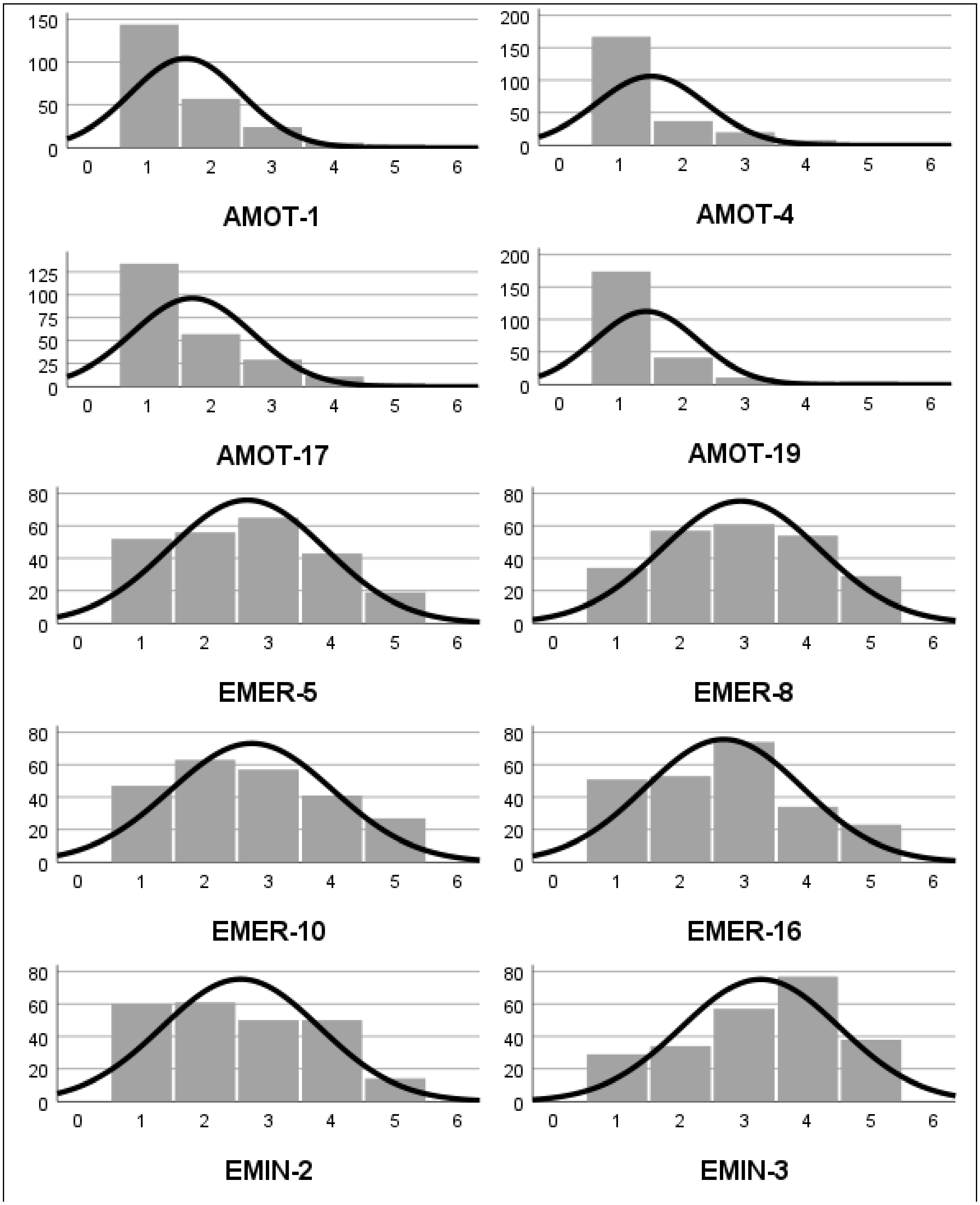
Descriptive Statistics for 21 AMS Item Variables

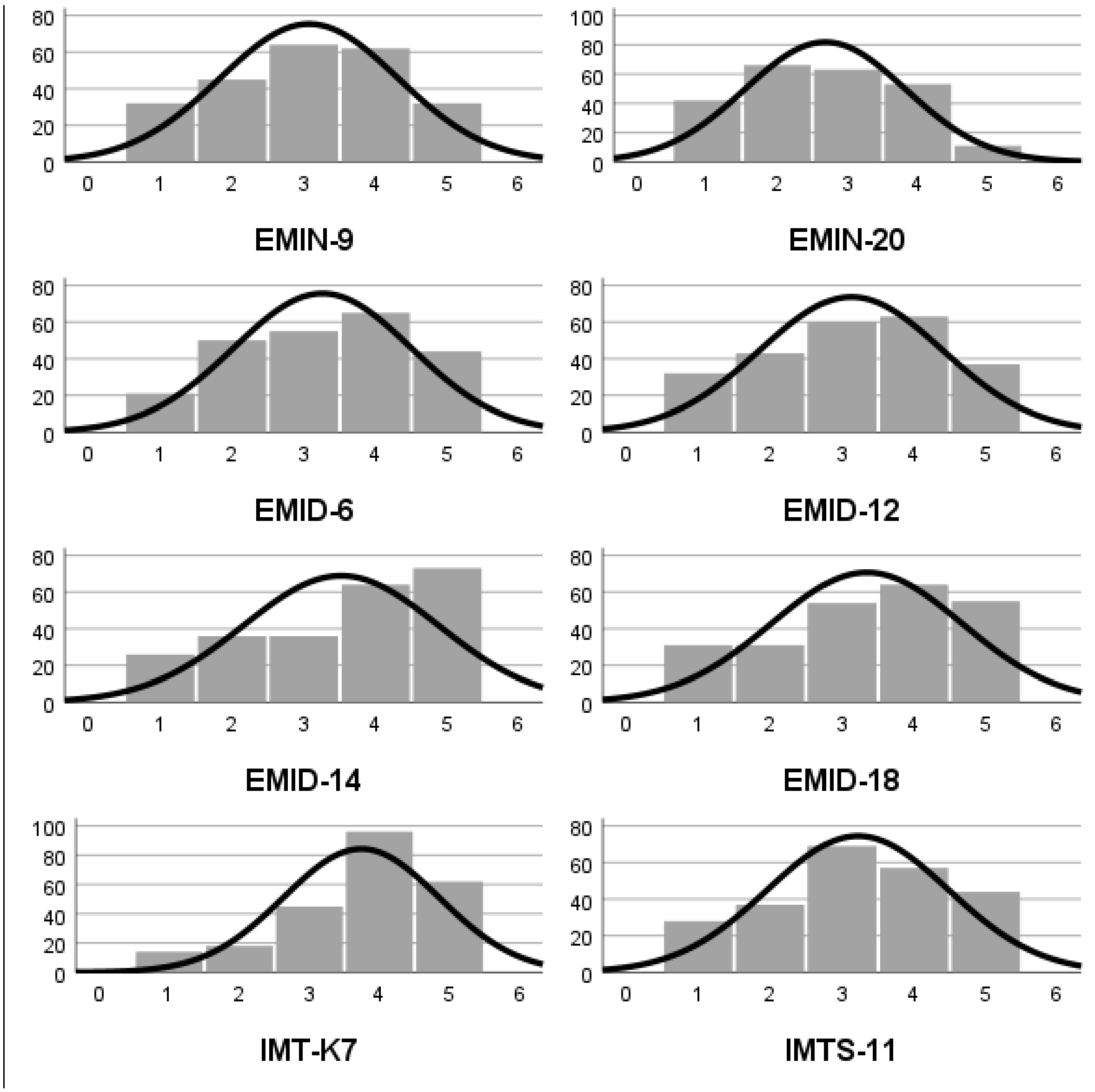
	Mean	SD	Variance	Skewness	Std. Err. of Skewness	Sig. of Skewness	Kurtosis	Std. Err. of Kurtosis	Sig. of Kurtosis
AMOT-1	1.59	0.898	0.807	1.686	0.159	10.60	2.724	0.316	8.62
AMOT-4	1.48	0.884	0.781	1.971	0.159	12.40	3.44	0.316	10.89
AMOT-17	1.7	0.973	0.947	1.396	0.159	8.78	1.364	0.316	4.32
AMOT-19	1.4	0.834	0.695	2.562	0.159	16.11	6.937	0.316	21.95
AMOT1_log	0.15	0.20	0.04	0.94	0.159	5.91	-0.405	0.316	-1.28
AMOT4_log	0.12	0.20	0.04	1.359	0.159	8.55	0.473	0.316	1.5
AMOT17_log	0.17	0.21	0.05	0.754	0.159	4.74	-0.821	0.316	-2.6
AMOT19_log	0.10	0.18	0.03	1.662	0.159	10.45	1.76	0.316	5.57
EMER-5	2.66	1.234	1.523	0.21	0.159	1.32	-0.935	0.316	-2.96
EMER-8	2.94	1.244	1.548	0.038	0.159	0.24	-0.997	0.316	-3.16
EMER-10	2.74	1.28	1.639	0.259	0.159	1.63	-0.984	0.316	-3.11
EMER-16	2.68	1.239	1.534	0.246	0.159	1.55	-0.828	0.316	-2.62
EMIN-2	2.56	1.244	1.546	0.261	0.159	1.64	-1.07	0.316	-3.39
EMIN-3	3.26	1.246	1.552	-0.383	0.159	-2.41	-0.83	0.316	-2.63
EMIN-9	3.07	1.243	1.546	-0.138	0.159	-0.87	-0.952	0.316	-3.01
EMIN-20	2.68	1.146	1.312	0.117	0.159	0.74	-0.929	0.316	-2.94
EMID-6	3.26	1.239	1.535	-0.192	0.159	-1.21	-0.998	0.316	-3.16
EMID-12	3.13	1.271	1.616	-0.179	0.159	-1.13	-0.997	0.316	-3.16
EMID-14	3.52	1.36	1.849	-0.519	0.159	-3.26	-0.992	0.316	-3.14
EMID-18	3.34	1.325	1.757	-0.388	0.159	-2.44	-0.959	0.316	-3.03
IMT-K7	3.74	1.112	1.236	-0.865	0.159	-5.44	0.191	0.316	0.60
IMTS-11	3.22	1.258	1.583	-0.217	0.159	-1.36	-0.895	0.316	-2.83
IMT-A13	3.26	1.225	1.501	-0.311	0.159	-1.96	-0.84	0.316	-2.66
IMT-K15	3.62	1.179	1.39	-0.491	0.159	-3.09	-0.68	0.316	-2.15
IMT-S-21	3.2	1.228	1.509	-0.212	0.159	-1.33	-0.928	0.316	-2.94

Note. All 21 ungrouped item scores were reviewed for plausible range and normality. AMOT variable scores were transformed with log due to high significance of skewness with values above 8, resulting in the additional AMOT_log variables. Displayed are mean, standard deviation (SD), variance, skewness and kurtosis with standard error (Std. Err.) and significance (Sig.). Per each variable 235 responses were available without missing scores. The minimum and maximum score for all variables but AMOT_log was 1 and 5. Minimum and maximum was the same for all AMOT_log values at 0 and 0.7.

Figure B-0-1

Histograms for AMS Variables with Normal Curve

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40
20
0
0 1 2 3 4 5 6
EMIN-9
100
80
60
40
20
0
0 1 2 3 4 5 6
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60
40
20
0
0 1 2 3 4 5 6
EMID-6
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EMID-12
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EMID-14
80
60
40
20
0
0 1 2 3 4 5 6
EMID-18
100
80
60
40
20
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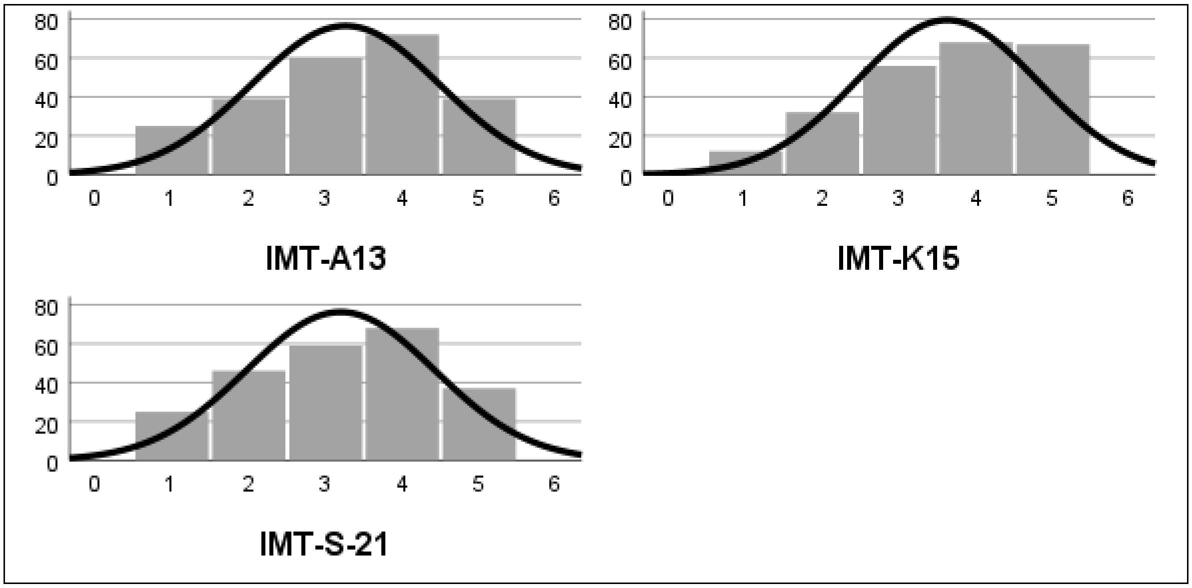
0 1 2 3 4 5 6
IMT-K7
80
60
40
20
0
0 1 2 3 4 5 6
IMTS-11

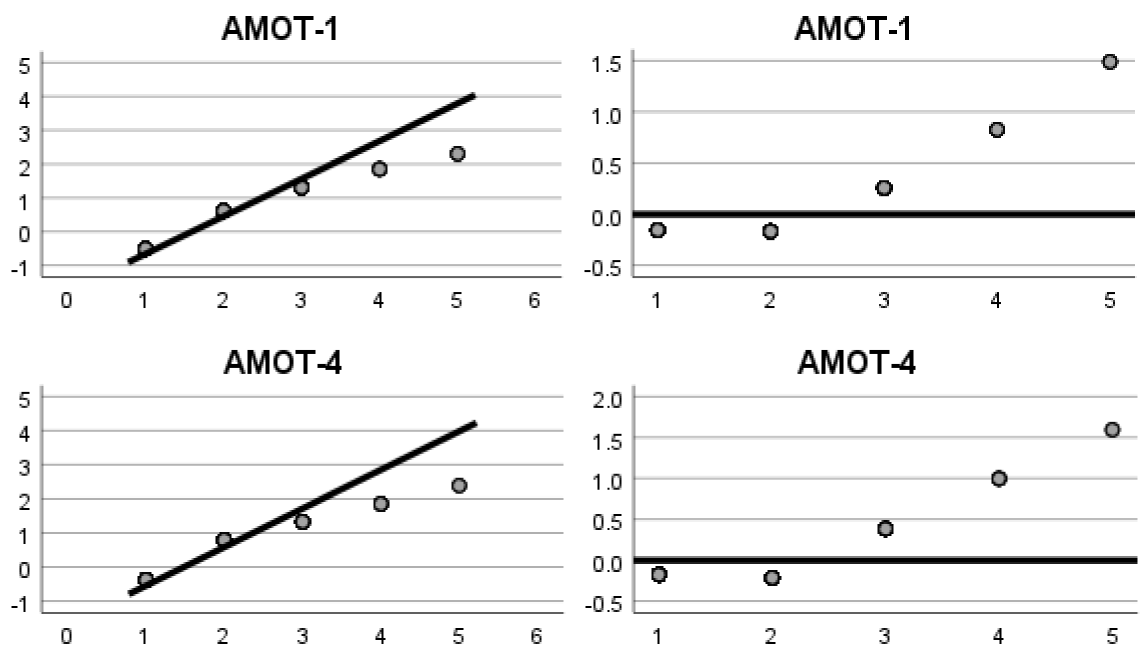


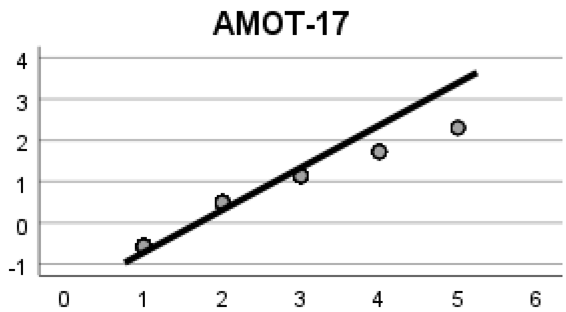
Note. Displayed are Histograms for the dataset of 235 cases.

Figure B-0-2

Normal and Detrended Q-Q Plots

Normal Q-Q Plots	Detrended Q-Q Plots

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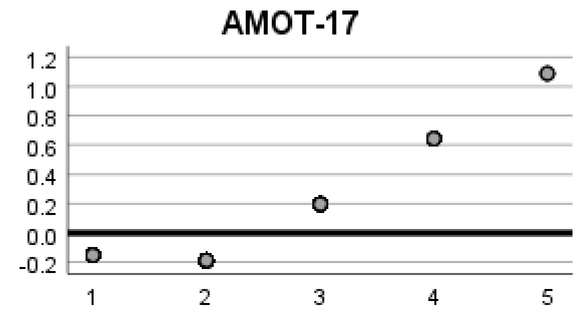
3
2
1
0
-1
0 1 2 3 4 5 6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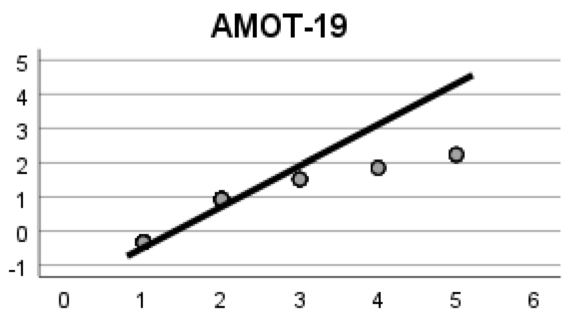
0.8
0.6
0.4
0.2
0.0
-0.2
1 2 3 4 5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3
2
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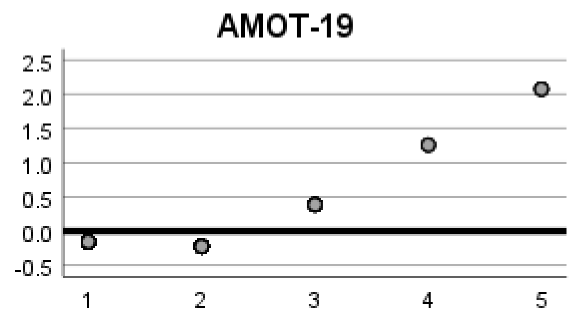
0
-1
0 1 2 3 4 5 6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2.0
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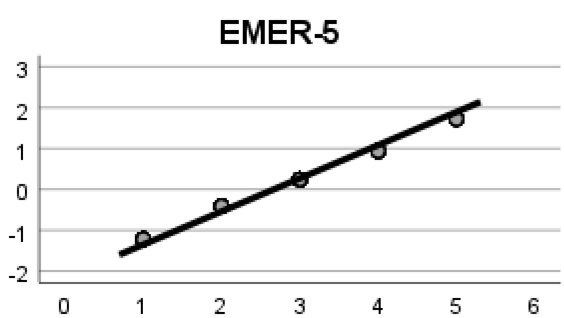
1.0
0.5
0.0
-0.5
1 2 3 4 5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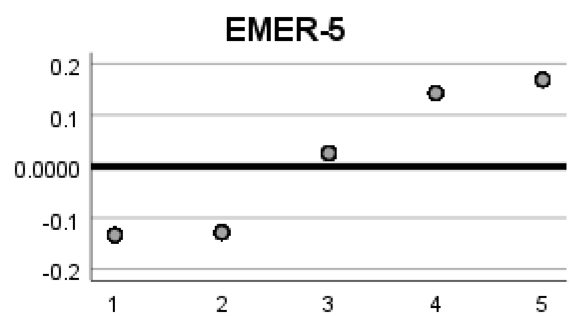
-1
-2
0 1 2 3 4 5 6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0.0000
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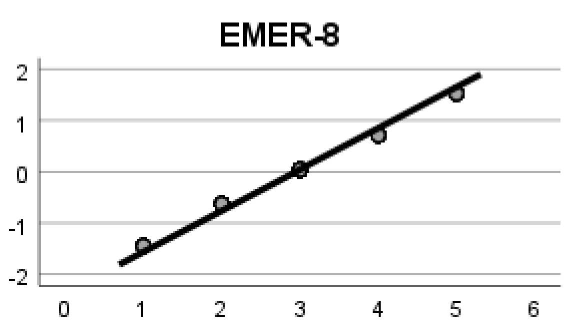
-0.2
1 2 3 4 5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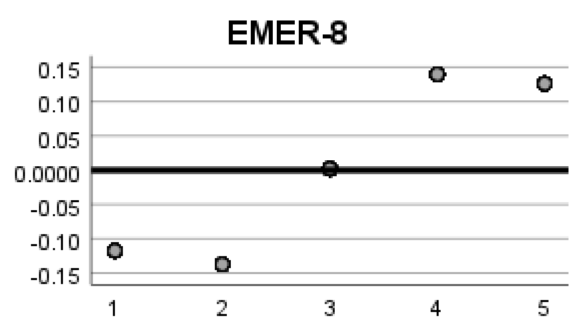
-2
0 1 2 3 4 5 6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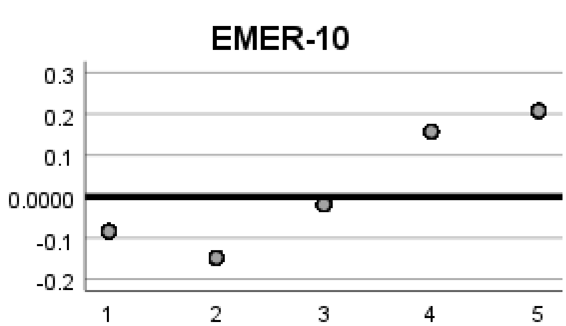
-0.05
-0.10
-0.15
1 2 3 4 5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0.0000
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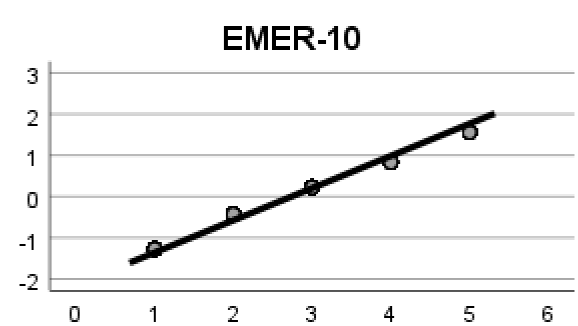
-0.2
1 2 3 4 5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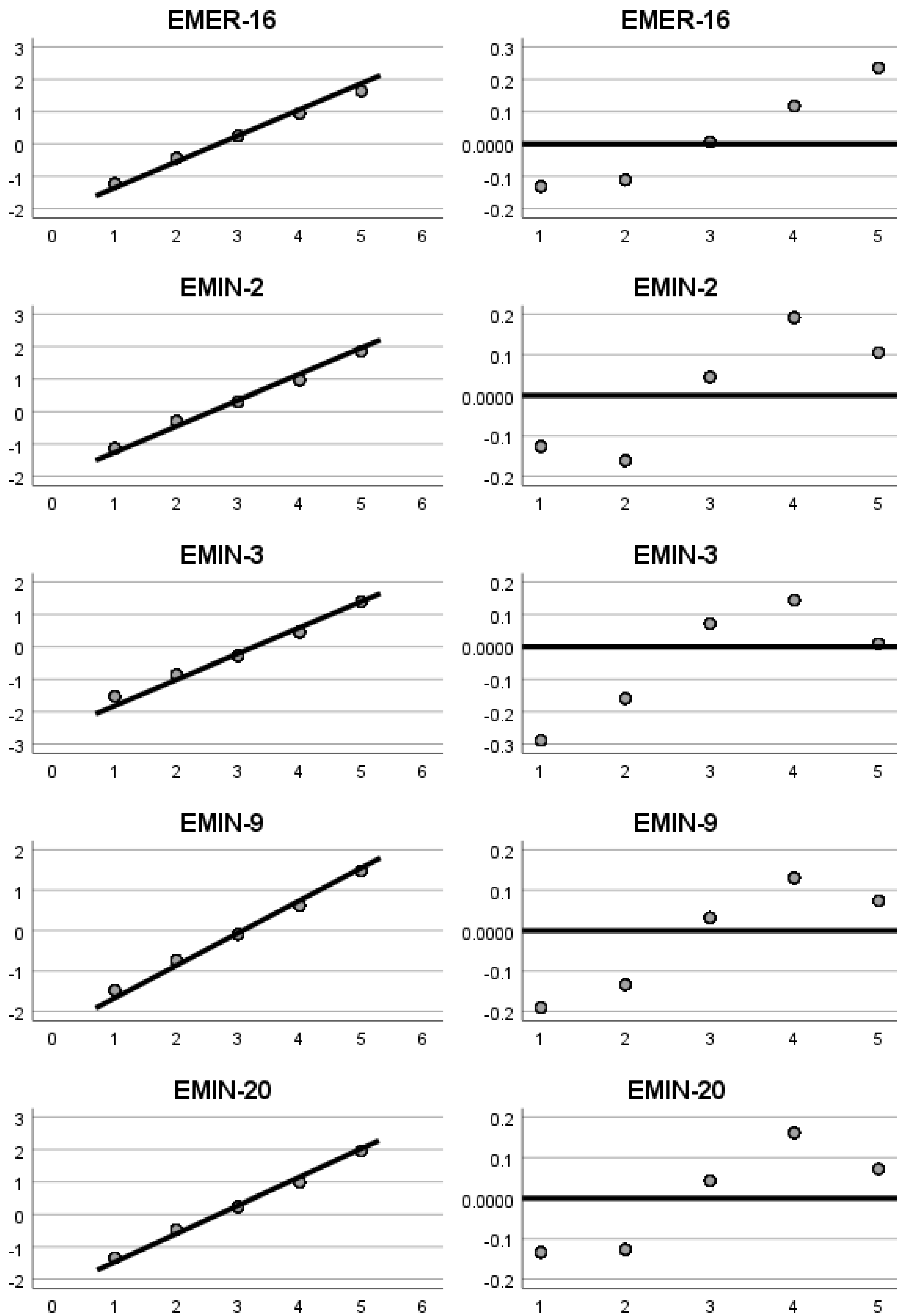
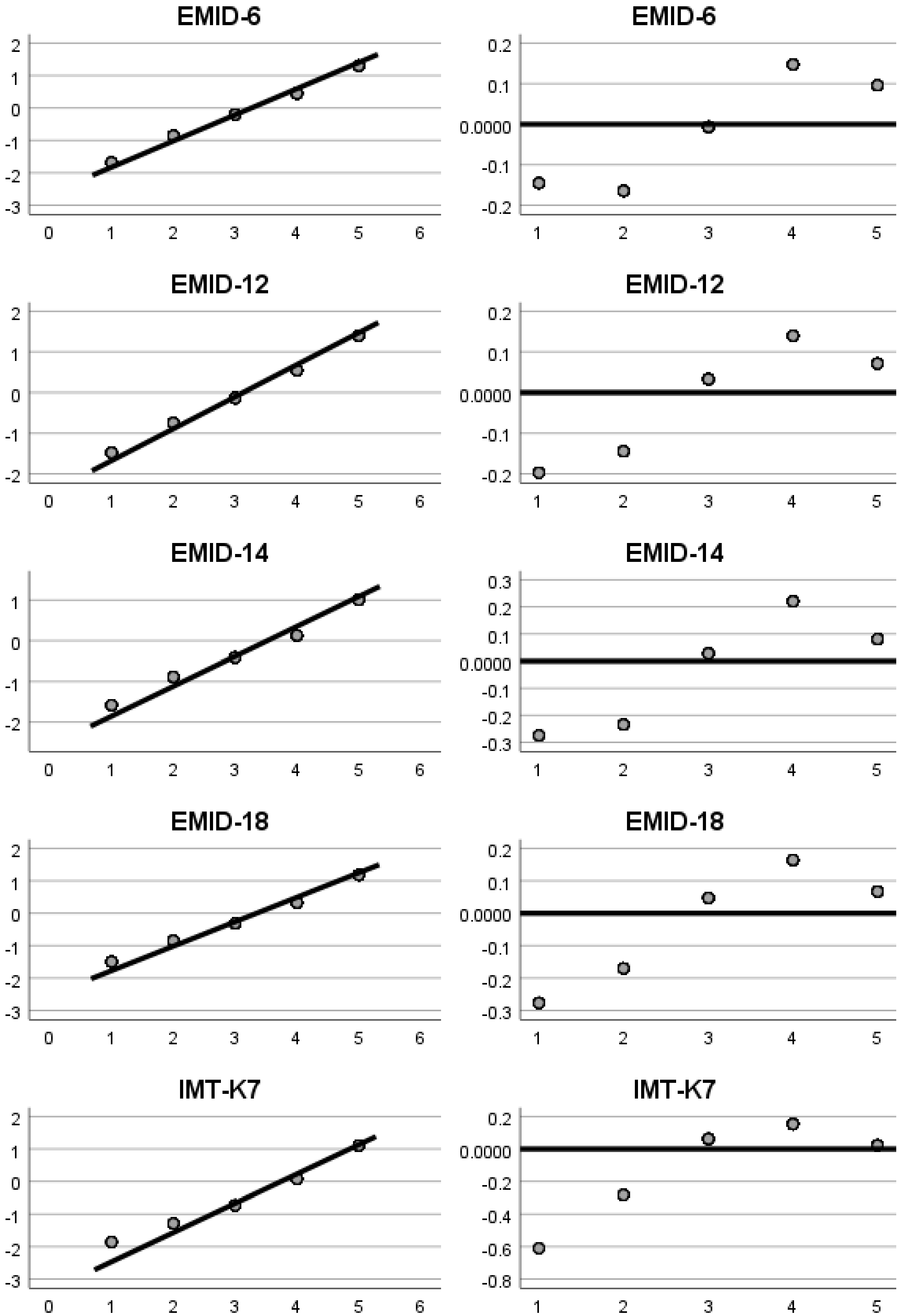
2
1
0
-1
-2
0 1 2 3 4 5 6


EMER-16
EMER-16
EMIN-2
EMIN-2
EMIN-3
EMIN-3
EMIN-9
EMIN-9
EMIN-20
EMIN-20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EMID-6
0.2
0.1
0.0000
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-0.2
1 2 3 4 5
EMID-12
2
1
0
-1
-2
0 1 2 3 4 5 6
EMID-12
0.2
0.1
0.0000
-0.1
-0.2
1 2 3 4 5
EMID-14
1
0
-1
-2
0 1 2 3 4 5 6
EMID-14
0.3
0.2
0.1
0.0000
-0.1
-0.2
-0.3
1 2 3 4 5
EMID-18
2
1
0
-1
-2
-3
0 1 2 3 4 5 6
EMID-18
0.2
0.1
0.0000
-0.1
-0.2
-0.3
1 2 3 4 5
IMT-K7
2
1
0
-1
-2
-3
0 1 2 3 4 5 6
IMT-K7
0.2
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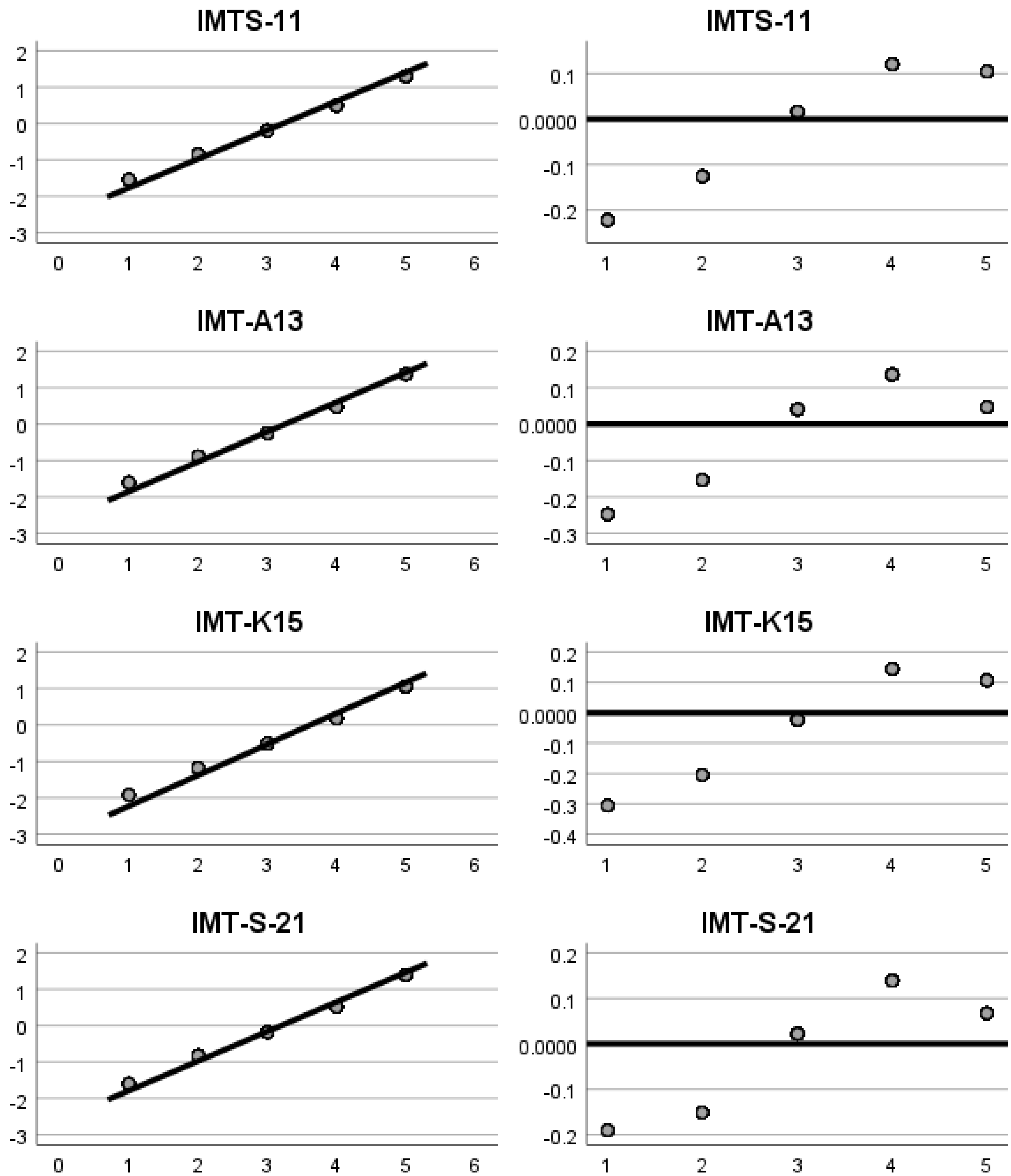
-0.8
1 2 3 4 5



Normal Q-Q Plots	Detrended Q-Q Plots

Note. Displayed are the normal Q-Q Plots of the 21 AMS Variables for the dataset of 235 cases on the left. The normal plot x axis shows observed value, the y axis shows expected normal. On the right, respected detrended Q-Q Plots are displayed. The detrended plot x axis shows observed value, the y axis shows dev from normal.

Table B-0-2

Z-Scores for 21 AMS Item Variables

	N	Minimum	Maximum	Mean	Std. Deviation
Zscore (AMOT1_log)	235.00	-0.74	2.72	0.00	1.00
Zscore (AMOT4_log)	235.00	-0.60	2.96	0.00	1.00
Zscore (AMOT17_log)	235.00	-0.80	2.46	0.00	1.00
Zscore (AMOT19_log)	235.00	-0.55	3.29	0.00	1.00
Zscore (EMER5) EMER-5	235.00	-1.35	1.89	0.00	1.00
Zscore (EMER8) EMER-8	235.00	-1.56	1.65	0.00	1.00
Zscore (EMER10) EMER-10	235.00	-1.36	1.77	0.00	1.00
Zscore (EMER16) EMER-16	235.00	-1.36	1.87	0.00	1.00
Zscore (EMIN2) EMIN-2	235.00	-1.26	1.96	0.00	1.00
Zscore (EMIN3) EMIN-3	235.00	-1.81	1.40	0.00	1.00
Zscore (EMIN9) EMIN-9	235.00	-1.67	1.55	0.00	1.00
Zscore (EMIN20) EMIN-20	235.00	-1.47	2.02	0.00	1.00
Zscore (EMID6) EMID-6	235.00	-1.82	1.40	0.00	1.00
Zscore (EMID12) EMID-12	235.00	-1.67	1.47	0.00	1.00
Zscore (EMID14) EMID-14	235.00	-1.85	1.09	0.00	1.00
Zscore (EMID18) EMID-18	235.00	-1.77	1.25	0.00	1.00
Zscore (IMTK7) IMT-K7	235.00	-2.47	1.13	0.00	1.00
Zscore (IMTS11) IMTS-11	235.00	-1.77	1.41	0.00	1.00
Zscore (IMTA13) IMT-A13	235.00	-1.84	1.42	0.00	1.00
Zscore (IMTK15) IMT-K15	235.00	-2.22	1.17	0.00	1.00
Zscore (IMTS21) IMT-S-21	235.00	-1.79	1.47	0.00	1.00
Zscore (IMTS21) IMT-S-21	235.00	-1.79	1.47	0.00	1.00
Valid N (listwise)	235.00				

Note. Z scores for the dataset of 235 cases are displayed, together with respective descriptive statistics.

Appendix C: Goodness of Fit for Factor Models

Table C-0-3

Fit Indices for AMS Factor Models

	5-Factor Model	3-Factor Model	Values Indicating Fit (Reference)
$\chi 2$	392.82	929.061	lower value is better fit (Tabachnick et al., 2019, p. 50-51)
$\chi 2$/df	2.20	4.995	2 - 5 (Byrne, 1994)
SRMR	.0687	.1082	0 perfect, 1 worst fit (Brown, 2015, p. 71)
RMSEA	.071	.131	0 perfect, 1 worst fit (Brown, 2015, p. 72)
CFI	.936	.774	0 worst, 1 perfect fit (Brown, 2015, p. 73)
TLI	.924	.745	0 lacks fit, close to 1 good (Brown, 2015, p. 73)

Note. Fit indices were calculated with SPSS Amos 25 (Arbuckle, 2019) for both 5-factor and the 3-factor model: $\chi 2$ chi-square, $\chi 2$/df chi-square divided by degrees of freedom, SRMR standardized root mean square residual, RMSEA root square mean error of approximation, CFI comparative fit index, TLI Tucker-Lewis index.

Table C-0-4

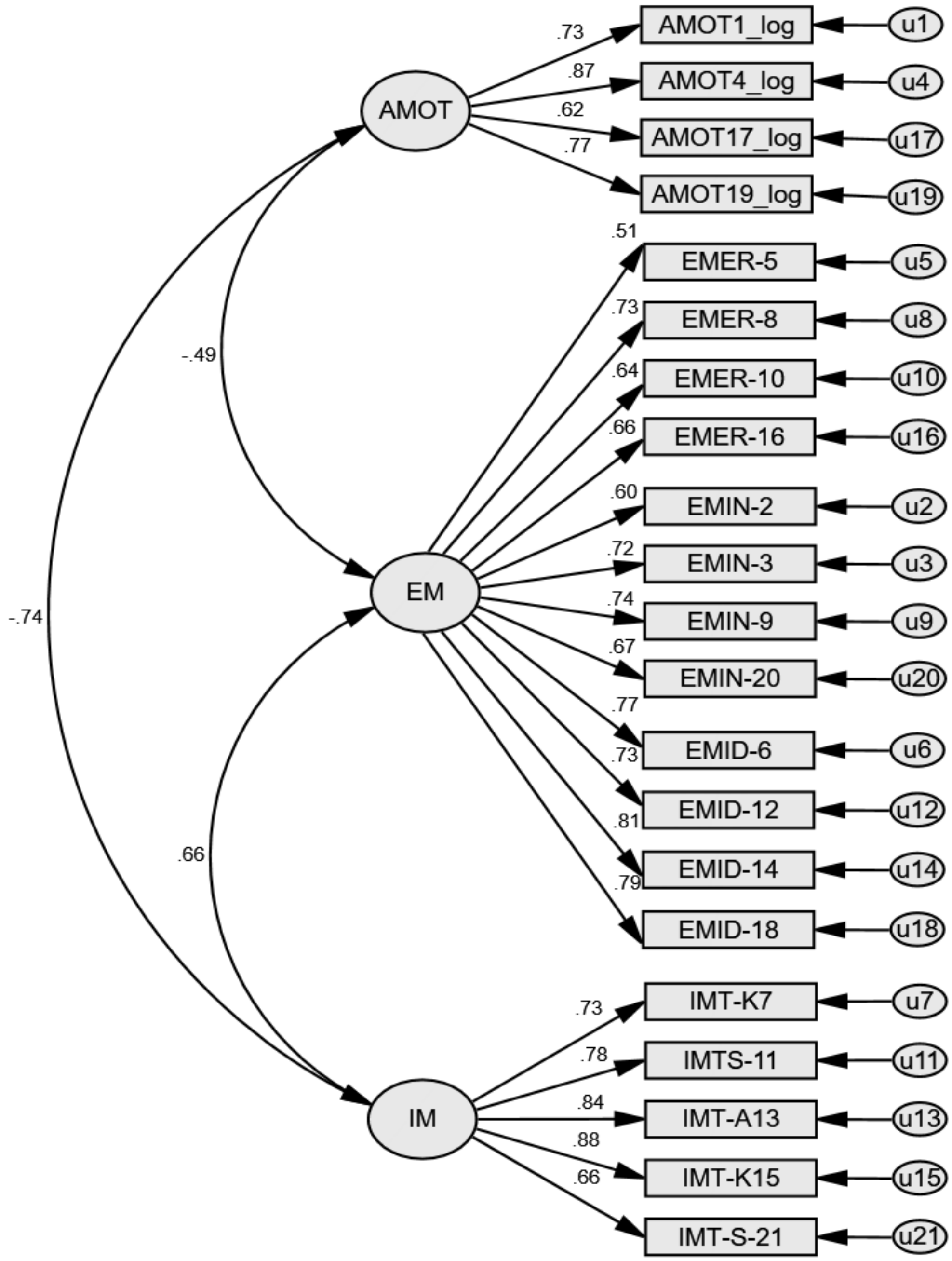
Inter-Item Correlation Matrix for AMS Survey of 21 Items

	AMOT -1	AMOT -4	AMOT -17	AMOT -19	EMER -5	EMER -8	EMER -10	EMER -16	EMIN -2	EMIN -3	EMIN -9	EMIN -20	EMID -6	EMID -12	EMID -14	EMID -18	IMT -K7	IMTS -11	IMT -A13	IMT -K15
AMOT-1	1.																			
AMOT-4	.66	1.																		
AMOT-17	.45	.57	1.																	
AMOT-19	.58	.67	.47	1.																
EMER-5	-.02	-.03	.05	-.06	1.															
EMER-8	-.19	-.3	-.06	-.19	.61	1.														
EMER-10	-.13	-.19	.05	-.12	.65	.83	1.													
EMER-16	-.18	-.22	.02	-.2	.53	.69	.73	1.												
EMIN-2	-.08	-.17	.03	-.21	.26	.33	.29	.34	1.											
EMIN-3	-.23	-.28	-.15	-.34	.28	.4	.36	.38	.66	1.										
EMIN-9	-.16	-.28	-.05	-.3	.38	.54	.46	.47	.58	.66	1.									
EMIN-20	-.17	-.22	-.06	-.24	.31	.42	.4	.43	.54	.6	.67	1.								
EMID-6	-.28	-.47	-.24	-.42	.37	.52	.35	.38	.44	.58	.53	.45	1.							
EMID-12	-.24	-.35	-.18	-.36	.28	.47	.36	.44	.38	.49	.5	.47	.62	1.						
EMID-14	-.4	-.53	-.32	-.48	.29	.54	.43	.46	.4	.56	.53	.47	.71	.66	1.					
EMID-18	-.3	-.4	-.18	-.37	.38	.58	.49	.53	.42	.51	.48	.44	.63	.63	.77	1.				
IMT-K7	-.44	-.48	-.39	-.51	-.05	.22	.07	.14	.26	.36	.3	.28	.42	.31	.41	.25	1.			
IMTS-11	-.43	-.5	-.42	-.43	.02	.19	.11	.19	.25	.34	.31	.3	.39	.39	.46	.32	.66	1.		
IMT-A13	-.4	-.47	-.26	-.45	.14	.37	.25	.32	.51	.63	.56	.54	.57	.52	.65	.48	.56	.62	1.	
IMT-K15	-.44	-.56	-.41	-.49	.02	.29	.14	.26	.37	.45	.45	.42	.52	.46	.61	.41	.63	.69	.74	1.
IMT-S-21	-.33	-.37	-.29	-.39	.09	.22	.14	.22	.36	.42	.4	.51	.45	.33	.37	.33	.48	.5	.57	.57

Note. Item-Item Correlations between the 21 AMS Items.

Figure C-0-3

Three-Factor Model with Correlations



Note. The three-factor model shows correlations between the three factors of AMOT, EM combined of EMER, EMIN, and EMID, and as third factor IM. Modeling was conducted with SPSS Amos 25 (Arbuckle, 2019).

Appendix D: Interview Protocol with Invitation and Consent

Invitation

Hello «First_Name»,
I hope your spring semester is going great. Last semester you participated in a survey on motivation to learn science in a science course you took.

Are you taking a science course this semester?
Are you between 18 and 26 years old?

If yes, I would like to interview you about what motivates your study of science in your science course this semester.
The interview takes approximately one hour, and you will earn $20 (venmo pay or check) for your time.

I so appreciate you participating last fall–I already learned some interesting things that hopefully will help future college students in science classes and their instructors.
Your answers in that fall survey helped me quantify student motivation toward science and I conducted some preliminary interviews in December. Now, I would really like to chat with you more about your motivations, and to understand what the contributing factors are, like motivations when learning in order to get a good job or when studying for the satisfaction of understanding the subject.
The interview will be conducted on Zoom and includes questions such as "Can you tell me about why you spend time studying science?" Your involvement in the study is voluntary. If you have any questions about this research project, please feel free to call the researcher Kirsten LaPaglia at 208-885-5819 or the principal investigator Tonia Dousay at 208-885-5724.

Interested in supporting this graduate research project?
Please tell me two options for day (next two or three weeks) and time (between 4 and 7PM) that would work well for you and I'll get back to you to schedule the interview.

Looking forward to talking to you,
<<Researcher Name>>

Interview Protocol

Interview Purpose and Consent
You are being asked to participate in a research study investigating motivation of undergraduate college students for science education. The purpose of this research is to understand students' motivation towards science better. You are invited to participate in this study because you are currently taking a science course in college. I find it important for educators and researchers to hear the voice of students on this topic.

Informed consent
Please submit the informed consent form that you have signed, signaling your willingness to participate (email the signed form as pdf or image).

I am recording the audio of this interview. After the interview it will be transcribed into anonymous text and the audio will be deleted permanently.

Do you have any questions before we start?

Ok, let’s begin.

Motivation Interview
Please tell me which science you are currently taking: ________________

(examples: anatomy, biology, chemistry, geology, chemistry, physics, physiology)

If more than one is mentioned, ask to please pick one to think of during the interview today. The answer provided will be used in the following interview instead of the word <science>.

Questions Specific to Participant’s Science Course

1. Please tell me one <science subject> you took this past semester. <_____>
2. Can you tell me more about what studying <science> looks like for you?
3. Please tell me more about what makes you study <science>?

Highlight phrases that interviewee uses to express AMS motivational constructs. Theses phrases for each <construct> are used in next section.

Motivation Constructs Volunteered
AMS construct question for key words used by student:
Please tell me more about <construct> (, e.g. I have no motivation to study <science>).

Motivation Constructs Elicited
AMS construct question for constructs not used by student:
Please tell me about <construct> (, e.g. I am motivated to study <science> to get a good salary or job).

Motivation Likert Scale Rating
Just briefly, I’d like you to rate five motivational types from 1 ‘does not correspond at all’ to 5 ‘corresponds exactly.’ to what best corresponds to the reasons of why you spend time studying <science> science.

(1 Does not correspond at all, 2 Corresponds a little, 3 Corresponds moderately, 4 Corresponds a lot, 5 Corresponds Exactly)

1) I have no motivation to study <science>. (AMOT)
2) I am motivated to study <science> to get a good salary or job. (EMER)
3) I am motivated by wanting to show myself or others that I can do well in <science>. (EMIN)
4) I am motivated by improving my competence in <science> for my future. (EMID)
5) I am motivated by discovering new things in <science>. (IMT)

What do you think can instructors do ...

1. to support motivation in science courses?
   - Can you provide examples?
2. To not frustrate students’ motivation to learn science in their courses?
   - Can you provide examples?

Questions to Follow Up on Survey Study Results
Now I’d like to ask you some questions that arose from the survey on motivation, so I can understand more.

1. Survey results suggest that (IMT) being motivated by discovering things in science is higher for 20 year olds than 18 year olds in college.
   - What do you think about that?
   - Can you tell me about change of motivation with age?
   - How does your motivation to study science now compare to your time in high school?

2. When comparing students planning on a job in science or engineering with students wanting a career in health, survey results suggest that being motivated by discovering new things is higher for students planning the science or engineering job.
    - Can you tell me more about that?

3. When comparing males and females, results suggest that males are more motivated to study to get a good salary or job than females.
    - Can you tell me more about that?

4. A few students rated their amotivation very high, so don't have motivation to learn for the course at all.
    - What do you think about that?

5. When asked for which career students are currently interested in, a lot of students naming a subject area as career goal and not an occupation or job.
    - Can you tell me more about that?

6. What else would you want science course instructors to know about what influence motivation for you to study.

7. How would you define what science is? <__________>
    - How do you (learn/do) <__________> in your science courses?
    - Can you tell me more about how <__________> influences motivation for studying science?

Demographics
We are almost done. I'd like to briefly ask you a few more basic questions to understand a bit more about what influences the success of students in science education. Rest assured that your answers will remain anonymous.

What are the top one or two careers you currently are considering?
1) _______________, 2) _______________

Please select the best answer.
In the last year, I have changed my mind about careers ...

a. ... multiple times, b) ... at least once c) ... not at all.

What major are you currently in in college? ________________

Please tell me if you attended the <science> class
a)... in person on campus, or b) ... online, c) … or both.

In the last six months, have you had any type of paid or unpaid experiences that relate to your major or potential career? (e.g. internships, practicum, jobs)

a. Yes
b. No. (if no, then ask:) Do you plan on it in the next year? _____ (yes/no)

What is your age and gender? __________________________
a) Female, Trans female, or Trans woman, b) Male, Trans male, or Trans man, c) Genderqueer/gender non-conforming, d) Self-Identify, e) Decline to respond

What do you consider your ethnicity and race? Please name all that applies.
a) Hispanic or Latino or Spanish Origin of any race, b) Black or African American, c) Asian, d) American Indian or Alaska Native, e) Native Hawaiian or Other Pacific Islander, f) White, g) Self-Identify, h) Decline to respond

Are you First College Generation? (yes - neither of my parents has a College Bachelor's Degree or higher College Degree, no - one or both of my parents has a College Bachelor's Degree or higher College Degree)

Closing
This is the end of this interview.
Thank you for participating. I appreciate you taking the time to interview with me today.

Information
You should receive the $20 stipend within one week.
If you have any questions about the payment or in general, please feel free to email or call me anytime. You can find my contact information at the bottom of my emails.

If you like to be notified when this study is completed to receive a summary report? We would be more than happy to provide you with a copy.

Thank you for participating in this interview. We appreciate you taking the time to do this. We may contact you in the future for the purpose of follow up interviews.

Let me assure you once more that this interview and your responses are kept anonymous.

If you have any questions, please feel free to contact me anytime at 208-885-5819 or via my cell phone at 208-596-5778.

Researcher Reference Sheet During Interview for <Construct> Phrases and Key Words for Prompts:

AMOT - Amotivation
I am not motivated to study <science>.
I don't know; waste of time; I am not sure; I don't see value; I can't understand

- Honestly, I don't know; I feel that it is a waste of time studying science.
- 19. I can't see why I study science and frankly, I couldn't care less.
- 17. I don't know; I can't understand what I am doing in science.
- 4. I am not sure; I don't see how science is of value to me.

EMER - Extrinsic Motivation External Regulation
I am motivated to study <science>to get good grades.
good grade; job; better salary, "the good life"

- 5. Because without a good grade in science, I will not be able to find a high-paying job later on.
- 8. In order to obtain a more prestigious job later on.
- 16. Because I want to have "the good life" later on.
- 10. In order to have a better salary later in life

EMIN - Extrinsic Motivation Introjected
I am motivated to study <science> to show others that I can do well in <science>.
by wanting to show yourself or others that you can do well in biology; show others; show myself; feel important

- 20. Because of the fact that when I do well in science, I feel important.
- 2. Because I want to show to others (teachers, family, friends) that I can do science.
- 9. To show myself that I am an intelligent person.
- 3. Because I want to show myself that I can do well in science.

EMID - Extrinsic Motivation Identified
I am motivated to study <science> to improve my competence in <science> for my future.
useful for me in future; better prepare me for career, my work competence

- 18. Because I think that science will help me better prepare for my future career.
- 14. Because studying science will be useful for me in the future.
- 6. Because I believe that science will improve my work competence.
- 12. Because what I learn in science now will be useful for college classes in the future.

IMT - Intrinsic Motivation
I am motivated by the satisfaction of discovering and understanding things in <science>.
IMTK–Knowledge: pleasure broadening knowledge, pleasure discovering

- 7. I feel good discovering new things in science that I have never learned before.
- 15. I feel good broadening my knowledge about science.

IMTA–Achievement: satisfaction of understanding, achievement

- 13. Because I want to feel the personal satisfaction of understanding science.

IMTS–Stimulation: pleasure feeling absorbed; learn how things in life work

- 11. I feel good getting lost in science learning and discovery.
- 21. I feel good learning how things in life work, because of science.

Consent Form

<<Researcher Name>>, from the College of Education, Health, and Human Sciences is conducting a research study. The purpose of the research is to better understand the motivation toward learning science. You are being asked to participate in this study because it is important for educators to hear the voice of students on this topic.

Your participation will involve providing feedback to questions about science learning motivation. The interview will take been 30 minutes and an hour to complete. The interview includes questions such as “Can you tell me about why you spend time studying science?” Your involvement in the study is voluntary, and you may choose not to participate. You can refuse to answer any of the questions at any time. There are no names or identifying information associated with your responses. There are no known risks in this study, but some individuals may experience discomfort or loss of privacy when answering questions. Data will be saved on secure servers of the University of Idaho. The audio file of the interview will be deleted once it is transcribed into text.

The interviews will be conducted with the audio/video software Zoom. The audio will be recorded, transcribed, and then deleted. The transcription of audio into text will be done with Zoom transcription software. The Zoom terms of service are available at https://zoom.us/terms, the privacy for Zoom software at https://zoom.us/privacy.

The findings from this project will provide information on motivation for science learning. If published, results will be presented in summary form only, anonymous quotes from the interviews may be included.

If you have any questions about this research project, please feel free to call the researcher <<Researcher Name at <<phone number>>. or the principal investigator <<PI Name>> at <<phone number>>. If you have questions regarding your rights as a research subject, or about what you should do in case of any harm to you, or if you want to obtain information or offer input you may call the Office of Research Assurances at <<phone number>> or mail <<email>>

By signing below, I certify that:

I am a student participant of at least 18 years of age, and I agree to participate in the research study described above.

____

Participant Signature Date

You will receive a $20 stipend via Venmo at the end of the interview.

Please provide your Venmo contact or an address for an alternate method of payment:

To receive a summary report once this study is completed

please provide an email or phone number. We will notify you once the summary report is available.

____

Email or Phone Number

Appendix E: IRB Approvals

University of Idaho
Office of Research Assurances

Institutional Review Board
875 Perimeter Drive, MS 3010
Moscow, ID 83844-3010
Phone: 208-885-6162
Fax: 208-885-6014
Email: irb@uidaho.edu

July 25, 2022

To: Brant G. Miller

Cc: Kirsten LaPaglia

From: University of Idaho Institutional Review Board

Title: 2021-05 Science Motivation Survey College
Protocol: 21-182, Reference: 018437

Review Type: Exempt

Protocol Approval Date: 09/09/2021

Amendment Approval Date: 07/25/2022

The Institutional Review Board has reviewed and **approved** the amendment to your above referenced Protocol.

This amendment is approved for the following modifications:

- Change of Primary Investigator

Should there be significant changes in the protocol anticipated for this project, you are required to submit another protocol amendment request for review by the committee. Any unanticipated/adverse events or problems resulting from this investigation must be reported immediately to the University's Institutional Review Board.

Forms can be found at https://veras.uidaho.edu
Templates can be found at https://www.uidaho.edu/research/faculty/research-assurances/human-protections/forms

Your approved internal personnel on this protocol are: LaPaglia, Kirsten; Miller, Brant G.

IRB Exempt Category (Categories) for this submission:
Category 2: Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met: i. The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects; ii. Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation; or iii. The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by .111(a)(7).

Note. This University of Idaho IRB approved conduct of survey and interview by the researcher.

North Idaho College
1000 West Garden Avenue, Coeur d'Alene, Idaho 83814
www.nic.edu

Department Name
(208)769-7835 phone
IRB@nic.edu

October 8, 2021

Tonia Dousay, Ph.D.
Kirsten LaPaglia
University of Idaho
Sent via email: kirsten@uidaho.edu

Dear Dr. Dousay and Ms. LaPaglia,

The North Idaho College Institutional Review Board (IRB) approved your application titled *Science Motivation Survey College* based upon documentation submitted during the review and information obtained during the interview. This approval is condition of the adherence of the responsibilities listed on page 4 of the NIC IRB Application for Human Subjects Research (Part 1).

The IRB is appreciative of Kirsten LaPaglia taking time out of her busy schedule to talk to the IRB. Several members of the IRB expressed appreciation of the quality of the application and the supporting documents.

Per IRB guidelines, this approval is good for a period of one year. Multi-year research projects require annual IRB approval. Please contact me if you have any questions. All the best to you as you conduct your research.

Sincerely,

Steven Kurtz, Ed.D.
IRB Facilitator

An Equal Opportunity/Affirmative Action Institution

Note. NIC requested this approval for their faculty to share the survey of this study to their students