

AUTONOMY SUPPORT IN US NINTH-GRADE
SCIENCE CLASSROOMS: EXPLORING A SELF-DETERMINATION MODEL OF
MOTIVATION USING NATIONAL IES DATA

by

ANTHONY C. DERRISO

CECIL ROBINSON, COMMITTEE CHAIR

JOHN DANTZLER
SHARON E. NICHOLS
RANDALL E. SCHUMACKER
JASON M. SCOFIELD

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ABSTRACT

Using self-determination theory (SDT) as a conceptual framework, this research examines motivation in our nation's science classrooms by conducting a secondary data analysis of the High School Longitudinal Study of 2009 (HSL:09). The study describes the creation of a valid measure of autonomy support within HSL:09 and validates critical components of SDT with a nationally representative sample of data. Results indicate males and females do not differ meaningfully on measures of autonomy support, science perceived competence, science interest, or science identity. Autonomy support was a statistically significant predictor of science perceived competence, science interest and science identity, and these relationships were the same for males and females. Among US ninth-graders intending to pursue STEM occupations, 84% are boys and 16% are girls. Science perceived competence and science identity mediated the relationship between science autonomy support and students' intentions to pursue a STEM career. Additionally, science perceived competence and science identity significantly discriminated between students who intended to pursue a STEM occupation and those who did not.

Keywords: autonomy support, perceived competence, interest, motivation, STEM, science identity, gender

LIST OF ABBREVIATIONS AND SYMBOLS

a	Cronbach's index of internal consistency
β	Standardized regression coefficient
η^2	Chi-squared: test for independence
d	Cohen's d : measure of effect size
df	Degrees of freedom: number of values free to vary after certain restrictions have been placed on the data
F	Fisher's F ratio: A ration of two variances
M	Mean: the sum of a set of measurements divided by the number of measurements in the set
N	Number in a sample
p	Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value
R^2	Coefficient of determination: how well the data fits a model
\bar{x}	Mean of a sample
r	Pearson product-moment correlation
t	Computed value of t test
$<$	Less than
$>$	Greater than
$=$	Equal to

ACKNOWLEDGMENTS

I would like to thank my wife for her patience and support, both literally and figuratively. Her selflessness and patience is summed up in a card she once gave me that read “You go your way. I’ll go your way, too. Life is better with you.” She is a brave, sweet soul and a faithful, loving companion for life’s journey. I would also like to thank the committee for their time and effort. Their advice and example has helped me see how to be a better scholar and mentor.

S.D.G.

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CHAPTER 1

INTRODUCTION

In the 21st century, scientific knowledge and inquiry are directly linked to our long-term economic and national security. We need citizens who know how to analyze data and make informed decisions, who can think critically and skeptically, who know how to ask new questions and then pursue avenues of inquiry. With a strong foundation in science, our young people today will have the knowledge, curiosity, creativity, and critical-thinking skills necessary to excel in the workforce of the future. (Duncan 2011)

While US Secretary of Education Arne Duncan is calling for a science education for the 21st century, the Program for International Student Assessment (PISA) indicates that the US lags far behind similar nations in science. PISA is an international assessment of 15-year-olds taken by students in 60 countries that is coordinated by the Organization of Economic Cooperation and Development (OECD) and is intended to measure the outcome of compulsory education. The latest results show that US students have moved up to average on the science scale score, an improvement over 2006 but still leaving the US lagging behind 18 countries and effectively tied with 13 others (OECD, 2010).

International comparisons such as PISA are frequently used to justify positions on educational policy, including calls for more funding, more teachers, or more professional development. Indeed, in response to the latest PISA results, Dr. Francis Eberle, executive director of the National Science Teachers Association (NSTA), released a statement noting “test scores for our students could be significantly improved if schools, states, and the federal government would commit to a larger investment in science teaching and learning” (Eberle,

2010, p. 1). However, greater educational expenditures do not guarantee higher PISA scores; the US spends about a third more per student than Finland, which ranks second from the top in science. And it's not just the Fins who accomplish more with less—of the 18 countries that scored higher in science on PISA 2009, only Switzerland spends more per student than the US (de Ruy, 2011).

Insufficient resources, therefore, may not explain the perceived problems in US science education; in order for the US to improve on international comparisons, reform or change will likely be required on multiple levels, but any comprehensive solution should take into consideration our fullest possible understanding of learning. A science of learning, though virtually nonexistent in the early 20th century when modern schooling was established, has emerged over the last several decades and contributed an enormous amount of empirical evidence related to learning and effective teaching. Much of this research was summarized by the National Research Council (NRC) in the 1999 report, *How People Learn: Brain, Mind, Experience and School* (National Research Council), which led to the book *How Students Learn: History, Mathematics, and Science in the Classroom* (National Research Council, 2005). Focusing on what the NRC describes as “three fundamental and well-established principles of learning,” (p.1) this volume is both a theoretical and practical resource for science educators as they consider students’ preconceptions, understanding and self-regulation in order to effectively design learning environments that equip students with 21st century science literacy.

Motivating Learning

Despite the importance of these principals for our understanding of learning and teaching and despite the relevance of the principles to the design of effective learning environments, science educators seem to be far more concerned about a factor not always associated with

learning. In the 2011 State of Science Education Survey, the National Science Teachers Association (NSTA) asked 400 members about their concerns as a science educator; student motivation was indicated as the area of greatest concern in the classroom. These results were identical to a similar 2009 survey. Surprisingly, the word “motivation” does not occur as a topic in the index of *HSL: Science in the Classroom*. In fact, the word “motivation” or “motivations” only occurs in the book six times, and in none of these instances is it used in the context of a broader discussion of the importance of motivation in education, science or otherwise.

Certainly the NRC, like the teachers in the NSTA survey, understands the importance and relevance of motivation in education, but the fact that motivation is not included in a volume that summarizes learning research highlights a possible divide—namely that the NRC considers motivation separate from learning. At best, learning and motivation might be considered two sides of a coin. Arguably this divide is a latent effect of a juncture that occurred in the 1930s, when Tolman demonstrated that learning could occur without rewards or drive reduction, thus providing the basis for the study of motivation outside the context of learning (Weiner, 1990). However, as noted by Weiner, “the prime issue always has been how to motivate people to engage in new learning” (p. 618).

The study of motivation has advanced dramatically from these early ideas of rewards and drive reduction. Modern theories of motivation still include early functionalistic ideas (e.g., innate psychological needs), but have advanced to include cognitive components such as the beliefs, values and expectations associated with action. Currently, the study of motivation involves a broad spectrum of questions that have led to empirical findings related to students’ self-efficacy, self-worth, learned helplessness, persistence, intrinsic vs. extrinsic motivation and cooperative vs. competitive goals among others (Graham & Weiner, 1996; Eccles & Wigfield,

2001). As our knowledge of motivation has broadened and deepened over the last several decades, it has become increasingly clear that an understanding of motivation is critical to our understanding of learning and effective teaching (see Perry, Turner & Meyer, 2006 for an examination of classroom tasks and activities that support student motivation).

Although general research in the field of motivation has been and continues to be extensive, research specific to science education, particularly secondary science education, has been somewhat thin and uneven. Koballa & Glynn (2007) note that motivation and other affective constructs have been investigated much less than cognitive constructs in the field of science education. Nevertheless, some research has been conducted regarding several affective constructs, including attitudes toward science, students' engagement in class, enrollment in science courses, and interest (Vedder-Weiss & Fortus, 2011). Emerging from much of this research are two disturbing findings: schools in the US are not producing students with positive feeling toward science (Simpson & Oliver, 1990) and students' motivation for science learning declines throughout schooling, especially in secondary education (Osborne, Simon, & Collins, 2003).

The purpose of this study is to broaden our understanding of motivation in secondary science by leveraging a nationally representative data set to provide a comprehensive analysis of motivation-related attitudes of US ninth-graders. Moreover, this study will explore the various ways these attitudes may affect students' intentions to enter a STEM career.

Self-Determination Theory

The current study will use self-determination theory (SDT) as a framework to examine motivation in our nation's science classrooms. SDT is a macro theory of motivation that posits an individual's optimal development and well-being occur under conditions that satisfy that

individual's innate psychological needs of competence, relatedness and autonomy (Deci & Ryan, 2000). Within SDT, the satisfaction of these basic psychological needs sustains intrinsic motivation, and therefore self-determined behavior (Niemic & Ryan, 2009). Further, SDT posits that activities vary in the extent to which they are self-determined, from intrinsically motivated activities pursued for enjoyment to more controlled environments where external contingencies (e.g. rewards, punishments) or internal pressures (e.g. shame, guilt) motivate behavior (Deci & Ryan, 2000).

Black and Deci (2000) investigated the relationship between autonomous and controlled sources of motivation and how each impacted various outcomes in a college-level organic chemistry class. The investigators found that students who entered the course with more autonomous motivation were more interested, enjoyed the course more, experienced lower anxiety, were less focused on grades-focused performance goals, and had higher indexes of perceived competence. Further, students who entered the course with more autonomous orientation were less likely to drop out of the course. Two related studies on motivation in science education have demonstrated the importance of parents' autonomy support for persistence in a science program (Ratelle, Larose, Guay, & Senécal, 2005) and the positive impact of instructor autonomy support on students' autonomous learning and perceived competence (Williams & Deci, 1996).

Autonomy support involves a social agent in a position of authority (e.g. teacher) empathizing with the other, providing pertinent information and opportunities for choice, while minimizing external pressure (Black & Deci, 2000). Within in the theory of self-determination, these autonomy-supportive contexts "tend to maintain or enhance intrinsic motivation and promote identification with external regulations, while controlling contexts tend to undermine

intrinsic motivation and forestall internalization” (p. 742). Among the benefits described by Black and Deci (2000) of autonomy-supportive contexts are more intrinsic motivation (Deci, Schwartz, Steinman, & Ryan, 1981), greater internalization (Grolnick & Ryan, 1989), better conceptual learning (Grolnick & Ryan, 1987), more creativity (Koestner, Ryan, Bernieri, & Holt, 1984), and more positive affect both in regular education (Ryan & Grolnick, 1986) and in special-education settings (Deci, Hodges, Pierson, & Tomassone, 1992).

Perceived competence, an individual’s perception of his or her ability to complete a task, has long been an integral component of expectancy-value theories of motivation, according to which motivation is a function of the value of what one expects to get and the perceived likelihood of getting it (see Graham & Weiner 1996). As noted earlier, the need for competence is considered an innate psychological need within SDT. Specific to science learning, Velayutham, Aldridge and Fraser (2011) provide an excellent summary of research related to the influence of perceived competence (or self-efficacy), noting that self-efficacy has been associated with science achievement at the college and high school level as well as among middle school students.

Although not considered an innate need in SDT, interest is a fundamental building block within SDT insofar as intrinsically motivated activities involve inherent interest and enjoyability. In other words, a student will be intrinsically motivated to engage in an activity if it is interesting and enjoyable, and the activity will be interesting and enjoyable if it satisfies the student’s needs for competence, autonomy and relatedness (Deci & Ryan, 2000). Moreover, interest facilitates cognitive functioning, an effect that has been established across individuals, knowledge domains, and subject areas (Hidi & Harackiewicz, 2000).

Gender Differences in Science Motivation

In the recently released *A Framework for K-12 Science Education*, the National Research Council (National Research Council, 2012) addresses student motivation as a part of a more broad discussion of the disproportionate representation of particular demographic groups in science, technology, engineering and math (STEM):

Low learning expectations and biased stereotypical views about the interests or abilities of particular students or demographic groups also contribute, in both subtle and overt ways, to their curtailed educational experiences and inequitable learning supports. Students' own motivation and interest in science and engineering can also play a role in their achievement and pursuit of these fields in secondary school and beyond. Thus attention to factors that may motivate or fail to motivate students from particular demographic groups is important to keep in mind when designing instruction. (p. 279)

The NRC framework, although primarily intended to identify the science that all K-12 students should know, challenges educators to also focus on key components not always associated with science achievement, recognizing that stereotypical views about interest and ability exist, that certain demographic groups are not proportionally represented in STEM, and that both motivation and interest can also play a role in achievement as well as in the pursuit of science related fields beyond school.

Girls outnumber boys in advanced science classes, yet the motivation-related beliefs of boys and girls follow gender stereotypes; boys report stronger ability and interest beliefs in science and these effects are moderated by ability (for a review of research see Meece, Glienke, & Burg, 2006). As noted in Meece, et al., teachers may contribute to gender differences in motivation by modeling sex-typed behavior, communicating different expectations or

encouraging different activities and skills for boys and girls (Eccles et al., 1983). The review of gender and motivation by Meece, et al. explored the issue from four contemporary theories of motivation (i.e., attribution, expectancy-value, self-efficacy, and achievement goal), but did not consider SDT. Because autonomy support, a central component of SDT, is considered a social determinant of motivation, the effects of this determinant and the social agent (e.g., teacher) may be different among boys and girls in a manner similar to the studies review by Meece, et al..

It is clear that our nation's students must be equipped with the science, technology, engineering and math skills necessary to compete in a global knowledge economy. However, *The Nation's Report Card: Science 2011* (National Assessment of Educational Progress, 2011) indicated only 32% of U.S. eighth graders scored at or above proficient levels. Adequately preparing our nation's young people to compete in a global knowledge economy is a critical issue and student motivation, indicated by science educators as a primary concern, should be a part of any comprehensive solution. As noted by Gary Cooper in *Building Engaged Schools*, "students can be required to take certain classes, but their psychological commitment to an activity can't be coerced. Forcing students to do more without considering how to trigger and sustain their emotional involvement may well have the unintended consequence of lowering engagement in required courses--and in learning itself" (2006, p. 73.). At its core, the science of motivation is about why people think and behave as they do (Graham & Weiner, 1996). After decades of exploring this basic idea, learning scientists can answer questions critical to our understanding of learning (e.g., Why do students' expectations affect their willingness to participate in an activity?). Self-determination theory provides a theoretically and empirically solid framework with which to understand motivation in our nation's science classrooms. However, few studies have investigated motivation in secondary education from a SDT

perspective and even fewer have looked specifically at SDT in science classrooms. Moreover, SDT has never been tested with a nationally representative sample, especially one specific to both science and secondary education. This study will address this gap by examining the motivation of US ninth graders from an SDT perspective using a large, nationally representative data set.

The Nation's Report Card also revealed that average science scores among eighth grade boys were 5% higher than girls. This achievement gap was actually a slight *increase* from the 2009 NAEP. In *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads*, the National Research Council (2011) argues

The United States stands again at the crossroads: a national effort to sustain and strengthen science and engineering (S&E) must also include a strategy for ensuring that we draw on the minds and talents of all Americans, including minorities who are underrepresented in S&E and currently embody a vastly underused resource and a lost opportunity for meeting our nation's technology needs" (p. 1).

It is essential that all US students are prepared with the skills necessary to compete in the 21st century, yet international indicators suggest the US lags far behind other developed countries and that certain demographic groups are underrepresented in STEM. Meanwhile, decades of research in the learning sciences have established well-documented and empirically proven principles of learning, but research on motivation has been thin and uneven in secondary science education despite the fact that science educators see motivation as a primary concern in their classrooms. Using self-determination theory, the proposed research will deepen our understanding of the critical issue of motivated learning in US science classrooms, paying particular attention to demographic groups underrepresented in STEM. Moreover, this study is in

keeping with the idea of data-driven decision-making, one of the four pillars in the American Recovery and Reinvestment Act of 2009, which urges federal education officials to use data and evidence to inform decisions regarding policy and practice (Mandinach, 2012).

Three separate but related papers will to explore several questions related to motivation in secondary science education. The first paper will describe the creation of a proxy for autonomy support within a nationally representative sample of US ninth-graders and then consider the effects of students' perceptions of autonomy support on perceived competence and interest. The second paper will consider whether or not ninth-graders' perceived competence, interest, and science identity are affected by their gender, and, if so, if this effect moderated by autonomy supportive environments. The third paper will build on the previous paper by considering whether ninth-graders' intentions to pursue a STEM career are influenced by autonomy support and science identity. The following section describes the methods, analysis and variables for each paper.

Paper 1

Paper one investigates the role of autonomy support and its effects on the science perceived competence and interest of US ninth-graders. Black and Deci (2000) found that autonomy support predicted increases in perceived competence and interest/enjoyment in a college-level organic chemistry course. This paper will attempt to validate this SDT finding with a nationally representative sample and also replicate it with students in a secondary science education setting. This study will be facilitated by the creation of a measure for autonomy support within the HSLs:09 data set. The following research questions guide this study:

1. Can items within the HSLs:09 data set be used to create a measure of autonomy support?

2. What is the relationship between perceived competence, interest and autonomy support among US ninth-graders?

Hypotheses for the question are elaborated below:

Hypothesis 1: HSLs:09 contains items that can be used to measure ninth-graders' perceptions of autonomy support.

Although NCES did not intentionally measure autonomy support, HSLs:09 contains several items that closely resemble items on validated measures of autonomy support. These items can likely be used to create a reliable scale that can be used to indicate ninth-graders' perceptions of autonomy support.

Hypothesis 2: US ninth-grade students' perceptions of autonomy support will impact their perceived competence for the course as well as their interest in the course.

As with Black and Deci (2000), it is predicted that ninth-graders will be more motivated as their need for autonomy is met. This motivation is likely to be reflected in heightened interest and increased perceptions of competence.

Method

Participants

The High School Longitudinal Study of 2009 (HSLs:09) is a nationally representative study of more than 21,000 9th graders in 944 schools from the 50 United States and the District of Columbia. The 944 schools were sampled from both public schools (including charter schools) and private schools enrolling both ninth and eleventh-grade students. The target population of students was defined to include all ninth-grade students who attended the study-eligible schools in the fall 2009 term. Approximately 24,000 ninth-graders were selected, an

average of 25 students per school. These students' parents, math and science teachers, counselors and school administrators were also invited to complete surveys.

Procedure and Measure

Paper one uses the High School Longitudinal Study of 2009 (HSLs:09), a public-use data set from the National Center for Education Statistics (NCES, 2011). The HSLs:09 base year took place in the 2009–10 school year with a randomly selected sample of fall-term 9th-graders. The student questionnaire for in-school administration was electronic and students reported on their experiences, expectations, plans and attitudes related to their Fall 2009 science course. In addition, data were also gathered from parents, teachers, counselors, and administrators.

Students were sampled through a two-stage process. First, 1,889 eligible schools were identified using stratified random sampling and school recruitment, of which 944 participated in the study, resulting in a 55.5 percent (weighted) or 50.0 percent unweighted response rate. The 944 schools were sampled from both public schools (including charter schools) and private schools enrolling both ninth and eleventh-grade students. The second stage involved randomly sampling students from school ninth-grade enrollment lists, resulting in 25,206 eligible selections, or about 27 per school. These students' parents, math and science teachers, counselors and school administrators were also invited to complete surveys. Students will be followed through their secondary school experiences and post-secondary or early work years. The survey was administered again in the spring of 2012 during most students' 11th grade year. A brief data collection occurred in the spring of 2013, the year most students should graduate, to obtain a postsecondary status update. A second follow-up is planned for 2015 and additional follow-up data collections are also planned.

Analyses

Paper 1 will involve a secondary data analysis of HSLs:09. Science perceived autonomy support will be created using four items from the HSLs:09 questionnaire. These items required students to indicate their level of agreement with phrases related to their current science teacher (e.g., “Your science teacher values and listens to student’s ideas”). These items were selected based on their similarity to items contained in validated measures of perceived autonomy support, such as the statement “I am able to be open with my instructor during class” from the Learning Climate Questionnaire (LCQ), formulated by Williams and Deci (1996). SPSS principal components analysis (PCA) will be used to reduce the questionnaire items to one factor. PCA was selected over confirmatory factor analysis because PCA was used by NCEs to create the interest and perceived competence scales. The scale will be standardized to a mean of 0 and standard deviation of 1.

A multivariate analysis of covariance (MANCOVA) will be used to assess the conformity of the HSLs:09 data to SDT. The research question investigated in this study includes three variables: science perceived autonomy support, science perceived competence, and science interest. The relationships will be specified based on the results of Black & Deci (2000) by

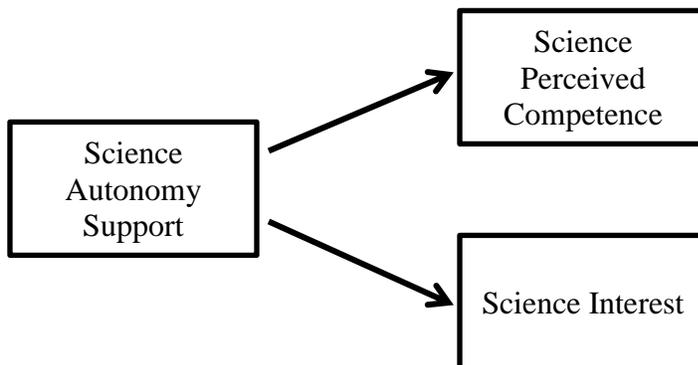


Figure 1.1 *Proposed model for Paper 1*

setting science perceived autonomy support as the independent variable (covariate) and both perceived competence and science interest as the dependent variables.

The perceived competence variable was created using four items from the HSLs:09 questionnaire (e.g., “You are certain that you can master the skills being taught in this course”). These items were selected based on face validity when compared with items (e.g., “I feel confident in my ability to learn this material”) from validated measures of perceived confidence such as the Perceived Competence Scale (Williams and Deci, 1996). Perceived competence was calculated as a scale of students’ science self-efficacy, where higher perceived competence values represent higher science self-efficacy. The variable was created through SAS proc factor (factor analysis) and standardized to a mean of 0 and standard deviation of 1. The coefficient of reliability (alpha) for the scale is .88 (Ingles, et al., 2011).

The interest variable is a scale of students’ interest in their 9th-grade science course, where higher values represent greater interest in the course. The variable was created using SPSS principal components and standardized to a mean of 0 and standard deviation of 1. Six items related to student interest were used as inputs for the scale (e.g., “You think this class is boring”). The coefficient of reliability (alpha) for the scale is .73 (Ingles, et al., 2011).

Paper 2

Paper two builds on the first paper by investigating possible gender-related differences in the model of motivation introduced in paper one. As noted earlier, learning environments created by teachers may contribute to gender differences in motivation (Eccles et. al., 1983). Because autonomy support is a controllable factor, an understanding of the differential effects of autonomy supportive environments on boys and girls may enable educators design better and

more inclusive learning environments. Specifically, paper two considers students' gender as well as students' responses to the questionnaire items "You see yourself as a science person" and/or "Others see me as a math person." As noted earlier, motivation-related beliefs of boys and girls follow gender stereotypes, with boys reporting stronger ability and interest beliefs in science (Meece, Glienke, & Burg, 2006). Paper two will use a nationally representative sample to validate these gender stereotypes among US ninth-graders. Three research questions will guide this investigation:

1. Do male and female students differ on measures of perceived competence, interest, and science identity?
2. What is the relationship between autonomy support, perceived competence, interest, and science identity?
3. Does the relationship between the variables of interest vary across gender?

Hypotheses for the questions are elaborated below:

Hypothesis 1: Male students will have higher values for perceived competence and interest and will tend to identify more with science.

Hypothesis 2: Learning environments that support a student's need for autonomy will lead to increased perceived competence and interest, and an increased likelihood of identifying with science.

Hypothesis 3: Autonomy supportive environments will benefit girls more than boys.

Method

Participants

As with Paper 1, the participants will be a nationally representative sample of US ninth-graders a sampled in HSL:09.

Procedure and Measure

The procedure and methods for Paper 2 are the same procedure and methods used by NCES in HSLS:09 and described for Paper 1.

Analyses

A multivariate analysis of covariance (MANCOVA) in SPSS will be used to investigate the four variables of interest: science perceived autonomy support, science perceived competence, science interest, and science identity. In part, the relationships will be specified based on the results of Black & Deci (2000) by setting science perceived autonomy support as the independent variable (covariate) and perceived competence and science interest as the dependent variables. This study will extend self-determination theory by also adding science identity as a dependent variable (see Figure 3.1).

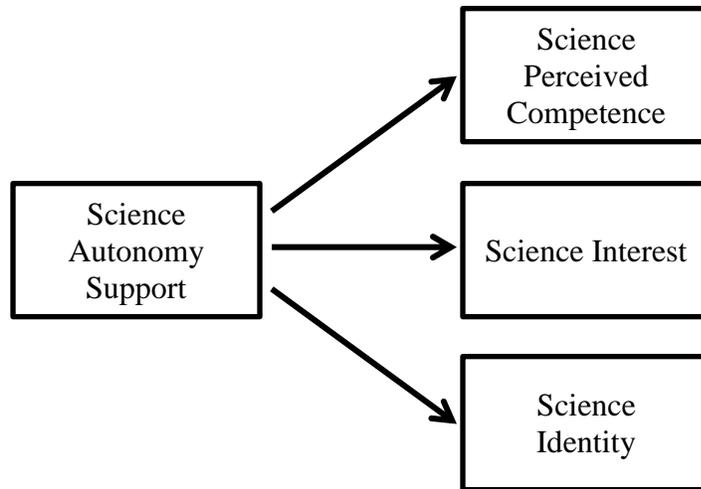


Figure 1.2 *Proposed model for Paper 2*

Paper two will use the variables from paper one plus the background variable, gender, as well as science identity. Science identity is a scale of the sample member's science identity created by NCES (2011). Students who tend to agree with the statements "You see yourself as a

science person" and/or "Others see me as a math person" have higher values for science identity. The coefficient of reliability (alpha) for the scale is .83 (Ingles, et al., 2011).

Paper 3

Paper three builds on paper two by investigating the effects of the previous model of science motivation on students' intentions to enter a STEM occupation. As noted earlier, certain demographic groups are underrepresented in STEM, and the model of motivation validated in paper two should clarify how motivational factors, especially malleable social determinants such as autonomy support, influence a student's intention to pursue science as a career. The following research questions will guide the investigations in paper three:

1. How do US ninth-graders' intentions to pursue a STEM-related career vary across gender?
2. Do autonomy supportive learning environments affect US ninth-graders' intentions to pursue a STEM career by influencing students' perceived competence, interest and science identity?

Hypotheses for the research questions are elaborated below:

Hypothesis 1: Males will be more likely than females to express an intention to pursue a STEM career.

Hypothesis 2: Both male and female students in autonomy supportive science classroom will be more likely to express an intention to pursue a STEM career.

Method

Participants

As with Papers 1 and 2, Paper 3 will use the nationally representative sample of US ninth graders described in HSLS:09.

Procedures and Measure

The procedure and measures used by NCES to obtain the data in HSLs:09 are the same described for Paper 1.

Analyses

Because HSLs:09 is a nationally representative data set, descriptive statistics will first be computed to give an general profile of US ninth-graders on the variables of interest in the HSLs base year of 2009. This analysis will, among other things, indicate the number and gender composition of US ninth-graders intending to pursue a career in the STEM disciplines.

In the proposed model (see Figure 1.3), perceptions of autonomy support, science perceived competence, science course interest, and science identity are hypothesized to affect students' intentions to pursue a STEM occupation. A mediation analysis followed by a discriminant analysis will be used to predict group membership in either the STEM (coded as 1) or Non-STEM (coded as 0) groups. *F* ratios will be used to determine whether each variable significantly discriminates between the two groups.

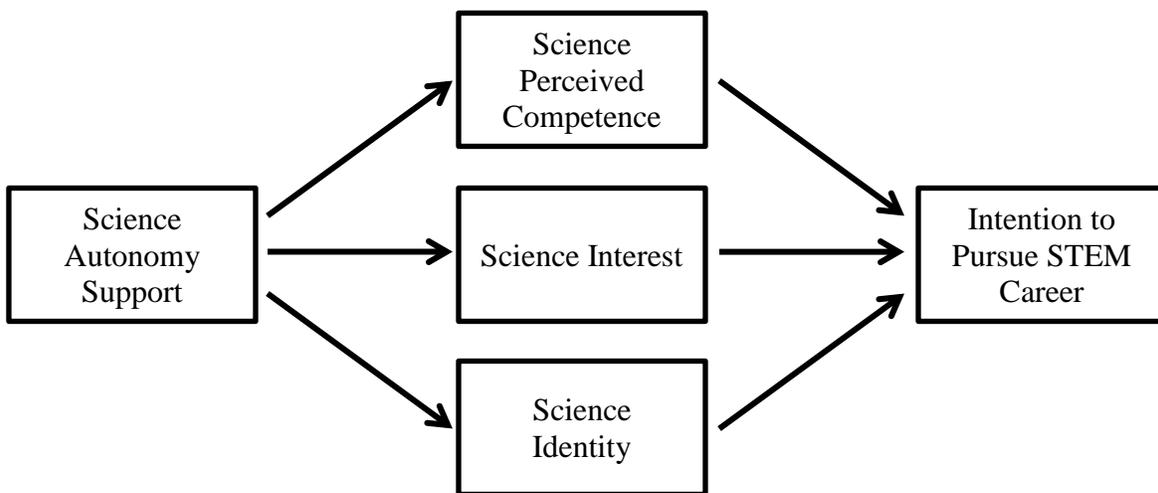


Figure 1.3 *Proposed model for Paper 3*

Paper three will include the variables from Paper 2 plus the variable intended occupation. Students were asked on the HSLs:09 student questionnaire to enter the occupation they expect or plan to have at age 30. Using the O*NET taxonomy (<http://www.onetcenter.org>), coding experts assigned a code to the student-entered job title indicating the corresponding O*NET category (e.g., the response “lawyer” or “attorney” would be coded 23 for legal occupations). For the purposes of this study, STEM occupations were considered to be all non-medical fields of fundamental science and engineering. NCES used 24 categories to code 21, 444 student responses. Of these categories, three indicated STEM occupations: 15 = computer and mathematical, 17 = architectural and engineering, and 19 = life, physical and social science. Within SPSS, these three categories will be coded “1” and all other categories will be coded as “0.”

In summary, schools in the US are not producing students with positive attitudes toward science and students’ motivation for science learning declines throughout schooling, especially in secondary education, yet motivation and other affective constructs continue to be investigated much less than cognitive constructs in the field of science education. Moreover, the motivation-related beliefs of boys and girls have been shown to follow gender stereotypes, but the influence of these stereotypes is moderated by classroom context, highlighting the potential of the local environment, including the influence of teachers, to moderate the effects of gender beliefs. Research on social determinants of motivation has demonstrated the importance of autonomy supportive environments for increasing students’ interest and perceived competence, but has not typically considered the varying effects of these environments in terms of gender or other background variables. Finally, considerable progress has been made closing the gender gap

in educational attainment but females remain underrepresented among students earning bachelor degrees in STEM. Research suggests these disparities are influenced by gender stereotypes, but that the influence of these stereotypes can be moderated by teachers and peers in the classroom. Using self-determination theory (SDT) as a conceptual framework, this body of work will examine motivation in our nation's science classrooms by conducting a secondary data analysis of the High School Longitudinal Study of 2009 (HSL:09). The study will create of a valid measure of autonomy support within HSL:09 and validate critical components of SDT with a nationally representative sample of data. The study will investigate the effects of autonomy supportive environments on students' perceptions of competence, interest and identity in science, as well as the effect of autonomy supportive science classrooms on students' intentions to pursue a STEM career.

CHAPTER 2

Perceived Autonomy Support in a Nationally Representative Sample of US Ninth-graders

Anthony Derriso

The University of Alabama

Abstract

Schools in the US are not producing students with positive attitudes toward science and students' motivation for science learning declines throughout schooling, especially in secondary education, yet motivation and other affective constructs continue to be investigated much less than cognitive constructs in the field of science education. Using self-determination theory (SDT) as a conceptual framework, this study examines motivation in our nation's science classrooms by conducting a secondary data analysis of the High School Longitudinal Study of 2009 (HSLs:09). The study describes the creation of a valid measure of autonomy support within HSLs:09 and validates critical components of SDT with a nationally representative sample of data by demonstrating that science perceived competence and science interest increase among US ninth-graders when their need for autonomy is met.

Keywords: autonomy support, self-determination theory, perceived competence, interest

Perceived Autonomy Support in a Nationally Representative Sample of US Ninth-graders

There is a growing consensus that scientific knowledge and skills are crucial for our nation's long-term economic and national security, yet the US continues to lag behind other developed countries on international comparisons. The Programme for International Student Assessment (PISA), an international assessment of 15-year-olds taken by students in 60 countries, shows that US students have moved "up" to average on the science scale score, an improvement over 2006 but still leaving the US lagging behind 18 countries and effectively tied with 13 others (OECD, 2010). Clearly our nation's students must be equipped with the science, technology, engineering and math (STEM) skills necessary to compete in a global knowledge economy. However, as noted by Gary Cooper in *Building Engaged Schools*, "students can be required to take certain classes, but their psychological commitment to an activity can't be coerced. Forcing students to do more without considering how to trigger and sustain their emotional involvement may well have the unintended consequence of lowering engagement in required courses--and in learning itself" (2006, p. 73.). Triggering and sustaining behavior lies at the core of the science of motivation, which is essentially the study of why people think and behave as they do (Graham & Weiner, 1996).

Research in the field of motivation is extensive, but motivation and other affective constructs have been investigated much less than cognitive constructs in the field of science education (Koballa & Glynn, 2007). Indeed, motivation research specific to science education, particularly secondary science education, has been somewhat thin and uneven, although, some research has been conducted on affective constructs, including attitudes toward science, students' engagement in class, and interest (Vedder-Weiss & Fortus, 2011). Emerging from much of this research are two disturbing trends: schools in the US are not producing students

with positive attitudes toward science and students' motivation for science learning declines throughout schooling, especially in secondary education.

Although not specific to science education, Gillet, Vallerand, & Lafrenière (2012) investigate potential influences on age related declines in motivation by considering autonomy support as a possible mediator. Autonomy supportive learning environments engage students' desire to be volitional agents through empathy, opportunities for choice, and minimized external pressure (Black & Deci, 2000). In a study of 1,600 elementary and high school students aged 9-17 years, Gillet, Vallerand, & Lafrenière found that autonomy support mediated age-related declines in intrinsic motivation.

The present paper explores autonomy support in the context of ninth-grade science classrooms in order to broaden our understanding of motivation-related psychological processes. This study will advance our current understanding by extending the study of these processes to secondary science education using a self-determination theory framework, an approach which has not been taken to this point. Confirming the effectiveness of autonomy supportive learning environments in secondary science education will give parents, teachers, administrators and policy-makers a valuable pedagogical tool with the potential to increase student engagement in ways that will increase achievement and encourage the participation of groups typically underrepresented in STEM fields. Specifically, this study explores the effect of autonomy supportive science classrooms on students' perceived competence and interest. This research will be conducted using the High School Longitudinal Study of 2009 (HSLs:09) and will be facilitated by creating a valid measure of autonomy support within this nationally representative data set.

Theoretical Framework

Self-determination Theory

The current study will use self-determination theory (SDT) as a framework to examine autonomy support as a motivational mediator of interest and perceived competence in our nation's science classrooms. SDT suggests that activities vary in the extent to which they are self-determined, from intrinsically motivated (autonomous) activities pursued for enjoyment to more controlled environments where external contingencies (e.g. rewards, punishments) or internal pressures (e.g. shame, guilt) motivate behavior (Deci & Ryan, 2000). Further, SDT emphasizes the innate psychological needs for competence (to believe one is able to complete a task), relatedness (to feel connection to others) and autonomy (to act of one's own accord), positing optimal development and well-being occur under conditions that satisfy that these needs (Deci & Ryan, 2000). Within SDT, the satisfaction of these basic psychological needs sustains intrinsic motivation, and therefore self-determined behavior (Niemiec and Ryan, 2009).

Autonomy Support

Cognitive evaluation theory (CET; Deci & Ryan, 1985), a subtheory of SDT, emphasizes the influence of social determinants in motivation. According to this theory, social agents can positively impact the intrinsic motivation of students through autonomy support (Deci, Schwartz, Sheinman, & Ryan, 1981). Autonomy support involves a social agent in a position of authority (e.g. teacher) empathizing with the other, providing pertinent information and opportunities for choice, while minimizing external pressure (Black & Deci, 2000). Autonomy-supportive contexts "tend to maintain or enhance intrinsic motivation and promote identification with external regulations, while controlling contexts tend to undermine intrinsic motivation and forestall internalization" (Black & Deci, 2000, p. 742). Among the benefits of autonomy-

supportive contexts described by Black and Deci are more intrinsic motivation (Deci, Schwartz, Sheinman, & Ryan, 1981), greater internalization (Grolnick & Ryan, 1989), better conceptual learning (Grolnick & Ryan, 1987), more creativity (Koestner, Ryan, Bernieri, & Holt, 1984), and more positive affect both in regular education (Ryan & Grolnick, 1986) and in special-education settings (Deci, Hodges, Pierson, & Tomassone, 1992).

Perceived Competence

An individual's perception of his or her competence, or self-efficacy, has long been an integral component of expectancy-value theories of motivation, according to which motivation is a function of the value of what one expects to get and the perceived likelihood of getting it (see Graham and Weiner 1996). Self-efficacy has been shown to influence engagement and achievement (Eccles, Wigfield & Schiefele, 1998), effort and the use of self-regulation strategies (Schunk & Pajares, 2005), as well as the likelihood of initiating and persisting tasks (Bandura, 1997; Schunk & Pajares, 2005; Wigfield & Eccles, 2002). Specific to science learning, Velayutham, Aldridge and Fraser (2011) provide an excellent summary of research related to the influence of perceived competence, noting that self-efficacy has been associated with numerous positive outcomes including science achievement and engagement in both secondary and post-secondary settings.

Interest

Although not considered an innate need in SDT, interest is a fundamental building block within SDT insofar as intrinsically motivated activities involve inherent interest and enjoyability. In other words, a student will be intrinsically motivated to engage in an activity if it is interesting and enjoyable, and the activity will be interesting and enjoyable if it satisfies the student's needs for competence, autonomy and relatedness (Deci & Ryan, 2000). Moreover, interest facilitates

cognitive functioning, an effect that has been established across individuals, knowledge domains, and subject areas (Hidi & Harackiewicz, 2000).

Self-determination Theory and Science Education

Black and Deci (2000) investigated the relationship between autonomous and controlled sources of motivation and how each impacted outcomes in a college-level organic chemistry class. The researchers found that students who entered the course with more autonomous motivation were more interested, enjoyed the course more, experienced lower anxiety, were less focused on grades-focused performance goals, and had higher indexes of perceived competence. Further, students who entered the course with more autonomous orientation were less likely to drop out of the course. Two related studies on motivation in science education have demonstrated the importance of parents' autonomy support for persistence in a science program (Ratelle, Larose, Guay, & Senécal, 2005) and the positive impact of instructor autonomy support on students' autonomous learning and perceived competence (Williams & Deci, 1996).

Few studies have investigated motivation in secondary education from a SDT perspective and even fewer have looked specifically at SDT in science classrooms (Lavigne, Vallerand & Miquelon, 2007). As a result, the impact of autonomy support in secondary science classrooms is not well-understood. This research will extend our understanding of autonomy support and likely demonstrate the effectiveness of this pedagogy for increasing ninth-graders' interest and perceptions of competence in science. Moreover, SDT has never been tested with a large-scale data set, especially one specific to both science and secondary education. By using a nationally representative sample of ninth-graders, the conclusions drawn as a result of this research will be useful for a broad range of parents, teachers, administrators and policy-makers. Finally, the creation of a measure for autonomy support within HSLs:09 will enable educational researchers

to leverage the power of this publicly available data set to investigate a host of other questions, including whether autonomy support may affect students' intentions to pursue a career in STEM.

The following research questions guide this study:

1. Can items within the HSLs:09 data set be used to create a measure of autonomy support?
2. What is the relationship between perceived competence, interest and autonomy support among US ninth-graders?

Hypotheses for the question are elaborated below:

Hypothesis 1: HSLs:09 contains items that can be used to measure ninth-graders' perceptions of autonomy support

Although NCES did not intentionally measure autonomy support, HSLs:09 contains several items that closely resemble items on validated measures of autonomy support. These items can likely be used to create a reliable scale that can be used to indicate ninth-graders' perceptions of autonomy support.

Hypothesis 2: US ninth-grade students' perceptions of autonomy support by their Fall 2009 science teacher will impact their perceived competence for the course as well as their interest in the course.

As with Black and Deci (2000), it is predicted that ninth-graders will be more motivated as their need for autonomy is met. This motivation is likely to be reflected in heightened interest and increased perceptions of competence.

Method

Participants and Data Sources

This paper will involve a secondary data analysis of the publicly available High School Longitudinal Study of 2009 (HSLs:09) database from the National Center for Education Statistics (NCES, 2011). HSLs:09 is a nationally representative study of more than 21,000 9th graders in 944 schools from the 50 United States and the District of Columbia. The 944 schools were sampled from both public schools (including charter schools) and private schools enrolling both ninth and eleventh-grade students. The target population of students was defined to include all ninth-grade students who attended the study-eligible schools in the fall 2009 term. Approximately 24,000 ninth-graders were selected, an average of 25 students per school. These students' parents, math and science teachers, counselors and school administrators were also invited to complete surveys.

Procedure and Measure

The HSLs:09 base year took place in the 2009–10 school year with a randomly selected sample of fall-term 9th-graders. The student questionnaire for in-school administration was electronic and students reported on their experiences, expectations, plans and attitudes related to their Fall 2009 science course. In addition, data were also gathered from parents, teachers, counselors, and administrators.

Students were sampled through a two-stage process. First, 1,889 eligible schools were identified using stratified random sampling and school recruitment, of which 944 participated in the study, resulting in a 55.5 percent (weighted) or 50.0 percent unweighted response rate. The 944 schools were sampled from both public schools (including charter schools) and private schools enrolling both ninth and eleventh-grade students. The second stage involved randomly sampling students from school ninth-grade enrollment lists, resulting in 25,206 eligible selections, or about 27 per school. These students' parents, math and science teachers, counselors

and school administrators were also invited to complete surveys. Students will be followed through their secondary school experiences and post-secondary or early work years. The survey was administered again in the spring of 2012 during most students' 11th grade year. A brief data collection is planned for the spring of 2013, the year most students should graduate, to obtain a postsecondary status update. A second follow-up is planned for 2015 and additional follow-up data collections are also planned.

Items and Constructs

Student Analytic Weight. Student responses for all items will be weighted using a student analytic weight. The student analytic weight was created by NCES in order to produce estimates for the target population (US ninth-graders), with appropriate standard errors (Ingels *et al*, 2011). The weight accounts for school and student nonresponse and will be used for all student-level analyses in this study.

Autonomy Support. As previously discussed, autonomy support is an essential component of SDT, and a student's perception of whether or not an environment supports his or her autonomy has motivational consequences. Autonomy support was not directly addressed by NCES in HSLs:09. However, the HSLs:09 student questionnaire includes several items conceptually and semantically similar to items contained in validated measures of autonomy support. These items will be used to create an autonomy support variable (described in the analysis section). Table 3.1 contains a complete list of the student questionnaire items used for the science perceived autonomy support measure.

Perceived competence. NCES (2011) created a science self-efficacy scale using four items from the student questionnaire that were designed to be analyzed as a psychological scale. The scale was created by principle components analysis using SAS PROC FACTOR and standardized to

have a mean of zero and a standard deviation of one. The internal consistency of the scale was evaluated using Cronbach's Alpha (Cronbach, 1951) and an alpha of .88 was reported by NCES in the *Base-Year Data File Documentation* (Ingles, et al., 2011). Using the rules of thumb provided by George and Mallery (2003), an alpha value greater than .7 is considered acceptable, greater than .8 is considered good, and greater than .9 is considered excellent. For the purposes of this study, the self-efficacy scale created by NCES will be used to describe students' perceived competence. Items used by NCES to create the self-efficacy scale (e.g., "You are certain that you can master the skills being taught in this course") were judged to have face validity because they were virtually identical to items (e.g., "I feel confident in my ability to learn this material") on validated measures of perceived competence such as the Perceived Competence Scale (Williams & Deci, 1996). Questionnaire items were coded so that higher levels of self-efficacy equated to larger scale values. Appendix A contains a complete list of the student questionnaire items used for the science perceived competence measure.

Science interest. NCES created the science course interest scale from six items in the student questionnaire. Item responses were weighted using the student analytic weight. As with self-efficacy, the scale was created by principle components analysis using SAS PROC FACTOR and standardized to have a mean of zero and a standard deviation of one. The coefficient of reliability (alpha) for the science course interest scale was .73 (Ingels, et al., 2011). This value is considered acceptable using the interpretation criteria discussed previously. Questionnaire items were coded so that students who tended to disagree with statements such as "You think this class is boring" had higher values for science course interest. Appendix A contains a list of student questionnaire items used for the science course interest scale.

Analyses

Research Question 1: Does HSLs:09 contain a valid proxy for autonomy support?

The purpose of this analysis is to create a valid indicator of science perceived autonomy support within the HSLs:09 data set. This measure will be created using a process similar to that used by NCES to create the perceived competence and interest scales. First, items will be selected from the student questionnaire that contain wording relevant to autonomy support. For instance, the student questionnaire item “Your science teacher values and listens to student’s ideas” is conceptually and semantically similar to the item “I am able to be open with my instructor during class,” which is contained in the Learning Climate Questionnaire (LCQ), a validated measure of perceived autonomy support by Williams and Deci (1996). In addition to face validity, SPSS principal components analysis (PCA) will be used to reduce the questionnaire items to one factor. PCA was selected over confirmatory factor analysis because PCA was used by NCES to create the interest and perceived competence scales. By remaining consistent with NCES, this analysis will create an observed variable that can be readily compared to the various other observed variables created by NCES (e.g. science interest and science perceived competence). The scale will be standardized to a mean of 0 and standard deviation of 1. The coefficient of reliability (alpha) for the scale will be determined. To establish convergent validity of the perceived competence measure, linear regression analyses will be conducted to ensure that higher levels of autonomy support separately predict higher levels of perceived competence and interest as indicated in the literature (Ryan & Grolnick, 1986; Black & Deci, 2000).

Research Question 2: What is the relationship between perceived competence, interest and autonomy support among US 9th graders?

The second research question will involve a secondary data analysis of HSLs:09. A multivariate analysis of covariance (MANCOVA) will be used to assess the conformity of the HSLs:09 data to SDT. The research question investigated in this study includes three variables: science perceived autonomy support, science perceived competence, and science interest. The relationships will be specified based on the results of Black & Deci (2000) by setting science perceived autonomy support as the independent variable (covariate) and both perceived competence and science interest as the dependent variables.

Results

The first research question concerned the creation of a valid measure of autonomy support within HSLs:09. Four items that exhibited face validity with existing validated measures of autonomy support were selected from the HSLs:09 student questionnaire (see Table 1 for a list of items). A principle components analysis yielded a single-factor solution for the four items ($\alpha = .90$), accounting for 77% of the total item variance. Table 3.1 presents descriptive statistics, principle component loadings and correlations for the Science Autonomy Support items.

Table 2.1

Science Autonomy Support Items with Principle Component Loadings and Correlations

Item	Mean	SD	Loading	1	2	3	4
1. Your science teacher values and listens to student's ideas.	3.10	0.73	0.87	1.00			
2. Your science teacher treats students with respect.	3.23	0.68	0.91	0.73**	1.00		
3. Your science teacher treats every student fairly.	3.15	0.75	0.89	0.68**	0.78**	1.00	
4. Your science teacher thinks every student can be successful.	3.26	0.68	0.84	0.63**	0.69**	0.67**	1.00

Note. Rows 1 and 2 $n = 2804$, Row 3 $n = 2799$, Row 4 $n = 2796$.

**Correlation is significant at the .01 level (2-tailed).

The principle component scores were output as a new variable in the form of a standardized scale ($M = 0, SD = 1$).

Consistent with previous research and to assess convergent validity of the science autonomy support scale, linear regression analyses were conducted to ensure that higher levels of science autonomy support separately predicted higher levels of science perceived competence and science interest. As expected, science autonomy support was a significant predictor of both science perceived confidence, $\beta = .33, t(2711) = 18.03, p < .05, R^2 = .11$ and science interest, $\beta = .49, t(2659) = 29.24, p < .01, R^2 = .24$.

The second research question concerned the interactions of the three variables of interest. The results from the MANCOVA revealed a significant multivariate test for the covariate science autonomy support, Hotelling's statistic = .42, $F(2, 645) = 135.40, p < .001$. Both science perceived competence and science course interest together are affected by students' perceptions of autonomy support. Univariate F tests for both dependent variables were examined to better understand the respective effect of each variable. Science autonomy support was a significant predictor of both dependent variables independently as well. Students who perceived their science classrooms as autonomy supportive were more likely to report being confident in their ability to be successful in their science class, $R^2 = .11, F(1, 647) = 82.19, p < .001, \text{partial } \eta^2 = .11, \beta = 1.0$. Similarly, students who perceived their science classrooms as autonomy supportive, were more likely to report being interested in their science class, $R^2 = .29, F(1, 647) = 257.83, p < .001, \text{partial } \eta^2 = .29, \beta = 1.0$.

Discussion

The first research question addressed by this study concerned the existence of a valid measure of autonomy support within HSLs:09. The findings were consistent with the hypothesis

that a valid measure of autonomy support is contained within HSLs:09. Four items in the student questionnaire exhibited face validity when compared to items on existing measures of autonomy support. These four items yielded a single factor with a high coefficient of reliability. The resulting autonomy support scale was highly correlated with the science perceived competence and science course interest scales contained in the HSLs:09 data set. These findings add convergent validity to the measure by demonstrating that it predicts in ways similar to previously validated measures of autonomy support. A valid measure of autonomy support within the HSLs:09 will provide numerous opportunities for researchers to investigate important questions related to self-determination. In addition to science interest, perceived competence and identity, the HSLs:09 data set contains other scales (e.g. sense of school belonging and school engagement) as well as demographic information and dozens of items from school, parent, administrator and counselor questionnaires. Although the focus of this study was science, HSLs:09 contains parallel information for mathematics. Finally, HSLs:09 is a longitudinal study. With the release of follow-up data sets, quasi-experimental methods may be employed to investigate causal relationships with autonomy support and the various scales.

The second research question concerned the main effects associated with the three variables of interest: science autonomy support, science perceived competence, and science course interest. The results are consistent with the hypothesis that students are more interested and confident when their need for autonomy is met. These findings provide additional empirical support for self-determination theory and the linkages between autonomy support and perceived competence and interest. Ninth-graders' perceptions of autonomy support in their science classrooms were positively related to their science perceived competence and science course interest. Although this correlational data does not address causality, it appears that ninth-graders

with science teachers who show empathy, provide opportunities for choice and minimize external pressure are more likely to be interested and confident in their abilities to be successful in the class. These findings parallel the work of Black and Deci (2000), who found that students who entered a college organic chemistry course with more autonomous motivation were more interested and had higher indexes of perceived competence. These findings provide an extension and elaboration of these linkages by testing them with secondary science students and by using a nationally representative sample. The results imply that autonomy support may be an important pedagogical consideration as educators strive to trigger and sustain student engagement in science.

There are at least two important limitations to these findings. Although this study was grounded in self-determination theory, the psychological need for relatedness was not addressed. The HSLs:09 data set did not contain sufficient items dealing with relatedness and so this important construct could not be considered. As previously mentioned, these findings are based on correlational data and therefore do not imply causality.

In summary, the results provide empirical evidence that a valid measure of autonomy support exists within the HSLs:09 data set. Moreover, autonomy supportive science learning environments lead to increased perceptions of competence and interest among US ninth-graders.

Appendix A

HSL:09 student questionnaire items included in perceived science autonomy support, science perceived competence and science course interest scales.

Perceived science autonomy support

Your science teacher...

values and listens to students' ideas.

treats students with respect.

treats every student fairly.

thinks every student can be successful.

Perceived competence

How much do you agree or disagree with the following statements about you fall 2009 science course?

You are confident that you can do an excellent job on tests in this course.

You are certain you can understand the most difficult material presented in the textbook used in this course.

You are certain you can master the skills being taught in this course.

You are confident that you can do an excellent job on assignments in this course.

Science course interest

How much do you agree or disagree with the following statements about your fall 2009 science course?

You are enjoying this class very much

You think this class is a waste of your time

You think this class is boring

What is your favorite subject in school?^a

What is your least favorite subject in school?^a

You really enjoy science^b

Note. Except where noted, student response options were *strongly agree*, *agree*, *disagree*, and *strongly disagree*.

a. Science was one of 13 choices.

b. Answers were yes or no.

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CHAPTER 3

Effects of Perceived Autonomy Support on Gender Stereotypes in a Nationally Representative
Sample of US Ninth-grade Science Students

Anthony Derriso

The University of Alabama

Abstract

The motivation-related beliefs of boys and girls have been shown to follow gender stereotypes, but the influence of these stereotypes is moderated by classroom context, highlighting the potential of the local environment, including the influence of teachers, to moderate the effects of gender beliefs. Research on social determinants of motivation has demonstrated the importance of autonomy supportive environments for increasing students' interest and perceived competence, but has not typically considered the varying effects of these environments in terms of gender or other background variables. The current study investigates the effects of autonomy supportive environments on students' perceptions of competence, interest and identity in science using a nationally representative sample of US ninth-graders. Results indicate males and females do not differ significantly on measures of autonomy support, science perceived competence, science interest, or science identity. Autonomy support was a statistically significant predictor of science perceived competence, science interest and science identity, and these relationships were the same for males and females.

Keywords: motivation, science, gender, autonomy support, self-determination

Effects of Perceived Autonomy Support on Gender Stereotypes in a Nationally Representative Sample of US Ninth-grade Science Students

Girls outnumber boys in advanced science classes, yet the motivation-related beliefs of boys and girls follow gender stereotypes. Boys report stronger ability and interest beliefs in science, but these effects are moderated by ability, ethnicity, socioeconomic status (SES) and classroom context (Meece, Glienke, & Burg, 2006). Unfortunately, teachers may contribute to gender differences in motivation by modeling sex-typed behavior, communicating different expectations or encouraging different activities and skills for boys and girls (Eccles et al., 1983). Teachers believe boys and girls differ in science and math (Tiedemann, 2000) and teachers have different expectations for their classroom behavior (Borg, 1998). Indeed, as noted by Legewie and DiPrete (2012), research has “under-appreciated” the influence of the local environment, including the influence of teachers, on gender beliefs.

A review of gender and motivation by Meece, Glienke, & Burg (2006) explored motivation-related beliefs of boys and girls from four contemporary theories of motivation (i.e., attribution, expectancy-value, self-efficacy, and achievement goal), but did not consider self-determination theory (SDT). Autonomy support, a central component of SDT, is a characteristic of learning environments that engage student’s desire to be volitional agents through empathy, opportunities for choice, and minimized external pressure (Black & Deci, 2000). According to cognitive evaluation theory (CET; Deci & Ryan, 1985), social agents influence individuals’ motivation by supporting autonomy. Additionally, autonomy support has been repeatedly associated with positive educational outcomes, both in general and specific to science education, and at various levels (see Black & Deci, 2000).

This research investigates gender-related differences in science motivation using the High School Longitudinal Study of 2009 (HSL:09), a nationally representative sample of US ninth-graders. This study will investigate the effects of autonomy supportive learning environments on students' science perceived competence, science course interest, and science identity. As a social determinant of motivation, autonomy supportive learning environments may create a classroom context that moderates the effects of gender stereotypes, particularly on students' interest and perceived competence. Of the four moderators of science ability and interest beliefs described by Meece, Glienke, & Burg, 2006, classroom context is the only one that is unquestionably malleable. To date, studies have not considered the effects of autonomy supportive classrooms on science ability and interest beliefs and how these beliefs affect students' science identity. Ultimately, this research will determine if autonomy support creates the type of classroom context that augments ability and interest beliefs, particularly among groups traditionally underrepresented in science, technology, engineering, and math (STEM) disciplines. Moreover, because this research uses a nationally representative sample of US ninth-graders, the findings of this study will be generalizable in ways that may inform multiple stakeholders, including parents, teachers, administrators and policy-makers.

Theoretical Framework

Self-determination Theory

SDT posits that individuals are intrinsically motivated, or self-determined, to engage in a behavior when it satisfies basic psychological needs (Niemi and Ryan, 2009). Moreover, these activities can vary in the extent to which they are self-determined, ranging from relatively autonomous to controlled. Autonomous behaviors are intrinsically motivated and pursued for the sake of enjoyment, whereas controlled behavior involves pressure, either internally through

feelings such as guilt or shame or externally in form of contingencies such as rewards or punishments (Deci & Ryan, 2000). For example, Black and Deci (2000) used a self-determination theory perspective (SDT) to investigate the effects of students' perceptions of their instructor's autonomy support in a college-level organic chemistry course, finding that both perceived competence and interest/enjoyment increased among students with autonomy supportive instructors; each of the three major components will be discussed below.

Perceived Competence

Competency beliefs have long been an integral component of theories of motivation that take into account the value of what one expects to get and the perceived likelihood of getting it (e.g. expectancy-value; see Graham and Weiner 1996). Numerous studies have indicated that these beliefs have a strong relation to academic performance (see Eccles et al., 1983), including science achievement (Wilkins, Zembylas, & Travers, 2002).

As cognitive perspectives on motivation evolved, Eccles et al. (1983) introduced a socialization component to earlier expectancy-value theories that included the role of culture, parents, and teachers in shaping achievement-related beliefs. Situating students' perceptions of competence in a sociocultural context highlights the possibility that this determinant of motivation can be favorably adjusted within our nation's science classrooms.

Interest

Within SDT, activities are considered intrinsically motivated when they involve inherent interest and enjoyability. Therefore, individuals who find an activity interesting and enjoyable will be intrinsically motivated to engage in the activity (Deci & Ryan, 2000). Across individuals, knowledge domains, and subject areas, research indicates that interest facilitates cognitive functioning (Hidi & Harackiewicz, 2000).

Autonomy Support

As noted earlier, the social cognitive expectancy-value model of motivation by Eccles, et al. (1983) included the role of culture, parents, and teachers in shaping achievement related beliefs. Within self-determination theory, autonomy support is considered a social determinant because it occurs within an interpersonal context that can influence the extent to which individuals feel their actions are controlled (Black & Deci, 2000). Black and Deci describe numerous benefits of autonomy support, including more intrinsic motivation (Deci, Schwartz, Steinman, & Ryan, 1981), greater internalization (Grolnick & Ryan, 1989), better conceptual learning (Grolnick & Ryan, 1987), higher self-esteem (Deci et al. 1981), and more creativity (Koestner, Ryan, Bernieri, & Holt, 1984). Additionally, autonomy supportive contexts result in more positive affect both in regular education (Ryan & Grolnick, 1986) and in special-education settings (Deci, Hodges, Pierson, & Tomassone, 1992).

Gender and Motivation

Early studies of the effect of gender on motivation were grounded in achievement motivation theories (Meece, Glienke, & Burg, 2006). Men and women, who differed in their educational and occupational pursuits, also differed in their motives to approach or avoid success, based in part on their differing expectancies and values. As the focus of motivation research shifted toward attribution, researchers began to explain differing achievement behaviors among men and women in terms of differing attributions for success or failure. Studies indicated that men tended to attribute their *successes* to ability whereas women tended to attribute their *failures* to ability, especially in achievement areas that were typically masculine or feminine. Moreover, men attributed both success *and* failure less to luck than women (Frieze, Whitley, Hanusa, & McHugh, 1982).

Contemporary theories of motivation have expanded to include the influence of social and cultural factors and gender differences continue to emerge. Competency beliefs can emerge as early as the first grade in specific areas such as reading, music, mathematics, and sports and follow gender stereotypes, despite the fact that girls and boys perform equally well in these areas (Eccles, Wigfield, Harold, & Blumenfeld, 1993). In science education, research indicates that competency beliefs of boys are higher than girls in science-related courses (Guimond & Roussel, 2001; Guimond, et al., 2006).

Previous SDT research has not always considered the role of gender. Black and Deci 2000, as mentioned earlier, indicated that autonomy supportive learning environments led to increases in perceived competence and interest/enjoyment in a college-level organic chemistry course. Surprisingly, this study did not consider gender or other background variables despite the studies emphasis on the manner in which the social context in influences perceptions of autonomy. In a study of SDT in physical education settings, Standage, Duda & Ntoumanis (2005) highlighted a void in the literature concerning the effects of gender, but noted that a fundamental precept of SDT is that “psychological processes and constructs embraced by self-determination theory are universal to all cultures, across gender, and throughout developmental periods” (p. 416). Accordingly, Standage, et al. did not predict, nor find, any variance across gender. However, because science is a domain prone to gender stereotypes, it is predicted that autonomy supportive learning environments may benefit girls more than boys. As previously discussed, research indicates girls continue to have lower competency beliefs in science. The support of autonomy by a teacher necessitates a belief in students’ abilities. In fact, the Learning Climate Questionnaire (Williams & Deci, 1996), a validated measure of perceived autonomy support, contains an item requiring individuals to agree or disagree with the statement “Your

instructor values and listens to student's ideas." It certainly seems plausible that a teacher who values and listens to a student's ideas might have a favorable impact on that student's competency beliefs, especially if the student's beliefs were initially low. The following research questions guide this study:

1. Do male and female students differ on measures of perceived competence, interest, and science identity?
2. What is the relationship between autonomy support, perceived competence, interest, and science identity?
3. Does the relationship between the variables of interest vary across gender?

Hypotheses for the questions are elaborated below:

Hypothesis 1: Male students will have higher values for perceived competence and interest and will tend to identify more with science.

Hypothesis 2: Learning environments that support students' need for autonomy will lead to increased perceived competence and interest, and science identity

Hypothesis 3: Autonomy supportive environments will benefit girls more than boys.

Method

Data Sources

This study will be conducted using the High School Longitudinal Study of 2009 (HSLs:09), a nationally representative longitudinal study of more than 21,000 9th graders in 944 schools. HSLs:09 sampled 944 schools from the 50 United States and the District of Columbia, both public (including charter schools) and private. Students reported on their experiences, expectations, plans and attitudes related to their Fall 2009 science course. In addition, data were also gathered from parents, teachers, counselors, and administrators.

Items and Constructs

Autonomy Support. Although NCES (2011) did not create an autonomy support scale, several items were included in the HSLS:09 student questionnaire that can be used as a proxy for autonomy support within the data-set. Four items on the student questionnaire (e.g. “Your science teacher values and listens to your ideas”) are highly similar to items on validated measures of perceived autonomy support, such as the statement “I am able to be open with my instructor during class” on the Learning Climate Questionnaire (Williams & Deci, 1996). Item responses will be reverse coded so that students who tended to agree with statements such as “Your science teacher treats students with respect” will have higher values for perceived autonomy support. The scale will be created using SPSS principal axis factoring. Appendix A contains a complete list of the student questionnaire items used for the scale of science perceived autonomy support.

Perceived competence. NCES (2011) created a science self-efficacy scale using four items from the HSLS:09 student questionnaire. Responses were weighted using a student analytic weight in order to produce estimates for the target population of US ninth-graders. The weighted scale was created using SAS *proc factor* and standardized to have a mean of zero and a standard deviation of one. The reliability of the scale was analyzed using Cronbach’s Alpha (alpha = .88, Ingles, et al., 2011). The self-efficacy scale created by NCES will be used in this study as a measure of perceived competence. Items used by NCES to create the self-efficacy scale (e.g., “You are confident that you can do an excellent job on assignments in this course”) were deemed to have face validity because of their similarity to items (e.g., “I feel confident in my ability to learn this material”) on validated measures of perceived competence such as the Perceived Competence Scale (Williams and Deci, 1996). Questionnaire items were reverse

coded so that students who agreed with items such as “You are certain you can master the skills being taught in this course” had larger scale values and therefore higher levels of self-efficacy. Appendix A contains a complete list of the student questionnaire items used for the scales of science perceived competence.

Science Identity. The science identity is a scale of the sample member's science identity created by NCES (2011). Responses to two student questionnaire items were weighted using a student analytic weight in order to produce estimates for the target population of US ninth-graders. The scale was created using SAS *proc factor* and standardized to have a mean of zero and a standard deviation of one. Students who tend to agree with the statements "You see yourself as a science person" and/or "Others see me as a math person" will have higher values for science identity. The coefficient of reliability (alpha) for the scale is .83 (Ingles, et al., 2011).

Science interest. The science interest variable is a scale of the sample member's interest in their science course and was created by NCES (2011) with SAS *proc factor* using six items in the student questionnaire. The scale was standardized to a mean of zero and a standard deviation of one. Questionnaire items were coded so that students who tended to agree with statements such as “You think this class is boring” had lower values for *Science Interest*. The coefficient of reliability (alpha) for the science course interest scale was .73 (Ingles, et al., 2011). Appendix A contains a complete list of the student questionnaire items used for the scale of science course interest.

Gender. Each sample member's gender will be coded 0 for male and 1 for female.

Analysis

Descriptive Analysis. Descriptive statistics will first be computed to give a general profile of US ninth-graders on the variables of interest in the HSLs base year of 2009.

Research Question 1: Do male and female students differ on measures of perceived competence, interest, and science identity?

Independent-samples *t* tests will be used to determine any potential differences between males and females in perceived competence, interest and science identity.

Research Question 2: What is the relationship between autonomy support, perceived competence, interest, and science identity?

A multivariate analysis of covariance (MANCOVA) in SPSS will be used to investigate the four variables of interest: science perceived autonomy support, science perceived competence, science interest, and science identity. In part, the relationships will be specified based on the results of Black & Deci (2000) by setting science perceived autonomy support as the independent variable (covariate) and perceived competence and science interest as the dependent variables. This study will extend self-determination theory by also adding science identity as a dependent variable (see Figure 3.1).

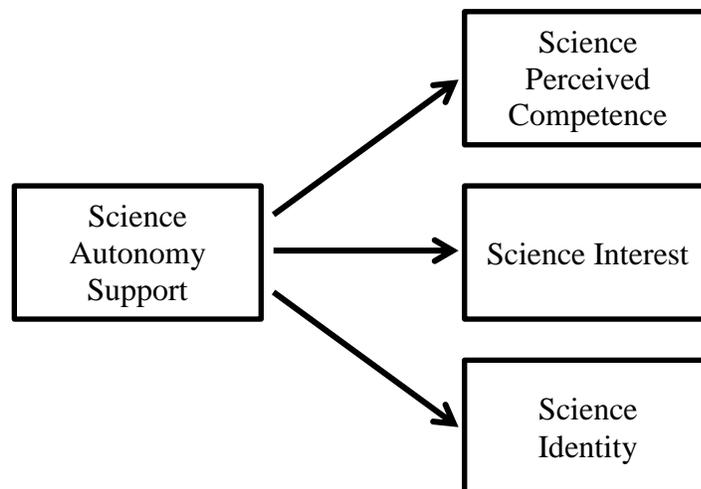


Figure 3.1 *Proposed model*

Research Question 3: Does the relationship between the variables of interest vary across gender?

A multivariate analysis of covariance (MANCOVA) in SPSS will be used to create parameter estimates for each dependent variable with associated standard errors. T-tests will be used to compare males and females on each relationship.

Results

The first research question concerned potential descriptive differences between males and females on the variables of interest. Table 3.1 presents these findings for the first research question. Using the Bonferroni procedure, P values were compared with α/n instead of α . Independent samples t -tests do not indicate a statistically significant difference in perceived autonomy support among US ninth-grade males ($M = .01$, $SD = 1.03$) and females ($M = -.01$, $SD = .97$), $t(2763) = .55$, $p > .0125$. Similarly, there was not a statistically significant difference in science identity between males ($M = .04$, $SD = 1.02$) and females ($M = -.04$, $SD = .98$), $t(3422) = 2.40$, $p > .0125$. There also was not a statistically significant difference in science interest between males ($M = .02$, $SD = 1.01$) and females ($M = -.02$, $SD = .99$), $t(2712) = .84$, $p > .0125$. There was a statistically significant difference in science perceived competence among ninth-grade males ($M = .09$, $SD = 1.02$) and ninth-grade females ($M = -.09$, $SD = .97$), $t(2767) = 4.73$, $p < .0125$, $d = .18$.

Table 3.1
Independent Samples t Test for Males and Females

Variable	Males			Females			\bar{x} diff	SE	t	p	d
	N	\bar{x}	SD	N	\bar{x}	SD					
1. Science Autonomy Support	1370	0.01	1.03	1394	-0.01	0.97	0.02	0.04	0.55	0.59	--
2. Science Perceived Competence	1368	0.09	1.02	1402	-0.09	0.97	0.18	0.04	4.73	0.00	0.18
3. Science Interest	1337	0.02	1.01	1377	-0.02	0.99	0.03	0.04	0.84	0.40	--
4. Science Identity	1711	0.04	1.02	1714	-0.04	0.98	0.08	0.03	2.40	0.02	--

The second research question concerned the interactions of the four variables of interest: science perceived autonomy support, science perceived competence, science interest, and science identity. Table 3.2 presents zero-order correlations and reliability (alpha) for the variables in this study.

Table 3.2
Zero-Order Correlations and Reliability for Study Variables

Variable	1	2	3	4	α
1. Science Autonomy Support	1.00				0.90
2. Science Perceived Competence	0.33	1.00			0.88
3. Science Interest	0.49	0.51	1.00		0.73
4. Science Identity	0.18	0.49	0.46	1.00	0.83

Note. $N = 2594$.

The results from the MANCOVA revealed a significant multivariate test for the covariate science autonomy support, Hotelling's statistic = .43, $F(3, 638) = 90.52, p < .001$. Science perceived competence, science course interest and science identity together are affected by students' perceptions of autonomy support. After obtaining a significant multivariate test for the main interaction, univariate F tests for each dependent variable were examined to better understand the respective effect of each dependent variable. Science autonomy support was a significant predictor of all three dependent variables independently as well. Students who perceived their science classrooms as autonomy supportive were more likely to report being confident in their ability to be successful in their science class, $R^2 = .11, F(1, 641) = 81.01, p < .001$, partial $\eta^2 = .11, \beta = 1.0$. Similarly, students who perceived their science classrooms as autonomy supportive were more likely to report being interested in their science class, $R^2 = .29, F(1, 641) = 256.03, p < .001$, partial $\eta^2 = .29, \beta = 1.0$. Finally, students who perceived their science classrooms as autonomy supportive were more likely to identify with science, $R^2 = .04, F(1, 641) = 29.08, p < .001$, partial $\eta^2 = .04, \beta = 1.0$.

The third research question concerned the effect of gender on the relationships examined in the second research question. Correlations among the four study variables for males and females separately are presented in Tables 3.3 and 3.4.

Table 3.3
Zero-Order Correlations of Study Variables for Males

Variable	1	2	3	4
1. Science Autonomy Support	1.00			
2. Science Perceived Competence	0.35	1.00		
3. Science Interest	0.49	0.50	1.00	
4. Science Identity	0.20	0.50	0.46	1.00

Note. $N = 1267$. Variables were standardized.

Table 3.4
Zero-Order Correlations of Study Variables for Females

Variable	1	2	3	4
1. Science Autonomy Support	1.00			
2. Science Perceived Competence	0.30	1.00		
3. Science Interest	0.49	0.53	1.00	
4. Science Identity	0.16	0.48	0.46	1.00

Note. $N = 1326$. Variables were standardized.

Table 3.5
MANCOVA Parameter Estimates

Variable	<i>b</i>	<i>SE</i>	<i>t</i>	<i>p</i>
Science Perceived Competence				
Male	0.11	0.07	1.52	0.13
Female	0 ^a			
Science Interest				
Male	0.03	0.07	0.5	0.62
Female	0 ^a			
Science Identity				
Male	-0.01	0.08	-0.1	0.94
Female	0 ^a			

Note. Path is from science autonomy support to the variable listed. $N = 287$ for males. $N = 355$ for females.

a. Female group set to zero for comparison.

Parameter estimates with associated standard errors are presented in Table 3.5. Coefficients for females were fixed at zero and used as the comparison group for males on each independent variable. T-tests suggest there is not a significant difference between males and females on any of the paths from autonomy support to perceived competence, interest and identity. Both sexes appear to benefit equally when their science teacher supports their need for autonomy.

Discussion

The results indicate male and female ninth-graders in the US do not differ significantly on four important aspects of motivation. These findings are contrary to the proposed hypothesis for the first research question. Male and female students equally perceive their teachers as supportive of their need for autonomy, meaning that female students are just as likely to report that their science teacher values and listens to their ideas, treats them with respect and treats them fairly. These findings are encouraging considering Eccles' (1983) fear that teachers may communicate different expectations or encourage different activities for male and female students. Moreover, male and female ninth-graders in the US are equally interested in their science courses. This finding stands in contrast to the work of Meece, Glienke, & Berg (2006), who found that boys reported stronger interest beliefs in science. Moreover, this finding also contradicts data from the National Center for Education Statistics demonstrating that girls are less likely than boys to report liking their science courses (2004). There were statistically significant differences between male and female ninth-graders in the US on measures of perceived competence. This finding seems to parallel the work of Guimond, et al., (2006), who found that the competency beliefs of boys were higher than girls in science-related courses. However, the effect size for the differences among male and female ninth-graders for both

perceived competence fell below the threshold estimated by Cohen (1988) for even a small effect. This implies that female ninth-graders in the US generally consider themselves as equally competent in science when compared with males.

As predicted, students in autonomy supportive science classes reported higher perceived competence and interest and were more likely to identify with science. These findings extend the work of Black & Deci (2000) by demonstrating that autonomy support is not only linked to science perceived competence and interest, but is also positively linked with science identity. US ninth-graders in autonomy supportive science classrooms were more likely to identify themselves as a science person. This is an important finding in light of the positive link between science attitudes and achievement (see Else-Quest, Mineo & Higgins, 2013).

Contrary to the hypothesis for the third research question, the effect of autonomy supportive environments did not differ among males and females. The effect of autonomy support on science perceived competence, interest and identity was the same for both males and females. This finding implies that science learning environments supporting students' need for autonomy are equally effective for both boys and girls in terms of increasing motivation stemming from higher levels of perceived competence, interest and identity. These results seem to confirm the speculation of Standage, Duda & Ntoumanis (2005) regarding a "void" in the literature concerning the effects of gender. Indeed, the need for autonomy support may be universal across gender.

In summary, US boys and girls in the ninth-grade are remarkably similar on several key aspects of motivation in science. HSLs:09 data suggest that girls are just as confident, interested and likely to identify with science as boys. Moreover, both boys and girls are more likely to be confident, interest, and identify with science when teachers value their ideas, show respect, treat

students fairly, and think all students can be successful. These autonomy supportive learning environments are a controllable factor and an understanding of the differential effects of autonomy supportive environments will likely enable educators design better and more inclusive learning environments.

Appendix A

HSL:09 student questionnaire items included in perceived science autonomy support, science perceived competence, and science course interest scales.

Perceived science autonomy support

Your science teacher...

values and listens to students' ideas.

treats students with respect.

treats every student fairly.

thinks every student can be successful.

Science perceived competence

How much do you agree or disagree with the following statements about you fall 2009 science course?

You are confident that you can do an excellent job on tests in this course.

You are certain you can understand the most difficult material presented in the textbook used in this course.

You are certain you can master the skills being taught in this course.

You are confident that you can do an excellent job on assignments in this course.

Science course interest

How much do you agree or disagree with the following statements about you fall 2009 science course?

You are enjoying this class very much

You think this class is a waste of your time

You think this class is boring

What is your favorite subject in school?^a

What is your least favorite subject in school?^a

You really enjoy science^b

Science identity

How much do you agree or disagree with the following statements?

You see yourself as a science person.

Other people see you as a science person.

Note. Except where noted, student response options were *strongly agree*, *agree*, *disagree*, and *strongly disagree*.

a. Science was one of 13 choices.

b. Answers were yes or no.

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CHAPTER 4

Effects of Autonomy Support on Students' Intentions to Pursue a STEM Career in a Nationally
Representative Sample of US Ninth-graders

Anthony Derriso

The University of Alabama

Abstract

Although considerable progress has been made closing the gender gap in educational attainment, females remain underrepresented among students earning bachelor degrees in science, technology, engineering, and mathematics (STEM). Research suggests these disparities are influenced by gender stereotypes, but that the influence of these stereotypes can be moderated by teachers and peers in the classroom. This study, conducted as a secondary analysis of data from the High School Longitudinal Study of 2009, investigated the effect of autonomy supportive science classrooms on students' intentions to pursue a STEM career, while also considering the effect of students' perceived competence, interest, and science identity. Among US ninth-graders intending to pursue STEM occupations, 84% were boys and 16% were girls. Science perceived competence and science identity mediated the relationship between science autonomy support and students' intentions to pursue a STEM career. Additionally, science perceived competence and science identity significantly discriminated between students who intended to pursue a STEM occupation and those who did not.

Keywords: autonomy support, STEM, science identity, motivation, science interest, perceived competence

Factors Influencing Students' Intention to pursue a STEM career in a Nationally Representative
Sample of US Ninth-graders

In *Crippled at the Starting Gate*, Robert Leslie Fisher suggest that “American prominence in science and engineering, a key to the nation’s prosperity and military superiority, is eroding, a victim of a current shortage of scientists with advanced degrees” (2010, p. 4). Over the last several decades, considerable progress has been made closing the gender gap in educational attainment. The gap has been reversed and women now outnumber men among college graduates (Buchmann & DiPrete, 2006). However, females remain underrepresented among students earning bachelor degrees in the physical sciences, mathematics and engineering and women continue to be underrepresented in science, technology, engineering and math (STEM) careers. Research suggests these disparities are influenced by gender stereotypes, an important consideration within the social context surrounding educational decisions and behavior (Legewie & DiPrete, 2012).

In the recently released *A Framework for K-12 Science Education*, the National Research Council (NRC, 2012) addresses the disproportionate representation of particular demographic groups in science, technology, engineering and math (STEM):

Low learning expectations and biased stereotypical views about the interests or abilities of particular students or demographic groups also contribute, in both subtle and overt ways, to their curtailed educational experiences and inequitable learning supports. Students’ own motivation and interest in science and engineering can also play a role in their achievement and pursuit of these fields in secondary school and beyond. Thus attention to factors that may motivate or fail to motivate students from particular demographic groups is important to keep in mind when designing instruction. (p. 279)

The NRC framework, although primarily intended to identify the science that all K-12 students should know, challenges educators to also focus on key components not always associated with science achievement, recognizing that stereotypical views about interest and ability exist, that demographic groups are not proportionally represented in STEM, and that motivation and interest can also play a role in achievement and in the pursuit of science related fields beyond school.

Mounting evidence indicates the underrepresentation of women in the STEM disciplines is not a factor of basic ability or aptitude, so research has begun to focus on the influence of STEM *attitudes* on students' intentions to pursue careers in these disciplines (Else-Quest, Mineo, & Higgins, 2013). The current study will explore what the NRC describes as “factors that may motivate or fail to motivate students” and the effect of these factors on students' decision to enter a STEM career. Specifically, a secondary data analysis of the High School Longitudinal Study of 2009 will be conducted in order to investigate the effect of autonomy supportive science classrooms on students' intentions to pursue a STEM career. This study leverages the potential of large-scale data in order to better understand the complex and nuanced story of the socialization that likely shapes career intentions. The ultimate goal of this line of research is to create learning environments that increase student engagement in ways that encourage the participation of groups traditionally underrepresented in the STEM disciplines. Moreover, nationally generalizable conclusions will inform a broad constituency, including teachers, parents and policy-makers as they confront what is anticipated to be a large gender gap in students' intentions to pursue careers in the STEM disciplines.

Theoretical Framework

Social Environments and Motivation

Meece, Glienke, and Burge (2006) reviewed gender differences in motivation from multiple achievement motivation perspectives, including attribution, expectancy-value, self-efficacy, and achievement goal perspectives. The authors found that motivation-related beliefs followed gender stereotypes across all of the theories, noting that boys reported stronger ability and interest beliefs in mathematics and science. Importantly, the authors cite data from the National Center for Education statistics demonstrating that more high school girls are enrolled in advance high school mathematics and science classes but that these girls are less likely than boys to report liking these courses. Research on children's self-concepts and self-perceptions has shown stereotypic patterns—the academic self-concept of boys correlates more strongly with their math self-perceptions, whereas the self-concept of girls correlates more strongly with their verbal self-perceptions (Skaalvik & Rankin, 1990). Among first-graders, math may not even be relevant for the self-concept of girls (Entwisle, Alexander, Pallas, & Cadigan, 1987). Although these differences in orientations towards the STEM disciplines emerge early in childhood, they are solidified during the high school years, a process influenced not only by gender stereotypes, but also by the local school environment (Legewie & DiPrete, 2012).

Self-determination Theory

Interestingly, self-determination theory (SDT) is a theoretical perspective not reviewed by Meece, Glienke, and Burge (2006). According to the self-determination theory of motivation, individuals are intrinsically motivated to engage in behaviors that satisfy the basic psychological needs of competence, relatedness, and autonomy (Niemic and Ryan, 2009). Within SDT, autonomy support is considered a social determinant of motivation (Deci & Ryan, 1985). Autonomy support involves someone in a position of authority minimizing external pressure by providing pertinent information and opportunities for choice (Black & Deci, 2000). Autonomy-

supportive contexts “tend to maintain or enhance intrinsic motivation and promote identification with external regulations” (Black & Deci, 2000, p. 742).

Numerous studies have demonstrated positive educational outcomes of autonomy supportive environments, including more intrinsic motivation (Deci, Schwartz, Steinman, & Ryan, 1981), greater internalization (Grolnick & Ryan, 1989), better conceptual learning (Grolnick & Ryan, 1987) and more creativity (Koestner, Ryan, Bernieri, & Holt, 1984). Additionally, autonomy supportive environments have been shown to result in more positive affect both in regular education (Ryan & Grolnick, 1986) and in special-education settings (Deci, Hodges, Pierson, & Tomassone, 1992).

Self-determination Theory and Science Education

Black and Deci (2000) investigated the relationship between autonomous and controlled sources of motivation and how each impacted various outcomes in a college-level organic chemistry class. The researchers found that students who entered the course with more autonomous motivation were more interested, enjoyed the course more, experienced lower anxiety, were less focused on grades-focused performance goals, and had higher indexes of perceived competence. Further, students who entered the course with more autonomous orientation were less likely to drop out of the course. Two related studies on motivation in science education have demonstrated the importance of parents’ autonomy support for persistence in a science program (Ratelle, Larose, Guay, & Senécal, 2005) and the positive impact of instructor autonomy support on students’ autonomous learning and perceived competence (Williams & Deci, 1996).

Perceived Competence

An individual's need to feel competent is considered an innate psychological need within SDT (Niemic and Ryan, 2009). Specific to science learning, Velayutham, Aldridge and Frase (2011) provide an excellent summary of research related to the influence of perceived competence (or self-efficacy), noting that self-efficacy has been associated with science achievement at the college and high school level as well as among middle school students.

Interest

According to SDT, a student will be intrinsically motivated to engage in an activity if it is interesting and enjoyable, and activities are more likely to be interesting if they satisfy the individual's innate psychological needs for competence, autonomy and relatedness (Deci & Ryan, 2000). More broadly, interest has been shown to facilitate cognitive functioning across individuals, knowledge domains, and subject areas (Hidi & Harackiewicz, 2000).

Autonomy supportive environments are characterized by teachers who value and listen to students' ideas. Teachers who support autonomy do not use controlling strategies, but rather create opportunities where students can make decisions and act more authentically, to be themselves. Legewie & DiPrete (2012) found that the gender gap in STEM bachelor degrees has been reduced by 25% among graduates of high schools supporting a positive orientation by females toward math and science. Legewie and Diprete argue the local environment, including peers and teachers, filter gender beliefs and influence the extent to which adolescents are exposed to information about STEM fields and occupations. Unfortunately, few studies have investigated motivation in secondary education from a SDT perspective, taking into consideration the influence of autonomy support. Even fewer studies have looked specifically at SDT in science classrooms (Lavigne, Vallerand & Miquelon, 2007), and no studies have

investigated these factors using a nationally representative sample. The following research questions will guide the study:

1. How do US ninth-graders' intentions to pursue a STEM-related career vary across gender?
2. Do autonomy supportive learning environments affect US ninth-graders' intentions to pursue a STEM career by influencing students' perceived competence, interest and science identity?

Hypotheses for the research questions are elaborated below:

Hypothesis 1: Males will be more likely than females to express an intention to pursue a STEM career.

Previous research has shown that the self-concepts of boys and girls follow stereotypic patterns, with boys' self-concepts correlating more with math self-perceptions and girls self-concepts correlating more with their verbal self-perceptions (Entwisle, Alexander, Pallas, & Cadigan, 1987). Girls may be more likely to avoid occupations in the STEM disciplines because these disciplines are perceived as less relevant for their evolving self-concept.

Hypothesis 2: Both male and female students in autonomy supportive science classroom will be more likely to express an intention to pursue a STEM career.

In theory, teachers who create environments that support autonomy should be less likely to have what the NRC describes as “low learning expectations and biased stereotypical views” that contribute to “curtailed educational experiences and inequitable learning supports” (2012, p. 279). Therefore, autonomy supportive learning environments may not only motivate students by increasing interest and perceived competence as research has demonstrated (see Black and Deci

(2000) , but these environments may also positively impact students intentions to pursue a STEM career by moderating the influence of gender stereotypes.

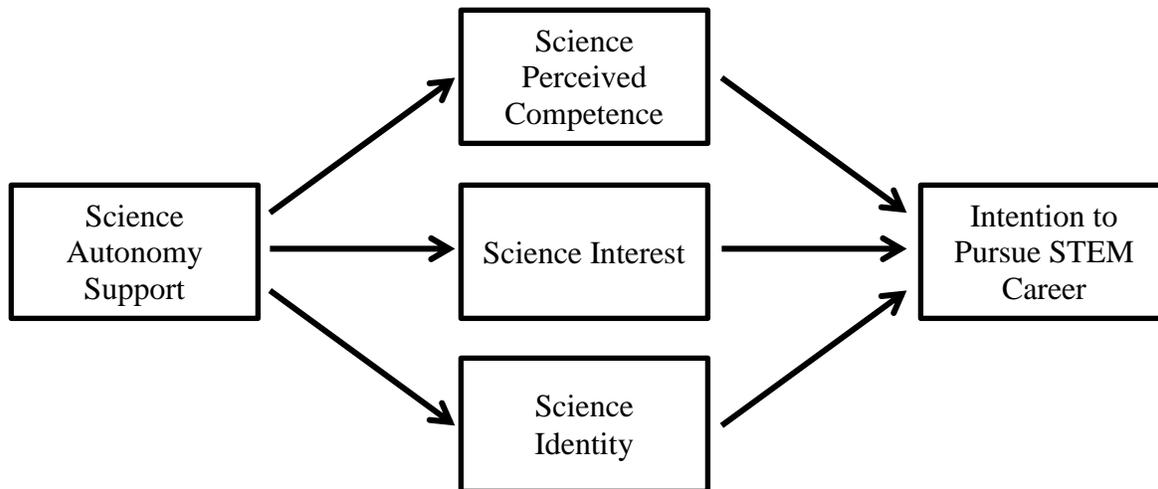


Figure 4.1 *Proposed model*

Method

Data Sources

The High School Longitudinal Study of 2009 (HSLs:09) is a nationally representative study of more than 21,000 9th graders in 944 schools from the 50 United States and the District of Columbia. Approximately 24,000 ninth-graders were selected from 944 schools (both public and private) enrolling both ninth and eleventh-grade students, an average of 25 students per school. Students reported on their experiences, expectations, plans and attitudes related to their Fall 2009 science course using an electronic questionnaire. Data were also gathered from parents, teachers, counselors, and administrators.

Items and Constructs

Stem-related career. Students were asked on the HSLs:09 student questionnaire to enter the occupation they expect or plan to have at age 30. Using the O*NET taxonomy

(<http://www.onetcenter.org>) , coding experts assigned a code to the student-entered job title indicating the corresponding O*NET category (e.g., the response “lawyer” or “attorney” would be coded 23 for legal occupations). For the purposes of this study STEM occupations were considered to be all non-medical fields of fundamental science and engineering. NCES used 24 categories to code 21, 444 student responses. Of these categories, three indicated STEM occupations: 15 = computer and mathematical, 17 = architectural and engineering, and 19 = life, physical and social science. Within SPSS, these three categories were coded “1” and all other categories were coded as “0.”

Autonomy Support. A measure of autonomy support will be created within HSLs:09 by using four items that required students to indicate their level of agreement with phrases related to their current science teacher (e.g., “Your science teacher values and listens to student’s ideas”). These items were selected based on face validity when compared to items contained in validated measures of perceived autonomy support. For instance, the above item is comparable to the statement “I am able to be open with my instructor during class” from the Learning Climate Questionnaire (LCQ), formulated by Williams and Deci (1996). Using four items from the HSLs:09 questionnaire, the variable *Science Autonomy Support* will be created with SPSS principal axis factoring . Appendix A contains a complete list of the student questionnaire items used for the science perceived autonomy support scale.

Perceived Competence. The perceived competence variable was created using four items from the HSLs:09 questionnaire (e.g., “You are certain that you can master the skills being taught in this course”). These items were selected based on face validity when compared with items (e.g., “I feel confident in my ability to learn this material”) from validated measures of perceived confidence such as the Perceived Competence Scale (Williams and Deci, 1996).

Perceived competence was calculated as a scale of students' science self-efficacy, where higher perceived competence values represent higher science self-efficacy. The variable was created through SAS proc factor (factor analysis) and standardized to a mean of 0 and standard deviation of 1. The coefficient of reliability (alpha) for the scale is .88. Appendix A contains a complete list of the student questionnaire items used for the science perceived competence scale.

Interest. The interest variable is a scale of students' interest in their 9th-grade science course, where higher values represent greater interest in the course. The variable was created using SPSS principal components and standardized to a mean of 0 and standard deviation of 1. Six items related to student interest were used as inputs for the scale (e.g., "You think this class is boring"). The coefficient of reliability (alpha) for the scale is .73. Appendix A contains a complete list of the student questionnaire items used for the science course interest scale.

Science Identity. The science identity variable is a scale of the sample member's science identity created by NCES (2011). Student responses to the questionnaire items "You see yourself as a science person" and/or "Others see me as a math person" were weighted using a student analytic weight in order to produce estimates for the target population of US ninth-graders. The scale was created using SAS *proc factor* and standardized to have a mean of zero and a standard deviation of one. Students who tended to agree with the statements will have higher values for science identity. The coefficient of reliability (alpha) for the scale is .83.

Gender. The gender variable will be coded 0 for male and 1 for female.

Analysis

Descriptive Analysis. Because HSLs:09 is a nationally representative data set, descriptive statistics will first be computed to give an general profile of US ninth-graders on the variables of interest in the HSLs base year of 2009. This analysis will, among other things, indicate the

number and gender composition of US ninth-graders intending to pursue a career in the STEM disciplines.

Mediation Analysis. A mediation analysis will be conducted to determine if the effect of autonomy support on students' intentions to pursue a STEM occupation is mediated by perceived competence, interest, and identity. Perceived competence, interest and identity will be considered mediators if the effect of autonomy support on students' intentions to pursue a STEM occupation is reduced when the effect of the mediators on the dependent variable is accounted for.

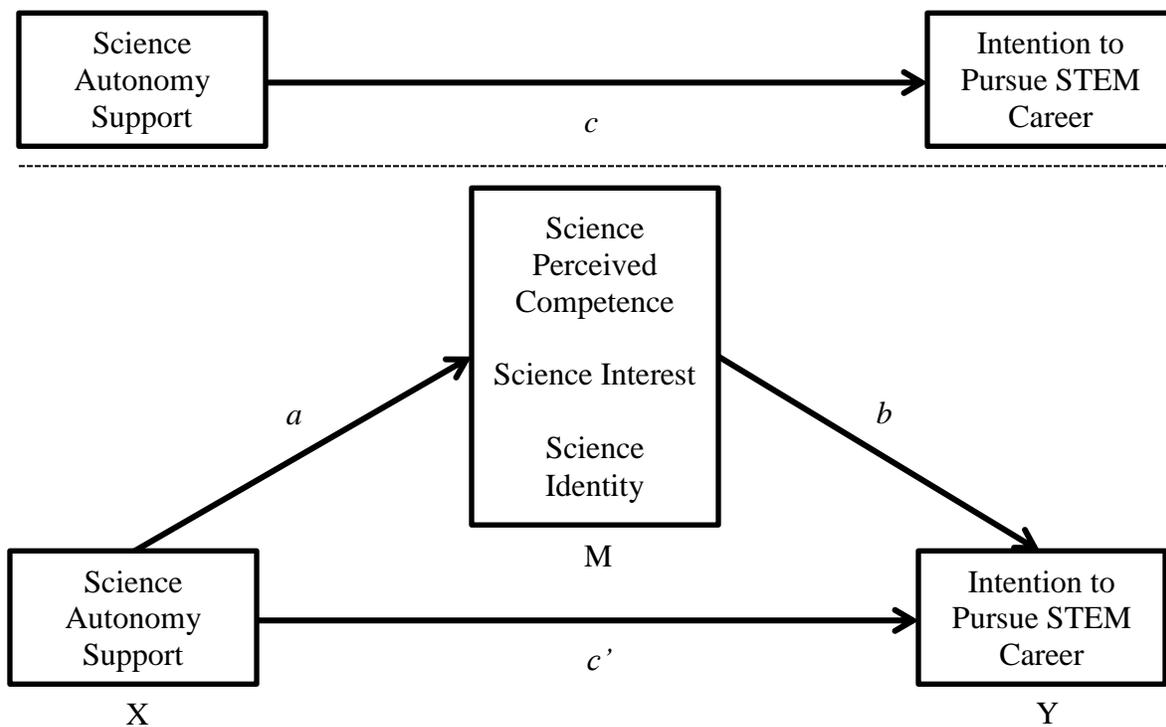


Figure 4.2 *Mediation analysis paths*

Complementary Analyses. To test the model more rigorously, discriminant analyses were used to predict group membership in either the STEM (coded as 1) or Non-STEM (coded as 0) groups. *F* ratios will be used to determine whether or not each variable significantly discriminates between the two groups.

Results

The first research question concerned the number and gender composition of US ninth-graders intending to pursue a career in the STEM disciplines. Table 4.1 presents the number and percentages of males and females intending to pursue a STEM or Non-STEM career.

Table 4.1
*Number and Percent of Students Intending to Pursue
a STEM or Non-STEM Career*

Group	Actual	Weighted	Percent
STEM			
Males.....	931	142	84
Females.....	178	27	16
Total.....	1109	169	100
Non-STEM			
Males.....	7085	1125	46
Females.....	7987	1300	54
Total.....	15072	2425	100

Note. N = 16,181 reduced by 5263 as result of missing responses.

Among US ninth-graders, 6% intend to pursue a career in STEM. Of those students intending to pursue a career in STEM, 84% are boys and the remaining 16% are girls.

Each of the three potential mediations was tested separately (see Figure 4.3). To begin, regression coefficients with associated standard errors were determined for each of four paths: path *a* from the causal variable (X) to the mediator variable (M), 2) path *b* from the mediator variable (M) to the outcome variable (Y) (controlling for the causal variable) 3) the direct path *c* from the causal variable to the outcome variable, and 4) path *c* ' from the causal variable to the outcome variable (controlling for the mediator variable). Accordingly, science perceived competence was regressed onto science autonomy support ($\beta = .33, SE = .02, p < .001$), students' intentions to pursue a STEM career was regressed onto science perceived competence,

controlling for science autonomy support ($\beta = .42, SE = .09, p < .001$), students' intentions to pursue a STEM career was regressed onto science autonomy support ($\beta = .08, SE = .08, p = .29$), and students' intentions to pursue a STEM career was regressed onto autonomy support, controlling for science perceived competence ($\beta = -.06, SE = .08, p = .47$). The effect of

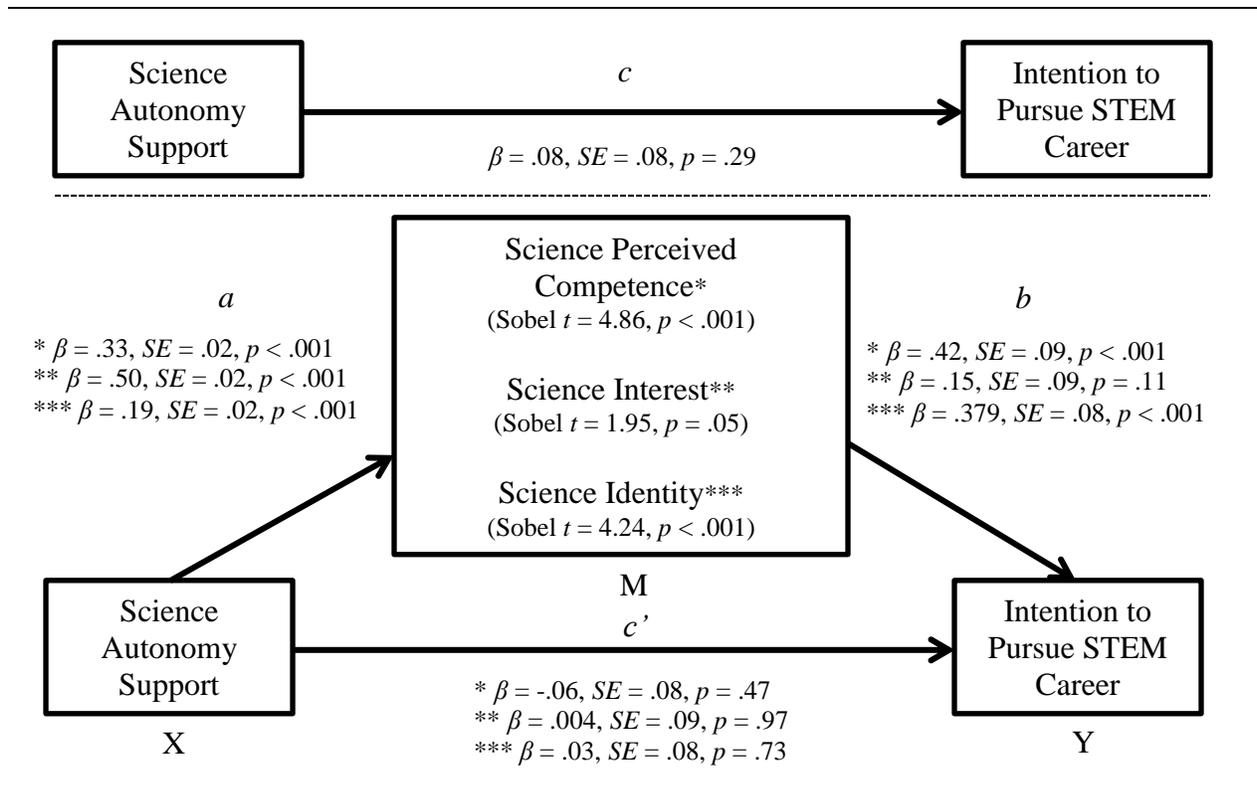


Figure 4.3 Mediation analysis results

autonomy support on students' intentions to pursue a STEM career was significantly reduced after including the mediator perceived competence in the model (Sobel test statistic = 4.857, $p < .001$). Similarly, science interest was regressed onto science autonomy support ($\beta = .50, SE = .02, p < .001$), students' intentions to pursue a STEM career was regressed onto science interest, controlling for science autonomy support ($\beta = .15, SE = .09, p = .11$), and students' intentions to pursue a STEM career was regressed onto autonomy support, controlling for science interest ($\beta =$

.004, $SE = .09$, $p = .97$). The effect of autonomy support on students' intentions to pursue a STEM career was not significantly reduced after including the mediator science interest in the model (Sobel test statistic = 1.95, $p = .05$). Finally, science identity was regressed onto science autonomy support ($\beta = .19$, $SE = .02$, $p < .001$), students' intentions to pursue a STEM career was regressed onto science identity, controlling for science autonomy support ($\beta = .379$, $SE = .08$, $p < .001$), and students' intentions to pursue a STEM career was regressed onto autonomy support, controlling for science identity ($\beta = .03$, $SE = .08$, $p = .73$). The effect of autonomy support on students' intentions to pursue a STEM career was significantly reduced after including the mediator science identity in the model (Sobel test statistic = 4.24, $p < .001$).

Perceived autonomy support did not discriminate significantly between students who intended to pursue a career in STEM and those who did not, $F(1, 2591) = 1.09$, $p > .05$. Table 4.2 presents the F ratio of this variable along with the F ratios associated with science perceived competence, science course interest, and science identity.

Table 4.2
Summary of Discriminant Analysis

Source of Variation	F	df	p	Standardized Discriminant Function Coefficient
Perceived Autonomy Support	1.09	2591	.297	-.014
Science Perceived Competence	23.35	2591	.000	.656
Science Course Interest	4.05	2591	.044	-.287
Science Identity	24.38	2591	.000	.660

Note. Variables are entered together. Group Centroids are .43 for STEM and -.03 for Non-STEM.

Science perceived competence $F(1, 2591) = 23.35$, $p < .05$, science course interest $F(1, 2591) = 4.05$, $p < .05$, and science identity $F(1, 2591) = 24.38$, $p < .05$ did significantly discriminate

between the two groups. Classification results for the analysis showed that 93.5% of the original grouped cases were correctly classified as STEM or Non-STEM. It should be noted that this result should be interpreted with caution. Prior probabilities for group membership were established based on the original size of the groups in the sample (STEM $N = 2425$, Non-STEM $N = 169$), which led to probabilities of .065 and .935 respectively. These probabilities, which represent the likelihood of a score belonging to a group given no other information, influence the score's group assignment within the discriminant analysis. Because of the high probability of an individual belonging to the Non-STEM group, SPSS assigned all 2594 individuals to the Non-STEM group, resulting in the high classification percentage of 93.5%. A follow-up analysis was run in which equal prior probabilities were assigned to each group. Classification results for this analysis showed that 59.8% of the original grouped cases were correctly classified as STEM or Non-STEM.

Discussion

The results support the hypothesis that ninth-grade males will be more likely to express an intention to pursue a STEM career. In fact, the results indicate a significant gender disparity exists among US ninth-graders regarding intentions to pursue STEM occupations. These findings are alarming in light of the concerns of Wang (2013) who documents a drastically increasing need for qualified graduates in the STEM workforce occurring at a time when there are serious shortages of students pursuing STEM disciplines.

The findings do not directly support the hypothesis that students in autonomy supportive classrooms will be more likely to express the intention to pursue a STEM career; there was no direct effect between autonomy support and intention to pursue a STEM career. However, Rucker, Preacher, Tormala, & Petty, 2011 argue that “the lack of an effect, whether it be total or

indirect, does not preclude the possibility of observing indirect effects” (p. 362). Among other things, Rucker, et al. indicate that suppression effects may undermine the total effect by their omission. Within the study model, various suppressors, including socioeconomic status, gender, and achievement may have caused the total effect of autonomy support to appear small or nonsignificant. Rucker, et al. offer several recommendations for practice to prevent the absence of a total or direct effect from restricting research by causing researchers to miss theorized relationships. In addition to considering and assessing suppression effects, the authors recommend that researchers focus on the magnitude of indirect effects, considering whether there is evidence for an indirect effect and, if so, the size of the effect. Of the three hypothesized mediators, science perceived competence and science identity significantly reduced the effect of science autonomy support on students’ intentions to pursue a STEM career and can be considered to mediate the relationship between the two variables. Based on the moderator-mediator distinction provided by Baron & Kenny (1986), science perceived competence and science identity speak to how or why autonomy support effects students’ intentions to pursue a STEM occupation. In other words, science autonomy support significantly increases perceived competence and science identity, which in turn significantly influence whether students intend to pursue STEM occupations. Science interest did not significantly affect the relationship between the causal variable and outcome variable.

Paralleling the results of the mediation analysis, science perceived autonomy support did not discriminate significantly between ninth-graders who intend to pursue a STEM occupation and those who do not. However, science perceived competence and science identity did significantly discriminate between the two groups. Science interest also significantly discriminated between the two groups, but it should be noted that the discriminant function

coefficient for science interest worked in the opposite direction of the coefficients for science perceived competence and science identity. This effect may expose a potential confounding aspect of the interest scale created by NCES. Science interest, as measured by the scale within the HSLS:09 data set, primarily reflects the students interest in their current science course, not an overall interest in science. On one hand, many students may intend to pursue a STEM career and yet be uninterested in their ninth grade science class. For instance, a student planning to become an engineer may be less interested in a ninth grade biology class. On the other hand, many students may not intend to pursue a STEM career and yet find their ninth-grade science class quite interesting. Most ninth grade science teachers are probably talented enough to make their class interesting to a broad range of students.

In summary, these findings indicate US ninth-grade girls are far less likely to intend to pursue a career in STEM. Further, students' intentions to pursue a STEM career were positively linked to higher levels of perceived competence and science identity. Although this study did not indicate a direct link from autonomy supportive environments to students' intentions to pursue a STEM occupation, science perceived competence and science identity mediated the relationship between the two variables, lending support to the hypothesized model that science autonomy support significantly increases perceived competence and science identity, which in turn significantly influence whether students intend to pursue a STEM occupation. This study affirms previous research suggesting that autonomy support, by increasing perceived competence and identification with science, may be an important factor when considering ways to broaden the participation of underrepresented groups in STEM.

Appendix A

HSL:09 student questionnaire items included in perceived science autonomy support, science perceived competence, science course interest and science identity scales.

Perceived science autonomy support

Your science teacher...

values and listens to students' ideas.

treats students with respect.

treats every student fairly.

thinks every student can be successful.

Perceived competence

How much do you agree or disagree with the following statements about you fall 2009 science course?

You are confident that you can do an excellent job on tests in this course.

You are certain you can understand the most difficult material presented in the textbook used in this course.

You are certain you can master the skills being taught in this course.

You are confident that you can do an excellent job on assignments in this course.

Science course interest

How much do you agree or disagree with the following statements about you fall 2009 science course?

You are enjoying this class very much

You think this class is a waste of your time

You think this class is boring

What is your favorite subject in school?^a

What is your least favorite subject in school?^a

You really enjoy science^b

Science identity

How much do you agree or disagree with the following statements?

You see yourself as a science person.

Other people see you as a science person.

Note. Except where noted, student response options were *strongly agree*, *agree*, *disagree*, and *strongly disagree*.

a. Science was one of 13 choices.

b. Answers were yes or no.

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CHAPTER 5

CONCLUSIONS

Put simply, the main goal of this body of work was to determine if autonomy supportive learning environments might lead to higher levels of motivation in secondary science. In terms of the variables used in this study, are students more confident in their abilities, more interested in their science class, more likely to identify with science, and more likely to pursue a STEM occupation when their teacher a) values and listens to students' ideas, b) treats students with respect, c) treats every student fairly, and d) thinks every student can be successful? The questions that guided this research emerged from the observation that the US continues to lag behind other developed countries on international comparisons at a time when scientific knowledge and skills are crucial for our nation's long-term economic and national security. Students must be equipped with the skills necessary to compete in a global knowledge economy and yet schools in the US are not producing students with positive attitudes toward science and students' motivation for science learning declines throughout schooling, especially in secondary education. The fundamental problem of this study was how to trigger and sustain students' emotional involvement in science.

Underlying questions related to the broader issue of US competitiveness in science was the fact that less than 25% of STEM jobs are held by women according to the US Department of Commerce (Beede, et al., 2011). Because research suggests these disparities are influenced by gender stereotypes, it was important to consider the social context surrounding educational decisions and behavior (Legewie & DiPrete, 2012). Indeed, as noted by Legewie and DiPrete (2012), research had "under-appreciated" the influence of the local environment, including the

influence of teachers, on gender beliefs. Little was known about how teachers may unknowingly contribute to gender differences in motivation and create unequal learning supports, perhaps by modeling sex-typed behavior, communicating different expectations or encouraging different activities and skills for boys and girls (Eccles et al., 1983). Moreover, it was noted that these differences in orientations towards the STEM disciplines were largely solidified during the high school years.

Autonomy support was introduced as a way social agents might influence students' motivation. Autonomy support has been repeatedly associated with positive educational outcomes, including enhance motivation, both in general and specific to science education, and at various levels (see Black & Deci, 2000). It was theorized that teachers who create environments that support autonomy might be less likely to have what the NRC describes as “low learning expectations and biased stereotypical views” that contribute to “curtailed educational experiences and inequitable learning supports” (2012, p. 279). Moreover, it was theorized that autonomy supportive learning environments might not only motivate students by increasing interest and perceived competence as research has demonstrated, but that these environments might also positively impact students intentions to pursue a STEM career by moderating the influence of gender stereotypes. To date, studies had not considered the effects of autonomy supportive classrooms on science ability and interest beliefs, nor how these beliefs might affect students' identification with science and intentions to pursue a STEM career.

After recognizing the problem and reviewing previous findings, three studies were conducted in an attempt to answer the questions and address the problem. All three studies involved secondary data analyses of HSLs:09. This nationally representative data set created the unique opportunity to answer the study questions in a manner that would be generalizable to all

US ninth graders and potentially provide answers that would inform a broad range of stakeholders, including parents, teachers, administrators and policy-makers.

The first study had two major goals: 1) to determine if a valid measure of autonomy support was contained in the HSLs:09 data set and 2) to verify that autonomy support functions according to theory in secondary science classrooms. The first research question addressed by this study concerned the existence of a valid measure of autonomy support within HSLs:09. The findings were consistent with the hypothesis that a valid measure of autonomy support is contained within HSLs:09. Four items in the student questionnaire exhibited face validity when compared to items on existing measures of autonomy support. These four items yielded a single factor with a high coefficient of reliability. The resulting autonomy support scale was highly correlated with the science perceived competence and science course interest scales contained in the HSLs:09 data set, adding convergent validity to the measure by demonstrating that it predicts in ways similar to previously validated measures of autonomy support. The second research question concerned the interactions of the three variables of interest: science autonomy support, science perceived competence, and science course interest. The results were consistent with the hypothesis that students are more interested and confident when their need for autonomy is met. Ninth-graders' perceptions of autonomy support in their science classrooms were positively related to their science perceived competence and science course interest. Although this correlational data does not address causality, it appears US ninth-graders with science teachers who show empathy, provide opportunities for choice and minimize external pressure are more likely to be interested and confident in their abilities to be successful in the class.

After verifying that autonomy support can be measured within HSLs:09 and demonstrating that autonomy support operates according to theory in US secondary science

classrooms, goals for the second study emerged: 1) introduce science identity, an important social determinant of motivation not previously investigated in SDT, 2) determine if boys and girls differ significantly on the variables of interest, and 3) determine if the effects of autonomy support are influenced by gender. The results indicated male and female ninth-graders in the US do not differ significantly on science autonomy support, perceived competence, interest or identity. These findings are contrary to the proposed hypothesis for the first research question. Male and female students equally perceive their teachers as supportive of their need for autonomy, meaning that female students are just as likely to report that their science teacher values and listens to their ideas, treats them with respect and treats them fairly. Moreover, male and female ninth-graders in the US are equally interested in their science courses and equally likely to identify with science. There was a statistically significant difference between male and female ninth-graders in the US in perceived competence; however, the effect size for the difference fell below the threshold estimated by Cohen (1988) for even a small effect. This implies that female ninth-graders in the US generally consider themselves as equally competent in science. As predicted, students in autonomy supportive science classes reported higher perceived competence and interest and were more likely to identify with science. Contrary to the hypothesis for the third research question, the effect of autonomy supportive environments did not differ among males and females. The effect of autonomy support on science perceived competence, interest and identity was the same for both males and females. This finding implied that autonomy supportive science learning environments are equally effective for boys and girls in terms of increasing motivation stemming from higher levels of perceived competence, interest and identity.

Having established that autonomy support is equally effective for boys and girls in secondary science classrooms, the focus of the study shifted to how these environments might affect students' intentions to pursue a STEM occupation. The final study had two major goals: 1) determine if US ninth-graders intentions to pursue a STEM career vary across gender and 2) determine if autonomy support influences these intentions. The results supported the hypothesis that ninth-grade males would be more likely to express an intention to pursue a STEM career. In fact, the results indicated a significant gender disparity exists among US ninth-graders regarding intentions to pursue STEM occupations. Although this study did not indicate a direct link from autonomy supportive environments to students' intentions to pursue a STEM occupation, science perceived competence and science identity mediated the relationship between the two variables, lending support to the hypothesized model that science autonomy support significantly increases perceived competence and science identity, which in turn significantly influence whether students intend to pursue STEM occupations. This study affirms previous research suggesting that autonomy supportive science classrooms, by increasing perceived competence and identification with science, may be an important factor when considering ways to broaden the participation of underrepresented groups in STEM.

The findings of this study were significant for several reasons. A valid measure of autonomy support within the HSLS:09 will provide numerous opportunities for researchers to investigate important questions related to self-determination. In addition to science interest, perceived competence and identity, the HSLS:09 data set contains other scales (e.g. sense of school belonging and school engagement) as well as demographic information and dozens of items from school, parent, administrator and counselor questionnaires. Although the focus of this study was science, HSLS:09 contains parallel information for mathematics. Furthermore,

HSL:09 is a longitudinal study. With the release of follow-up data sets, quasi-experimental methods may be employed to investigate causal relationships with autonomy support and the various scales. Also, the results provide additional empirical support for self-determination theory and the linkages between autonomy support and perceived competence and interest, paralleling the work of Black and Deci (2000), who found that students who entered a college organic chemistry course with more autonomous motivation were more interested and had higher indexes of perceived competence. Moreover, these findings provide an extension and elaboration of these linkages by testing them with secondary science students and by using a nationally representative sample. The results imply that autonomy support may be an important pedagogical consideration as educators strive to trigger and sustain student engagement in science. These results of the study were encouraging considering Eccles' (1983) fear that teachers may communicate different expectations or encourage different activities for male and female students. Girls were equally likely as boys to perceive their science classrooms as autonomy supportive, meaning they feel their science teachers value and listen to their ideas, treat them fairly and with respect. Moreover, male and female ninth-graders in the US are equally interested in their science courses. This finding stands in contrast to the work of Meece, Glienke, & Berg (2006), who found that boys reported stronger interest beliefs in science. Moreover, this finding seems to contradict data from the National Center for Education Statistics demonstrating that girls are less likely than boys to report liking their science courses. Another apparent contrast arose related to perceived competence. Guimond, et al., (2006), found that the competency beliefs of boys were higher than girls in science-related courses, but the results of this study indicate the effect size for this difference fell below the threshold estimated by Cohen (1988) for even a small effect. These findings extend the work of Black & Deci (2000) by

demonstrating that autonomy support is not only linked to science perceived competence and interest, but is also positively linked with science identity. US ninth-graders in autonomy supportive science classrooms were more likely to identify themselves as a science person. This is an important finding considering the link between science attitudes and achievement (see Else-Quest, Mineo & Higgins, 2013).

The finding that autonomy supportive learning environments are equally effective for both boys and girls in terms of increasing motivation stemming from higher levels of perceived competence, interest and identity affirms the speculation of Standage, Duda & Ntoumanis (2005) regarding a “void” in the literature concerning the effects of gender. Indeed, the need for autonomy support may be “universal to all cultures, across gender, and throughout developmental periods” (p. 416). The enormous disparity between boys and girls intending to pursue a STEM occupation is alarming in light of the concerns of Wang (2013) who documents a drastically increasing need for qualified graduates in the STEM workforce occurring at a time when there are serious shortages of students pursuing STEM disciplines. This finding highlights the need to ensure that science learning environments do not create differential opportunities that may create and sustain this disparity. Finally, a major goal of this study was to determine if autonomy supportive environments influence students’ intentions to pursue a STEM occupation. Although students’ perceptions of autonomy support did not directly influence students’ intentions, mediation analyses verified that perceived competence and science identity mediated this relationship. Various suppressors, including socioeconomic status, gender, and achievement may have caused the total effect of autonomy support to appear small or nonsignificant. Because of the abundant research indicating that autonomy supportive environments are positively linked with higher levels of science perceived competence, science interest and identification with

science, it is likely that autonomy support still plays an important role in the interaction. It should be noted that the science interest was not a mediator and the discriminant function coefficient for science interest worked in the opposite direction of the coefficients for science perceived competence and science identity. These effects may expose a potential confounding aspect of the interest scale created by NCES. Science interest, as measured by interest scale within the HSLs:09 data set, primarily reflects the students interest in their current science course, not an overall interest in science. On one hand, many students may intend to pursue a STEM career and yet be uninterested in their ninth grade science class. For instance, a student planning to become an engineer may be less interested in a ninth grade biology class. On the other hand, many students may not intend to pursue a STEM career and yet find their ninth-grade science class quite interesting. Most ninth grade science teachers are probably talented enough to make their class interesting to a broad range of students.

There are several future directions for this research. As noted, Standage, Duda & Ntoumanis speculated that the need for autonomy support may be “universal to all cultures, across gender, and throughout developmental periods” (2005, p. 416). This study partially verified this speculation by demonstrating that the positive effects of autonomy supportive environments positively affected ninth-grade boys and girls equally. Because HSLs:09 is a longitudinal study, the effects of autonomy support can also be investigated across developmental periods as these same students complete high school and enter college or the job-market. Moreover, several other background variables are included in the HSLs:09 data set. With this information, the universal nature of autonomy support can be further tested by looking at socioeconomic status, ethnicity, and school characteristics among other things. This study verifies previous findings that students benefit when teachers value and listen to their ideas, treat

them fairly and with respect. These results were expected given the numerous studies documenting the negative effects of controlled environments where external contingencies (e.g. rewards, punishments) or internal pressures (e.g. shame, guilt) motivate behavior (see Deci & Ryan, 2000). Future research might consider the characteristics of teachers who tend to use autonomy supportive strategies. It is theorized that teachers who are given more autonomy are more likely to support the autonomy of their students, whereas teachers who are subject to external contingencies might in turn impose controlling strategies on their students.

Science education was the focus of this study but HSLs:09 contains parallel information for mathematics. Replicating the current findings for math would potentially reinforce the importance of autonomy supportive environments for boosting participation in STEM. Finally, the recently released follow-up wave of HSLs data enables researchers to use quasi-experimental methods to establish causal relationships between the study variables as well as possible changes in the variables over time. For instance, HSLs longitudinal data could be used to evaluate the notion that students' motivation for science learning declines throughout schooling, especially in secondary education (Osborne, Simon, & Collins, 2003).

In summary, this study will advance our current understanding by extending the study of autonomy support to secondary science education using a self-determination theory framework, an approach which has not been taken to this point. The results provide empirical evidence that a valid measure of autonomy support exists within the HSLs:09 data set. Moreover, autonomy supportive science learning environments lead to increased perceptions of competence and interest among US ninth-graders. US boys and girls in the ninth-grade are remarkably similar on several key aspects of motivation in science. HSLs:09 data suggest that girls are just as confident, interested and likely to identify with science as boys. Moreover, both boys and girls

are more likely to be confident, interested, and identify with science when teachers value their ideas, show respect, treat students fairly, and think all students can be successful. Finally, these findings indicate US ninth-grade girls are far less likely to intend to pursue a career in STEM. However, students' intentions to pursue a STEM were positively linked to higher levels of perceived competence and science identity. Although this study did not indicate a direct link from autonomy supportive environments to students' intentions to pursue a STEM occupation, this study affirms previous research suggesting autonomy supportive science classrooms (by increasing perceived competence and identification with science) positively impact motivational factors associated with achievement and positive affect. Confirming the effectiveness of autonomy supportive learning environments in secondary science education gives parents, teachers, administrators and policy-makers a valuable pedagogical tool with the potential to increase student engagement in ways that will increase achievement and encourage the participation of groups typically underrepresented in STEM fields.

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