The Influence of Science Teachers on High School Students' Science Motivation: An Analysis Using a Nationally Representative Large-Scale Data Set

Adem Ekmekci
Rice University, Houston, TX, USA
ekmekci@rice.edu

Danya Serrano Corkin
University of Houston-Downtown, Houston, TX, USA
corkind@uhd.edu

Abstract: This study examined the degree to which science teacher qualifications, characteristics, and practices influence high school students' motivational beliefs about science. Marrying a social cognitive career theoretical framework with a teacher quality theoretical framework, this study explored teacher-related variables as a contextual variable shaping students' motivation towards science. A nationally representative, large-scale data set—the High School Longitudinal Study 2009 (HSLS:09) was used to conduct hierarchical regression analyses. After controlling for student demographics, results indicated that teacher's self-efficacy beliefs, a college or graduate science degree, and science instructional practices were found to be positively associated with students' motivation in science.

Introduction

Given the critical role of science, technology, engineering, and mathematics (STEM) fields in the nation's economy and defense (National Research Council, 2013), this study aims to explore the factors affecting high school students' behavioral and motivational outcomes in science and future career plans in STEM areas. More specifically, this project will explore the extent to which high school students' science teachers' (the most effective contextual factor) personal characteristics, qualifications, and practices relate to student outcomes using a nationally representative, large-scale data set: High School Longitudinal Study 2009 (HSLS:09). In addition, this study explores how these relations compare across different subpopulations of students' based on their gender and ethnic background (underrepresented minority [URM] status in STEM). This study is grounded in two distinct but related frameworks: Lent, Brown, and Hackett's (1994) social cognitive career theory (SCCT) and Goe's (2007) teacher quality framework (TQF). The two frameworks and prior research on factors related to student academic choices and outcomes at the secondary level are utilized to understand the extent to which teacher level factors as contextual factors within the SCCT framework and as central to TQF framework predict students' science motivation outcomes and to understand the extent to which the relation between teacher factors and student outcomes differ based on students' gender and ethnic background.

While a myriad of studies have examined the relation between teacher qualifications, characteristics and their practices, the relation between teacher quality and student outcomes has been investigated to a lesser extent and with a narrower focus (i.e., including only on a small number of teacher factors). This study extends this line of research by looking at several dimensions of teacher factors (e.g., characteristics and practices) "collectively," and provide deeper exploration of the "teacher" factor as it relates to students' science motivation. This study also complements the studies on students' STEM persistence by exploring the role of teacher factors—the most influential "institutional" factor for student outcomes (Hattie, Masters, & Birch, 2016). Findings of this study inform policies to increase and broaden students' participation in STEM by improving our understanding of students' individual and behavioral factors relating to their science motivation in general and URMs in particular (Crisp, Nora, & Taggart, 2009). This study fills the gap in research on teacher factors and their impact on student outcomes by investigating the role that science teachers have on students' science motivation and course-taking by using a nationally representative large-scale data set—HSLS:09, which is developed by the National Center for Education Statistics (NCES). The NCES's HSLS:09 database has not been explored much by the researchers. Given the vital role that the information collected by NCES in this large-scale database may have on our education system and policies (Ingels, Dalton, Holder Jr., Lauff, & Burns, 2015), this study provides new insights about the nexus of teacher quality and student STEM outcomes. Lastly, this study will provide information for science teacher preparation and professional development programs about the types of teacher dispositions, qualifications, and practices that positively relate to student outcomes (Darling-Hammond, 2000; National Council on Teacher Quality [NCTQ], 2004).

The following research questions guided this study:

1. To what extent do science teacher characteristics, qualifications, and instructional practices relate to students' motivation in science (i.e., self-efficacy identity, utility, and interest)?
2. To what extent do science teacher characteristics, qualifications, and instructional practices relate to students' advanced science course taking behavior?

Literature

This study is framed by two complementary theories: social cognitive career theory (SCCT; Lent et al., 1994) and teacher quality framework (TQF; Goe, 2007). The two theories are integrated to explore the predictive value of both student level factors central to SCCT and teacher level factors central to TQF on students' science motivation and course-taking. The two theories complement each other through the centralization of teachers as the main contextual (environmental) factor within the SCCT framework. (Hattie, 2003; Hattie et al., 2016). This study enhances our understanding of the interplay between teacher quality and students' motivational outcomes in science by building upon these well-established theories and prior research on student outcomes at the secondary level by utilizing a large-scale data set for analysis.

Social cognitive career theory (SCCT)

SCCT is an extension and application of social cognitive theory to career choice. SCCT asserts that career choice is influenced by motivational beliefs a person cultivates through the complex interaction among the *individual*, *environmental*, and *behavioral* factors (Lent et al., 1994; Yu, Corkin, & Martin, 2016). SCCT further posits that the most important factors influencing students' future career decisions relate to their motivational beliefs such as self-efficacy, interest, identity, and utility value (Eccles, 2005; Schunk, Meece, & Pintrich, 2014). These motivational beliefs can also mediate the effect of other personal and contextual factors on a person's future career choice and decisions (Lent & Brown, 2006). Research indicates that students with higher mathematics and science self-efficacy and utility value for engaging in mathematics and science are more likely to be successful and persist in these areas (Lee, Min, & Mamerow, 2015).

In addition to personal motivation, the SCCT framework highlights several contextual factors that shape an individual's career aspirations and choices (Lent & Brown, 1996). Supports and barriers at school and at home fall under these contextual factors. In addition, parents and teachers are part of these contextual factors as socializing agents that may have a significant impact on students' academic outcomes and career-related choices. Teachers in particular have been found to be the most significant contextual factor associated with student outcomes (Hattie, 2003; Hattie et al., 2016). Therefore, with TQF embedded within the SCCT framework as the contextual component follows a very conceivable approach and provides a more comprehensive look into development of students' motivational outcomes. More specifically, the inclusion of teacher characteristics, qualifications, and practices that inherently affect K-12 learning experiences can provide a better understanding of that factors that influence students' motivation for STEM.

Teacher quality framework (TQF)

TQF is the most comprehensive teacher quality framework to date. TQF, as proposed by Goe (2007), focuses on the impact teachers have on students' academic outcomes. TQF contains three major components: *inputs*, *processes*, and *outcomes*. *Inputs* focus on two different but related ways of looking at teacher quality: teaching credentials and teachers characteristics. Credentials include postsecondary coursework and degrees, professional degrees, teacher preparation routes, certification types, and years of teaching experience (Darling-Hammond, 2000; Ingersoll, 2007). Teacher characteristics include teachers' beliefs and motivation such as subjective judgements, organization skills and attitudes, and self-efficacy beliefs (NCTQ, 2004; Pajares, 1992). *Processes* involve teachers' instructional practices such as teaching methods, instructional approaches, and classroom management (Goe, 2007).

Outcomes relate to the ultimate success of teachers and often include value-added measures to evaluate teachers' performance, which mostly correspond with students' achievement performance on standardized assessments (Goe & Stickler, 2008). This component is highly controversial given that the validity of these measures have been questioned as well as the ethics of using such measures for high-stakes purposes (Klees, 2016).

Because of its highly controversial nature, this study does not address this last component of *outcomes*. Therefore, the first two components of the TQF *inputs* (teacher credentials and characteristics) and *processes* (teacher practices) will be addressed in this study by integrating them as part of the contextual factors of SCCT. Demographic information of teachers (i.e., gender and racial/ethnic origins) will also be controlled.

Teacher factors and student STEM outcomes

In an extensive meta-analysis of more than 60,000 research papers examining the impact of hundreds of interventions on student learning internationally, Hattie et al. (2016) found that teacher-related factors, and in particular teaching expertise, were the strongest predictors of student learning after controlling for student-level factors when compared to other environmental factors, including the home and school environment, principals and peers. Additional research indicates that teachers' educational background in a teaching discipline and other teacher attributes have significant associations to student-related outcomes (Wayne & Youngs, 2003). For example, Lubienski, Lubienski, and Crane (2008) found that teacher certification had a positive effect on student achievement-related outcomes (see also Darling-Hammond, 2000). Research also indicates that teachers' domain-specific knowledge for teaching and their educational beliefs about teaching have strong connections to their knowledge development, decision-making, planning, and instructional practices (Hill, Umland, Litke, & Kapitula, 2012; Philipp, 2007), which in turn affects student outcomes. Moreover, this connection may be amplified for underrepresented minority students (URMs) in STEM (Berry, Bol, & McKinney, 2009) given that teacher quality has a greater influence on students' math achievement among underrepresented racial/ethnic student groups compared to their non-minority counterparts (Heck , 2007). Because factors associated with highly qualified teachers strongly relate to student outcomes, one of the major goals of this study is to investigate minimally-explored teacher-related factors at the secondary education level that may contribute to students' science motivation and course-taking.

Analytic Techniques

A nationally-representative large-scale data from the NCES's HSLS:09—a study of more than 23,000 ninth grade students as of 2009 will be used. This data set includes demographic information and survey responses from nationally representative students in both public and private schools and from their mathematics and science teachers. The goal of HSLS:09 is to explore high school students' STEM career trajectories starting from the 9th grade all the way to postsecondary education and beyond.

Multiple regression analyses (logistic regression for binary outcomes) will be used to answer research questions. Appropriate weights and design effects will be incorporated into analyses to properly calculate standard error terms for each variable (Ingels et al., 2011; 2013; 2015). Data are analyzed using *SPSS 24,* which can produce proper estimates using sampling weights (Meyers et al., 2006).

Results

We investigated the impact that factors related to science teachers had on students' motivational beliefs about science and advance course taking in science controlling for students' sex, URM-status, and SES. Table 1 presents the results of the hierarchical linear regression analysis predicting motivational beliefs about science. In the regression predicting self-efficacy, gender (β=.08, favoring males) and SES (β=.08) emerged as statistically significant predictors. Among teacher level variables, female teachers (β=-.04) and teachers' inquiry based approaches to teach science (β=.05) were significant predictors of self-efficacy in science. In the regression predicting students' identity in science, gender (β=.03, favoring males) and SES (β=.13) emerged as statistically significant predictors. Among teacher level variables, only teachers' self-efficacy for teaching science (β=.04) was a significant predictor of students' identity in science. In the regression predicting students' utility value for science, gender (β=-.04, favoring females) and SES (β=.08) emerged as statistically significant predictors. Among teacher level variables, teachers' connections to real life and history when teaching science (β=.03) was the only significant predictor of students' utility value for science. In the regression predicting interest in science, only SES (β=.05) emerged as a statistically significant predictor. Among teacher level variables, teachers' degree in science (β=.03), teachers' inquiry based approaches to teach science (β=.03), and teachers' connections to real life and history when teaching science (β=.03) were significant predictors of students' interest in science.

Regarding the advance course taking in science, binary logistic regression analysis was conducted where the dependent variable was AP science course enrollment (see Table 2). When entering all of the variables, results from the model with AP science as the criterion indicated that students' who had a URM science teacher had 50% greater odds of taking AP science course compared their peers whose science teachers were from URM background. A surprising results was found regarding science teachers' instructional practices. That is, students of teachers who employed inquiry-based approaches to their science teaching at a greater extent had lower odds of enrolling in an AP science course.

Collectively, results indicate that teacher degree in science, self-efficacy beliefs, and instructional practices including inquiry-based approach and making connection between science instruction and real life have positive impact on students' science motivation. Teaching certification type (traditional versus alternative) and years of teaching experience did not have an impact on students' science motivation. An interesting finding is that teachers' inquiry-based approaches to teach science had a negative relation to students advanced science course-taking (c.f., Bryan, Glynn, & Kittleson, 2011). However, having an URM science teacher positively predict advanced science course taking. Perhaps, URM teachers attract more students from similar/same background because students see their URM teachers as role models (Crombie et al., 2005).

Variable	Self-efficacy	Identity	Utility	Interest
	β	*β*	*β*	*β*
Step 1				
Male	.08*	.03*	-.04*	.02
URM	.02	-.02	.03*	-.01
SES	.08*	.13*	.08*	.06*
R-square	.01	.02	.01	.00
Step 2				
Male	.08*	.03*	-.04*	.02
URM	.01	-.02	.03*	-.01
SES	.08*	.13*	.08*	.05*
Teacher male	-.04*	-.01	-.02	-.01
Teacher URM	.01	.01	.02	.01
Teacher self-efficacy	.01	.04*	.01	.02
Teacher certification	-.01	.01	-.01	-.01
Teacher degree in science	.01	.02	.01	.03*
Teacher experience	-.02	-.01	.02	.02
Inquiry	.05*	.02	.01	.03*
Connection	.01	.02	.03*	.03*
R-square	.02	.02	.01	.01

Note. *β* indicates standardized regression coefficient. n = 18,600. *p < .01.

Table 1. Summary of Regression Analyses Predicting Students' Motivational Beliefs about Science

Conclusions

National calls and reports highlight the importance of STEM due to its critical role in securing a competitive edge in an increasingly global economy (NRC, 2013). Given this critical role of STEM, educators, policymakers, and scientists have stressed the need to broaden participation in STEM and increase students' motivation and achievement in the STEM fields, especially among those students underrepresented in these fields (NRC, 2013). To address this need, the current study seeks to understand teacher factors that predict student motivation and learning in science. Understanding the extent teacher factors contribute to students' motivation in science is crucial step for identifying policies that can address and improve science teacher qualifications. Results of this study have implications for developing timely policies for teacher education and professional development. These implications include but are not limited to producing, retaining, and promoting highly qualified teachers. For example, since having a degree in science is an important factor found in this study teacher preparation programs should consider rigorous subject matter training or degree plans where students can concurrently complete a teacher certification in addition to their STEM degree. For in-service teachers, this would mean providing support structure for them to further develop professionally to reach desired qualifications such as PD programs to improve their pedagogical content knowledge and incentivizing them to take graduate credits in STEM subjects. Findings from this study may also inform professional development programs necessary to support teachers in the areas and that could potentially improve students' science learning and motivation. In addition, findings may encourage rigorous program evaluations of professional development programs for teachers. Results also promote additional research in areas that may help motivate students in science and broaden their participation in science.

Variable	Advance science	
	β	*Exp(β)*
Step 1		
Male	-.04	.959
URM	.20	1.22
SES	.24	1.28
Pseudo R-square	0.01	
Step 2		
Male	-.04	.96
URM	.16	1.17
SES	.24	1.27
Teacher male	-.07	.929
Teacher URM	.40*	1.50
Teacher efficacy	.02	1.02
Teacher certification	-.08	.92
Teacher degree in science	.12	1.12
Teacher experience	.012	1.012
Inquiry	-.29*	.748
Connection	-.20	.815
Pseudo R-square	0.02	

Note. *β* indicates standardized regression coefficient. $n = 18{,}600$. *$p < .01$.

Table 2. Summary of Binary Logistic Regression Analyses Predicting Advanced Science Course-Taking

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Acknowledgements

This study is based on a research project funded through the Spencer Foundation (Grant #201800021).