EDUCATIONAL EXPERIENCES AND THEIR INFLUENCE ON DEVELOPING STEM IDENTITIES IN STUDENTS

Dissertation Presented to

The Faculty of the School of Education and Human Development

University of Virginia

In Partial Fulfillment

of the Requirement for the Degree

Doctor of Philosophy

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by

Ryan Burke, M.Ed.

March 2025

UNIVERSITY of VIRGINIA | SCHOOL of EDUCATION and HUMAN DEVELOPMENT

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Co-Chair **(If applicable.)**		
Bethany Bell **Committee Member**	Education Leadership, Foundations, & Policy Education and Human Development, University of Virginia	Signed by: Bethany Bell 4/1/2025
Katrina Debnam **Committee Member**	Education Leadership, Foundations, & Policy Education and Human Development, University of Virginia	DocuSigned by: Katrina Debnam 4/1/2025
Rob Tai **Committee Member**	Curriculum, Instruction & Special Education Education and Human Development, University of Virginia	Signed by: 4/3/2025
Committee Member		
Committee Member		
Committee Member		

School of Education and Human Development
Registrar's Office
Office of Admissions and Student Affairs

Ehd-registrar@virginia.edu
Ridley Hall 102D, 417 Emmet Street
Charlottesville, VA 22903

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DEDICATION

As I reflect upon this body of work and my time throughout this program, I am beyond thankful to so many wonderful people. The proverb – "*it takes a village to raise a child*" – has been indicative of my PhD journey. This dissertation is dedicated to my amazing "village" that has always supported me with love, unwavering support, and the freedom to follow my dreams.

First, thank you to my entire family. Your support and love have meant more than words can express (but I'll try!). My parents, brothers, sister-in laws, nieces, and nephew have always been my rock and cornerstone. To my mom and dad who have believed in all my pursuits wholeheartedly. They have instilled in me the courage to dream big while engaging in work to improve systems for others. To Doug and Mike, thank you for being my best friends, forever role models, biggest supporters, and best sounding boards. To Jen and Kristin, thank you for showing me how to be strong, altruistic, and confident. To Mallory, Blake, Claire, and Graysen, thank you for bringing me so much joy and allowing me to channel my inner child. You can now finally stop wondering why your uncle is still in school.

To my life-long friends from Middle Township, Lafayette College, WestEd, and Charlottesville, who have provided endless laughs, love, and encouragement. Despite living far from many of you, thank you for staying connected with me through phone calls, facetimes, road trips, and visits. I could not have made it this far without the immeasurable joy you bring to my life.

Finally, and for whom I hope this work has some impact, this dissertation is dedicated to future scientists.

"*To recognize diversity is science, to celebrate it is humanity.*" – Abhijit Naskar

ACKNOWLEDGEMENTS

I am deeply grateful to my dissertation committee for their guidance, encouragement, and thoughtful feedback throughout this journey. To Jamie Jirout, thank you for your mentorship, kindness, expertise, and belief in me – I truly could not have made it through without you! To Bethany Bell, Katrina Debnam, and Rob Tai, thank you for your generosity of time, critical perspectives to make this body of work better, and meaningful engagement with my research. I have grown as a scholar because of your guidance.

I also want to extend my sincere thanks to the University of Virginia and IES Fellowship. The resources, opportunities, and community here have shaped not only this dissertation, but my development as a researcher.

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Careers in science, technology, mathematics, and engineering (STEM) are quickly evolving and require adapting to new skillsets; providing critical context to understand and evaluate how we are preparing our students to engage in this developing environment (Atkinson & Mayo, 2010; Deming & Noray, 2020, Lillard, 2023, OECD, 2018). When there is space for diversity in thought, experiences, and perspectives, such space brings about opportunities for continued discovery, innovation, and societal improvement (Hill et al., 2018; Talafian et al., 2019). With this in mind, all students should feel as if they can contribute to the science field; yet this is not always the case (National Science Board, 2021; Rainey et al., 2019). Many students within the U.S. do not feel prepared or welcomed to enter the STEM field (Rainey et al., 2019).

In terms of preparedness, results from the National Assessment of Educational Progress (NAEP) science assessment, which measures students' proficiency in life, earth, and physical science in grades four, eight, and twelve, revealed that many U. S. students across grade levels are not able to demonstrate adequate scientific content knowledge. From this snapshot, the U.S. saw science scores decrease from 2015 to 2019 (The Nation's Report Card, 2023). Similarly results from the 2022 Programme for International Student Assessment (PISA) showed decreases in math achievement across the globe and within the U.S. (OECD, 2023). These declines in STEM scores prompt the question of how we are preparing and teaching students to engage with STEM. The following dissertation work aims to explore how different educational practices or experiences may influence building students' science identities, self-efficacy, and curiosity.

Patterns that Contribute to Gaps in Science Education

In order to identify areas to help improve science education, it is important to understand where and why gaps exist. Race, gender, and SES gaps in interest, retention, and engagement in science increase as individuals' progress through education (National Science Board, 2021; Osborne, 2003; Rainey et al., 2019). Underrepresented minorities in STEM (i.e., non-White and non-East Asian, low SES, and female students), are often not afforded opportunities to prioritize their science-related interests, feel as if their teachers recognize their scientific abilities and knowledge, or develop a sense of belonging within their science classrooms (Morgan et al., 2016; van den Hurk et al., 2019). To identify the patterns and factors that contribute to maintaining and widening these gaps it is important to explore patterns throughout the trajectory of education.

Early in a students' education there are already significant gaps between underrepresented minorities in terms of teacher perceptions and science achievement. Based on data from The Early Childhood Longitudinal Study-Kindergarten cohort (ECLS-K), researchers found that kindergarten through 3rd grade children from high SES backgrounds tended to be rated as more motivated to learn by their teachers when compared to their middle and low-SES peers (Saçkes et al., 2011). In terms of gender, teachers provide equal science learning opportunities to boys and girls in kindergarten and there were no differences in participation in science activities; yet boys score higher on pre and post science content knowledge assessments in kindergarten and gaps expand as they reach 3rd grade (Saçkes et al., 2011). Moreover, Morgan and colleagues (2016) found that Black children have lower achievement scores in kindergarten and slower science achievement growth as they progress through school compared to white students (Morgan et al., 2016). These trends in performance differences in early childhood proceed throughout education and differences in interest and perceptions have been documented in high school (Hill et al., 2010).

Hill and colleagues (2010) found that explicit and implicit biases in the workplace deter many underrepresented groups from their interest in pursuing STEM careers. Martin and Fisher-Ari (2021) conducted a qualitative analysis of 52 high-school students' (mostly black (90%) female (78%)) perceptions of race and gender representation in STEM careers and educational spaces. The authors found numerous themes relating to the factors that contribute toward a lack of interest of pursuing STEM. Students described that 1) STEM education or extracurriculars are pushed upon them rather than the STEM field making necessary changes to create space for them to join 2) there is a lack of representation or recognition of people working in STEM within their community and examples they receive about black females in STEM are limited in their curriculum or school lessons, and 3) wealth of white people (namely men) open up more education and job market opportunities (Martin & Fisher-Ari, 2021). There are considerable barriers to overcome when attempting to diversify participation in STEM throughout the kindergarten through 12th grade landscape.

At the higher education level, many underrepresented minority students leave a STEM major after only taking lecture-based classes and are not given the chance to engage in more active instruction (Rainey et al., 2019). This high-level developmental overview paints a discouraging trajectory in terms of how we prepare and serve students from underrepresented and minoritized backgrounds in STEM education; yet it identifies gaps and provides focus in where we need to consider improvement. It is important to understand the perceptions and barriers students face, and the limitations within our education system in order to enact change and begin to remedy these inequalities. One consistent finding throughout the literature is that there is a need to address science curriculum and teaching practices to make it more relevant, skills-driven, and active (Hill et al., 2018; Martin & Fisher-Ari, 2021; Rainey et al., 2019), a need that likely generalizes across

STEM domains. These instructional practices may help increase student's self-perceptions as a scientist.

STEM Identity

Students' STEM identity has been explored in research to unpack how students are perceiving their role in the science field and bolster interest in pursuing careers (Capobianco et al., 2012; McDonald et al., 2019; Paul et al., 2020). Science identity is guided by theories from social and cognitive psychology that aim to understand how students' academic identity influence educational achievement and attainment (Hill et al., 2018). A significant amount of the science identity research builds off of Gee's (2000) framework which emphasizes that individuals adopt certain ways of thinking, speaking, and behaving that align with their communities, social groups, and environment, and the process of adopting identities is crucial for learning. Brown and colleagues (2005) theorize that the role of science learning and identity is interactional, developmental, and historical in students' decisions to participate in science.

Trujillo and Tanner (2014) posit that science identity is a combination of recognition (self-recognition as a scientist and recognition from others as a science person), competence (self-efficacy in science knowledge and skills), performance (demonstrating competence in front of others, being able to perform science tasks in a group setting), and interest (in science and career or future as a scientist). This framework is consistent amongst many researchers' interpretations of science identity (Hill et al., 2018; Paul et al., 2020).

A student's science identity has important implications for their ability to persist in challenging activities, retention in science classes, and motivation to pursue STEM careers

(Dou et al., 2019; Pantoya et al., 2015; Trujillo & Tanner, 2014; Vincent-Ruz & Schunn, 2018). Researchers have found that science identity may begin to develop earlier than adolescence; which is the developmental period previous studies have typically investigated the concept (Ata-Aktürk & Demicran, 2021; Dou et al., 2019; Pantoya et al., 2015). Specifically, a study examining early science experiences found that communicating with friends or family about science and interacting with various scientific media during the kindergarten to 4th grade years, had significant-positive influences on students' STEM identity (Dou et al., 2019).

Science teaching practices should give all students the opportunity to see the relevance and real-world application of what they are learning and the opportunity to see themselves as current and future scientists (Archer et al., 2015; Cunningham & Lachapelle, 2014; Morgan et al., 2016). van den Hurk and colleague's (2018) metanalysis of interventions (N = 71) aimed at increasing student interest, retention, and/or persistence in STEM found that interventions focused on changing pedagogical approaches through improving content knowledge, ability, motivation, and feelings of belonging may increase student interest and persistence in STEM (van den Hurk et al., 2018). Only nine studies were conducted within a school setting and none of these studies were at the elementary school level. Furthermore, only two were conducted within the U.S. This highlights a need for further work in this area and an examination of these constructs in the American education system.

Curiosity and Science Learning

Curiosity for science is something that develops very early in childhood (Engel, 2011). As children, we are naturally curious about the world around us and ask questions to figure out how things work or function (Engel & Randall, 2009; Engel, 2011). Jirout and Klahr (2012) posit that curiosity is “the threshold of desired uncertainty in the environment that leads to exploratory behavior” (p. 127). Within science classrooms, curiosity enables students to investigate, question, and explore phenomena that interests them (Jirout, 2020). It not only allows students to engage in deeper levels of understanding content, but it can also motivate students to engage in more information seeking behaviors (Jirout, 2020; Jirout & Klahr, 2012). Curiosity has been linked to increases in students’ academic achievement, self-efficacy, and motivation (Gottfried et al., 2016; OECD, 2021).

Unfortunately, as children advance through schooling, particularly as students reach upper elementary and middle school, curiosity and interest in science wans (Bennett & Hogarth, 2009; Engel, 2011). This decrease may be a result of how students are taught during formal schooling, rather than natural declines student’s own curiosity (Vedder-Weiss & Fortus, 2011). This raises the question of why and how schools are diminishing students’ natural curiosities for science.

Science education is a space that can allow students to engage in behavior during instances of uncertainty (Schwarz et al., 2017). New standards set by the Next Generation Science Standards (NGSS) call for scientific practices such as question asking, planning and carrying our investigations, and obtaining and evaluating evidence that are intended to promote student curiosity (Schwarz et al., 2017). These mirror ways in which teachers can help promote curiosity within their classroom which include allowing students to investigate topics of interest and emphasize the value of this process; encourage question asking and probe for deeper questions; and reinforce alternative solutions (Jirout, 2020; Jirout & Klahr, 2012).

Few studies have examined the link between curiosity and science identity. Sitt and colleagues (2024) found that undergraduate students’ curiosity predicted positive associations with their science identity and self-efficacy. Considering the link between curiosity and science education, it is important to understand and further study how students' curiosity may be linked with their identity as a scientist.

Self-Efficacy and Science Learning

Another important component of fostering future scientists is making sure they feel confident in their abilities to do science. Student's self-efficacy has important implications for science learning and engaging with STEM content (Sheldrake, 2016; Rittmayer et al., 2009; Stankov et al., 2012; Tyler et al., 2018). Bandura (1997) theorized that self-efficacy describes an individual's beliefs about their ability to perform a specific task or activity. Self-efficacy is developed through mastery experiences (reflections on previous tasks and performance), vicarious experiences (learning through observing others), social persuasion (receiving other's judgements, feedback, or support), and physiological reaction (emotional or physical responses) (Bandura, 1997; Pajares, 1996).

Within STEM specifically, self-efficacy is important for setting challenging yet manageable goals (Rittmayer et al., 2009), achievement in science class (Britner & Pajares, 2006), and interest and engagement in STEM (Schunk & Pajares, 2002). Rittmayer and colleagues (2009) theorize that educators can increase students' self-efficacy during science class by incorporating hands-on laboratory activities, scaffold activities to students' current ability, work closely with more advanced STEM students or professionals, and convey the importance, and value of STEM fields and careers.

Self-efficacy also has positive associations with student's science identity (Byars-Winston, 2016; Sitt et al., 2024). Byars-Winston (2016) posits that learning activities centered upon the sources of self-efficacy influence STEM identities directly and indirectly through student's self-efficacy. This demonstrates that as students build their self-efficacy in a given subject and task they continue to develop or reinforce their perceptions in that specific STEM field (Byars-Winston, 2016). Self-efficacy is important to investigate in the context of science learning considering its ties with developing students' STEM identities.

Gaps in the Literature

There are several gaps in prior research that this dissertation aims to fill. A majority of the past literature looks at ways to advance and improve STEM curriculum with a lens of increasing STEM interest, identities, and equity in countries outside of the U.S. (i.e., Australia, UK, Netherlands, China, etc.). Considering the inequities that exist within the American education system (The Nation's Report Card, 2022; Putnam, 2016), it is important to study ways to improve STEM learning, especially for youth underrepresented in those who pursue STEM domains through college and beyond. Specifically in the context of the U.S., research focused on classroom learning and how it can serve as a tool for preparing minoritized youth to actively engage in STEM is needed.

Additionally, a majority of prior research occurs at the high school or higher education level; yet perceptions of self-efficacy, how you relate and compare to your peers, and interest begin to form earlier in development (Hidi & Renninger, 2006; Schunk & Hanson, 1985). Little research examines science interventions and the perceptions and experiences of youth during elementary schools, particularly youth from backgrounds underrepresented in STEM (Wang & Degol, 2013). Some studies retroactively ask students to reflect on their early elementary schooling (Dou et al., 2019), but it would be beneficial to access this information directly from elementary students. As noted, considering the gaps within science are evident at such an early age, there is a pressing need to understand and explore student perceptions on children's STEM identity, how their teachers make them feel during science class and, if science is important, applicable, and valuable to learn. This will give us valuable insight to address negative perceptions that have been observed more thoroughly later in education (Morgan et al., 2016).

Current Work

The purpose of the current work is to shed light onto educational practices and experiences that may help influence students' identity as scientists. This work is focused across the developmental spectrum of education to provide more context into how students are learning science and perceiving their academic identities and competency in science. This work highlights areas in which we can improve or modify classroom practices to better prepare all students (particularly students from backgrounds underrepresented in STEM) to engage with science, dream of STEM-related careers, and feel as if they belong within the scientific community.

The first paper, *Encouraging Future Engineers: A Look at Undergraduate Research Opportunities*, uses a mixed methods design to examine how engineering research experiences influence students' career aspirations and understand experiences that increase student's engineering identity. Students (N = 769) from an engineering school in a medium-sized southeastern U.S. university completed a survey about their undergraduate research experiences. Students responded to open and close ended questions from the Undergraduate Research Experience Survey (URES; Wylie & Neeley, 2020) regarding their engineering identity (and factors that contribute to this), career aspirations, and belonging. Open-ended responses were qualitatively coded and analyzed for themes while a logistic regression was used to understand the relationship between engaging in formal research experiences and career aspirations. There was no significant association between research experiences and engineering career aspirations; yet engineering identity was positively related to future careers in engineering. Student responses highlighted that engaging in hands-on experiences and projects rather than more abstract research related experiences made them feel more like an engineer.

Considering that the first paper highlights the role of making work meaningful and valuable for the learner, the second paper, *Making Math Matter: Exploring the Influence of Relevance on Student Math Attitudes*, takes a global view of students' math attitudes, self-efficacy, and general curiosity and how incorporating relevance into math instruction may influence these constructs. Students (N = 58,595) and teachers (N = 12,208) from 13 countries completed surveys from the 2022 PISA which focused on mathematics learning and teaching. Students responded to questions about their math attitudes, belonging, math self-efficacy, and prevalence of relevance in their math instruction. A weighted survey regression was used to understand how relevance pedagogy may influence students' math attitudes. Country's level of STEM emphasis was explored to understand if there are societal influences that may be associated with student's math perceptions. This study suggested that incorporating relevance during math instruction was not associated with students' math attitudes, but there are differences in student's perceptions across different levels of country emphasis on STEM. Countries with medium STEM emphasis were the highest amongst all student math perception variables, which may indicate that having opportunities for STEM careers, but less societal pressure may have positive influences on student's math attitudes.

Lastly, the third paper, *Exploring Science Identities in Upper Elementary Classrooms*, explores elementary aged students' science identity, self-efficacy, and curiosity, and how teacher's attitudes toward teaching science may influence these perceptions. Considering that the first two papers did not uncover instructional practices that help influence STEM perceptions, this paper gives students a voice to inform what experiences make them feel most like a scientist in the classroom. Students (*N* = 156) completed a survey asking questions about their science identity, self-efficacy, and curiosity, and their sense of belonging in the school. Teachers (*N* = 25) responded to a survey that asked about their attitudes toward teaching science. A multi-level model was used to understand the relationship between teacher's attitudes toward teaching science and student's science identity. Thematic qualitative analysis was used to understand educational experiences that made students feel most like a scientist. There was no significant relationship between teacher's attitudes toward teaching science and student's science identity, but science identity was positively related to student's science self-efficacy and curiosity. Students felt most like a scientist when they were able to engage in hands-on activities, teachers gave them positive affirmations, and when they solved difficult problems.

Ultimately, these papers provide insight into the factors that contribute to a students' STEM identity or attitudes across the developmental spectrum of childhood to emerging adulthood. These papers cover different content areas to encompass the vast spectrum of STEM education. Each paper aims to identify areas in which we can improve or focus educational experiences and efforts to better prepare and cultivate the next generation of scientists.

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Encouraging Future Engineers: A Look at Undergraduate Research Opportunities

Interest in and passion for science and engineering develop early in childhood (Capobianco et al., 2012; Maltese & Tai, 2010; Paul et al., 2020) and relate to academic achievement and participation (Leibham et al., 2013; Maltese & Tai, 2010). Yet, interests wane as individuals advance through schooling (Engel, 2015; Hill et al., 2018). This is particularly true when examining typically underrepresented and minoritized students in engineering (i.e., non-White or East Asian, female, and low SES; National Science Board, 2021). Within the engineering workforce, women make up 16% of the population (Alburakeh, 2024) and underrepresented racial minorities (e.g., Hispanic, Black, American Indian) comprise of 16.5% (National Science Foundation, 2023). Gaps in interest, retention, and engagement in science increase as individuals' belonging to underrepresented minoritized groups (URMs) progress through education (National Science Board, 2021; Osborne, 2003; Rainey et al., 2019). Reaching the post-secondary level, students who are part of historically marginalized groups continue to be underrepresented across engineering majors (National Science Foundation, 2023). Thus, there is a need to understand how to make college engineering programs more diverse and inclusive.

Within college, students are learning skills needed to enter and prepare for the workforce (Chan, 2016). Within engineering, hands-on projects allow for students to feel confident in their abilities and build their sense of belonging within their engineering field (Lucas & Hanson, 2016; Schauer et al., 2023). One way in which students can engage in hands-on experiences is by participating in research. Engaging in research has been examined more recently within the engineering context and has important implications for student's motivation and pursuit of engineering careers (AUTHORS, 2022; Buchanan & Fisher, 2022; Little, 2020; Lopatto, 2007; Mada & Teitge, 2013, Russell et al., 2007).

Building upon student's motivation, these educational opportunities highlight the importance of the Self-Determination Theory (SDT) framework (Deci & Ryan, 2012). This framework emphasizes that it is important to consider students' competence and relatedness (Deci & Ryan, 2012). According to SDT, student's relatedness (feelings of belonging) and competence (perceptions in ability to perform tasks or engage with work) have important implications for students' intrinsic motivation and interest in a subject (Trenshaw et al., 2016). These internal motivational factors also influence a student's ability to persist in science, technology, engineering, and mathematics (STEM) educational programs (Simon et al., 2015). With this in mind, understanding the experiences of undergraduate engineering students can help inform how to best cultivate and support the next generation of engineers. The following paper examines student's experiences participating in undergraduate research and aims to understand ways to support student's career aspirations to help increase diversity and representation in the workplace.

Higher Education and Creating Engineers

Careers in STEM are quickly evolving and require adapting to new skillsets, creating increasing need to understand and evaluate how we are preparing our students to engage in this developing environment (Atkinson & Mayo, 2010; Deming & Noray, 2020; Lillard, 2023). This is particularly important in higher education settings where students are actively engaging in a range of educational experiences geared toward advancing and starting their careers. Higher education is a space where students can develop skillsets, prepare to engage in the workforce, and ultimately build their academic identity in their field of study (Chan, 2016), making it the ideal time to intervene to support the pool of potential engineering students needed for the growing demand.

One way to support students is to help cultivate their academy identity. Within engineering, academic identity refers to one's sense of membership derived from participation in engineering-related activities or roles (Godwin & Kirn, 2020; Meyers et al., 2012). Godwin (2016) posits that self-recognition and recognition from others, interest, competence, and performance are key constructs that impact an individual's engineering identity development. This is an important to foster in students because it contributes to a student's ability to persist during challenging activities, adapt to changing contexts, and can also influence career decisions (Godwin & Kirn, 2020; Godwin et al., 2016; Talafian et al., 2019; Syed et al., 2018; Vincent-Ruz & Schunn, 2018).

There are several ways to foster engineering identity within education (Pantoya et al., 2015; Rhode et al., 2019). Within higher education engineering programs, there is a push to incorporate meaningful learning experiences that align closely with activities or tasks students will be expected to perform in their future workplace (Lucas & Hanson, 2016; Schauer et al., 2023; AUTHOR, 2022). In addition to the learning benefits, these experiences are important for motivation to continue in the program and developing students' engineering identity. When students have the opportunity to perform hands-on and real-world collaborative projects in their classes, they are more likely to recognize themselves as an engineer (Meyers et al., 2012).

Early educational experiences may have important implications for underrepresented minorities students in engineering. Rainey and colleagues (2019) found that many students withdraw from STEM majors before they have the chance to engage in classes or experiences that offer more hands-on and real-world experiences. These meaningful, hands-on experiences may be particularly important for underrepresented minority students to experience early in their academic career to help address retention and graduation rates (Chang et al., 2014; Rainey et al., 2019).

Because early classes tend to be large and focused on lower-level content, extracurricular research experiences could provide a way of students getting such experiences.

Undergraduate Research Experiences

Undergraduate research opportunities are a beneficial way to engage in meaningful STEM-related experiences (Buchanan & Fisher, 2022; Little, 2020; Lopatto, 2007; Mada & Teitge, 2013, Russell et al., 2007) and opportunities to engage in research may contribute to developing perceptions of oneself as an engineer (Faber et al., 2020; Hunter et al., 2006; Syed et al., 2018). There are numerous benefits of engaging in research at this level of academic training, including an understanding of the research process (start to finish), collaborating with mentors and other students, determine interests, and develop relevant skillsets (Little, 2020; Mada & Teitge, 2013; Sadler et al., 2010, Syed et al., 2018; AUTHOR, 2022). Engaging in research as undergraduates also makes students more marketable when looking for jobs in their target careers (Russell et al., 2007).

Buchanan and Fisher (2022) conducted a systematic literature review of 220 articles that examined the implementation of course-based undergraduate research experiences, which involved embedding research practices into the normal course structure. This included developing hypotheses, designing research methods, reviewing literature, or disseminating results to classmates. These classroom-based experiences led to higher retention, specifically for more marginalized youth, offer insight and more depth into the scientific process, and foster student self-efficacy, persistence, and motivation (Buchanan & Fisher, 2022). The authors noted that course-based research experiences were most frequently observed in biology courses, yet within more recent years, engineering departments have been incorporating these experiences into their normal classroom practices (Buchanan & Fisher, 2022).

AUTHOR (2022) describes the close connectivity between engaging in research and the engineering culture. Meritocracy (individuals who succeed deserve it), empiricism (knowledge is objective and truth is obtainable through research), and innovation and creativity are foundational to engineers' values and culture (AUTHOR, 2022). These ideals do not promote and may discourage diversity and equity in engineering communities (AUTHOR, 2022). Lopatto (2007) created the Survey of Undergraduate Research Experiences (SURE) to assesses students' undergraduate research experiences and subsequent outcomes (career interest, retention of minoritized students, and learning gains). Students participating in research-related experiences showed positive associations between these experiences and their motivation to learn, ability to think independently, and perceptions of becoming a more active learner (Lopatto, 2007).

Syed and colleagues (2018) found that engineering students' academic identity mediated the relationship between students engaging in research activities (such as writing an article, generating research questions, or developing data collection methods, etc.) and commitment to an engineering or science career. This study examined a mix of formal and informal opportunities (Syed et al., 2018). Contributing to research may provide experiences where students can feel they have a role in creating new knowledge as part of a collaborative group. Thus, there is an opportunity to study associations between research participation and students' engineering identity within more formalized contexts.

Most studies of research experience focus on required courses that include hands-on research tasks, such as using equipment and replicating classic research procedures. Fewer studies have examined the impact of students participating in extracurricular research with faculty members - an experience that provides a more authentic understanding of the scientific process, includes various types of uncertainty that students will grapple with, and offers the opportunity for students to contribute to science in a meaningful way through their participation. By examining these rich experiences, the current study provides context into how universities can best support students in their pursuit of becoming engineers.

Motivation and Student Success in Engineering

Across several of the most widely used contemporary frameworks of motivation, factors including students' self-efficacy and sense of belonging, values for learning, and interests and curiosity are important in understanding motivation (Deci & Ryan, 2012; Cook & Artino, 2016; Transhaw et al., 2016). Students' sense of belonging, self-efficacy, and the development of ones' engineering identity play important roles in student decisions to persist and pursue engineering careers (Trujillo & Tanner, 2014). These constructs have been more recently studied together as opportunities for supporting students' long-term success in engineering careers and academics (Godwin & Kirn, 2020; Meyers et al., 2012). Understanding these relationships in general and their relationship to research experiences outside the classroom can contribute to a conceptual framework for fostering or encouraging more diversity in engineering positions to set students up for success.

Students' perception of their competence and self-efficacy, or their ability to grasp and complete STEM problems or perform science-related tasks, is critical for learning (Sheldrake, 2016; Stankov et al., 2012; Tyler et al., 2018). Self-efficacy is domain- and even task-specific in that a student may have high self-efficacy in chemistry for example, but low self-efficacy in writing (Trujillo & Tanner, 2014). Undergraduate students' self-efficacy is related to their interests in pursuing STEM-related careers academic achievement and perseverance during challenges (Alhadabi & Karpinski, 2019; Luzzo et al., 1999; Trujillo & Tanner, 2014).

Related to competence perceptions, a student's sense of belonging is also essential for academic success (Korpershoek et al., 2020). Furrer and Skinner (2003) found that a student's sense of belonging (defined by feelings of connectedness to friends, teachers, parents, and classmates) played a critical role in their academic outcomes. Students that had high perceptions of belonging demonstrated more engagement and academic persistence (Furrer & Skinner, 2003). Within higher-education spaces in particular, belonging has been commonly used to measure typically marginalized individual's connection to a certain space (Trujillo & Tanner, 2014). Chen and colleagues (2022) found that minoritized students' belonging mediated the relationship between a students' science identity and their performance in science classes. These results highlight an avenue to test this specifically within the engineering context.

As previously discussed, URMs in STEM tend to have more obstacles during their college trajectory that influence their motivation to pursue and stay in the field (Riegle-Crumb et al., 2019). In engineering specifically, students' gender (Amelink & Creamer, 2010; Buontempo et al., 2017; Godwin et al., 2016; Hilpert et al., 2014; Ross et al., 2021) and parental level of education (Archer et al., 2012; Martin et al., 2014) have also been observed to influence students' motivation to pursue engineering careers. Students that identify as women or come from first-generation homes may experience lower self-efficacy, sense of belonging, and engineering identities when compared to their male and continuing generation college student peers (Archer et al., 2012; Ross et al., 2021; Patrick et al., 2021). With this in mind, the current study will continue to investigate these trends and understand how engaging in research opportunities may be influenced by these demographic factors.

Current Study

This study builds on prior studies of students' engineering identity and extracurricular research engagement, and how these undergraduate research experiences may influence individuals' engineering career aspirations. Specifically, the research questions were:

1. Do undergraduate engineer students feel like engineers or someone who wants to pursue engineering?
    a. Does sense of belonging relate to engineering identity?
    b. What experiences do students report as influencing their engineering identity?
2. Does participation in extracurricular undergraduate research relate to students' engineering career aspirations?
3. Why do students choose to participate in extracurricular research opportunities?
    a. How can programs encourage student participation in extracurricular research?

First, we aimed to understand student's perceptions of engineers and what makes them feel like an engineer to help make connections to their perceptions of why they want to participate in undergraduate research opportunities. Next, we used a logistic regression to understand the relationship between research experiences and career aspirations including student's engineering identity, belonging, gender, year in program, and parent education. Consistent with previous research, we predict that engaging in research opportunities will relate to student's engineering career aspirations (Little, 2020). Finally, we wanted to qualitatively explore why students choose to participate in research.

Method

Participants

All students in the engineering school at a medium-sized southeastern United States university were invited to participate in a research study by responding to an emailed survey invitation (Authors, 2020). A total of 769 students (with a response rate of 28% of eligible students) completed the survey. Class years were evenly represented, and student demographics were comparative to the engineering school's demographic makeup in terms of age, gender, race, ethnicity, first-generation status, and distribution amongst majors (See Table 1). A majority of students (61%, n = 466) indicated that they have not participated in a research experience outside of normal classroom practices, whereas 39% of students (n = 303) participated in at least one research experience since enrolling in college.

Table 1. Participant Demographics

Demographic	Frequency	Percent
Major		
Aerospace	40	5%
Biomedical	155	19.36%
Chemical	54	6.75%
Civil	57	7.13%
Computer Engineer	51	6.36%
Computer Science	196	24.5%
Electrical	23	2.88%
Engineering Science	9	1.13%
Mechanical	82	10.25%
Systems	123	15.38%
Other	10	1.25%
Year		
First	221	28.89%
Second	183	23.92%
Third	172	22.48%
Fourth	187	24.44%
Other	2	0.26%
Race		
American Indian/Native Hawaiian	6	0.80%
Asian	238	30.59%
Black	39	5.01%
White	467	60.03%
Category not listed	15	1.9%
Prefer not to answer	13	1.67%
Parent Education		
Some High School	4	0.55%
High School	43	5.96%
Some College	21	2.91%
Associate's	15	2.08%
Bachelor's	189	26.21%
Master's	284	39.39%
Professional	76	10.54%
Doctorate	86	11.93%
Not sure/no answer	3	0.42%
Gender		
Male	364	51%
Female	345	48%
Category not listed	3	0.5%
Prefer not to answer	3	0.5%

Measure

The Undergraduate Research Experience Survey (URES) was administered to undergraduate engineering students in the spring of 2019 (Authors, 2020). The goal was to assess how many students were participating in research, and whether access to research experiences was equitable across demographic groups. The results were intended to inform the school's approach to supporting student researchers and encouraging other students to seek out research experiences. The survey includes multiple-choice questions regarding students' undergraduate research experiences and how they have affected professional and technical skills. Several questions were adapted from the Survey of Undergraduate Research Experience (SURE) which was validated within a group of students similar to those in the current study (Lopatto, 2004). The URES also includes open-ended questions from the Undergraduate Research Student Self-Assessment (URSSA), which focuses on students' perceived learning, sense of belonging, and engineering identity (Laursen, 2010). Additionally, Authors (2020) incorporated questions regarding student participation in extracurricular activities, and reflections on researcher skills such as communication, leadership, and teamwork. This paper examines and analyzes the following constructs from these URES survey results:

Research Experience – Students either responded with a yes or no to the following question: "Outside of capstones and course-structured lab research projects, have you had any experiences doing research since enrolling in college."

Engineering Identity – Students responded from strongly disagree (1) to strongly agree (7) to "I feel like an engineer" (M = 5.418, SD = 1.456).

Engineer Career Aspirations – Students were asked to select their plans for the future from a list of 10 items. Items ranged from job as an engineer, job not as an engineer but using the major training, graduate school in engineering or science, professional school, and job or school unrelated to engineering. Binary scores were assigned to students to indicate no engineering career aspirations (0) or interest in an engineering related career (1) (M = .792, SD = .406). A total of 147 students did not want to pursue a career in engineering compared to 559 students that are interested in an engineering career.

Belonging – Belonging was measured using two items ("I feel like I belong in (school of engineering)"; "I feel like I belong in my major"). Students responded from strongly disagree (1) to strongly agree (7) with the statements. Scores were aggregated to create a single belonging variable (α = .831 , M = 5.713, SD = 1.318).

Data Analysis

This study used a convergent mixed methods design in which quantitative and qualitative survey responses were collected simultaneously but analyzed separately. The results from the qualitative responses are used to elaborate upon the quantitative results.

Qualitative Analysis

Researchers employed a two-stage approach to the qualitative coding. First, two researchers independently read through all student responses for each open-ended question to develop codes. The following open-ended survey questions were examined: describe an experience that made you feel like an engineer (N = 641), how would you define an engineer (answered only by students who agreed with feeling like an engineer, N = 498), and why do you think it is you don't feel like an engineer (answered only by students who disagreed with feeling like an engineer, N = 74), why would you like to do research (N = 253) and what could the school of engineering do to encourage you to try undergraduate research (N = 348).

Discussions were held to develop codes for a qualitative codebook (Authors, 2024). Researchers coded subsections of the data and continued to meet until an inter-rater reliability (IRR) of .80 was met. Once IRR was reached the researchers independently coded student responses. Many student responses included more than one code; thus, responses were double coded (and in some instances triple coded) responses when applicable.

After coding, researchers used a thematic coding analysis to identify and interpret broader themes and patterns within the data. Themes and patterns were used to interpret student's perceptions of being an engineer and what experiences make them feel like an engineer (RQ 1) and student's motivations for participating in extracurricular research and how schools can encourage research participation (RQ 3).

Quantitative Analysis

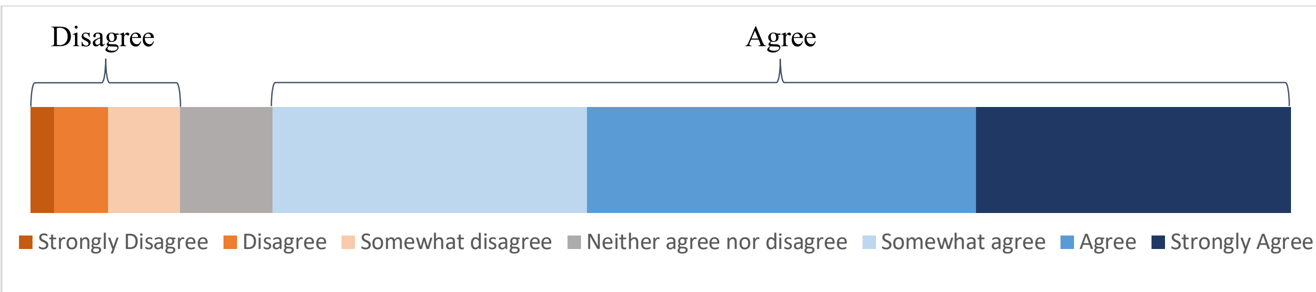
Descriptive data from survey responses were explored to understand students' sense of engineering identity and a correlation was used to understand the relationship between a student's sense of belonging and engineering identity (RQ 1). A logistic regression using STATA (StataCorp, 2023) was used to understand the relationship between engaging in research and engineering career aspirations (RQ 2). The final model included student's engineering identity, sense of belonging, gender, year in program, and parent education.

Results

Research Question 1: Do undergraduate engineer students feel like engineers or someone that wants to pursue engineering?

A majority of students had strong positive perceptions of themselves as an engineer. When students were asked if they felt like an engineer, a majority (55.85%) of students agreed or strongly agreed whereas only few students (6.17%) strongly disagreed or disagreed (See Figure 1). Many students (37.98%) were less decided on their engineering identity and responded with somewhat disagree to somewhat agree. Additionally, a majority of students feel like they at least somewhat belong in both their major (86.24% of respondents) and the engineering school (84.98% of respondents). A student's sense of belonging was positively correlated with their identity as an engineer ($r = .677$, $p < .001$).

Figure 1. Student Self-Perceptions as an Engineer: "I feel like an engineer."



Building upon this, student open-ended responses ($N = 641$) provided further context into who they perceive engineers to be. A major theme in the qualitative data showed that students saw engineers as problem solvers. Some students expanded upon this and mentioned engineers solve problems to improve societal systems or apply STEM content knowledge to address technology or construction-based issues. For example, one student said: "*someone who is able to solve problems and build things in an efficient and/or structured way applying the fundamentals of science, mathematics, and design*." Another themes was that students emphasized the physical aspects of being an engineer and highlighted that engineers are people that build, construct, create or design. These students mentioned that engineers bring physical products, structures, or materials to life. Students also thought engineers were critical thinkers. These students thought of engineers as people who bring things to life and actively solve problems, yet few highlighted that engineers also abstractly think of solutions or ideas and research ideas.

In terms of engineering as a future career, a total of 509 students (80.1%) indicated that their future plans included a job as an engineer or continuing education in the engineering field. To understand trends across demographics, we further examined students' engineering identity and engineering career aspirations between different years, gender, and parental education (See Table 2). Students' engineering identity was high amongst all demographics of students, but third and fourth year, male, and students whose parents received a bachelor's or professional degree had the highest self-perceptions as an engineer compared to their counterparts. Engineering career aspirations had the highest averages amongst first and second year, male, and students that are first generation or have parents with a bachelor's degree.

Table 2. Engineering Identity and Aspirations by Student Characteristics

	Engineer ID	**Career Aspirations**
Student Year		
First	5.333 (1.491)	.877 (.023)
Second	5.448 (1.388)	.832 (.029)
Third	5.470 (1.423)	.776 (.033)
Fourth	5.47 (1.482)	.676 (.035)
Gender		
Male	5.522 (1.487)	.822 (.021)
Female	5.28 (1.432)	.771 (.024)
Parent Education		
First Gen	5.256 (1.609)	.88 (.038)
Bachelors	5.473 (1.457)	.841 (.028)
Professional	5.428 (1.437)	.765 (.021)

*Note: Reported means and (standard deviations)

What experiences influence whether or not students feel like an engineer?

A total of 498 students described experiences that made them feel like an engineer. Students reported that being in class or working on capstone projects within a team made them feel like an engineer. Students associated being an engineer with learning and applying material from their academic training. Specifically, students often reflected on projects that aimed to address real world problems, and many described these experiences in positive ways. These projects required students to develop and design new materials (such as medical equipment, musical instruments, etc.), creatively plan out logistics or methods to solve existing structural, mechanical, or procedural issues, or identify inefficiencies in technology and address them. For example, one student mentioned:

> Just this week I had a project due where we were tasked with solving a real problem with a real building at [school], and all of the massive complexities of the problem were overwhelming but also exhilarating to confront. At the end we had applied all that we have learned in college to creatively solve a problem that would make the university better, and it felt very fulfilling.

Students' responses highlight the importance of getting hands-on experiences or applying course related knowledge in relation to students' self-perceptions of and identification as an engineer.

In addition to mentioning course-specific activities, students spoke about experiences outside the classroom that made them feel like an engineer. Students reflected that being able to bring their ideas to life to help daily functions was a contributing factor to their perceptions as an engineer. This was described in many forms from creating furniture out of everyday objects, repairing complex electronics and machinery, to coming up with logistics in how to efficiently organize spaces. These responses reflected application of both the skills they are developing and how their knowledge influences their view of the world and how the world views them, as well as influencing motivation in engineering. For example, one student commented:

> One day I realized that I had a lot of miniature coke bottles and I felt bad about getting rid of them because plastic is bad for the environment, so I made a shelf for my wardrobe out of it.

Another responded:

> [University] staff saw me with my engineering shirt and asked for advice on how to best setup their floor plan with tables and chairs to best get people through their small event. I helped them set it up in a way that allowed people to move through efficiently and get all the special entrees without congestion. Being able to solve a problem using logical techniques and see the results of that work was really gratifying and further encouraged me to study engineering.

Together, these examples demonstrate that when students get the opportunity in or out of the classroom to develop and use creative solutions to problem solve or create and construct, they feel like an engineer.

Students also credited their out-of-class activities such as internships and research labs to their feelings of being an engineer. These students reflected that getting the chance to connect with other engineering professionals outside of the university (at conferences or different companies), having ownership over an aspect of a research project (running analyses, brainstorm alternative methods, answering questions as a content expert in the group) or simply getting the opportunity to be use their engineering content knowledge in a professional setting outside of the classroom were contributing factors toward their self-perceptions as an engineer. This indicates that students may feel more like an engineer in environments in which they are choosing to participate that are outside of their courses. Mentions of engaging in research opportunities or labs was few in comparison to experiences in classrooms, clubs, and everyday life; this may indicate that research is an extracurricular that many students do not align with feeling like an engineer.

Alternatively, some students' responses indicated that they did not feel like an engineer. A theme from these responses showed how despite their major being in the school of engineering and applied sciences, it was different from other engineering programs. These responses were a theme within computer science or systems engineering majors. This suggests that students may perceive certain majors or types of engineering as being more closely related to the broad field of engineering than others. For example, one student explained:

> Systems is not a technical major in the same way other engineering majors are (I haven't really "mastered" anything technical other than putting together a neat PowerPoint). Although we have the science and math pre-requirements to qualify as an engineer, I personally do not feel like I have the skillset to confidently identify as an engineer. This is mainly because most jobs labeled "engineer" are not looking for Systems Engineers. Systems engineers look for jobs labeled "consulting" or "analyst". Just a misalignment of definitions I'd say.

Another theme within students that did not feel like an engineer that emerged was that students said they “don't think like an engineer”. These students explained that within their courses they often struggle to understand engineering or STEM concepts. Students reflected on their self-efficacy to complete class assignments and how they felt less confident when compared to their peers, which further leads to feeling discouraged and ultimately unlike an engineer. For example, two students elaborated:

> I do not think like an engineer. I am ultimately able to complete my work and do fairly well on my exams, but it doesn't come naturally to me. I feel I need to put in more work than other to achieve the same outcome. I am not good at learning underlying concepts and applying them to new or unfamiliar concepts. That’s what engineering is all about.

> I just struggle in all of my classes, and I see my classmates around me being quick to understand how to go about doing their assignments, which makes me think that something is fundamentally anti-engineering about the way that I approach designs in my classes. I recorded this in my journal on October 26, 2017: "I wish that I were good at the logic of coding, that it came naturally to me… but it doesn't, not even the simple assignments that are meant to be freebies". I was good at the humanities in high school (I love writing essays, debating philosophy, etc), so I decided to come to the engineering school so that (1) I can challenge myself in a field that I seem to be good at from high school but still don't know much about, and (2) so that the good technical skills that I learn from Engineering [School] can be combined with the good writing and communication skills that I already have to open more doors for me in community service, which is what I love doing more than anything else. This past year, I've found comfort in recalling that I entered the E-School to challenge myself, so I shouldn't be too harsh on myself when I struggle

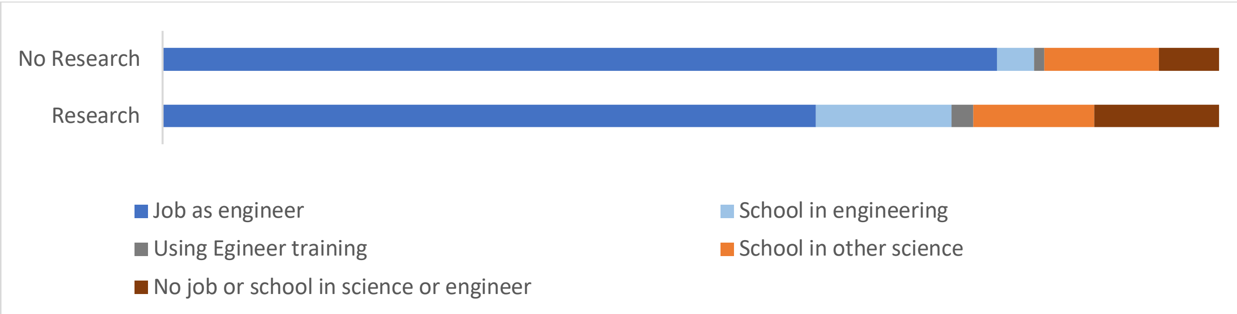
> in classes, but it is a hard mindset to change when I have been a perfectionist all the way through high school.

Some of these students expressed that they do not foresee themselves going into an engineering profession. They have either changed their interests after taking some courses within their major, or they want to use their knowledge to do other work outside of engineering. Ultimately, the students that do not feel like an engineer are socially comparing themselves to their peers, feel like they cannot catch up or grasp course material, or have realized through their time within courses and the Engineering School that they are no longer interested in this field.

Research Question 2: Does participation in extracurricular undergraduate research relate to students' engineering career aspirations?

A majority of students aspire to work as an engineer after completing their program, yet these numbers differ when examining students who did and did not participate in research experiences (See Figure 2). When comparing career aspirations between students who participated in research opportunities and those who did not, more students who did not engage in formal research opportunities indicated they would continue into an engineering career (78.96%) compared to those who did participate (61.8%). Proportionally, more students who participated in research indicated they were seeking careers outside of science and engineering (11.8%) compared to those who did not participate (5.67%).

Figure 2. Engineering Career Aspirations between Engaging in Research



A logistic regression was used to understand if engaging in a formal research experience relates to a student's engineering career aspirations (See Table 3). There was no significant relationship between participating in a research experience and engineering career aspirations; yet student's engineering identity was predictive of pursuing an engineering career. Additionally, there were significant differences between first generation students and students with parents that have earned a professional degree. First year students also had higher career aspirations compared to third- and fourth-year students. There were no significant differences between gender and belonging was not a significant predictor of career aspirations.

Table 3. Logistic Regression Results on Student's Engineering Career Aspirations

Variable	Comparison Group	Odd's Ratio	Confidence Interval
Research Experience			
Did not participate	Participated	.707, $p = .104$	[.466, 1.073]
Engineering Identity		**1.381*, p < .001**	[1.149, 1.659]
Belonging		.963, p = .718	[.786, 1.181]
Gender			
Male	Female	.721, p = .111	[.492, 1.106]
Parent Degree			
First Gen	Bachelors	.816, p = .350	[.352, 1.891]
First Gen	Professional	**.465*, p = .048**	[.218, .994]
Year in Program			
First	Second	.643, p = .186	[.335, 1.236]
First	Third	**.460*, p = .017**	[.243, .872]
First	Fourth	**.288*, p < .001**	[.157, .530]

Note: ** means the result is significant at the .05 level.*

Research Question 3: Why do students choose to participate in extracurricular research opportunities?

A total of 254 students explained why they would like to participate in a research experience. Students reported wanting to gain experience, but did not expand upon what type of experience they would like to gain. This may indicate that students are unsure of what research in engineering looks like, but are generally interested in gaining some research-related skills. Of the students who did say more about wanting to gain experience, they described feelings that engaging in research would help them explore or better understand whether or not engineering is an area they may be interested in pursuing for a career. For example, one student said, "*I think it will help me get an understanding of the applications of engineering and give me experience to see if this is the right field for me*". Other students expressed wanting to enter the job market with research experience to increase their marketability or network. One student remarked "*research is a good opportunity to get experience within a given field, and also a great way to branch out and meet other people who could further my future*".

Another theme from the data was that students demonstrated more specific interests in using a research experience to learn more about their specific field of engineering, develop knowledge about the research process, and getting the chance to participate in it. Students reported wanting to apply their coursework to a research lab and were excited by the idea of having an opportunity to advance knowledge in the field. These students spoke to several of these themes, for example one student mentioned:

> I think it is a good way to experience real world concepts that aren't necessarily covered in courses offered here. Would not only provide an opportunity to do more creative and independent work but would also help me form an opinion on whether I want to go into a certain field after I graduate or not.

When describing the utility of research experience for future careers, students rarely mentioned engineering careers when describing reasons for wanting research experiences; instead, they described engaging in research as more of a stepping-stone to help them get other non-research related engineering jobs.

Alternatively, students (N = 277) in the survey indicated they did not want to do research as an undergraduate and described their reasons. They expressed disinterest in research because they wanted to go into more applied work. Additionally, students mentioned that they were disinterested because research involves trying many different methods to find a solution and they would rather use methods they are already familiar with to solve problems. For example, one student said:

> I feel like discovering new solutions to problems is not something that everyone enjoys. I am the type of person that likes to know what I am doing and why I am doing something. Research feels very tedious to me because it involves trying many different methods until a desired outcome is obtained rather than simply performing a task with a known outcome. However, I am taking a research course (3 credits) since I do feel like every scientist needs to develop an appreciation for research and for the efforts of scientists who perform it.

Students did not see engaging in research opportunities as a priority because they were seeking other opportunities for hands-on experiences, or indicated in their responses that research opportunities were not perceived to have direct benefits to their career or future. For example, one student expressed:

> I am going into a clinical field not a research field. I think there is an overemphasis on research by the faculty because most of the faculty is primarily a researcher. I would much rather spend my time doing other things, plus research positions require 10-15 hours of your time a week - that's a part time job and just not realistic for many people.

Students mentioned they would be willing to try research if they received payment, course credit, or reduced workload, but without these incentives they were unlikely to be motivated to engage in these opportunities. These sentiments from students suggest that research in this field is not necessarily a priority for many students, and of those most explain that they do not see how participating in it could benefit them.

A total of 47 students responded to a question asking for further explanation about why they felt research was not a priority for them. One theme was that students felt that prioritizing their classes and course work was more important than engaging in a research experience. Additionally, students wanted to prioritize more social aspects of the college experience such as clubs, sports, and simply having time to connect with friends and peers. First year students mentioned that they wanted to focus on adjusting to college. These responses echo the previous findings that students are gaining hands-on experiences within the classroom; therefore, participating in a research experience is not a high priority when considering all the other social and extra-curricular commitments college students juggle.

How can programs encourage student participation in research?

Students (N = 347) also described what their school could do to encourage more undergraduates to participate in research. Students offered that their school could have better communication about available research positions. Students felt that positions needed to be more publicized and accessible – having student fairs, posters, or more email communication advertising these opportunities would be beneficial for spreading knowledge. One student stated, "*advertise positions and opportunities better and provide resources to connect students with professors/projects*". Along with this, students expressed that providing more information on what a research opportunity looks like for participating students would be helpful. For example, one student expressed this confusion saying, "*I don't know what research entails. What would I research? How do I do the research?*". Giving students ideas on what roles they may take on, skills they could learn, and descriptions of research projects could help increase interest and visibility. Ultimately, students may be more interested in research if it was easier to become involved, more transparent in terms of communication, and detailed in what is expected from students. Additionally, similar to student responses in why they do not participate currently, some students suggested that receiving payment and/or course credit would increase their ability or motivation to participate in research.

Discussion

This study explored undergraduate engineering students' identity as engineers, motivations to participate in research, and the relationship between extracurricular research experiences and students' career aspirations. The findings from this study have interesting implications for increasing engineering identity and offering research opportunities to undergraduate engineering students.

Perspectives as an Engineer and Program Implications

Overall, most students saw themselves as an engineer, and consistent with prior work (Godwin & Kirn, 2020; Godwin et al., 2016; Starr et al., 2022; Syed et al., 2019), students' engineering identity was an important influence on engineering career aspirations. This study also revealed that many students were still unsure or did not feel like an engineer. Consistent with prior literature (Archer et al., 2010; Amelink & Creamer, 2010; Patrick et al., 2021; Ross et al., 2021), many students that felt less like an engineer were those that identified as a female and first generation. Thus, it is important to consider how to make all students (particularly those that continue to be marginalized) feel like an engineer to increase participation in the engineering profession.

From our qualitative findings, student pinpointed instances that made them feel most like an engineer. When students were actively constructing, building, or creating new systems, devices, or every-day appliances they felt most like an engineer. The examples students provided occurred both within and outside the classroom, but students were describing how they were applying concepts they learned from course material. This is consistent with prior work (Lucas & Hanson, 2016; Schauer et al., 2023), where students felt like engineers when they had courses that incorporated hands-on projects aimed at solving challenges on campus or in the local community, or opportunities to build and design physical materials. Students saw these experiences as providing meaningful opportunities that solidify engineering concepts and prepare them for careers in engineering. Students from this study commonly referenced experiences where they built musical instruments, made improvements to buildings on campus, or designed prototypes for medical or technology equipment. These activities left an impression on students and helped validate their perceptions of themselves as engineers and increased their self-efficacy and competence to do engineering-related tasks. Implementing activities like these could be a way for engineering programs to support students' learning, self-efficacy, and developing identity as engineers, given their motivational impact. It is important to recognize that the school of engineering studied here is well-funded and has access to many resources, so these types of activities may look different when resources are more limited at other institutions, but finding ways to incorporate meaningful hands-on experiences can be beneficial for students.

Research Experiences and Students' Identity and Outcomes

We were interested in exploring how formal research experiences relate to pursuing engineering careers. Within our sample, participating in research experiences outside of the classroom did not relate to students' wanting to pursue careers or future schooling in the engineering field. This was inconsistent with prior literature that suggests that participating in engineering-based research leads to engineering career aspirations and identity development (Faber et al., 2020; Hunter et al., 2006; Syed et al., 2019). The explanations students gave for their motivation to participate in research offer some possible explanations for the lack of associations observed in our sample.

First, students participating in formal research opportunities reported seeking these experiences to accomplish goals beyond an interest in going into the typical engineering profession. Students also reported seeking research experience to understand if they were interested in the field or not, so it could be that this type of experience and developing research skills helps students to recognize that they have other interests for future careers. These experiences may not be promoting future careers as engineers, but they are giving students an idea of what they may want to pursue professionally following their current degree. Additionally, for many students, research was viewed as something that is separate from engineering, perhaps explaining why participating in these experiences did not relate to a students' self-perception as an engineer.

Unlike prior literature (Buontempo et al., 2017; Godwin et al., 2016; Hilpert et al., 2014; Ross et al., 2021), there were no significant differences between gender in terms of research experiences influencing career aspirations, but there were observed differences in terms of parent education and year in program. Students with parents that have received professional degrees had the lowest association between participating in research and pursuing an engineering career compared to first generation students. This may be because these students may have more insights into careers where they can apply their engineering knowledge outside of the field. According to Martin and colleagues (2014) first generation students have a narrower focus on engineering careers compared to students whose parents may have earned engineering or other professional degrees. It is thus important to provide a holistic overview of how engineering degrees can be use used both within and outside of more traditional engineering jobs.

Perspectives on Research and Designing Opportunities

The findings of this study also suggest considerations for offering extracurricular research experiences to undergraduate engineering students. Prior literature has shown the benefits of participating in research activities (Faber et al., 2020; Hunter et al., 2006; Syed et al., 2018; Wylie, 2022), yet few studies have explored students' perceptions of their experiences and what motivated them to participate (or not). Broadly, students were interested in pursuing research as a way to gain skills that were not emphasized in their classroom experiences. According to students, many engineering courses offer hands-on application of skills, but students did not express that research skills were accentuated within their courses. If research opportunities are designed to assist students in future engineering careers, emphasizing the importance of research for the field and promoting its contributions to the profession may make students more interested in participating and may increase the connection to engineering professions.

Another aspect that could be improved is the visibility and transparency of research position offerings. Students who have not participated, but have interest in participating, offered ideas how this can be improved. For example, engineering programs should clearly communicate (through emails or fairs/events) what research opportunities are available and include descriptions of the role, expected hours, and goals of the research projects. Creating more paid or course credit opportunities within these experiences may also help increase student interest or ability to participate, with paid opportunities also addressing a potential issue of equity not unique to engineering (King, 2023).

Limitations and Future Work

This study had several limitations that open avenues for future work in this area. First, a few of our constructs (belonging, engineering identity, and research attitudes) only had one or two survey items. Future work should include more items related to these constructs to have a more complete view of student's perceptions. Additionally, a majority of students identified as White or Asian, thus we could not examine differences in terms of perceptions and experiences based on race. Future work should aim to examine the experiences of Black, Latino, and Indigenous populations. Finally, this survey was captured at one time-point making it difficult to understand how these variables and perceptions may change over time. Future research should explore student's experiences over time to understand how self-perceptions change for those that participate in research opportunities. Asking students directly about benefits, highlights, and shortcomings of their research experiences will help add context to how these opportunities are influencing student career aspirations.

Conclusion

This research offers important insight into how research opportunities and engineering identity influence student outcomes in undergraduate settings. This study also has considerations for designing research opportunities for undergraduate engineering students. This mixed-methods study surveyed 769 undergraduates in a school of engineering to understand perceptions of student's engineering identity, ways in which participating in research experiences outside of the classroom relates to engineering career aspirations, and reasons students participate in research opportunities. Participating in research opportunities did not have an influence on students' engineering career aspirations. Open-ended responses revealed that students were not making clear connections between engineering and research. Students were also mixed on wanting to explore research opportunities, yet those that did want to participate saw it as a beneficial option to apply their knowledge and learn more about using their engineering skills outside of more traditional engineering jobs. Ultimately, engineering programs may benefit from making connections between research and engineering more transparent for students.

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Making Math Matter: Exploring the Influence of Relevance on Student Math Attitudes

In the wake of the global pandemic, math scores have declined (National Science Board, 2024; OECD, 2023) with scores widening especially for students during secondary school (NAEP, 2022). This is concerning as math is important for functioning in everyday life and has substantial impacts on society and local communities (OECD, 2006). Mathematical literacy is essential for being critical consumers of news, performing basic functions such as cooking, making financial decisions, and adapting to quickly evolving science and technology job markets (Byun et al., 2015; Haigh, 2016; Marginson et al., 2013; Rizki & Priatna, 2019; Rubin, 2005). Math knowledge is foundational for entry to STEM fields (Byun et al., 2015; Loewenberg, 2003) and is a cornerstone in building competence in STEM (Marginson et al., 2013). Identifying methods of encouraging students to feel comfortable and confident learning and applying math can help prepare students for daily life and their future careers. The current study explores both external (societal and teacher) and internal (self-efficacy, belonging, and demographic) factors, examining their associations with math attitudes.

Motivational beliefs and supports have been investigated to support students' achievement in mathematics (Akin & Kurbanoglu, 2011; Fast et al., 2020; Gaspard et al., 2015). The expectancy-value framework developed by Eccles and Wigfield (2002) suggests there are several contributing factors that influence a person's attitudes toward a given subject. First, individuals are situated within larger cultural contexts, and this has important influences on a person's interpretations of their academic experiences or motivations (Eccles & Wigfield, 2020). Cultural influences such as societal values, norms of child-adult interactions, gender biases, or career opportunities may influence an individual's academic attitudes (Eccles & Wigfield, 2020). Thus, grounding math concepts within a student's specific culture or life may be important for fostering positive attitudes.

Researchers have begun evaluating how connecting the relevance of mathematics topics to everyday life may be beneficial to supporting students' motivational beliefs in STEM (Gaspard et al., 2021; Harackiewicz et al., 2012; Hulleman & Harackiewicz, 2009). At the individual level, Expectancy-Value Theory suggests there are several important factors to consider. A person's self-efficacy or belief in their ability to perform domain-specific tasks influences their interest, enjoyment, and value toward a subject (Eccles & Wigfield, 2020). Additionally, a students' sense of belonging within their social learning setting is related to a person's academic experience and attitudes (Ostermann, 2000). This paper aims to contribute to this work by exploring how relevance within math instruction and cultural emphasis on STEM, along with individual factors like a sense of belonging and demographic factors, may influence students' math attitudes.

Students' Math Attitudes

Math attitudes refer to how students feel about math as a subject, and have to increase students' interest in pursuing more math-related careers, though measuring and defining math attitudes is innately complex (Wen & Dubé, 2022). Math attitudes have been conceptualized in different ways, with some studies taking a unidimensional perspective, examining the basic emotional or affective liking or disliking of math (Mavridis et al., 2017; Murimo, 2013). Other researchers use a bi-dimensional perspective examining the emotional and cognitive components that include students' perceptions of the importance, enjoyment, and biases related to math (Kiwanuka et al., 2017; Yang, 2015). Finally, many studies, including the current one, use a multidimensional approach which examines the affective, cognitive, and behavioral components of math attitudes. This builds upon the bidimensional definition and includes how students engage or avoid mathematics related activities (Etuk et al., 2013; Sengul & Dereli, 2013).

Math attitudes are associated with mathematics performance or success in courses and higher interest in pursuing math related careers and fields (Akin & Kurbanoglu, 2011; Gijcali & Lipnevich, 2021). Unfortunately, math attitudes decline as students' progress through school; this is particularly salient during secondary schooling (Wen & Dubé, 2022). Increasing students' math attitudes may have important implications in readying students for the increasingly popular STEM-related careers, and can also make high school students generally less anxious and more excited about math (Akin & Kurbanoglu, 2011; Gijcali & Lipnevich, 2021). Considering these important implications on a student's trajectory, it is worth investigating ways to positively influence students' math attitudes.

External Influences

Relevance in Math Education

Teachers are one influence on students' math attitudes (Blazer & Kraft, 2017; Domino, 2009; Haladyna et al., 1983). For example, Domino (2009) conducted a qualitative study in which students shared that their attitudes toward math were influenced by their teacher's method of teaching. Specifically, some students mentioned that lessons involving active engagement from the class and connections to how the learning was related to their lives positively impacted their math attitudes (Domino, 2009). Conversely, when teachers did not show the relevance or importance of learning math or did not actively engage the class, students disliked math and had more negative math attitudes (Domino, 2009). The current study builds on this prior work using a quantitative approach to understand how incorporating relevance-based teaching practices may influence students' math attitudes.

More generally, it is not surprising that teaching practices have an impact on students' learning and attitudes (Blazar & Kraft, 2017; Domino, 2009; Evertson et al., 1980; Good & Grouws, 1979). While there is limited research identifying specific teaching practices most effective in engaging students and increasing learning gains (Hiebert & Grouws, 2007), several studies do show that adding language regarding the relevance and utility value of course concepts impacts students' motivation and learning (Gaspard et al., 2021; Harackiewicz et al., 2012; Hulleman & Harackiewicz, 2009; Linnenbrink-Garcia et al., 2016). In one experimental study, Hulleman and Harackiewicz (2009) prompted students to write summaries about the usefulness and value of what they learned in their STEM classes to their own lives. The results showed that this intervention increased grades for students that belong to typically marginalized youth. Similarly, in a study conducted by Gaspard and colleagues (2021), teachers or researchers gave students interview prompts from young adults that described situations where math was useful to them. These interventions or teaching practices encourage interest and motivation in the topic by allowing students to see how they are connected to the material (Gaspard et al., 2021; Hulleman & Harackiewicz, 2021).

Several early studies show that activities or prompts in which students reflect on the relevance of mathematics increase students' STEM career choices, interest, persistence in STEM, engagement, academic achievement, and emotions or attitudes toward a topic (Brisson et al., 2017; Harackiewicz et al., 2012; Hulleman & Harackiewicz, 2009; Linnenbrink-Garcia et al., 2016 Piesch et al., 2020). However, more recent work examining these interventions at a wider scale have shown somewhat mixed results in terms of its effectiveness (Brisson et al., 2019; Gaspard et al., 2021). For example, Gaspard and colleagues (2021) found that students within a relevance instruction group reported higher perceived cost associated with math and little difference in student's intrinsic motivation compared to the business-as-usual classes. Emphasizing the relevance and value of math concepts in the classroom is a relatively low-cost intervention, so it is important to pursue further work in this area to understand how to implement these methods effectively, especially at scale (Gaspard et al., 2021). The current study explores teachers' and students' perceptions of relevance in mathematics learning in a large international sample using the Programme for International Student Assessment (PISA) 2022, and the associations between these perceptions and student mathematics attitudes.

Societal Emphasis on STEM

Because attitudes are influenced by cultural and societal values (e.g., Bronfenbrenner, 1979), it is important to explore associations between different influences and math attitudes across different countries. Assessments like Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) allow for more cross-country comparisons related to mathematics achievement, literacy, and skills (OECD, 2023). With the importance of culture and societal values on student attitudes (Eccles & Wigfield, 2002), one indicator of cultural value of math is a country's investment or emphasis in related subject areas, as investing in education is important for protecting and growing economies and preparing citizens to engage in their communities (Education, 2022). Recently many countries have been focusing on educational policies to try and keep up with the evolving demand of the science and technology market and graduate more STEM majors from universities (Freeman et al., 2019). Subsequently, these policies have an influence on teachers' pedagogical practices and educational approaches to teaching STEM subjects (Powell & Anderson, 2002; Stuckey et al., 2013). For example, within the last 40 years there was a shift in science education in industrialized nations to prepare students for potential careers in STEM by grounding it in relevance to careers and society (Stuckey et al., 2013).

Previous international assessment studies have attempted to explore societal level influences and students' perceptions with learners' affect and relationship with STEM learning. The Relevance of Science Education (ROSE) research project examined students' interests, attitudes toward, aspirations, and views of science in society (Schreiner & Sjoberg, 2006). The study showed that students in countries with a higher index of development (which is linked to countries with a robust STEM labor market) have less positive attitudes toward STEM (Schreiner & Sjoberg, 2006). Across many wealthy countries with robust STEM markets, students were less enthusiastic about STEM in school than those in less wealthy countries, and had lower perceptions of its importance for everyday life and its ability to increase their career chances compared to less STEM focused countries (Sarwar et al., 2011; Sjøberg & Schreiner, 2010). Alternatively, Han (2017) found that more positive public attitudes toward STEM is positively associated with students wanting to pursue STEM careers. Additionally, the association between attitudes about and desire to pursue STEM careers was stronger for lower performing students (Han, 2017). A significant amount of this work is conducted in science education, thus, there is a need to further investigate it within the math education context, considering math's importance for entering and staying in STEM-related careers.

Individual Influences

Math Self-efficacy

Self-efficacy broadly refers to peoples' beliefs about their capabilities related to succeeding on specific tasks and influence feelings, behavior, and motivation when engaging in those specific tasks (Bandura, 1994; Bandura, 2006). In mathematics specifically, math self-efficacy refers to the individuals' expectations or beliefs in their ability to successfully perform a given mathematics task or confidence to do well in their math courses (Akin & Kurbanoglu, 2011; Pajares, 1996). Math self-efficacy develops from direct experience (evaluation of own experiences) and vicarious (observing others) experiences, social persuasions (such as encouragement from others), and physiological states (emotional and physical responses; Usher & Pajares, 2009).

Math self-efficacy is associated with students' positive emotions or enjoyment toward math (Akin & Kurbanoglu, 2011; Eccles & Wigfield, 2020; Laranang & Bondoc, 2020), lower math anxiety (Živković et al., 2023), and better performance on math tasks (Fast et al., 2020; Živković et al., 2023). Fostering high math self-efficacy within students is important if students are to succeed and feel comfortable pursuing math and STEM related majors or careers.

School Belonging

Students' sense of belonging within their classroom and school has important implications for academic success during school (Hamm & Faircloth, 2005; Neel & Fuligni, 2013; Osterman, 2000). Osterman (2000) posits that belonging in educational settings is not only linked to connecting with peers, but also has an influence on their academic performance, engagement, and can influence the quality of their learning. According to McMillan and Chavis's (1986) framework, a sense of belonging to any community draws upon individual's interpersonal experiences with others in the community, perceptions they can rely on other members, and a sense of security within the community. This is particularly important within both mathematics classrooms where many students (such as female and racial-ethnic minorities) may feel marginalized (Good & Dweck, 2012; Hughes et al., 2015), and during adolescence when relationships with others are particularly salient (Crone & Dahl, 2012; Newman et al., 2007). Within math classrooms, a sense of belonging within the school relates to students' attitudes toward liking and valuing math (Smith et al., 2021) and active engagement during class (Graham et al., 2023). Ultimately, students' sense of belonging within school has important implications for their motivation, engagement, and self-efficacy and should be considered when understanding these constructs.

Demographics

Recent trends in mathematics achievement show that gender and SES group differences are narrowing, but disparities in students' perceptions of math attitudes and self-efficacy are still apparent (Cvencek et al., 2021; Else-Quest, 2010). Female students typically report lower self-efficacy and math attitudes compared to male peers (Else-Quest, 2010; Louis & Mistele, 2021). Internationally, the most affluent countries in the world (which aligns with those that have big STEM-related industries) have students with the largest math attitude gender gaps (Charles et al., 2014; Eriksson, 2020). This suggests that countries with more focus on STEM-related professions tend to have more gendered ideology of who can or should participate in these spaces.

When examining socio-economic status (SES), students from lower SES families have lower math achievement when compared to higher SES peers (Cheema & Galluzzo, 2013; Shakeel & Peterson, 2022); yet there is little research examining the influence of SES on math attitudes. Many students from lower SES backgrounds do not have the same resources or opportunities to succeed in their math classes (Flores, 2007) and this may have an influence on their perceptions toward math. Given the prevalence of these demographic factors, the following study will examine how gender and SES may influence math attitudes and self-efficacy.

Current Study

Since 2000, the Organization for Economic Co-operation and Development (OECD) administers the PISA to 15-year-old students every two years in more than 80 countries (OECD, 2023). With the latest iteration in 2022, the focus of the assessment was on mathematics. The current study used the 2022 public use PISA data (OECD, 2024) to explore how teachers' integration of relevance and utility value in their mathematics teaching is associated with students' math attitudes. The assessment was administered to teachers and students to understand these concepts.

The following research questions were examined:

1. Does teachers' math relevance emphasis relate to students' math attitudes when considering students' math self-efficacy, gender, SES, school belonging, and relevance perceptions?
    a. Do these associations differ across countries' levels of STEM emphasis?
2. More generally, what are the patterns of students' math attitudes, math self-efficacy, and students' perceptions of relevance of their math instruction?
    a. Are there differences between gender and SES levels?
    b. Are there differences across societal emphasis on STEM?

Based on prior research, we hypothesize that math relevance instruction in the classroom and students' perceptions of relevance during learning will relate to students' math attitudes (Hulleman & Harackiewicz, 2009; Linnenbrink-Garcia et al., 2016). Additionally, we believe that students' self-efficacy (Akin & Kurbanoglu, 2011; Laranang & Bondoc, 2020) and belonging (Smith et al., 2021) will be associated with student's math attitudes. We also hypothesize that a country's emphasis on STEM education will relate to student's math attitudes (Han, 2017; Schreiner & Sjoberg, 2006). Finally, we predict that demographic variables such as gender (Cvencek et al., 2021) and SES (Shakeel & Peterson, 2022) will relate to student's math attitudes.

Method

Participants

Participants in this study were from the 2022 PISA database (OECD, 2023). PISA provides international, school-level estimates of students' performance, along with information about the classroom environment and students' attitudes collected through student questionnaires. For this study, we focused on the individual student and teacher questionnaires only. A total of 81 countries completed the assessment in 2022; of these, 18 countries had data on teacher's inclusion of relevance instruction during math and we used the 13 of these countries that had data from the World Data Bank on tertiary education rates that we used to estimate country STEM emphasis (World Bank Group, 2012). These countries included Azerbaijan, Brazil, Colombia, Dominican Republic, Georgia, Germany, South Korea, Macao, Malaysia, Morocco, Peru, Portugal, and the United Arab Emirates.

Analytic Sample

A total of 109,025 students participated in the 2022 PISA from our 13 countries of interest. Students were removed from the sample if they were missing any variable of interest. Most students were removed for missing self-efficacy (*N* = 31,474), math attitudes (*N* = 26,930), perceptions of relevance (*N* = 35,019), belonging (*N* = 9,502), and SES (N = 6,394). Few students were removed for missing gender (*N* = 1). This represents 14.32% of missing data across the data matrix. The total analytic sample included 58,595 15-year-old students. Across countries, missing data was consistent across most countries with an average of 51.69% of students removed. Finally, to adjust for the probability of selecting particular students in the sample, a variable indicating student weights were used ("W_FSTUWT" in the PISA dataset; OECD, 2009).

Student Sample

From the 58,595 students, 48.95% of the sample identified as a girl and 51.05% identified as a boy. On a 10-point relative SES scale (see below), students on average, students placed their family at a value of 6.61 (*SD* = 2.25).

Teacher Sample

The total analytic sample was comprised of 12,208 math teachers (51.95% women, 45.61% men, 2.44% did not respond; M_{age}= 43.55, *SD*= 10.97, Range: 20-70). Through PISA data we are unable to match teachers with students, thus teachers were averaged at the school level to create a school-level relevance variable. There was an average of 1.20 (*SD* = .49) teachers per school with a minimum of one teacher and a maximum of 5 teachers per school.

Measures

The following constructs were taken from the 2022 PISA student survey

Math attitudes – Items from the PISA student survey were selected by the research team to represent students' math attitudes based on definitions describing students' liking or disliking of math, willingness to engage in math activities, and beliefs in the importance of math (Etuk et al., 2013; Sengul & Dereli, 2013). Students responded to eight items (*a* = .75) that focused on student's affective, behavioral, and cognitive perceptions of math (See Table 5).

Math self-efficacy – Students responded to items that asked about their confidence levels in completing different specific math tasks (*a* = .94). For example, these tasks ranged from algebraic expressions, extracting information from graphs, tables, or other figures to coding and using computing math systems (See Table 5). Prior research indicates that more specific questions regarding students' confidence in their ability to complete specific mathematics tasks were more predictive of student outcomes (Bandura, 2006; Pajares, 1996).

Student relevance– Relevance instructional practices was examined using items from both the student and teacher questionnaires. Students were asked to indicate how often their teachers engaged in relevance related instructional practices. Students responded to six items that asked about how often they felt their math lessons connected to everyday life, larger contexts, and were personally relevant (*a* = .93; See Table 5). These items were selected based on prior literature that describes different ways to incorporate relevance in the classroom (Harackiewicz et al., 2012; Linnenbrink-Garcia et al., 2016; Rose & Bowen, 2021).

School belonging – Students responded to six items that asked about their agreeableness to statements about their feelings of connectedness to peers and the larger school environment (*a* = .79; See Table 5). These items were selected based on prior work that describes belonging as individual's interpersonal experiences, connections to others, and a sense of security (McMillan & Chavis, 1986).

The following construct was taken from the 2022 PISA teacher survey:

Teacher Relevance- Teachers were asked to assess how often they engaged in relevance-related instructional practices. Teachers responded to six items that asked about how often they connected math to everyday life, larger contexts, and made it personally relevant to students (*a* = .93; See Table 5). These items were selected based on prior literature that describes different ways to incorporate relevance in the classroom (Harackiewicz et al., 2012; Linnenbrink-Garcia et al., 2016; Rose & Bowen, 2021). To protect student privacy, PISA student data cannot be linked to specific teachers or classrooms; thus, teacher's relevance was averaged across the school in which the student belongs.

SES – Using 10-point scale, students self-rated their perception of their family standing in terms of money, education, and job. Students rated a 1 if they felt their family earns the least money, received no education, and has no jobs or the least respected jobs and a 10 if they earn the most money, received the best education, and has the most respected jobs. Subjective social status scales have been found be reliable and predictive of student's mental health and well-being (Goodman et al., 2001), and attitudes toward education (Onofrei, 2020).

STEM emphasis – Each country's graduation rates from STEM tertiary programs compared to all degrees awarded in 2017 and 2018 were collected from the World Bank Group (2024; See Table 1). These rates were used to determine a country's emphasis on STEM education (M = 23.70, SD = 9.06, Minimum = 7.66, Maximum = 40.77). Countries were grouped into High, Medium, and Low (See Table 1). Countries less than 20% graduation rates were classified as low, between 20% and 29% medium, and more than 29% high. Graduation rates are linked to a country's focus on readying students for STEM related careers and government's focus on creating STEM education policies across schooling (Freeman et al., 2019; Marginson et al., 2013).

Table 1. Classification of STEM Emphasis by Country

Country	% STEM graduates	STEM emphasis
Macao	7.66	Low
Dominican Republic	11.55	Low
Brazil	18.37	Low
Morocco	19.05	Low
Georgia	21.24	Medium
Colombia	23.13	Medium
Azerbaijan	23.5	Medium
United Arab Emirates	27.73	Medium
Portugal	29.09	High
South Korea	29.34	High
Peru	29.64	High
Germany	35.31	High
Malaysia	40.77	High

Procedure

Student Questionnaire

The Student Questionnaire was administered in the Fall of 2022. The questionnaire was computer-based and took students approximately 30-to-35-minutes to complete. Approximately half of the student questionnaire focused on mathematics literacy, aiming to gauge students' abilities in formulating, applying, and interpreting mathematical concepts across diverse contexts. While the major domain of assessment was mathematics literacy, reading and science literacy were also evaluated in addition to the student's demographics. To address our research questions, we focused on students' math attitudes, math self-efficacy, belonging, and their impressions of relevance during their math instruction, excluding all other measures.

Teacher Questionnaire

The optional Teacher Questionnaire was administered online in the Fall of 2022. It consisted of general questions for all teachers in addition to distinct blocks of questions for teachers of specific subjects, such as mathematics. The total questionnaire took approximately 45 minutes. To address our research questions, we focused on teachers' relevance pedagogy in math, excluding all other measures.

Analytic Plan

All data were analyzed using STATA (StataCorp, 2024). All analyses include student weights considering these populations did not have the same probability of selection, have differential participation rates based on student or school characteristics, and some strata were over-sampled (OECD, 2009). Survey weighted regressions were used to understand how teachers' incorporation of relevance in math classrooms influence students' math attitudes (RQ 1). This analysis method is appropriate when working with PISA data because it incorporates student sampling weights to provide unbiased population parameter estimates (Bruin, 2006; OECD, 2009). Additionally, once school-level data is merged with student-level variables, school data is considered as an attribute of the student (OECD, 2009). Balanced Repeated Replication (BRR) calculations provided by PISA were also used to appropriately adjust standard errors (OECD, 2009). “W_FSTR” was used as the replicate weights to be used for BRR calculations. Within STATA svyset was used to calculate statistics with BRR-adjusted standard errors. The weighted survey regression model included self-efficacy, belonging, student relevance perceptions, gender, and SES. We included country level dummy variables to control for variability at the country level. Following this analysis, we wanted to see if there were differences based on STEM emphasis at the country level. We ran three models stratified across country’s STEM emphasis (low, medium, high) to account for differences that may occur regarding education systems, teaching relevance, and student’s math attitudes. Country level dummy variables were included in these models. The final samples consisted of 22,703 students in the high model, 23,209 students in the medium model, and 12,683 students in the low model.

Descriptive data from survey responses were explored to understand students’ math attitudes, math self-efficacy, belonging, and perceptions of their teacher’s relevance instructional practices (RQ 2). Descriptive data were further explored across the different levels of STEM emphasis. Regressions were used to understand differences between gender and SES on the different math perceptions. According to prior research, a country’s STEM emphasis influences math perceptions between genders (Charles et al., 2014; Eriksson, 2020), thus it was included within the analysis to account for differences at the country level.

Results

Research Question 1: Does teachers’ math relevance emphasis relate to students’ math attitudes when considering students’ math self-efficacy, gender, SES, school belonging, and relevance perceptions?

A weighted survey regression was conducted to understand the relationship between teacher's relevance during math instruction and student's math attitudes. Student's perceptions of their belonging, math attitudes, self-efficacy, student's perception of relevance in their classroom were included in this analysis (See Table 2).

Table 2. Descriptive Data of Relevant Variables

	Weighted Mean	Weighted STD	Unweighted Mean	Unweighted STD
Belonging	3.02	.58	3.00	.57
Math Attitudes	2.97	.68	3.03	.70
Self-efficacy	2.49	.67	2.60	.67
Student Relevance	2.97	1.20	3.00	1.21
Teacher Relevance	3.58	.81	3.64	.81

Results from the weighted survey regression found that teacher relevance during math instruction showed almost no relation to student's math attitudes when considering a student's perception of relevance, gender, SES, belonging, self-efficacy, and country (See Table 3). To assess potential multicollinearity amongst the variables, we examined the variance inflation factors (VIFs). All VIF values were below 1.50, indicating that multicollinearity is not a concern in this model (UCLA, 2024).

Stratified analyses were conducted to explore differences across country STEM emphasis levels in the relationship between teacher relevance and student's math attitudes (See Table 3). The stratified models revealed similar trends across the different STEM emphasis groups. A notable difference between the different models is that teacher relevance was only positively related to math attitudes within the high emphasis group.

Table 3. Regression Results Research Question 1

	Model 1[a] All Countries *B* (SEs.)	Model 2[b] High-STEM *B* (SEs.)	Model 3[c] Med.-STEM *B* (SEs.)	Model 4[d] Low-STEM *B* (SEs.)
Belonging	.07(.003)*	.08(.01)*	.08(.01)*	.05(.01)*
Student Relevance	.07(.003)*	.05(.004)*	.09(.01)*	.09(.01)*
Self-efficacy	.34(.004)*	.40(.01)*	.32(.01)*	.28(.01)*
Gender	.06(.01)*	.08(.01)*	.04(.01)*	.04(.01)*
SES	.002(.002)*	.01(.002)	.001(.002)	.002(.003)
Teacher Relevance	-.01(.004)	.001(.01)	-.01(.01)	-.01(.01)*
R^2	.31*	.35*	.29*	.26*

Notes. * $p < 0.05$; data were weighted, and standard errors were adjusted using BRR.
[a] Model 1: All countries controlling for individual countries
[b] Model 2: Countries with high STEM emphasis controlling for included countries
[c] Model 3: Countries with medium STEM emphasis controlling for included countries
[d] Model 4: Countries with low STEM emphasis controlling for included countries

Research Question 2: More generally, what are students' math attitudes, math self-efficacy, and students' perceptions of relevance of their math instruction?

In research question one we statistically controlled for country, gender, and SES to explore the association between teacher relevance and math attitudes specifically, but we were also interested in exploring trends between math perceptions across these variables. Overall, students within this sample had somewhat positive attitudes toward math (See Table 2). Student's average self-efficacy was more neutral and fell between not confident (2) and confident (3). In terms of student's perceptions of relevance in their math classes, on average, students indicated that relevance was incorporated in about half of their lessons across the different surveyed examples of ways teachers can incorporate relevance.

Are there differences between gender and SES levels?

Descriptive analyses revealed little differences between gender amongst the math perception variables (See Table 4). The biggest difference was observed in math self-efficacy with boys having high means than girls. Regressions were conducted to understand differences between boy and girl students on student's math attitudes, self-efficacy, and perceptions of math relevance when accounting for their country's STEM emphasis. Girls had slightly less positive math attitudes (R = -.04, $F(2, 58595) = 361.61$, $p < .001$), lower math self-efficacy (R = -.15, $F(2, 58595) = 709.05$, $p < .001$), and reported lower perceptions of relevance (R = -.03, $F(2, 58595) = 198.54$, $p < .001$) when compared to boys.

Table 4. Math Perceptions by Gender

Gender	Math Attitudes	Math Self-Efficacy	Math Relevance
Girls	3.03 (.69)	2.54 (.64)	3.00 (1.19)
Boys	3.04 (.70)	2.66 (.70)	3.01 (1.19)

*Note: Gender Means and (Standard Deviation) for each mathematics construct

Regressions were also used to understand how students' self-reported SES related to their math attitudes, self-efficacy, and relevance. There were significant, yet small influences on SES and math attitudes (R = .002, $F(1, 58595) = 153.89$, $p < .001$), self-efficacy (R = .01, $F(1, 58595) = 563.42$, $p < .001$), and relevance (R = .0001, $F(1, 58595) = 5.59$, p < .001).

Are there differences across societal emphasis on STEM?

Descriptive data was further examined across all countries (See Table 4) and across different levels of STEM emphasis. At the country-level there was some variations across student's math attitudes, ranging from 2.83 in Morocco to 3.15 in Peru. Math self-efficacy was similarly variable with ratings ranging from 2.37 in Brazil to 2.75 in United Arab Emirates. We see the biggest variation when examining math relevance. Students thought teachers incorporated the most relevance in Peru (M = 3.53) and students from South Korea felt like relevance was incorporated the least (M = 2.3).

Table 5. Math Perceptions by Country

Country	Math Self-Efficacy	Math Attitude	Math Relevance
Azerbaijan	2.69(0.75)	3.03(0.73)	3.28(1.21)
Brazil	2.37(0.69)	2.84(0.66)	3.02(1.19)
Colombia	2.67(0.57)	3.05(0.64)	3.28(1.16)
Dominican Republic	2.46(0.74)	2.97(0.71)	3.35(1.24)
Georgia	2.54(0.67)	2.96(0.72)	3.12(1.20)
Germany	2.66(0.62)	3.01(.72)	2.61(1.06)
Macao	2.65(0.65)	2.9(0.70)	2.70(1.08)
Malaysia	2.40(0.58)	2.95(0.66)	2.98(1.07)
Morocco	2.47(0.67)	2.83(0.59)	2.69(1.21)
Peru	2.61(0.62)	3.15(0.64)	3.53(1.12)
Portugal	2.63(0.64)	3.07(0.73)	2.93(1.19)
South Korea	2.45(0.75)	2.99(0.76)	2.3(1.14)
United Arab Emirates	2.75(0.69)	3.13(0.70)	3.20(1.20)

*Note: Country Means and (Standard Deviation) for each mathematics construct

Examining the different STEM emphasis groups, self-efficacy perceptions were highest amongst students within countries with medium STEM emphasis (*M* = 2.71, *SD* = .69) compared to the high (*M* = 2.54, *SD* = .65, *d* = .25) and low (*M* = 2.49, *SD* = .69, *d* = .32) groups. There was a similar pattern of differences in math attitude scores. The highest average perceptions were with students in the medium STEM emphasis group (*M* = 3.11, *SD* = .70) compared to the high (*M* = 3.04, *SD* = .71, *d* = .10), and low (*M* = 2.88, *SD* = .67, *d* = .34) groups. Finally, students' perceptions of relevance during their math instruction were highest amongst the medium STEM emphasis countries (*M* = 3.22, *SD* = 1.2), compared to students in the low (*M* = 2.88, *SD* = 1.20, *d* = .28) and high (*M* = 2.85, *SD* = 1.19, *d* = .31) groups.

Discussion

First this study explored teacher's use of incorporating relevance during math instruction and its influence on student math attitudes. The results showed little association between teacher's incorporation of relevance in the classroom with student's math attitudes; yet there were stronger associations between student's math self-efficacy and belonging with math attitudes. This study also descriptively explored high school students' perceptions of their mathematics attitudes, math self-efficacy, and sense of how math is relevant to their own lives and explored these variables between country's STEM emphasis. Students had relatively neutral views of their math attitudes, math self-efficacy, and math relevance. Countries in the medium STEM emphasis group had significantly higher means across student's math attitudes, self-efficacy, and relevance. Ultimately, the findings from this study have interesting considerations for understanding students' experiences during math class and reflections on student's perspectives of math.

Incorporating Relevance in Math Instruction

Overall, the results revealed little evidence of any relation between teacher's incorporation of relevance in the classroom and students' math attitudes. This is inconsistent with findings from classroom or school level studies which have shown that the incorporation of more relevance related activities during math instruction is positively associated with students' STEM attitudes (Domino, 2009; Harackiewicz et al., 2012; Hulleman & Harackiewicz, 2009). At a larger scale, however, this aligns with previous work that suggests that relevance during math instruction has little influence on mathematics outcomes (Gaspard et al., 2021). This may demonstrate that relevance in classrooms may not increase attitudes within all settings or across all students. Harackiewicz and Hulleman (2012) highlight that these interventions are most successful for students that are from typically marginalized backgrounds or have history of lower achievement. On average, students within this sample reported relatively high perceptions of their socio-economic status which may not be representative of the samples where there have been stronger associations between relevance and student attitudes. Another possibility is that the use of teacher reports might be limited in what teachers are actually doing or what students are experiencing, which is what would be expected to have an impact on math attitudes. In fact, the data here suggests no association between teachers' reporting of relevance instruction and students' perceptions of relevance in their courses. Further work should investigate when relevance during math instruction yields the best results for increasing students' attitudes and interest toward math.

Similarly surprising is that student's perceptions of relevance was only weakly related to their math attitudes. This is again inconsistent with prior work that demonstrates that when students see the relevance of what they are learning in math to their everyday life they have more positive perceptions toward math (Leyva et al., 2022). Most of this research is conducted within tertiary education or advanced secondary courses, thus students at the secondary level may see the relevance of math, but are still disinterested in engaging with math. These results may also pinpoint a gap between students and teachers in their perspectives of relevance during math instruction. Köning and colleagues (2013) found that most students and teachers have different perceptions of the learning environment; meaning there is oftentimes a mismatch between how the teachers think they are approaching content, and how students are receiving content (Köning et al., 2013). Future work should continue to examine relevance from the lens of students and teachers. More qualitative work may shed light onto why this may or may not be important for students as they are learning math.

Students' Math Perceptions

Overall, students within this sample had relatively neutral views of their math attitudes and self-efficacy. This is consistent with previous PISA data that found only 40% of students had positive views toward learning mathematics (OECD, 2016). This may also reiterate the trend that math attitudes and self-efficacy are lower when students reach secondary school (TIMMS, 2019; Wen & Dubé, 2022). Results from the 2019 TIMSS assessment revealed that 70% of students had positive or neutral views on math in 4th grade and these perceptions decline to 59% once students are in 8th grade (TIMMS, 2019). It is important to consider what factors may contribute to this decline. First, as mentioned, the global pandemic was a difficult time for students as they had to navigate new challenges in and out of the classroom. Generally, achievement scores decreased across the globe which may have led to more students decreased attitudes toward math or academic subject in general (National Science Board, 2024; OECD, 2023). Additionally, from a more developmental perspective, students take increasingly more difficult courses and make more social comparisons to peers as they progress through schooling and development (Dijkstra et al., 2008). These factors may contribute to more students feeling less positive toward math when they are faced with more challenges and comparing themselves to high performing peers.

Another key takeaway within this study is the importance of students' self-efficacy on math attitudes, which was by far the strongest predictor of math attitudes across models. This is consistent with prior research, which shows that bolstering student's self-efficacy may be imperative for their math attitudes (Eccles, 2002; Akin & Kurbanoglu, 2011, Laranang & Bondoc, 2020). Ultimately, across all models, these results continue to echo the importance of students' self-efficacy in math and has important implications for focusing on the sources of efficacy when teaching mathematics to create more confident students that have positive emotions toward math.

A student's sense of belonging was significantly associated with math attitudes across all models, though to a lesser degree than self-efficacy. While belonging is not situated within the expectancy-value framework (Eccles & Wigfield, 2020), this adds to the literature that feeling safe and connected to an educational environment has meaningful influences on students' academic outcomes (Osterman, 2000). As countries offer more educational opportunities and develop policies within mathematics education there should be careful consideration in how schools are fostering a sense of belonging and relatedness.

Demographics and Math Perceptions

Results from the survey regression and t-tests showed that gender had a very small influence on students' math attitudes. This aligns with recent work that some gender gaps have been narrowing in mathematics (Else-Quest, 2010), and may demonstrate that attitudes toward math may be narrowing. It is important to note that gender differences were doubled within countries with more STEM emphasis. This compliments other findings that showcase more industrialized, and STEM focused nations have larger gender-related gaps in terms of math attitudes (Charles et al., 2014). There were more notable differences between gender observed in self-efficacy which is consistent with prior work that demonstrate female students typically have lower confidence in their ability compared to their male peers (Else-Quest, 2010; Louis & Mistele, 2021). Recent work highlights that gender-responsive pedagogy that explicitly debunks gender stereotypes, teacher awareness of their own biases, and after-school enrichment programs are influential in reducing this gender gap (Chan, 2022). These practices should be further investigated within these countries that have large STEM labor markets.

There were nearly no differences in terms of student's perceptions of their SES and their perceptions toward math. This is inconsistent with prior literature that demonstrate that students from lower SES have lower perceptions of their math attitudes and self-efficacy (Cheema & Galluzzo, 2013; Shakeel & Peterson, 2022). Students from this sample had high perceptions of their SES, so further work should be done to examine perspectives from students with fewer resources or perceptions of their SES compared to their peers.

Societal STEM Emphasis and Math Perceptions

Lastly, this study examined the role of society's influence on student's math attitudes. First, there were similar trends across the three emphasis groups showing that there was a very weak relationship between relevance in math instruction on student's math attitudes. This may demonstrate that there is little variation between teaching the relevance of subjects between countries with varying levels of STEM emphasis. The importance of math or situating math concepts in everyday life may happen more outside of the classroom than within the classroom. This is similar to findings from Han (2017) that demonstrate public or societal attitudes outside of schools permeate into student's attitudes toward subjects. Considering the complex nature of societal influences and internal psychological factors, more work should examine additional factors outside of the expectancy-value framework (Eccles & Wigfield, 2020) that may highlight other influences that are important in different global settings. There may be additional cognitive skills important to consider, such as creativity and curiosity, that may also be linked to student's interest and pursuit of STEM careers (Cui et al., 2022; Jirout, 2020).

A second aim of this study was to describe student's math self-efficacy, attitudes, and perceptions of relevance between levels of country STEM emphasis. There were differences in the math attitude averages across the high, medium, and low emphasis groups. Countries within the medium and high emphasis groups had higher perceptions of their math attitudes compared to countries in the low group. This may reveal that access to opportunities to graduate from STEM tertiary programs or overall investment in STEM may have some relation to students' attitudes toward math in school. This is inconsistent with findings from the ROSE studies which found that secondary students in countries that have more focus on STEM related careers had more negative views toward math (Schreiner & Sjøberg, 2006; Sjøberg & Schreiner, 2010), but is in alignment with prior work that found positive societal perceptions on STEM led to student's interest in pursuing STEM-related careers (Han, 2017). These findings continue to provide insight into the complex nature between societal influence and individuals' perceptions and may demonstrate that societal emphasis and career opportunities influences student's academic perceptions.

These findings also pinpointed an interesting trend that self-efficacy was more highly associated with math attitudes in countries within the medium emphasis group when compared to the high and low groups. This is similar to findings from Randel and colleagues (2000) which found that students from countries with high math expectations and value were more critical of their academic ability. Conversely students in countries with lower emphasis may feel less confident to pursue math if they do not see a need to pursue a STEM related career. These trends may emphasis the happy medium of having the opportunities for STEM based careers, but not the pressure associated with needing to pursue STEM to be successful. Further research should examine how students' math self-efficacy is influenced by country-level policies and its subsequent association with math attitudes.

Limitations and Future Directions

There are several limitations to consider within this study. First, to maintain the confidentiality of participants we were unable to match student data with specific teachers and classrooms. Associating student and teacher data could only be done by aggregating relevance at the school level, which may not adequately capture each student's experience. Additionally, it is difficult to capture and compare each country's emphasis on STEM in their education system. Student graduation rates from tertiary degrees do not fully capture the policies and societal influence on their STEM education, it does capture an important piece of the overall picture. Future work should embed more student and teacher voice to help understand what happens in the classroom that makes them enjoy math, under what conditions relevance during math instruction is influential on student's attitudes, and what outside sources impact their perceptions toward math.

Conclusion

Using data from the 2022 PISA, this study examined the relation between teacher's use of relevance in mathematics classrooms and student's math attitudes. A weighted survey regression and descriptive analyses explored student's math attitudes, math self-efficacy, and perceptions of relevance from 13 countries. Students within this sample had neutral math attitudes and math self-efficacy and reported that half of their math lessons included relevance beyond the classroom. The findings further revealed that there was no association between teacher's incorporation of relevance during math instruction and student's math attitudes. Examining trends across country's emphasis on STEM, countries that had a medium emphasis on STEM had the highest math attitudes, math self-efficacy, and perceptions of math relevance during instruction. These trends may reveal that having career opportunities for STEM, but less societal pressures to need to pursue STEM to be successful, may help promote more positive math attitudes in students.

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Appendix

Table 5. PISA Questionnaire Items and Scales (OECD, 2023).

Math Attitudes

Question: To what extent do you agree or disagree with the following statements?
4-pt Scale: Strongly Disagree (1), Disagree (2), Agree (3), Strongly Agree (4)

- **ST268Q01JA.** Mathematics is one of my favourite subjects.
- **ST268Q04JA.** Mathematics is easy for me.
- **ST268Q07JA.** I want to do well in my mathematics class.

Question: This school year, how often did you do each of the following?
5-pt Scale: Never or almost never (1), Less than half of the lessons (2), About half of the lessons (3), More than half of the lessons (4), Every lesson or almost every lesson (5)

- **ST293Q03JA.** I put effort into my assignments for mathematics class
- **ST293Q01JA.** I actively participated in group discussions during mathematics class
- **ST293Q05JA.** I made time to learn the material for mathematics class
- **ST293Q04JA.** I gave up when I did not understand the mathematics material that was being taught [R]
- **ST293Q07JA.** I lost interest during mathematics lessons [R]

Math Self-Efficacy

Question: How confident do you feel about having to do the following mathematics tasks?
4-pt Scale: Not at all confident (1), Not very confident (2), Confident (3), Very Confident (4)

- **ST275Q01WA**. Working out from a [train timetable] how long it would take to get from one place to another
- **ST275Q02WA.** Calculating how much more expensive a computer would be after adding tax
- **ST275Q03WA.** Calculating how many square metres of tiles you need to cover a floor
- **ST275Q04WA.** Understanding scientific tables presented in an article
- **ST275Q05WA.** Solving an equation like $6x^2 + 5 = 29$
- **ST275Q06WA.** Finding the actual distance between two places on a map with a 1:10,000 scale
- **ST275Q07WA.** Solving an equation like $2(x+3) = (x + 3) (x - 3)$
- **ST275Q08WA.** Calculating the power consumption of an electronic appliance per week
- **ST275Q09WA.** Solving an equation like $3x+5= 17$
- **ST276Q01JA.** Extracting mathematical information from diagrams, graphs, or simulations
- **ST276Q02JA.** Interpreting mathematical solutions in the context of a real-life challenge
- **ST276Q03JA.** Using the concept of statistical variation to make a decision
- **ST276Q04JA.** Identifying mathematical aspects of a real-world problem
- **ST276Q05JA.** Identifying constraints and assumptions behind mathematical modelling

ST276Q06JA. Representing a situation mathematically using variables, symbols, or diagrams
ST276Q07JA. Evaluating the significance of observed patterns in data
ST276Q08JA. Coding/programming computers
ST276Q09JA. Working with computer mathematics systems (e.g. spreadsheets, programming software, graphing calculators)
ST276Q10JA. Calculating the properties of an irregularly shaped object

Relevancy Pedagogy

Question: This school year, how often did your teacher do the following things in your mathematics lessons?
5-pt Scale: Never or almost never (1), Less than half of the lessons (2), About half of the lessons (3), More than half of the lessons (4), Every lesson or almost every lesson (5)
ST283Q01JA. The teacher asked us to think of problems from everyday life that could be solved with new mathematics knowledge we learned
ST283Q02JA. The teacher showed us how mathematics can be useful in our everyday lives
ST283Q06JA. The teacher gave problems from everyday life involving numbers and asked us to make a decision about the situation
ST283Q07JA. The teacher asked us how different topics are connected to a bigger mathematical idea
ST283Q08JA. The teacher encouraged us to think about how a problem from everyday life could be solved using mathematics
ST283Q09JA. The teacher explained how different mathematical ideas connect to a larger context

School Belonging

Question: Thinking about your school: to what extent do you agree with the following statements?
4-pt Scale: Strongly agree (1), Agree (2), Disagree (3), Strongly Disagree (4)
I feel like an outsider (or left out of things) at school
ST034Q02TA. I make friends easily at school
ST034Q03TA. I feel like I belong at school
ST034Q04TA. I feel awkward and out of place at school [R]
ST034Q05TA. Other students seem to like me
ST034Q06TA. I feel lonely at school [R]

Note: [R] the item has been reverse coded.

Exploring Science Identities in Upper Elementary Classrooms

The science, technology, engineering, and mathematics (STEM) labor force is rapidly growing within the U.S. and forecasts predict that it will continue to increase by nearly 10% in the next 10 years (Burke et al., 2021). Secondary and higher education is typically the point at which we aim to prepare students for engaging in the workforce (Chan, 2016), yet students begin developing their interests, career aspirations, and personal identities as early as elementary school (Archer et al., 2010; Maltese & Tai, 2010; Paul et al., 2020). At this younger age many students begin to conceptualize what it means to “do science” and act like a scientist (Dickson et al., 2021; Zhai et al., 2014). In a lab setting, researchers find that incorporating instances of guided discovery and hands-on experiences provides elementary-aged children with active and beneficial learning opportunities (Yannier et al., 2020); yet students often feel like their classroom activities are not representative of what scientists do because they lack discovery, authentic science exploration, and feel a lack of agency (Dickson et al., 2021). Feeling like a scientist is not only important for encouraging students to pursue careers in science, but it is also important for engaging in everyday life. Science education is important for improving student’s problem-solving, critical thinking, communication, and creative thinking skills (NSTA, 2020). Thus, there is a need to further explore what classroom practices make students feel most like a scientist to provide beneficial learning opportunities.

This relates to a current interest in examining students’ perceptions of themselves as scientists early in their education (Trujillo & Tanner, 2014). Experiences with science (inside or outside of the classroom) can encourage or discourage a persons’ science identity development (Kim & Sinatra, 2018). Kim and Sinatra (2018) theorize an interactionist framework of developing science identity, which incorporates the students’ past experiences, environment, feelings of belonging, self-efficacy, and interest. Within classrooms it is important to consider how we are constructing the environment to encourage students' interest, belonging, and self-efficacy. The proposed study builds upon this theory by incorporating teacher's attitudes toward teaching science. Students' sense of belonging, science self-efficacy and curiosity is investigated, along with how these motivational constructs relate to a student's science identity. This study further examines what teaching practices and activities in elementary classrooms relate to students' perceptions of themselves as scientists.

Science Identity

A student's science identity refers to their self-perception as a scientist (Trujillo & Taner, 2014). This includes feelings related to a student's interest in and enjoyment of science, their own and others' perceptions of them as a scientist, and their perceived personal usefulness of science (Hill et al., 2018; Paul et al., 2020; Trujillo & Taner, 2014). A students' science identity contributes to their ability to persist in challenging activities, adapt to changing contexts, and set attainable goals (Talafian et al., 2019; Trujillo & Taner, 2014; Vincent-Ruz & Schunn, 2018). Young children's science identity has important implications for how they engage in science classrooms, pursue science careers later in life, and generally develop useful everyday skills like critical thinking, creativity, and problem-solving (Dou et al., 2019; NSTA, 2020; Pantoya et al., 2015; Talafian et al., 2019). Unfortunately, it is difficult for many students to picture themselves as a scientist; as early as pre-kindergarten, most students have the pre-conceived notion that only white men belong in science-related careers (Ata-Aktürk & Demicran, 2021). Thus, it is important to understand what classroom practices may be successful at broadening children's ideas about scientists and support the development of science identities in those from backgrounds traditionally underrepresented (girls, non-White or Eastern Asian) in STEM (Morgan et al., 2016).

Researchers find that science identity may begin to develop before adolescence, which is the developmental period typically investigated (Ata-Aktürk & Demicran, 2021; Dou et al., 2019; Pantoya et al., 2015). For example, a retroactive study examining early science experiences found that communicating with friends or family about science and interacting with various scientific media during the kindergarten to 4th grade years, had positive influences on feeling like and wanting to be a scientist (Dou et al., 2019). Additionally, higher science identity scores were more predictive of student's odds of choosing a STEM career (Dou et al., 2019). This study was limited in using retroactive reports of science identity; given these insights, it is important to evaluate these perspectives from current elementary students. Further, few studies explore students' science identity in elementary school using quantitative or mixed methods, which would provide generalizable results. The current study addresses this gap in the literature by investigating elementary student's science identity, experiences in the classroom that make them feel like a scientist, and teacher's influence on fostering science identity.

Influences on Science Identity

Motivational Factors

Curiosity in Science. Children and scientists have more in common than people may think. Both aim to understand the world around them and ask questions as to how and why things work (Engel, 2011). Children are naturally curious about science starting at a very young age (Engel, 2011). Broadly, curiosity describes an individual's recognition of an information gap and belief they can resolve this gap (Loewenstein, 1994), and the intrinsic motivation to attempt to do so (Jirout et al., 2024). This normally occurs through different exploratory behaviors that mirror and support the development of scientific thinking (Jirout, 2020). Jirout (2020) theorizes that curiosity is an essential tool for active learning in science because the process of seeking more information about a topic of interest involves meaningful cognitive engagement and constructive processing of information. While curiosity may support deeper learning, educational practices that promote curiosity are rarely observed in elementary classrooms (Jirout et al., 2022). This creates a concerning mismatch, as curiosity is viewed as an important attribute within the science field (Von Stumm et al., 2011). This calls for further work examining curiosity in science learning.

Within research examining curiosity, it can be thought of as a trait or state. State describes in-the-moment or domain specific, and trait describes stable characteristic or general trait across situations (Jirout et al., 2023). Peterson and Cohen (2019) theorize that when examining curiosity in school settings, a state or domain specific examination of curiosity provides a clearer indication of how curiosity may influence student's motivation and learning. For example, within a science classroom, examining a students' science curiosity specifically may better predict student outcomes than their general curiosity. Gottfried and colleagues (2016) found that when parents stimulated their young children's curiosity through encouragement of asking questions, exposing children to new experiences, or taking children to museum, there were positive relations to students' later science intrinsic motivation. The authors further identify the possibility of a link between students' science curiosity and their science identity years later (Gottfried et al., 2016). The current study aims to understand this relationship between science identity and curiosity considering that, to our knowledge, no prior studies have examined this link within elementary classrooms.

Outside of the classroom, Talafian and colleagues (2019) examined the ways in which a space-themed summer camp program motivated students' STEM identities. This camp was designed to allow for students to explore their own projects and act upon their curiosity. Students explored their own interests and completed individual science projects during the one-week camp.

By the end of camp, students developed perceptions of themselves as scientists, reflected on possible STEM careers, and had more interest pursuing more science-based projects, visiting science centers, and meeting scientists (Talafian et al., 2019). Given these findings, curiosity and science identity should be investigated within the formal classroom to better understand how to maximize young student's natural curiosity toward science.

Science Self-Efficacy. Student's self-efficacy, which involves self-perceptions of their capabilities to perform activities in a given domain, has an influence on their academic outcomes (Eccles, 2009; Lei et al., 2019; Sheldrake, 2016; Stankov et al., 2012; Usher & Pajares, 2008). Bandura (1997) proposed that students get their perceptions of self-efficacy from evaluating previous experiences, observing others in vicarious experiences (particularly if they feel related to the other), social persuasions or encouragement from others (teachers, peers, parents, etc.), and their emotional or physiological reactions. These sources have been found to influence students' perceptions as early as elementary school (Joët et al., 2011; Usher & Pajares, 2008).

Students who feel more self-efficacy in their academics are more likely to engage in academic activities, demonstrate more persistence when working on complex problems, and exhibit less cognitive anxiety (Yang et al., 2021). Science self-efficacy describes an individual's judgement of their capabilities to solve science problems, perform tasks, or succeed in courses (Aurah, 2017; Kwon et al., 2019). Within education contexts, science self-efficacy is important for retention and pursuit of more advanced science classes and careers in science (Britner & Pajares, 2006; Kwon et al., 2019), and has important implications for developing students' science identity (Byars-Winston, 2016).

Teacher pedagogical practices influence student's self-efficacy (Blazar & Kraft, 2016). Blazer and Kraft (2016) found that elementary teacher's emotional support or ability to create a positive classroom environment and their ability to present content with clarity and without mistakes is related to students' self-efficacy. This has important implications for teacher's attitudes and confidence in teaching a subject as these may have subsequent impacts on students' confidence to engage with the content. Better understanding teachers' influence on self-efficacy and other motivational constructs are important, as self-efficacy differs across student from different backgrounds underrepresented in STEM. For example, students from groups traditionally underrepresented and minoritized in STEM tend to have lower self-efficacy from their peers, and this gap increases as they progress through school (Lofgran et al., 2015). Although there are little differences in academic performance in science between genders, elementary aged girls tend to underestimate their ability and thus have lower self-efficacy compared to their boy peers (Webb-Williams, 2018).

Belonging. Feelings of belonging in the classroom is important for student success (Anderman, 2002; Osterman, 2000). School belonging refers to the extent to which students feel personal acceptance, respect, inclusion, and support by others in their environment (Goodenow & Grady, 1993). It has been typically explored in middle school and later grades, yet students begin developing a sense of belonging early in their education (Arslan, 2019; Sari, 2012; Ward, 2021). Sari (2012) found that as early as elementary school, students rely on their relationships to their teachers and peers to develop positive educational experience. Elementary students' sense of belonging influences their academic achievement, and internalizing and externalizing behaviors (Arslan, 2019).

A students' sense of belonging also has important implications for developing academic identities. According to Ryan and Deci (2000), a student's sense of belonging is a basis for engagement, which has important considerations for building a sense of self in the classroom. The current study aims to extend a growing body of literature examining elementary aged student's sense of belonging and its relationship with developing academic identities.

Demographic factors: Gender and Race

Gaps in science achievement between underrepresented minorities exist early in a student's educational journey (Morgan et al., 2016; National Science Board, 2021; Sackes et al., 2011). Students that identify as girls, non-binary, Black, Latino, Indigenous American, or Pacific Islander often feel like science careers are out of reach or not for them (Bodnar et al., 2020; National Science Board, 2021; Rainey et al., 2019; Riegle-Crumb et al., 2011; Wong et al., 2015). Despite pushes for more diversity in the STEM workforce, students as early as elementary school still depict scientists are white men (Hayes et al., 2020; Kelly, 2018). Within the classroom, students that identity within these underrepresented groups often feel as if they are not given chances to prioritize their science interests, feel like their teachers do not recognize their science abilities and knowledge, and are less likely to develop a sense of belonging within their science classrooms (Morgan et al., 2016; van den Hurk et al., 2019). It is important to understand how this may relate to their feelings related to being able to pursue science and be a scientist.

In terms of science identity specifically, Bodnar and colleagues (2020) found that science identity and science career aspirations in adolescent youth were highest in White boys and lowest for Black girls. To our knowledge, studies have not examined these differences in gender and race in student's science identity within elementary students; thus, this study aims to explore if these patterns are present this early in a student's education.

Teacher factors: Attitudes Toward Science

Individuals come into any situation with prior experiences that shape their beliefs or attitudes about a specific topic or subject, and teachers are no different. Elementary school teachers may feel less confident in their ability to adequately teach science compared to other subjects. Previous studies have found that teachers report difficulties with teaching science due to lack of knowledge, materials, and time (Haney et al., 2002). Teacher beliefs and attitudes are important to consider as they subsequently influence students' beliefs, interests, motivation, and engagement in a certain class or subject (Ekmekci & Serrano, 2022).

At the primary school level, teachers have positive or negative attitudes toward teaching specific subjects (Wilkins, 2009). These attitudes develop as a result of cognitive beliefs (perceived relevance, difficulty, stereotypes), affective states (enjoyment or anxiety), and perceived control (self-efficacy, contextual circumstances, or constraints; van Aaldermenen-Smeets et al., 2012). From a sample of nearly 500 elementary school teachers, reading and language arts were ranked among the most enjoyed subjects to teach, whereas science ranked amongst the least favorite subjects to teach (Wilkins, 2009). These attitudes have important implications on students' attitudes and outcomes in a specific subject. Teacher's attitudes have been demonstrated to influences student's attitudes toward a given subject (Denessen et al., 2015). The National Assessment of Educational Progress (NAEP) examined instructional methods used in science classrooms and 30% of 4th grade teachers responded that they never to once or twice a year engage in scientific inquiry-related classroom activities and 52% responded that it occurred once or twice a month (The Nation's Report Card, 2022), likely in part related to teachers' feelings about teaching science. To better understand the impacts of these feelings on students, the current study investigates how teacher's attitudes toward teaching science relate to students' science identity.

Current Study

This study aims to understand elementary school students' science identity and internal and external influences on science identity. Differences amongst demographic groups are explored to better understand the experiences of typically marginalized students in STEM. This study further examines educational experiences that influence their perceptions as a scientist. Specifically, the research questions are:

1. How does teachers' science attitudes influence students' science identity considering factors such as students' self-efficacy, curiosity, gender, grade, race, and school belonging?
2. Do third and fourth grade students identify as a scientist or someone who wants to pursue science?
    a. What experiences make students feel most like a scientist?

Method

Procedures

This research used a mixed method design in which qualitative data from the student surveys was used to elaborate upon the quantitative data from the student surveys. This study was approved for research by the University of Virginia IRB #6715 and preregistered (https://doi.org/10.17605/OSF.IO/RYQU7) with the Center for Open Science and any non-preregistered exploratory analyses are specified. A total of 10 public schools in 6 districts across 2 states in the Mid Atlantic were recruited to participate in the study. We first used a convenience sampling and recruited from schools where we had existing partnerships. We then used a snowball sampling approach and district leaders were asked to help connect our team to other school districts in the area to see if they were interested in participating. Principals and superintendents invited all 3rd and 4th grade teachers to participate in the study, by sending informational letters and consent forms. Once teachers signed a consent form, they sent informational letters, parent consent, and student assent forms home to families.

Teachers: Teachers completed a 15-minute online Qualtrics survey that focused on their attitudes toward teaching science and science content that has been covered before their students took the survey. Teachers also distributed and collected consent forms from students and parents. Teachers administered the student survey during their designated science teaching time. Teachers received a $50 gift card for completing study activities.

Students: Students completed a 20-minute online Qualtrics survey during their science class. All students in classes participating completed the survey but only data from children with parent consent were included for the analyses.

Participants

Teachers: Third and fourth grade teachers participated in this study ($N = 25$). To participate in this study, all teachers reported as having instructional time dedicated to science. One teacher was the designated science teacher for the school and her third and fourth grade classrooms participated in this study, bringing the total number of classrooms to 26. A total of 50% of potential teachers participated in this study. Schools were from a mix of suburban ($N = 3$) and rural ($N = 7$) settings and served a range of 85 to 945 students ($M = 386$, $SD = 283.02$).

Students: All students of participating teachers were invited to participate and given parent consent forms. Third ($N = 101$) and fourth ($N = 55$) grade students from 26 public school classrooms participated in this study ($N = 156$; average of 6 students per class; 13.6% of students participated). In terms of race, 107 students identified as either White or Asian (labeled as racially non-marginalized) and 47 students identified as either Black, Hispanic/Latino, Indigenous American, or Pacific Islander (labeled as racially marginalized). We used these classifications of students because prior research has shown that students that identify as Asian and White typically have higher perceptions of their STEM identity when compared to other races (Morgan et al., 2016; van den Hurk et al., 2019), and most race groups were too small to examine on their own. For example only nine students identified as Asian. Additionally, student race demographics were collected using a questionnaire from TIMSS (TIMSS, 2019) which did not examine ethnicities within the different race groups. In terms of gender, 72 students identified as a boy, 85 identified as a girl, and one student identified as non-binary.

Measures

Teacher Surveys: Teachers responded to a 15-minute online Qualtrics survey to provide details regarding science course content and attitudes toward teaching science. Teachers answered 20 questions about their attitudes toward teaching science using an adapted version of the 22 item Early Childhood Teachers' Attitudes Toward Science Teaching scale (Cho et al., 2003; α = .90). Cho and colleagues (2003) pilot tested this measure with 100 elementary school teachers and found strong internal reliability. This survey evaluates teacher's comfort and discomfort with teaching science, science classroom preparation, perceptions of developmental appropriateness of science topics and managing hands on science activities (Cho et al., 2003). Two questions ("I am interested in handling certain animals and insects to teach science"; "I feel that young children cannot learn science until they are able to read") were removed for the purposes of this study because many teachers may not be using live animals or insects within their schools and learning to read is not developmentally appropriate for 3rd and 4th grade students. Researcher created questions about instructional hours dedicated to teaching science and topics or units already covered during the school year were added to the survey. These items gave context into how much dedicated science time students receive during the week.

Student Surveys: Students responded to a 20-minute online survey during their science class using Qualtrics. Students answered questions related to their science identity, curiosity, self-efficacy and belonging. Three open ended questions asked students to think about what it means to be a scientist, when they feel most like a scientist during class, and what their teacher does to make them feel most like a scientist. Students were asked to respond to these questions using one to two sentences. Demographic questions were modeled off of the TIMMs 2019 Grade 4 assessment. Students were asked how they identify in terms of their gender and race. The constructs of interest were measured using the following scales and questions:

Science Identity: The 26-item Role Identity Survey – STEM (RIS-STEM) science identity scale was developed by Paul and colleagues (2020), and consistent with Trujillo and Tanner's (2014) definition of science identity, focus on students' self-recognition as a science kind of person, other's perceptions of their science identity, interest, and competence (α = .91). Students respond to these questions on a 4-point scale (NO!, no, yes, YES!). For the purposes of this study, this scale was adapted by changing the acronym "STEM" to "science". This allows students to only respond to these items solely thinking about science rather than the larger STEM context.

Science Self-Efficacy: The seven item Students Confidence in Science Scale was developed for the Trends in International Mathematics and Science Study 4th grade assessment (Yin & Fishbein, 2019; α = .77). This measure uses a 4-point scale from "agree a lot" to "disagree a lot". Within the U.S., this scale was positively correlated with students' science achievement, indicating it is an adequate measure of student's self-efficacy in science. While this scale is titled as a measure in confidence, it is capturing other components of self-efficacy beyond just confidence by examining mastery experiences, emotional reactions, and social persuasions.

Science Curiosity: A five-item curiosity scale developed by Jirout and colleagues (2024) was used to measure student's science curiosity (α = .85). This scale asks questions about student's interest with exploring or seeking new information and embracing novelty and uncertainty. Students responded to these questions on a 5-point scale from "Not at all" to "Very very much".

Belonging: Students answer four items related to their school belonging on a 5-point scale from "strongly agree" to "strongly disagree" (α = .74). This scale was developed by Anderman (2002). These questions focus on student's perceptions of their membership to the school, relatedness to others, and feelings related to being at the school. The scale has been used with middle and high school students, but the questions were developmentally appropriate for elementary students.

Data Analysis Plan

This study used both qualitative and quantitative analyses to examine the research questions.

Quantitative Analysis

Mean composite scores of relevant latent variables were created using survey questions for student's perceptions of belonging, science curiosity, science self-efficacy, and science identity and teacher's attitudes toward teaching science. Demographic variables were labeled as binary variables. Race was defined as marginalized status (1) or not (0) to understand the influence of being an underrepresented minority in STEM. Student's grade was coded as 3rd (0) or 4th (1) to account for differences across grade. Student's gender was coded as girl (1) or boy (0).

A multi-level model (MLM) was used to understand the influence of gender, race, self-efficacy, belonging, curiosity, and teachers' science teaching attitudes on students' science identity (RQ 1). The final analytic sample included 148 students. Two students were removed who did not provide their race, one student was removed who identified as non-binary (since the sample size was too small to include as a category), and six students were removed because they selected all strongly agree (even when questions were negatively worded). Teacher attitudes toward teaching science was a Level-2 predictor at the classroom level and students' gender, grade, race, belonging, science curiosity, and science self-efficacy will be nested within classrooms as the Level-1 predictors. The following equation was used:

$$\text{ScienceIdentity}_{ij} = g_{00} + g_{10}(\text{Gender}_{ij}) + g_{20}(\text{Race}_{ij}) + g_{30}(\text{Belonging}_{ij}) + g_{40}(\text{Curiosity}_{ij}) + g_{50}(\text{Efficacy}_{ij}) + g_{60}(\text{Grade}_{ij}) + g_{01}(\text{TeacherAttitude}_{ij}) + u_{0j} + e_{ij}$$

After employing the full model, researchers conducted another MLM taking out demographic variables that were not significant to find the best fitting model. Additional exploratory MLM analyses were conducted to examine interactions between significant intersecting demographics and psychological predictors.

Descriptive analyses from the science identity survey data were used to understand students' perceptions as a scientist (RQ 2). T-tests were used to understand trends within different student groups.

Qualitative Analysis

Researchers used a two-stage inductive coding approach followed by an inductive thematic analysis (Clarke & Braun, 2017) to analyze the open-ended survey data. First, members of the research team independently read through all student responses from the open-ended survey responses to identify codes and develop a codebook. Rounds of discussion took place between researchers to develop and modify a codebook. Following the creation of the codebook, researchers independently coded and until they reached an inter-rater reliability of .80 (Gisev et al., 2013). Following the coding, codes were grouped and turned into broader themes understand patterns in student's perceptions as a scientist (RQ 2). Further analysis explored patterns by level of science identity to understand if there were key differences in student's perceptions across students with high or low perceptions of being a scientist. Qualitative data was grouped by student's placement in high or low science identity groups after the qualitative coding was complete. If student were higher or lower than one standard deviation from the average science identity score, they were grouped in the high and low groups. Across the 156 students and three open-ended survey question, there was a 92% response rate. Data for each group was then analyzed for patterns and themes.

Results

Research Question 1: *How do teachers' science attitudes influence students' science identity considering factors such as students' self-efficacy, curiosity, gender, and school belonging?*

Student's belonging, science curiosity, science self-efficacy, and teacher's attitudes toward teaching science were examined (See Table 1) in relation to student's science identity. Students within this sample had high perceptions of their belonging, and fairly high perceptions of their science curiosity and science self-efficacy. Teachers also held positive attitudes toward teaching science.

Table 1. Descriptive Data of Relevant Variables

	Mean(SD)	Scale	Min, Max
Science Identity	2.84(.54)	1 – 4	1.35, 4
Belonging	4.32(.78)	1 – 5	1.25, 5
Curiosity	3.48(1.08)	1 – 5	1.2, 5
Self-efficacy	2.96(.71)	1 – 4	1, 4
Teacher Attitudes	3.72(.45)	1 – 5	2.45, 4.8

Table 2 presents the results of five different multi-level models that were used to understand how teacher's attitudes toward teaching science relates to students' science identity. Results from the unconditional model, full model (using all demographic variables and psychological constructs), final model (taking out the non-significant demographic variables), and two interaction models (curiosity and gender; self-efficacy and gender) were fitted using maximum likelihood.

The full model, which included all predictors and demographic variables, showed that teacher's attitudes toward teaching science was not statistically significant in its relation to student's science identity; yet student's science curiosity, science self-efficacy and gender were statistically significant. The final model, which did not include the non-significant demographic variables from the full model (grade, race), found similar results to the full model with science curiosity, science self-efficacy, and gender as significant, and teacher's attitudes toward teaching science as non-significant. Considering the statistical significance of gender, curiosity, and self-efficacy, exploratory analyses that were not preregistered were conducted to examine interactions between gender and curiosity and gender and self-efficacy. These models did not reveal significant interactions and the final model (Model 3) remained the best fitting (lower AIC and BIC).

Table 2. Multi-Level Model Results

	Model 1[a]	Model 2[b]	**Model 3[c]**	Model 4[d]	Model 5[e]
	b (SE)	*b* (SE)	***b* (SE)**	*b* (SE)	*b* (SE)
Fixed effects					
Intercept	2.85(.06)*	1.39(.39)*	**3.18(.08)***	3.17(.08)*	3.20(.08)
Belonging		.02(.05)	**.02(.05)**	.02(.05)	.03(.05)
Curiosity		.25(.04)*	**.25(.04)***	.24(.05)*	.25(.04)*
Self-Efficacy		.20(.06)*	**.19(.06)***	.19(.06)*	.22(.07)*
Teacher Attitudes		.004(.09)	**.01(.09)**	.01(.09)	.01(.09)
Gender		-.17(.06)*	**-.18(.06)***	-.17(.06)*	-.24(.10)*
Grade		-.07(.08)			
Race		.07(.07)			
Interactions					
Curiosity* Gender				.02(.06)	
Self- Efficacy* Gender					-.08(.09)
Random Effects					
Intercept	.18(.06)	.12(.04)	**.13(.04)**	.13(.04)	.13(.04)
Fit Statistics					
df	3	10	**8**	9	9
AIC	238.51	149.53	**147.19**	149.04	148.43
BIC	247.51	179.50	**171.165**	176.01	175.41

Notes. * $p < 0.05$; Race = typically marginalized coded as 1, non-marginalized coded as 0; Gender = female coded as 1, male coded as 0; Grade = third coded as 0, fourth codes as 1; AIC = Akaike Information Criterion; BIC = Bayesian information criterion

[a] Model 1: Unconditional main effects model

[b] Model 2: Building on Model 1 to include predictors

[c] Model 3: Simplifying Model 2 by taking out non-significant demographic variables

[d] Model 4: Building on Model 3 to include interaction with curiosity and gender

[e] Model 5: Building on Model 3 to include interaction with self-efficacy and gender

RQ 2: Do students identify as a scientist or someone who wants to pursue science?

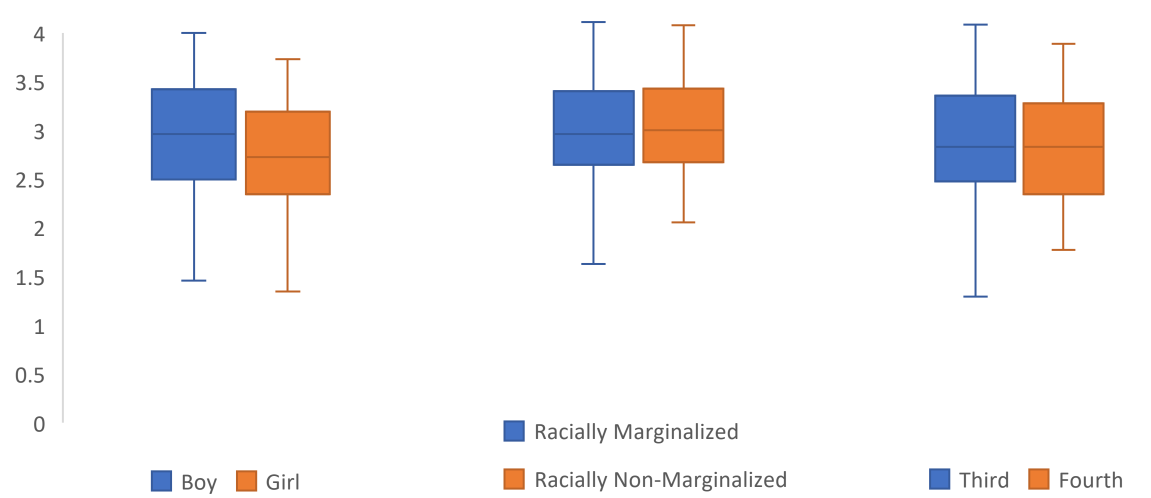
On average, students have slightly positive views of themselves as a scientist (M = 2.84, SD = .54). Means across student's gender, race, and grade were examined for trends in perceptions in science identity across different groups (See Table 1).

Table 3. Science Identity Means by Demographic Group

	N	Mean(SD)
Gender		
Boy	66	2.95(.55)
Girl	82	2.75(.51)
Race		
Non-Marginalized	105	2.87(.53)
Marginalized	43	2.77(.57)
Grade		
Third	98	2.87(.54)
Fourth	50	2.77(.53)

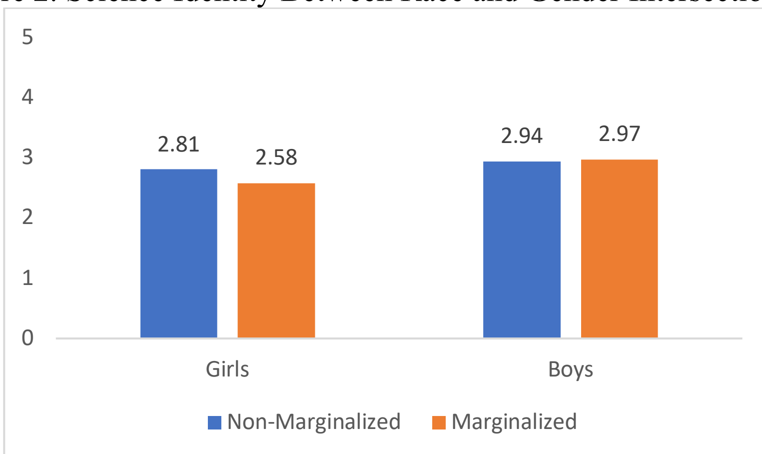
Boys had higher perceptions of themselves as a scientist when compared to girls (See Figure 1; $t(146) = 2.22$, $p = .01$). There were no statistically significant differences in science identity between students that identify as racially marginalized and non-marginalized ($t(146) = .97$, $p = .17$), or students in third and fourth grade ($t(146) = 1.08$, $p = .14$).

Figure 1. Science Identity Comparison Between Demographic Variables



Considering the intersectionality of students typically marginalized in STEM fields, race and gender were further examined together (See Figure 2). Racially marginalized girls ($N = 21$) had the lowest science identity ($M = 2.58$, $SD = .59$) when compared to racially non-marginalized girls ($N = 61$, $M = 2.81$, $SD = .48$) and both racially marginalized ($N = 25$, $M = 2.97$, $SD = .50$) and non-marginalized (N = 44, M = 2.94, SD = .59) boys. There was a statistically significant difference between racially marginalized girls and the rest of the sample ($t(146) = 2.42$, $p = .01$).

Figure 2. Science Identity Between Race and Gender Intersectionality



We conducted a thematic analysis to identify patterns in student's perceptions of scientists and what makes them feel like a scientist from student's open-ended responses. Students responded with what they thought it means to be a scientist. A theme within this data was that students thought that scientists learn new things about the world and explore the unknown. One student said, "*[scientists] learn about secret things and discover new animals and medicines and sicknesses and new tech to use and new things like parasites.*" Students associated being a scientist with discovery and the process of learning more about the natural world. Students also had a laboratory-based idea of what scientist do. These students thought scientists are people who conduct experiments and test new things; oftentimes using chemicals, technology, or lab equipment.

Another theme that emerged was that students associated being a scientist with personal qualities such as being smart, altruistic, curious, or creative. For example, a student responded that, "*to be a scientist you MUST be smart, creative, and willing to try new things*". Being a scientist also means that you help people and solve problems in society. One student said, "*I think what it means to be a scientist is that a lot of people rely on you for a lot of projects and keeping them safe. For example, when there is a type of storm somebody has to count on you to tell if it's bad or good*". Overall, students held perceptions of scientists as people who are on the path toward making new discoveries and conducting experiments with the goal of helping society or adding knowledge.

When exploring patterns by student's science identity (i.e., high or low; See Table 4), we found that students who were lower on science identity often attributed scientists as having qualities like smart or being able to do hard things. For example, these students said things like, "*[to be a scientist] means you have to be good at [science]*" or "*I think being a scientist mans that you are smart and creative and good at projects*". Conversely, students who had higher science identity perceptions, more frequently identified scientists as people who learn new things, make discoveries, and explore to make new knowledge. These students also mentioned how scientists are creative and many learn more with the purpose of helping people.

What experiences make students feel most like a scientist?

Students also shed light onto when they felt most like a scientist during class time and what their teacher does to make them feel like a scientist. Students simply said they feel most like a scientist during STEM, science, or math class. Those that extrapolated about what specifically happens in their class mentioned times when they could engage with hands-on activities. For example, one student said they felt most like a scientist "*when I lit a tiny light bulb with only a battery, two wires, and a light bulb holder*". Another theme was that students focused upon the fun aspect of doing hands-on science, "*when we do a fun activity, I feel like a real scientist learning new things*". Bringing science to life and engaging with experiments or making learning relevant was an important part in making students feel like a scientist. Students also revealed that they feel like a scientist when they are learning about science from their teacher, reading science textbooks, or watching videos and movies.

Students also mentioned that when they are challenged in science class they feel most like a scientist. One student mentioned, "*I feel like a scientist most when we do a hard project and I learn more about it, and I can get better at it*". Other students described similar feelings and expanded upon this, explaining that they feel like a scientist when they get answers right, are able to explain science concepts well, or are asked questions by their peers about science. These students said things like, *"when people ask me questions science related and when I know a lot about what we are learning in science*" and "*when I get the answer right and work very hard to be a scientist*". Students that shared these types of responses were those that were higher in science identity. Alternatively, another theme was that students said they do not feel like a scientist and there aren't experiences in the classroom that make them feel like one. These students said, "*I usually don't feel like a scientist during class*" or "*none of the time sadly*". These responses were more common within students that had lower science identity and rare within students with higher science identity (See Table 4).

Digging more into how teachers make them feel like a scientist, students revealed that when teachers lead hand-on science activities, give encouragement or positive affirmations, help or expand upon science concepts, and make science fun it makes them feel like a scientist. Again, for hands-on activities, students mentioned that when their teacher gives them the chance to do experiments and use physical objects to learn science concepts they feel like a scientist. In terms of affirmations, these students reporting feeling more like a scientist when their teacher tells them that they are a scientist, assigns them a job as a scientist, encourages them that they can do something, or otherwise supports students' confidence to do science. For example, a student said, "*[my teacher] makes me feel like I'm wanted, and she makes me feel like I'm good in science when I'm really struggling*". This also speaks to the support that other students mentioned. Teacher's help in guiding students when they are having trouble was important for many students in making them feel like a scientist. One student explained, "*what my teacher does to make me feel like a scientist is when she goes slowly and goes step by step or question by question*". This matches findings from the multi-level model where student's science self-efficacy was related to their feelings of being a scientist. Finally, students mentioned that promoting science as something that is fun and creative makes students feel like a scientist. For example, one student mentioned, "[our teacher] *helps [us] and lets us be creative and have fun in groups*". Another theme was that students did not know how their teacher supported them in feeling like a scientist or felt like their teacher does not support them. These students said things such as, "*[my teacher does] nothing absolutely nothing*".

When examining trends by student's science identity perceptions (See Table 4), numerous students who had lower science identity did not feel like their teacher was engaging with them in a way that made them feel like a scientist. Students with higher science identity wrote that their teachers supported them through their questions and referred to them as scientists. Students with both high and low science identity perceptions had similar perceptions that having fun and interactive lessons were important in making them feel like a scientist.

Table 4. Qualitative Results Summary Table by Science Identity Groups

Science Identity	Demographics	Scientist Perceptions	Classroom Experiences	Teacher Influences
Low (Below 2.3) *n* = 25	Boys = 9 Girls = 15 Third = 15 Fourth = 10 Racially Marginalized = 6 Racially Non-Marginalized = 17	- Smart - Hard-working - Discoverers	- None - Being in science class - Hands-on projects	- Not Feeling Supported - Makes it fun
High (Above 3.38) *n* = 30	Boys = 19 Girls = 11 Third = 22 Fourth = 8 Racially Marginalized = 7 Racially Non-Marginalized = 17	- Curious - Explorers - Discoverers - Helpful	- Hands-on projects - Being in science class - Doing hard things	- Positive affirmations - Answers questions - Makes it fun

Discussion

This study provided insight into third and fourth grade student's perceptions of their science identity, how their science identity relates to their belonging, science curiosity, science self-efficacy, teacher's attitudes toward teaching science, and individual demographic factors. It also gave further context into what happens in classrooms that make students feel more like scientist. The results from this study have implications for classroom practices.

Student's Identity as a Scientist

Most students within this study saw themselves as a scientist, yet these perceptions differed across different groups of students. Unfortunately, gender continues to play a role in influencing student's science identity. This study was consistent with prior findings that girls had lower perceptions of their science identity (Morgan et al., 2016). Additionally, when examining the intersectionality of race and gender, consistent with Bodnar and colleagues (2020), racially marginalized girls had lower perceptions of their science identity than their peers, and white boys had the highest average perceptions of science identity. This continues to highlight a concerning pattern and demonstrates these perceptions are forming at an early age (Ata-Aktürk & Demicran, 2021).

There is a definite need to make racially minoritized girls more empowered to do and pursue science. Based upon Talafian and colleague's (2019) study with underrepresented racial and gender minority students in STEM, the researchers found that when integrating Black women role models during science activities, students were more interested in doing science projects and understood how they fit within future science related careers. Providing more representation and role models for typically marginalized students during science class may allow students to see more of themselves in science.

Similar to previous work, students within this study already had conceptualizations as to what it means to be a scientist and what they contribute to society (Dickson et al., 2021; Zhai et al., 2014). Students within this study emphasized that scientists are explorers, and people who make discoveries, actively seek new knowledge, want to help people, and believe that scientists are smart and hardworking. There were interesting patterns from the data that demonstrated that students with higher science identity perceptions were those that focused on how scientists help people, make discoveries, and experiment to make new knowledge, whereas students with lower science identity focus on more of the individual qualities of scientists where they are smart, have high self-efficacy in science, and are hard-working. These trends demonstrate that students with higher science identity focus on more of the real-world implications of doing and being a part of the science community, and students with lower identity lower science identity narrowed in on personal qualities and focused on cognitive abilities and work-ethic. One possible explanation for this pattern is that students who identify more as a scientist focus on the exciting and beneficial aspects of doing science, whereas students who are less comfortable with science or do not feel like a scientist focus on things like efficacy and intelligence. This has important implications for classroom practices, especially when considering motivational science (Ryan & Deci, 2000). An emphasis that you do not need to know everything, and scientists often work from a place of uncertainty, may make students feel more comfortable and interested in pursuing science.

Experiences that Make Students Feel Like a Scientist

Students identified several experiences that happen within their science classes that make them feel like a scientist. This extends the interactionist framework by Kim and Sinatra's (2018) that posits student's perceptions of their environment are linked to their science identity. Consistent with Yannier and colleagues (2020), hands-on experiences were beneficial in making student's feel like a scientist. Students within this study mentioned that when teachers build in opportunities for them to engage with physical materials or explore concepts through hands-on activities, many students feel like a scientist. This aligned with many of their responses to what they believe scientists do as a part of their job. Consistent with prior research, students felt most like a scientist when they were doing activities that mirrored their beliefs about what scientists do (Dickson et al., 2021; Zhai et al., 2014).

Some students highlighted that opportunities to work on difficult science-related tasks were important for making them feel like a scientist. This is consistent with prior science identity work that highlights that feeling satisfied when completing science tasks and enjoying the challenge of science activities are key components in student's science identity development

(Trujillo & Taner, 2014; Vincent-Ruz & Schunn, 2018). Many other students also described times where they received affirmations or support from their teachers. Affirmations included telling students that they were doing a good job or were scientists. This aligns with previous work emphasizing the role of appropriate praise on student's effort and journey to getting to answers (Burnett & Mandel, 2010; Droe, 2013).

It is important to note that many students, particularly those with lower science identity, did not feel like there were experiences that made them feel like a scientist and did not feel supported by their teacher during science class. If students are feeling like their teacher or environment is supportive of them during science class, they may not feel excited about participating in science. These students may subsequently develop more negative views toward science and have lower perceptions of themselves as a scientist. This is consistent with the science identity literature that highlights the importance of teacher's views on student's self-perceptions as a scientist (Paul et al., 2020); Trujillio & Tanner, 2014).

Based upon student responses, it may be beneficial to challenge students with hands-on activities or experiments while providing scaffolded support, especially for students who belong to groups traditionally underrepresented in different science fields. During these activities it is also important to emphasize to students that they are scientists even when they are unsure of answers or still in the process of getting to the answer. Building comfort with uncertainty, promoting question-asking, and debunking that scientists know everything may help students feel as if they can be scientists.

Influences on Student's Science Identity

Similar to the interactionist framework of science identity development proposed by Sinatra and Kim (2018), students' classroom experiences, science self-efficacy, and science curiosity were related to their science identity. First, unlike findings from Wilkins (2009), teachers within this study had positive attitudes toward teaching science. Considering this study was solely examining teachers' and students' perceptions toward science, only teachers that were more confident in their science instructional practices may have wanted to participate. According to Ekmekci and Serrano (2022) teacher's beliefs toward a teaching a subject subsequently influences student's interests and beliefs, yet the current study did not support these findings. Considering that teacher's attitudes were positive, and student's science identity were high this may demonstrate that the sample of positive teacher attitudes was linked to the sample of high science identity perceptions, but without much variation amongst teachers we are unable to understand this relationship further.

Science curiosity was related to science identity, and this is in line with prior work that highlights that building upon student interest or curiosity is important for making them feel like a scientist (Gottfried et al., 2016; Talafian et al., 2019). Again, this relationship was corroborated from the qualitative data where many students with high science identity mentioned exploration and hands-on discovery is important for making them feel most like a scientist. These responses also matched student's perceptions of who they think scientist are and what they do. Students think that scientists are curious about creating new knowledge and making discoveries, therefore in order to feel like a scientist, these students want to have opportunities where they can discover, explore, and learning interesting new content.

Self-efficacy was also significantly related to student's science identity. This is consistent with prior work that highlights the relationship between science self-efficacy and pursuing science careers or developing student's science identity (Britner & Pajares, 2006; Byars-Winston, 2016; Kwon et al., 2019). Many students with high science identity mentioned that when they complete difficult problems or get support from teachers to help during challenging tasks they feel like a scientist. Inversely, students that are low on science identity feel like they are not good enough at science to feel like a scientist. Building in opportunities for students to feel confident in their ability to do science may be important for creating a generation of future scientists.

Limitations & Future Work

There were several limitations within this study. First, there was a potential selection bias where teachers that were more comfortable with were more likely to want to participate in the study. As a result, most teachers had positive attitudes toward teaching science which may not be representative of third and fourth grade teachers. A larger sample of teachers may give a more representative view of the relationship between teacher's attitudes and student's science identity. Additionally, a majority of participating students were either White or Asian, and our sample overall was smaller than we planned for. Future work should aim to include more students from racially marginalized backgrounds to understand differences compared to their non-marginalized peers. More work should continue to incorporate student voices to understand how marginalized youth can be better supported during elementary science. Future work with a subsample of students from this study will include student interviews to collect more detailed information on what happens in the classroom that makes students feel more or less like a scientist.

Conclusion

Science identity and factors that influence science identity were examined in third and fourth grade classrooms. The findings reveal that science learning environments have influences on student's feelings as a scientist. The science content itself may be an important component, but students more so emphasized the ways in which they experience their learning as contributing toward their science identity. This has important implications for classroom practices. Teachers' language (such as telling students they are scientists), support of self-efficacy, and implementation of hands-on activities to engage their curiosity are ways to help nurture student's science identity. More prioritization of how we are engaging students during science lessons to match their perceptions of what scientists do in the field may help foster future scientists.

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Appendix

Student Survey

<u>Information</u>

Name: _______________
Teacher: ______________

<u>Science Identity Questions</u>

NO!, no, yes, YES!

I think I am very good at coming up with questions and problems related to science.
I am confident that I can understand science activities in class.
Others ask me for help on science activities.
I like to design solutions to problems during science design challenges.
I can apply science ideas to solve challenges.
I am able to do well in activities that involve science.
I usually understand what we are talking about during science activities.
I love designing things!
I like to figure out how things work.
I feel satisfied when completing science activities.
After a really interesting science activity is over, I can’t stop thinking about it.
I enjoy learning about science.
Doing science is fun.
I like the challenge of science activities.
It is likely that science will be part of my job someday.
I want to learn as much as possible about science.
When I grow up, I want to work on a team with science professionals.
When I grow up, I want to work in science.
I see myself as a science person.
I feel like a science person when I apply science ideas to my life.
My teacher sees me as a science person.
My best friends see me as a science person.
My family sees me as a science person.
My parents would like it if I chose a science career.
Others think that I would be a good a science person.
Other kids in my class see me as a science person.

<u>Curiosity Questions</u>

Not at all, A little, Some, A lot, Very very much

In science class, I ask questions to learn more about things.
In science class, am excited to learn new things.
In science class, when I don’t know something, it makes me want to learn more.
In science class, when something is surprising, I want to know more about it.
In science class, I enjoy discovering something new.

Science Self-efficacy Questions

Agree a lot, agree a little, disagree a little, disagree a lot

I usually do well in science.
Science is harder for me than for many of my classmates.
I am just not good at science.
I learn things quickly in science.
My teacher tells me I am good at science.
Science is harder for me than any other subject.
Science makes me confused.

Belonging Questions

Strongly agree, Agree, Not sure, Disagree, Strongly disagree

I feel like I am part of this school.
I am happy to be at this school.
I feel close to people at this school.
The teachers at this school treat students fairly.

Open-ended

What do you think it means to be a scientist?
When do you feel most like a scientist during class time?
What does your teacher do to make you feel like a scientist?

Demographic Questions

Which of the following best describes you?

Asian
American Indian or Alaska Native
Black or African American
Hispanic or Latino
Native Hawaiian or Pacific Islander
White

Which of the following best describes you?

Boy
Girl
Non-binary
Other

Teacher Survey

Name: ______________

How many hours per week do you have science class?

- 0 – 1 hours
- 2 – 3 hours
- 3 – 4 hours
- 4 – 5 hours
- 5 – 6 hours
- 6+ hours

What science topics are you planning to teach this year? (open-ended)

What science topics have you already covered with your class? (open-ended)

Strongly Agree, Agree, Neither Agree nor Disagree, Disagree, Strongly Disagree

I feel comfortable doing science activities in my early childhood classroom.
I fear that I am unable to teach science to children adequately.
I feel comfortable with the level of scientific knowledge necessary for teaching children.
I am afraid that children may ask me a question about scientific principles or phenomena that I cannot answer.
I hope to excite children about science in my classroom.
I am willing to get involved in children's scientific inquiries.
I am willing to spend time setting up materials for scientific exploration.
I am ready to learn and use scientific knowledge and scientific skills for planning hands-on science.
I like to discuss ideas and issues of science teaching with my colleagues.
I am familiar with raising open-ended questions to encouraging children's scientific exploration.
Preparation for science teaching generally takes more time than other subject areas.
I am not afraid of demonstrating experimental procedures in the classroom.
I enjoy collecting materials and objects to use in my science teaching.
I am comfortable using any classroom materials (e.g., blocks, toys, boxes, so forth) for science activities.
I do not mind the messiness created when doing hands-on science in my classroom.
I do not believe it is appropriate to introduce science to children at an early age.
I am comfortable with determining the science curriculum that is developmentally appropriate for children.
I don't feel that children are curious about scientific concepts and phenomena.
I am familiar with the processes and ways that children learn science.
I enjoy reading resource books to obtain ideas about science activities for young children.

Dissertation Conclusion

This dissertation includes three papers, *Encouraging Future Engineers: A Look at Undergraduate Research Opportunities, Making Math Matter: Exploring the Influence of Relevance on Student Math Attitudes*, and *Exploring Science Identities in Upper Elementary Classrooms,* addressing questions of STEM identity across both student developmental levels and different STEM domains. These papers explored educational experiences and their influence on students' engineering identity and engineering career aspirations in undergraduate students (paper 1), math attitudes in adolescent students (paper 2), and science identity during late childhood (paper 3). Educational and psychological factors that may influence students' STEM identity development were explored to better understand ways in which we can foster STEM identity in students and particularly in those that have been typically marginalized in STEM spaces. This work also aimed to expand the literature by exploring these concepts earlier in education, prioritize student voice, and consider educational implications for STEM classrooms in the U.S. Across this work, themes emerged when exploring student development, the cognitive and psychological constructs that contribute to STEM identity and attitudes, and implications for educational practices.

Internal and External Factors that Contribute to STEM Identity

Overall, these papers have interesting insights into the development of students' STEM identity over the course of a students' educational career. Students in elementary school had high STEM identity perceptions, yet students in secondary and tertiary school had lower perceptions. This adds to prior research that demonstrates that passion for science and engineering develop early in childhood (Capobianco et al., 2012; Maltese & Tai, 2010; Paul et al., 2020) but decrease over the course of a students' educational career (Engel, 2015; Hill et al., 2018).

This work also further emphasizes the importance of internal psychological constructs and external environmental factors that influence a students' STEM identity. These papers support Kim and Sinatra's (2018) interactionist framework of science identity which theorizes that a students' past experiences, environment, feelings of belonging, self-efficacy, and interest have important roles in shaping a students' science identity. These papers focused internal factors such as belonging, self-efficacy, and curiosity and external factors of educational practices and pedagogy, and demographic characteristics such as race, gender, and SES.

Internal Factors

These papers highlighted cognitive and psychological constructs important for developing students' STEM identity. Promoting self-efficacy, engaging curiosity in science, and fostering a sense of community and belonging in the classroom are all important components of building students' feelings of being a scientist. Insights from both quantitative and qualitative data revealed that students' perceptions of their self-efficacy were associated with positive STEM identity perceptions. This is consistent and expands prior literature that describes the importance of self-efficacy in developing an individual interest in a subject (Deci & Ryan 2012; Trenshaw et al., 2016). Qualitatively, across elementary and college students, there were similar themes. Students mentioned that getting to use the skills they learned in the classroom to solve hands on science-related problems, being "good at science" and feeling confident in doing science-related tasks supported student perceptions of identifying as a STEM person.

A students' sense of belonging or connection to peers, teachers, and the school positively related to their STEM identity and is shown in prior research to be important across a students' educational career (Osterman, 2000). While Kim & Sinatra (2018) theorize the importance of belonging in relation to a students' science identity, little work studies this relationship. The current work extends prior work by demonstrating the importance of how a students' sense of belonging is important for engagement, academic success, and motivation (Ostermann, 2000; Ryan & Deci, 2000) and how it is specifically important for developing a students' STEM identity. Within secondary and undergraduate students belonging was significantly related to students' STEM identity. It was not significantly related quantitatively to science identity within elementary students, but students qualitatively described that their relationships with peers and teachers were important factors in making them feel like a scientist or not. This body of work demonstrates that belonging is an important construct to consider when fostering future scientists.

Finally, students' science curiosity was also associated with students' STEM identity. Curiosity may be an important construct in science classrooms because the process of seeking more information about a topic of interest involves meaningful cognitive engagement and constructive processing of information (Jirout, 2020), yet it is rarely studied in relation to a students' STEM identity (Gottfried et al., 2016). Curiosity had the strongest association to science identity for elementary students. Students within this age group also had impressions that scientists are people who are curious about the world and act upon these curiosities to make discoveries and improve society. Curiosity was less of a theme for older students, which may continue to highlight a decrease in curiosity as students' progress through schooling (Engel, 2011); yet some undergraduate student responses mentioned pursuing their curiosity in STEM. Few college students spoke about wanting to explore their personal interests through research, but mentioned wanting to pursue their interests in applied settings more generally. This research highlights the potential value of incorporating more opportunities to engage in curiosity in STEM classes throughout education for developing STEM identities in students.

External Factors

Unfortunately, this work continues to highlight gaps in STEM attitudes and identity within underrepresented minority students in STEM. As early as elementary school there were gender differences in students' science identity where girls had lower views of themselves as a scientist compared to boys. These gaps were specifically driven by racially marginalized girls who had the lowest science identity compared to other groups. These trends continue across secondary education where girls were less confident in their math abilities compared to boys and girls, and undergraduate education where girls had lower views of their engineering identity and engineering career aspirations. This is consistent with prior work that shows that these gaps start early within a students' educational experience (Saçkes et al., 2011) and continue throughout schooling (Martin & Fisher-Ari, 2021; Rainey et al., 2019).

Results from these studies were mixed in terms examining the influence of SES or parent education level, and race. Contrary to previous work (Morgan et al., 2016), students' SES was not found to be predictive of math attitudes, yet parent's educational background was related to students' career aspirations. Students from first generation families had the highest engineering career aspirations. This may indicate that as students' progress through schooling their SES may not influence their STEM attitudes or identity or even provide motivation to succeed, or we need better ways of assessing students' access to resources and SES. It is also important to consider the potential selection effect of our sample, which was drawn from a prestigious, selective engineering program.

Given the low number of racially marginalized students within the datasets, these papers were unable to identify trends in terms of race over a students' development. The third paper found that there may be gaps in terms of race as early as elementary school. This is consistent with previous literature (Morgan et al., 2016) as we found that girl students from typically marginalized racial groups in STEM feel significantly less like a scientist than other groups. This calls for further work to address ways in which we can foster science identities in younger marginalized students.

Educational Implications

While teacher's inclusion of relevance in the classroom, engaging in research opportunities, or attitudes toward teaching science were not significantly related to students' STEM identity and attitudes, qualitative work from these papers highlighted teaching practices and educational experiences that students identified as influencing their feelings as a scientist. One major theme that threaded across the first and third paper is that students feel most like a scientist when they are doing activities or tasks that match their perceptions of what they think scientists do as a part of their job. This is consistent with prior literature that generally addresses to the importance of incorporating meaningful hands-on applications during science class (Lucas & Hanson, 2016; Schauer et al., 2023; Yannier et al., 2020). This work emphasizes the importance of hands-on real-world applications of course materials and speaks to their significance for fostering STEM identities in students. Ultimately, incorporating more hands-on activities and exploration for students to pursue their interests and curiosities in their STEM classes may help support STEM identity development and provide meaningful experiences that can prepare students for STEM careers.

Positive affirmations from teachers, such as calling students a scientist or complimenting their efforts when working on hard problems, is another important takeaway to consider for practice. A part of students' perception of their STEM identity is their teacher's perceptions of them as a scientist (Trujillo & Tanner, 2014) and this was corroborated through elementary student survey responses in the final paper. Students who had higher perceptions of their science identity talked more about how they received positive affirmations from their teachers, whereas students with lower perceptions of science identity did not mention this as frequently and focused more on how teachers were not engaging with them during science class. This extends prior work that highlights the importance of appropriate praise on student academic outcomes (Burnett & Mandel, 2010; Droe, 2013) and demonstrates that calling students scientists may have important implications on their STEM identity.

Finally, across all studies, students' self-efficacy related to their STEM identity; thus, paying attention to how students are viewing their ability to complete tasks or assignments may be important for building a students' STEM identity. Students within the first and third studies expanded upon this idea. Within the first study, engineering students focused on how engaging in hands-on experiences gave them the opportunity to apply course content and gave them more confidence in their abilities to apply their skills and subsequently increased their self-perceptions as an engineer. Within the third study, students with lower science identity highlighted that scientists were people that were smart or good at science and may be feeling like they are not good at science and are not scientists. Students that held high perceptions of themselves as a scientist focused more on the exploration and process of learning new knowledge. Based upon these responses there may be two ways in which educators can help students feel like a scientist. First, incorporating activities that are meeting students at their current level (Shabani et al., 2010) can help increase their science efficacy. Second, emphasizing that you do not yet need to know everything and focusing on the discovery aspect of science may make students feel like they do not need to know all the answers to feel like a scientist.

Future Work

Future work should continue to examine educational practices that may address and tackle barriers that typically marginalized students in STEM face that lessen their feeling like a scientist or pursuing further education and careers in the field. Future work should also continue to apply a developmental lens to the work to understand what components of STEM identity are most salient to students across their educational journey. Using network analyses like the science interest network model (SINM; Sachisthal et al., 2020) may be an important consideration for future work to understand how the different components of a students' identity (perceptions of peers, parents, and teachers, competence, value, interest, career) shift across development. This would subsequently have important implications for how we can best support students. Finally, this work helps to pinpoint important psychological factors that should continue to be studied within the context of students' STEM identity development. Using an interactionist lens, belonging, curiosity, self-efficacy, and other environmental pedagogical factors should be considered in future work that examines ways in which we can support students' STEM identity.

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