Conceptualizing Science Identity:

Its Nature and the Gendered Role It Plays in Early Secondary Students' Science Choices

by

Paulette Vincent-Ruz

B.Sc. Chemical Engineering, Universidad Nacional Autónoma de México, 2013

Submitted to the Graduate Faculty of

the School of Education in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2019

UNIVERSITY OF PITTSBURGH

SCHOOL OF EDUCATION

This dissertation was presented

by

Paulette Vincent-Ruz

It was defended on

May 7, 2019

and approved by

Valerie Kinloch, Ph.D., Dean, School of Education

Tanner LeBaron Wallace, Ph.D., Associate Professor, Psychology in Education

Kevin R. Binning, Ph.D., Assistant Professor, Department of Psychology

Dissertation Director: Christian D. Schunn, Ph.D., Professor, Department of Psychology

Conceptualizing Science Identity:

Its Nature and the Gendered Role It Plays in Early Secondary Students' Science Choices

Paulette Vincent-Ruz, PhD

University of Pittsburgh, 2019

Research on the persistence of minoritized populations within science trajectories has often highlighted identity as a particularly important factor in those choices (Archer et al., 2010; Barton & Calabrese, 2007; Barton et al., 2013; Merolla & Serpe, 2013). However, identity has often been studied from a qualitative perspective or in college populations. To push the field forward by addressing several key open questions, this dissertation consists of three quantitative studies that I argue have deepened and broaden the field of science identity. A central underlying goal of this dissertation is to address the issue of equity in science, with a particular focus on patterns of marginalization through the lens of science identity that emerge in early secondary school, particularly gender. These results are consistent with the lack of representation and power of minoritized populations in science careers. The first empirical paper clarifies the nature of science identity as integrating internal and external recognition components and establishes it as different from other attitudinal variables. The second study provides the framework of topical identity complexes for studying the interaction of different topical identities. The empirical results reveal a surprising finding about which identity complexes involving science are (and are not) found in early secondary student as well as their impact of student's choices. The third study focuses on understanding career affinities of early secondary school students and their relationship to science identity for both science and science-related careers. Finally, I also reflect on the use of quantitative

methods in this work since such methods have been long critiqued for their inability to capture the nuance of everyday experience or further an equity agenda in education.

Table of Contents

List of Tables

List of Figures

Acknowledgements

“Si te quiero es porque sos mi amor, mi cómplice y todo.

Y en la calle codo a codo, somos mucho más que dos” Mario Benedetti

Mi amor, mi mejor amigo, el mejor compañero de vida, esta tesis esta dedicada a ti. Te amo Erich Helleman Holguin.

I’m deeply indebted to Dr. Chris Schunn. Thanks for being the #BestAdvisorEver, over the years you have not only taught me how to be a researcher but also you have been one of my best critics and supporters.

Ross, Marcy and Lana thanks for being not only friends but also family.

The Schunn Lab over the years but specially: Meghan B. (and family), Eben (and Amy), Carmella, And Anita. Anita you made me feel at home in a tough transition will be forever grateful for that.

I would like to express my deepest appreciation to my committee who pushed me and gave me essential feedback that made the dissertation better.

I was blessed with an amazing community of students in my cohort Maggie, Katelynn, Laura, Annie. We grew, cried and learned together and we came stronger in the end.

Thanks to the LSAP faculty for being there at every step of the road. Special mention to Jen Russell that made me believe in my writing on my first semester.

I would also like to extend my deepest gratitude to Dean Valerie Kinloch. Dean Kinloch’s vision that inspired me. It allowed me to believe that it was possible to build an academic community that would welcome those who have been kept on the sidelines for too long.

My success would not have been possible without the support and nurturing of: Lori, Gina, Nik, Shey, Bianca, and Ashley.

To every single worker and staff member at the School of Education and the LRDC. You guys run the ship and make sure it doesn’t sink. Thanks to that I got to nerd with my data.

A mi maravillosa familia. Yo se que no ha sido fácil y no siempre estoy presente pero los amo.

#ChemTwitter thank you for supporting me, believing in me and watching me grow

Clapp Computer Lab all of you became so essential to me in so little time. Neerja, & Alethia #goblin sisters forever.

I am huge believer that as scientists we contribute to building something that we cannot see yet. I can only hope that this dissertation makes its part to make STEM a more welcoming place. And that the bridges I built survive the test of time. To whoever comes after me I hope they continue to be agitators and disruptors. And remember caminante no hay puentes, se hacen puentes al andar.

1.0 Conceptual Overview

"Living on borders and in margins,

keeping intact one's shifting and multiple identity and integrity,

is like trying to swim in a new element, an 'alien' element."

— Gloria E. Anzaldúa

Identity is the core, distinguishing aspect of an individual, and it relates both to the enacting present as well as ''the 'kind of person' one is seeking to be" (Gee, 2017). Identity has been studied across many different disciplines like philosophy, sociology, psychology, political science, among others. This disciplinary diversity has created a wide array of conceptualizations that are often not overlapping. The concept of identity used in this work is positioned in terms of the aspects of self that are malleable and therefore strongly influenced by educational experiences. Further, because identity cannot be separated from the different modalities of power in society, it is the product of the difference and exclusion created by them.

My conceptualization of science identity is focused upon the self-views that emerge from participation in certain activities and self-categorization in terms of membership in particular communities or roles (Stets & Burke, 2001). More generally, research has suggested that science not only involves whether an individual wants to become a "science type person," but also as the socialization of individuals into the norms and discourse practices of science (Brown, 2001). That is, identity is built through an internalization of experiences and is socially constructed with others in a particular context. Science identity is then be enacted through the expression of knowledge and choices people make (Aschbacher, Li, & Roth, 2001). Research on persistence of minoritized populations within science trajectories has often highlighted identity as a particularly important factor on those choices (Archer et al., 2010; Barton & Calabrese, 2007; Barton et al., 2013; Merolla & Serpe, 2013).

The centrality, power dynamics, and complexity of identity make the study of identity critical in education. For example, studying identity is central to understanding the strong guiding effects of gatekeepers and power stakeholders (Gee, 2017). Therefore, it can be a useful lens in particular educational fields like science education where we have failed to support minoritized and marginalized populations and their educational pathways.

The purpose of this chapter is to provide a roadmap for the reader about the three open questions/issues surrounding science identity that are explored in the dissertation. To push the field forward and address some of its current questions, this dissertation consists of three empirical papers, which I will argue have each deepened and broaden the field of science identity (see Figure 1.1 for an overview map). Unlike more traditional dissertations, this overview chapter is brief and does not provide the literature review for each question. In addition to being unwieldy to the reader, a more traditional overview chapter would also be highly redundant with the text found elsewhere in the dissertation: each paper provides its own specific literature and conceptual framework relevant to the specific research questions/ topic at hand.

Before proceeding to the overview summary of each paper, it is important to note that each of the three papers discuss literature suggestions for how to empirically answer the research questions taken up in the paper. Further, all three studies provided detailed analytic rationale for each of the decision-making process from the choice of quantitative methodology, model interpretation, and results discussion. Implicit in each of them is a desire to respond to concerns that have been recently made about the challenges of doing equity-centered work within quantitative methods (Crawford, 2018; Garcia, López, & Vélez, 2017; Gillborn, Warmington, & Demack, 2017; Huber, Vélez, & Solórzano, 2017). In the final chapter of the dissertation, I devote explicit attention to the ways in which the main concerns from the QuantCrit community were addressed (or not) in the dissertation work. Moreover, given the nature of the sample distribution and statistical analysis used on this dissertation, gender will be treated as a binary in the analyses. However, I want to acknowledge the limitations of this conceptualization: First, gender is fluid and is better conceptualized as a spectrum/fluid rather than as specific categories (Zamani-Gallaher, 2017). Second, the acknowledgement of non-binary identity is an important step towards creating safe spaces for LGBTQ students. Third, there is lack of data on understanding LGBTQ school experiences (Ressler & Chase, 2009), and binary conceptualizations further put obstacles on this understanding. Finally, there is a pervasiveness of negative experiences in multiple contexts for LGBTQ youth (Higa, et al., 2012) and it is important that researchers help to surface these concerns as they connect to identity development within specific topics such as science. Early secondary is generally an important stage of identity development and trans and non-binary youth generally face greater vulnerability to a wide range of health, mental health, and social problems (Austin et al., 2009; Blake et al., 2001; Bontempo & D'Augelli, 2002; Cochran, Stewart, Ginzler, & Cauce, 2002; Garofalo, Wolf, Kessel, Palfrey, & Durant, 1998; Perdue, Hagan, Thiede, & Valleroy, 2003; Thiede et al. 2003).

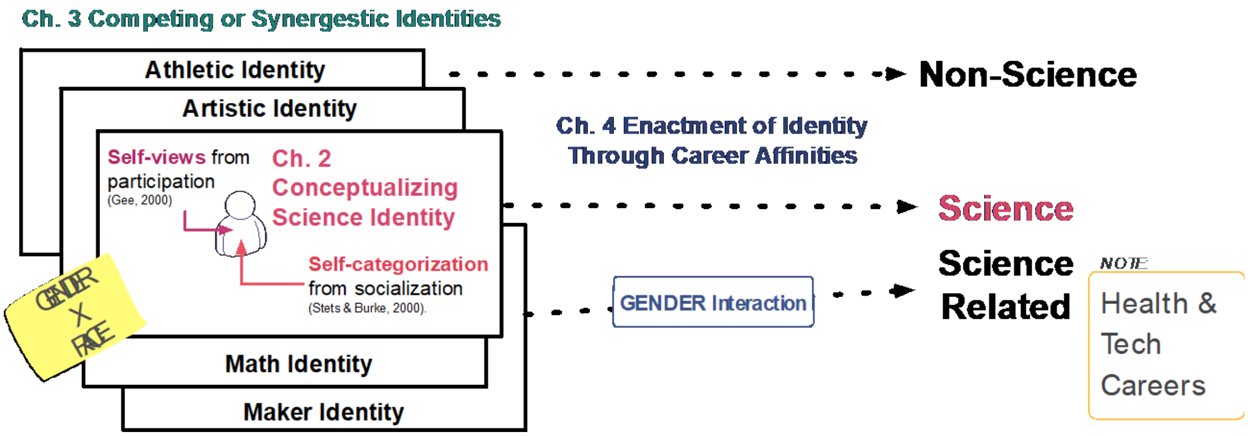

Figure 1.1. Conceptual representation of the three empirical studies addressed by this dissertation and how they are related to each other.

1.1 Chapter 2: Conceptualizing Science Identity

This empirical paper dives into the question of what science identity is and how is it different from other attitudinal factors. This chapter dives into the three main conceptualizations of science identity presented in the literature: 1) *a sense of community and affiliation* (Carlone & Johnson, 2001)*;* 2) *built by consistent extrinsic and intrinsic attitudinal factors* (Aschbacher et. al., 2010); 3) a *match between school science and real science* (Archer et al., 2001). I also discuss the different methods regarding whether identity can only be assessed indirectly through the actions a learner takes (Archer et al., 2010; Barton et al., 2013) or whether it can be assessed through asking learners via surveys about their retrospective internalization of the identity (Barton & Calabrese, 2007). Finally, I present a new conceptualization that science identity consists of two factors: perceived internal and perceived recognized identity. This conceptualization is then subjected to quantitative research focused on validating the claim using psychometric analyses for internal coherence, discriminant validity analyses for separation from other motivational constructions, and predictive validity analyses to show the factors do similar and important work.

1.2 Chapter 3: Science Identity in Competition with Other Possible Topical Identities

Traditionally, topical identities (e.g., math, science, art) have been studied in isolation (Archer, DeWitt, & Willis, 2013), which is problematic if there are important phenomena at the intersection of topical identities. Drawing attention to this possibility, I propose a way of studying science identity and its interaction with other topical identities at a larger grain size: a topical identity complex. An identity complex refers to the bundling of different identities as part of one's core self. Early secondary school is a particularly important stage when multiple identities may develop (Auger, Blackhurst, & Wahl, 2005). I briefly review possible cultural pressures related to race/ethnicity and gender that could shape the formation of these multiple identities (Bagwell, Coie, Terry, & Lochman, 2000; Kahan, Braman, Gastil, Slovic, & Mertz, 2007; Nichols & White, 2014). Most centrally, I note that these cultural pressures may cause students to not feel safe in enacting isolated science identities (Kahan, et al., 2007). I also problematize why these different identities may interact with one another and the whole may have consequences for further participation and choices (Bathgate & Schunn, 2001; Crowley, Callanan, Tenenbaum, & Allen, 2001). A quantitative study examines common identity complexes that occur in early secondary among urban students overall, and then how these complexes are distributed by race/ethnicity, gender, and grade. The study reveals a surprising lack of isolated STEM identities despite the frequency existence of other narrow topical identity complexes. It also tests the impact of these topical identity complexes on student choices.

1.3 Chapter 4: Differential Enactment of Science Identity on Career Affinities

The investigation begins with a focus on the importance of making distinctions between science and science-related careers when talking about worker shortages and equity issues. Centering the need to focus on the importance of diversification of science and science related careers from an equity perspective (Espinosa, 2001; Holdren, Cora, & Suresh, 2013; Wegemer & Eccles, 2002), I discuss the nature of shortages in science, technology and health fields (National Science Foundation, 2015): these fields are very different in distributions by gender despite all being related to science in particular and STEM overall. I also review the literature on career interest and how different researchers have conceptualized it and measured it (Archer et al., 2001; Vincent-Ruz & Schunn, 2001), noting the value of studying career interest via career affinities. The study then consists of a quantitative investigation of relationship of science identity to career interest in science and science-related career affinities. Not only is science identity shown to be relevant in a positive way to all three kinds of careers, but the relationship to two of them is found to be very gender-specific.

1.4 Chapter 5: Critical Use of Quantitative Methodologies

A central underlying goal of this dissertation is to address the issue of equity in science, with a particular focus on patterns of marginalization through the lens of science identity that emerge in early secondary school and are consistent with the lack of representation and power of minoritized populations in science careers. The final chapter of this dissertation presents the argument that indeed quantitative methods can be used to issue equity and justice agendas. This evidence is presented by addressing the five main concerns of the QuantCrit community and discuss the ways in which the empirical work presented here furthers a notion of critical use of quantitative methods as well as its limitations.

1.5 References

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2001). "Balancing acts''': Elementary school girls' negotiations of femininity, achievement, and science." *Science Education*, *96*(6), 967–989. doi: 10.1002/sce.21031

Aschbacher, P. R., Li, E., & Roth, E. J. (2001). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *47*(5), 564–582.

Austin, S. B., Ziyadeh, N. J., Corliss, H. L., Rosario, M., Wypij, D., Haines, J., ... & Field, A. E. (2009). Sexual orientation disparities in purging and binge eating from early to late adolescence. *Journal of Adolescent Health*, *45*(3), 238-245.

Bathgate, M., & Schunn, C. (2001). The psychological characteristics of experiences that influence science motivation and content knowledge. *International Journal of Science Education*, *39*(17), 2402–2432.

Blake, S. M., Ledsky, R., Lehman, T., Goodenow, C., Sawyer, R., & Hack, T. (2001). Preventing sexual risk behaviors among gay, lesbian, and bisexual adolescents: the benefits of gay-sensitive HIV instruction in schools. *American Journal of Public Health*, *91*(6), 940.

Bontempo, D. E., & d'Augelli, A. R. (2002). Effects of at-school victimization and sexual orientation on lesbian, gay, or bisexual youths' health risk behavior. *Journal of Adolescent Health*, *30*(5), 364-374.

Brown, B. A. (2001). Discursive identity: Assimilation into the culture of science and its implications for minority students. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *41*(8), 810–834.

Carlone, H. B., & Johnson, A. (2001). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187–1218.

Cochran, B. N., Stewart, A. J., Ginzler, J. A., & Cauce, A. M. (2002). Challenges faced by homeless sexual minorities: Comparison of gay, lesbian, bisexual, and transgender homeless adolescents with their heterosexual counterparts. *American Journal of Public Health*, *92*(5), 773-777.

Crawford, C. E. (2018). The one-in-ten: quantitative Critical Race Theory and the education of the 'new (white) oppressed.' *Journal of Education Policy*, 1–22. doi: 10.1080/02680939.2018.1531314

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2001). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science*, *12*(3), 258–261.

Espinosa, L. (2001). Pipelines and Pathways: Women of Color in Undergraduate STEM Majors and the College Experiences That Contribute to Persistence. *Harvard Educational Review*, *81*(2), 209–241. doi: 10.17763/haer.81.2.92315ww157656k3u

Garcia, N. M., López, N., & Vélez, V. N. (2017). QuantCrit: rectifying quantitative methods through critical race theory. *Race Ethnicity and Education*, 1–9. doi: 10.1080/13613324.2017.1377675

Garofalo, R., Wolf, R. C., Kessel, S., Palfrey, J., & DuRant, R. H. (1998). The association between health risk behaviors and sexual orientation among a school-based sample of adolescents. *Pediatrics*, *101*(5), 895-902.

Gee, J. (2017). Identity and diversity in today's world. *Multicultural Education Review*, *9*(2), 83–92. doi: 10.1080/2005615x.2017.1312216

Gillborn, D., Warmington, P., & Demack, S. (2017). QuantCrit: education, policy, 'Big Data' and principles for a critical race theory of statistics. *Race Ethnicity and Education*, 1–22. doi: 10.1080/13613324.2017.1377417

Higa, D., Hoppe, M. J., Lindhorst, T., Mincer, S., Beadnell, B., Morrison, D. M., … Mountz, S. (2014). Negative and Positive Factors Associated With the Well-Being of Lesbian, Gay, Bisexual, Transgender, Queer, and Questioning (LGBTQ) Youth. *Youth & Society*, *46*(5), 663–687. https://doi.org/10.1177/0044118X12449630

Holdren, J. P., Cora, M., & Suresh, S. (2013). *Federal STEM education, 5-year strategic plan: a report from the Committee on STEM Education*. 1–30.

Huber, L., Vélez, V. N., & Solórzano, D. (2017). More than 'papelitos:' a QuantCrit counterstory to critique Latina/o degree value and occupational prestige. *Race Ethnicity and Education*, 1–23. doi: 10.1080/13613324.2017.1377416

Perdue, T., Hagan, H., Thiede, H., & Valleroy, L. (2003). Depression and HIV risk behavior among Seattle-area injection drug users and young men who have sex with men. *AIDS Education and Prevention*, *15*(1), 81-92.

Stets, J. E., & Burke, P. J. (2001). Identity Theory and Social Identity Theory. *[Sage Publications, Inc., American Sociological Association]*, *63*(3), 224–237. doi: 10.2307/2695870

Thiede, H., Valleroy, L. A., MacKellar, D. A., Celentano, D. D., Ford, W. L., Hagan, H., ... & Torian, L. V. (2003). Regional patterns and correlates of substance use among young men who have sex with men in 7 US urban areas. *American Journal of Public Health*, *93*(11), 1915-1921.

Vincent-Ruz, P., & Schunn, C. D. (2001). The nature of science identity and its role as the driver of student choices. *International Journal of STEM Education*, *5*(1), 48.

Wegemer, C. M., & Eccles, J. S. (2002). Gendered STEM career choices: Altruistic values, beliefs, and identity. *Journal of Vocational Behavior*, *110*, 28–42. doi: 10.1016/j.jvb.2018.10.020

2.0 Conceptualizing Science Identity

A major concern in science education involves the under-representation of many groups in science and technology fields, especially by gender (Brotman & Moore, 2008; Clark Blickenstaff, 2006), race/ethnicity (Archer, DeWitt, & Willis, 2014; McGee & Bentley, 2017). Particularly, there is the need to understand how major systems of oppression (e.g., racial, heteropatriarchal) hinder development of science related attitudes (Cantú, 2012; Rosa & Mensah, 2016). Among the attitudes connected with under-representation in science, identity has generally received less attention than other attitudinal constructs (e.g., in comparison with interest or self-efficacy) and it has been studied from highly varied disciplinary perspectives (e.g., science education, social psychology, educational psychology, and sociology) with strong conceptual and methodological differences. As a result, there are key open questions about the nature and measurement of science identity. The objective of this study was to quantitatively investigate the nature of science identity in middle-school and high-school students with a focus on what are the components of identity and whether this conceptualization of identity was useful for predicting participation in science at this crucial developmental period.

Identity can be defined as the composition of self-views that emerge from participation in certain activities and self-categorization in terms of membership in particular communities or roles (Stets & Burke, 2000). More generally, when it comes to science identity, research has suggested that it not only involves whether an individual wants to become a "science type person," but also as the socialization of individuals into the norms and discourse practices of science (Brown, 2004). That is, identity is built from internalization from our experiences and socially constructed with others in a particular context.

2.1 The Nature of Science Identity

Researchers have presented three conceptualizations for what drives science identity: 1) *a sense of community and affiliation* (Carlone & Johnson, 2007); 2) *built by consistent extrinsic and intrinsic attitudinal factors* (Aschbacher et. al., 2010); 3) a *match between school science and real science* (Archer et. al., 2010).

2.1.1 A Sense of Community and Affiliation

Youth development can involve a tension between differentiation (how am I different?) and fitting-in (do I match group norms?), especially during adolescence (Kroger, 2003). Many contextual factors shape these interactions, including stereotypes rooted in historical inequities (Schiebinger, 2000). Further, understanding the role of science identity in persistence involves understanding how people negotiate the cultural norms within their community communities and in turn become affiliated with or alienated from science (Stets, Brenner, Burke, & Serpe, 2017). The perceived interactions with others are likely critical in influencing identity development and internalization, particularly via perceptions of how others view them and how these views are built on these systemic inequities. Influential others (family, friends, and teachers/mentors) can play a large role in providing a feeling of community and affiliation, which then shapes identity, especially in early adolescence. An open question, though, is whether this perception of whether influential others view the individual defines their identity or simply acts as one of many attitudes, beliefs, and experiences that influence identity development overall.

2.1.2 Built by Consistent Extrinsic and Intrinsic Attitudinal Factors

Several attitudinal constructs have been linked to science identity. Most commonly, interest (intrinsic motivation) has been linked as a primary driver of science identity: the bigger the science interest, the more solidified the science identity (Maltese & Tai, 2010). Other conceptualizations assume that when interest leads to participation in science pathways and this participation leads to the development career goals, then a science identity exists (Crowley, Barron, Knutson, & Martin, 2015). Furthermore, under expectancy-value theory, science identity can lead to science-related choices when the learner also has strong perceptions about the (extrinsic) value of science and high levels of science self-efficacy or competency beliefs (Eccles, Fredricks, & Baay, 2015).

However, it is important to note that there is disagreement whether the related attitudinal constructs drive identity development or whether these other attitudinal constructs are part of identity. For example, measures of identity often included items closely associated with these other concepts (Chang, Eagan, Lin, & Hurtado, 2016; Hazari, Sadler, & Sonnert, 2013; Trujillo & Tanner, 2014). This raises an important question regarding the nature of science identity: is science identity different from these other attitudinal constructs in that students can be high or low on science identity independently of being high or low on these other attitudes?

2.1.3 Match Between School Science and Real Science

Learners may form a topical identity (e.g., science identity) by comparing their own performance/characteristics with the perceived characteristics of adults associated with the topic (e.g., scientists). The experiences youth have with science in school shape the perceptions they have about their performance/ characteristics. Unfortunately many students perceive a mismatch between what it means to do science in the classroom and what science in real-life entails (Zhai, Jocz, & Tan, 2013), and this mismatch influences identity development (Braund & Driver, 2005; Emvalotis & Koutsianou, 2017; A.-L. Tan, Jocz, & Zhai, 2015; Zhai et al., 2013).

More importantly, most science experiences at this age will come from formal environments rather than informal environments. Informal environments can provide minoritized students with specific opportunities to understand themselves as scientists and have a more realistic experience of how science works (Farland-Smith, 2012). However, there are important concerns about access when it comes to informal environments (Dawson, 2014; Jones, 1998) in the sense that there is not equal access by demographic variables as well as optional experiences producing positive feedback loops that accentuate initially small differences. Thus, it is important to understand the ways in which identity connects to participation in optional experiences (e.g., how robustly is it connected to participation across contexts?).

2.2 Conceptualizing Components of Science Identity

The literature is clear that influential others are likely to be important in the development of science identity for a variety of possible reasons. However, the literature on science identity is inconsistent conceptualizations regarding whether science identity is a latent construct built upon other attitudinal drivers such as interest and external perceptions (Hazari et al., 2013), an expected success from science experience (Barton & Tan, 2010; Trujillo & Tanner, 2014; Wigfield & Eccles, 2000), or an independent construct. The literature is also inconsistent in methods regarding whether identity can only be assessed indirectly through the actions a learner takes (Archer et al., 2010; Barton et al., 2013) or whether it can be assessed through asking learners via surveys about their retrospective internalization of the identity (Barton & Calabrese, 2007). We explore the survey approach, and then apply common psychometric analysis techniques to examine the internal components of identity as well as its independence from other attitudinal constructs to improving understanding of what should be included in such a conceptualization. We also testing its predictive validity—constructs are useful when the organize phenomena. Such foundational construct testing and development work is important when a field of research has relatively high levels of disagreement about the nature of a construct and how it should be measured.

Construct development in a complex domain like science identity should involve a variety of methods, particularly a balance between qualitative and quantitative methods. There have already been many rich qualitative investigations of science identity, especially case studies constructed through semi-structured interviews. For example, Kozoll et al. (2002) and Palmann and Miller (2010) conducted interviews focused on how students' experiences with science influenced their pathways, highlighting the role of identity. Similarly, Archer et al. (2010) connected students' views of science to their aspirations for the future. However, it is not clear whether career aspirations should be taken as synonymous with identity since career aspirations can also be influenced by other, external factors. Gee's (1999) oft-cited definition of identity speaks of "who one wants to become," but this definition is also unclear about when something becomes part of the self. This concern about current vs. career orientation in identity is especially at issue for younger learners who are still many years away from a professional role, and thus a science identity might exist without a commitment to a particular career.

By contrast, Aschbacher et al. (2009) focused more on peer and family expectations of science, arguing for the centrality of these perceived expectations on identity. However, it is unclear whether such expectations are part of an identity or whether they shape identity (Hazari et al., 2010). Clearly the actual expectations that influential others (e.g., family, friends/peers, teachers/mentors) hold are external to the learner and therefore would be factors that shape identity rather than be a component of identity itself. Particularly, these external actors can enact consciously or unconsciously oppressive behaviors leading to an internalization inconsistent to what students perceive a scientist to be (David, 2014; Reynolds & Pope, 1991). In other words, perhaps identity is better conceived as a general construct in which beliefs about identity with components of personal identity and perceived external identities.

Building upon these views of what identity is and does, we propose a conceptualization of identity that draws upon both the internalized view of self and the perceived view of external others regarding one's science identity. The approach builds upon prior work of Hazari et al. (2010), but it was adapted for middle school and early high school. The primary goal was to understand the relationship between internal and perceived external elements of science identity and the independence from other attitudinal measures such as interest or competency beliefs, which others have conceptualized as part of identity.

This question of construct content can be examined from multiple perspectives. The current study focuses on two perspectives that are most effectively conducted through quantitative research: psychometric coherence (i.e., an individual differences construct is meaningful if its components cohere internally and discriminate against other constructs across individuals) and predictive validity (i.e., components form a coherent construct if each of the components does similar work above other attitudinal constructs for the individual). In particular for predictive validity, the second research question examines whether the different components of science identity each underlie preferences towards and actual participation in optional learning experiences.

It is possible that such quantitative measures and analysis obscure meaningful variation by context and subgroup, but such quantitative investigations do highlight patterns that hold across a broader set of learners and contexts. Specifically looking at broad patterns in a particular population reveals whether youth participation in optional science experiences at this age (and in their US, urban context) is only determined by science identity or whether there are important regular interactions of science identity with patriarchal and racist values in science to hinder participation in science.

2.3 Research Questions

1. What are the components of science identity for students at this age that are distinct from other attitudinal constructs?
2. To what extent does science identity predict student's choices overall and separately by gender and race/ethnicity?

2.4 Methods

2.4.1 Participants

Our sample is a subset of the ALES15 dataset (Activated Learning Enables Success 2015). This data was collected by a research team from the Activation Lab (activationlab.org) in a diverse range of public urban schools from two different regions in the United States with approval from the University of Pittsburgh and University of California-Berkeley Institutional Review Boards. The full dataset is longitudinal and includes a wide range of demographic, attitudinal, and experience measures, and is available upon request by contacting the Activation Lab team. The current study uses the subset of schools that participated in both pre and post data collection points reported in this study. The current analyses focus on the science identity scale, which has not been reported elsewhere.

The schools in this study were chosen to represent different historical emphases on STEM and different distributions of ethnicities. Data was collected from recruited 23 seventh grade, and 32 ninth grade classes from 19 public schools, also with widely varying demographics (Minoritized groups in science; 23-99%; Free/Reduced Lunch; 26-84%). Table 1 presents overall demographic characteristics of each group. Overall, the sample is similar to US urban middle school students on key demographic distributions relevant to science education (e.g., sex and race/ethnicity) (Archer et. al 2012, Brown, 2004; Oakes, 1990), except for a slight over-representation of African Americans and under-representation of Hispanic/Latino and Asians (NCES, 2014): 50% White, 25% Hispanic/Latino, 16% African American, and 5% Asian.

Table 2.1. Participant age (in years), sex, and ethnicity information across grades

Grade	Age		% Female	Race/Ethnicity				
	M	SD		% White	% Black	% Asian	% Latinx	% Other
7	13.5	0.6	51%	56%	34%	9%	12%	12%
9	15.4	0.6	50%	49%	41%	10%	11%	11%

Note: Percentages add to more than 100% due to multi-ethnic identities

Sample sizes varied across measures due to student absence across data collection points. The primary sample of this study consisted of 1,322 students. The percentage of missing item data for all the scales employed had a mean of 0.2% and no higher than 4.8% for any item. We therefore did not use data imputation methods since those are typically recommended for datasets with an average of 4% to 15% missing data (Gold & Bentler, 2009). Instead, missing items were dropped from the computation of mean scores, and students simply needed to have at least half the items on a scale for a mean to be computed.

2.4.2 Measures

Four types of constructs were assessed via surveys: 1) *Science Identity*; 2) three other forms of science attitudinal factors to test discriminant validity; 3) two measures of optional science learning experiences to test predictive validity; and 4) multiple demographic measures.

2.4.2.1 Science Identity

The *Science Identity* scale was designed to reveal the components of students' endorsement of a science identity. The scale was adapted from Aschbacher, Li, and Roth (2010) and Hazari, Sonnert, Sadler, and Shanahan (2010), and designed in particular to test whether and which external components of science identity cohere with internal components as a construct: 1) *Perceived Personal Science Identity*, where students with high science identity would see themselves as being the kind of person who is associated with science, and 2) *Perceived Recognized Science Identity*, where they perceive that influential others (friends, family, and teachers) see them in this way (with one item per each of the three influential others). Ratings were given on a 4-point Likert scale (4=YES!, 3=yes, 2=no, 1=NO!).

Psychometric properties of the *Science Identity* items (item means, standard deviations, and EFA statistics) are presented in Table 2. If treated as a coherent scale, the reliability is high (Cronbach alpha = .84, Polychoric alpha, which does not assume the Likert scale is an interval scale, =.88). The sample was split at random to create two independent groups to conduct the exploratory and confirmatory factor analyses (Browne & Cudeck 1993; Robida 2013).

Table 2.2. Mean, SD, and EFA factor loadings of the Science Identity Scale

Survey Items	Mean	SD	Factor Loading
I am a science person	2.3	0.9	0.66
My family sees me as a science person	2.2	0.9	0.85
My friends see me as a science person	2.0	0.8	0.87
My teachers see me as a science person	2.3	0.9	0.63
Total	2.2	0.7	

An exploratory factor analysis (EFA) was conducted on the first random dataset subset and all items loaded into a single factor with acceptable loadings; see Analysis section for more information on the EFA technique. That is, the external items did not separate from the internal item, nor did some of the external items separate from each other. A confirmatory factor analysis (CFA) on the remaining data produced satisfactory levels on all three fit statistics: 1) CFI = 0.99: The comparative fit index (ranging 0 to 1) tests how well the data fits the hypothesized unidimensional scale. Values of 0.95 or above are considered satisfactory; 2) TLI = 0.98: The Tucker-Lewis index (ranging 0 to 1) represents the extent to which the hypothesized model produces a better fit than a null model in which none of the items are assumed to be related to one another. Values of 0.95 or more are considered satisfactory; 3) RMSEA = 0.059: The root mean square error of approximation index (ranging 0 to 1) determines how well our model reproduces the data. Values of 0.06 or less are considered satisfactory (Osborne & Costello, 2009). In sum, internal and all three external identity items cohere strongly as a single scale construct.

Finally, Differential Item Functioning (DIF) analyses were conducted by gender, ethnicity, and age to test for measurement bias or differential functioning by subgroup. For example, it is possible that teacher perceptions are less meaningful in defining identity to older or minority students. Without this test, it would not be meaningful to make comparisons across those subgroups' groups (Gregorich, 2006). Importantly, we did not find any differential functioning by gender, race/ethnicity or age on any of the identity items.

2.4.2.2 Attitudes Towards Science

Attitudes towards science can include ideas, values, beliefs and perceptions regarding the general enterprise of science, school science, or another context where students interact with scientific knowledge and ideas (Gardner, 1975). This study focused upon three commonly implicated constructs in science identity and previously found to be predictors of student choices. For information about the theoretical foundation, development, reliability, and validity of the scales, see (Dorph, et. al., 2016); in each cases, scales were constructed using items that showed adequate psychometric properties for the sample studied.

1) *Fascination* - Fascination in science refers to interest and positive affect towards science, curiosity about the natural world, and goals of acquiring and mastering scientific skills and ideas. The scale (□ =0.83) was computed as a mean across the five items, each involving a four-point Likert scale (e.g. "I need to know how objects work." 4=YES!, 3=yes, 2=no, 1=NO!).
2) *Values* - Values refers to the importance placed on knowing and being able to do science because of its usefulness in meeting personal goals (e.g., fixing a problem at

home) and its utility to society (e.g., solving environmental problems). The scale (α =0.73) was computed as a mean across three items, each involving a four-point Likert scale (e.g. "Knowing science helps me understand how the world works" 4=YES!, 3=yes, 2=no, 1=NO!).

3) *Competency Beliefs* - Competency beliefs are the learner's beliefs about their ability to successfully participate in diverse science learning situations as well as their beliefs about having the core skills of science to have a good performance in specific activities. The scale (α =0.63) was computed as a mean across four items, each involving a four-point Likert scale (e.g. " I can do the science activities I get in class" 4=YES!, 3=yes, 2=no, 1=NO!).

2.4.2.3 Choice Preferences

Choice preferences for optional science learning experiences was measured as a mean of ten items (□=0.85) on a Likert scale. These items ask about students preferences to participate in the future in common optional learning experiences involving science at home, at school, or in other locations (e.g. "I would like to attend a science camp next summer" 4=YES!, 3=yes, 2=no, 1=NO!). The choices ranged from situations that could happen in the immediate future to choices about preferences for the next year.

Science Experiences - To complement the measure of student preferences, students were later asked what actual optional science learning experiences they had experienced in the intervening time since the initial *Science Identity* and other attitudinal measures were collected. The 12 items measured a range of recent experiences that students had recently had, many of which were STEM-related optional experiences. All items were measured on a 4-point Likert regarding amount of exposure to the experience (4=Many days, 3=A few days, 2=One day, 1=Never). These recent experiences were conceptually grouped by location (related to school or at home), based on prior work showing that relative amounts of experiences tended to group this way and had different effects on learners (Liu & Schunn, 2018), and psychometric analyses. The resulting scales were the following:

1. *Formal Recent Science Experiences* during the school year – Measured as the mean across seven items (α =0.72) (e.g., "I did an extra-credit research project for science class"). Formal experiences were defined as optional science learning experiences that were school related (i.e., happened in school after class hours or related to science class) but were not just regular homework activities.

2. *Informal Recent Science Experiences* at home during the school year – Measured as the mean of five items (α =0.77). Informal experiences refer to those experiences related to science that were not closely connected to formal curriculum and where students were free to explore the topics at their own pace (e.g., "I read books about science or science fiction").

2.4.2.4 Demographics

Participants provided basic demographic information, from which variables were derived for sex, age, and race/ethnicity. Students were asked to select among four different gender identities (e.g., boy, girl, trans, non-binary); this study kept only the students that identified as boy and girl given the very low rate of the other two categories. Students were asked to select among six different racial/ethnicity categories with which they identified and were allowed to choose more than one. From this ethnicity data, a binary variable called *Minoritized Students* was created, with a 0 for students who selected only White or Asian, and 1 for students belonging to racial/ethnic groups underrepresented in science.

2.4.3 Data Collection Procedure

Students completed all but one of the surveys early in the Fall semester on paper during one class period as a single packet distributed by members of the research team. The administration procedure was consistent across schools. The demographics questions were given last in the packet to avoid the effect of stereotype threat on attitudinal survey responses (Steele & Aronson, 1995). Students separately completed the survey regarding recent academic year science experiences (informal and formal) early in the Spring semester.

2.4.4 Analyses

Analyses were conducted and reported in the following order corresponding to the two research questions:

1. To understand whether *Science Identity* is different from other attitudinal constructs (discriminant validity), an exploratory factor analysis (EFA) was conducted using all the items from the four attitudinal scales. EFA is a statistical technique that uncovers how survey items should be grouped into empirically-determined clusters according to similar response patterns. Each resulting group is thought to measure a different theoretical construct. In this study, the EFA tests whether the identity items are measuring a construct that is separable from the other three attitudinal constructs. The Factor analysis was

conducted using a Promax Rotation that allows the underlying factors to be correlated, which is almost always the case for attitudinal variables.

2. A multiple regression model was applied to the data to test whether science identity predicted subsequent Student Experience Outcomes (predictive validity) and whether perceived personal and perceived external science identities serve different functions when predicting these outcomes. The model included other motivation constructs as possible predictors to establish the relative strength of identity in predicting student choices (i.e., is identity particularly important for predicting participation). The model also included demographic variables to show that it was identity *per se* rather than correlated demographic factors that predicted participation.

3. A more complex moderation analysis was conducted to understand whether there were differential relationships between science identity and subsequent science experiences across gender and ethnicity. A moderation analysis is a variant of the multiple regression in which interactions terms are added and tested for statistical significance. Moderation refers to when the relationship between two variables depends on a third variable (e.g., science identity may be highly predictive of science experiences for girls but not for boys). For statistical power reasons, the ethnicity analysis focused on white and black students.

2.5 Results

2.5.1 Discriminant Validity: Is *Science Identity* a Separate Attitudinal Construct for Students in 7th and 9th Grade?

The EFA applied to all the survey items from the science identity and attitudinal constructs returned a four-factor solution (four groups that are correlated with one another but are nonetheless distinctly different) in which Perceived Personal *Science Identity* and Perceived Recognized *Science Identity* components closely cohered. *Science Identity* cleanly separated from the other three attitudinal measures without significant cross-loading (no item is loading in multiple factors; see Table 3). In fact, the cross-loadings of the other attitudinal items on the science identity factor were almost all below 0.1 (Costello & Osborne, 2005). The same clean separation occurred with factor analyses conducted separately within each grade, sex, and race/ethnicity (see Appendix for tables). These results suggest that in the middle school and early high school grades:

1) *Science Identity* is psychometrically distinct from the other science attitudinal measures often attributed to identity.
2) Perceived Personal *Science Identity* and Perceived Recognized *Science Identity* cohere strongly into one overall identity construct.

Table 2.3. Exploratory Factor Analysis loadings for Science Identity, Fascination, Values, and Competency Belief survey items. Loadings below .3 are shown in grey font.

Theoretical Construct	Item	Factor 1	Factor 2	Factor 3	Factor 4
Science Identity	I am a science person	0.52	0.15	0.03	0.09
Science Identity	My family thinks of me as a “science person”	0.91	0.01	-0.01	-0.10

Table 2.3 continued

Science Identity	My friends think of me as a "science person"	0.99	-0.03	-0.06	-0.15
Science Identity	My teachers/instructors think of me as a	0.62	0.04	-0.00	0.11
Fascination	After a really interesting science activity is over,	0.06	0.65	0.05	-0.02
Fascination	I need to know how objects work.	-0.10	0.41	0.03	0.20
Fascination	I want to read everything I can find about	0.07	0.76	-0.03	-0.05
Fascination	I want to know everything about science.	-0.01	0.80	0.03	-0.02
Fascination	I want to know how to do everything that	0.06	0.78	0.02	-0.07
Values	Knowing science is important for:	-0.12	0.02	0.72	0.03
Values	Knowing science helps me understand how the	0.06	0.00	0.59	0.08
Values	Thinking like a scientist will help me do well in:	0.03	0.11	0.78	-0.16
Competency	Figuring out how to fix a science activity that	0.29	-0.03	-0.02	0.44
Competency	I think I am very good at coming up with	0.05	0.15	0.02	0.39
Competency		-0.19	0.10	-0.14	0.82

2.5.2 Consequential Validity: Differential Relationships of *Science Identity* to Participation on Optional Science Experiences

To assess whether science identity serves as a critical attitudinal construct (i.e., predicts important learning behaviors), multiple regression tests examined whether it uniquely predicted participation in out-of-school Science Experiences above and beyond established other science attitudinal measures like fascination or competency beliefs. Follow-up analyses tested for similar contributions from each of the internal and external identity components.

Table 4 presents the means, standard deviations, and inter-correlations for each of the predictor and outcome measures. The standard deviation of each of the predictors is sufficiently large that each measure has sufficient variability to serve as an important predictor, and the inter-correlations among the predictors is sufficiently low that there should not be collinearity problems given the size of the dataset (except for overall identity against its two components). Mean and SD were also calculated within subgroups by gender and race/ethnicity to make sure there were no ceiling/floor effects or restricted range issues within a subgroup. Interestingly, the mean differences for *Science Identity* showed relatively small effects although statistically significant and in the expected direction by gender ($\eta 2=0.015$, $p=0.001$) and by race/ethnicity ($\eta 2=0.008$, $p=0.015$).

Table 2.4. Means, SD, and Pearson correlation coefficients among the attitudinal predictors and the optional science learning measures

			Science Identity	Perceived Personal	Perceived External			Competency Beliefs	Choice Preferenc
Identity	2.1	0.7							
Perceived	2.1	0.9	0.81						
Perceived	2.1	0.7	0.97	0.65					
Fascination	2.5	0.6	0.54	0.48	0.51				
Values	2.7	0.6	0.48	0.42	0.45	0.52			
Competency	2.9	0.5	0.47	0.46	0.42	0.50	0.44		
Choice	2.4	0.6	0.44	0.40	0.41	0.48	0.38	0.35	
Formal Science	1.9	0.7	0.23	0.21	0.21	0.20	0.20	0.18	0.32
Informal Science	2.3	0.7	0.30	0.27	0.28	0.32	0.26	0.23	0.61

The multiple regression results are shown in Table 5. Across all three measures of participation in optional science learning experiences, *Science Identity* not only significantly predicted participation (preferred and actual of both types), it was always one of the stronger predictors, and for Informal it was the strongest predictor (Table 5). The relatively weaker predictions for Formal experiences may be explained by relative levels of access (e.g., whether the school provided access and whether the student's family attended museums in general), as suggested by the lower R^2 for the overall model using attitudinal variables. Note that although the predictors were correlated with one another, there were not problems of separating the individual contributions of each predictor in any of the regression models as indicated by relatively low Variable Inflation Factors (VIF). These results suggest:

1) *Science Identity* overall is a strong predictor of students' science related choices
2) *Science Identity* behaves separately from other attitudinal factors and has a unique contribution to our understanding of students' choices.

Table 2.5. Multiple Regressions of attitudinal factors predicting different out-of-school science experiences controlling for sex and race/ethnicity, along with overall model R2 and the largest VIF value in each model

	Choice Preferences		Formal Science Experiences		Informal Science Experiences	
	β	p	β	p	β	p
Science Identity	0.22	<.001	0.15	<.001	0.27	<.001
Fascination	0.27	<.001	0.18	<.001	0.11	0.008
Values	0.09	0.02	0.09	0.04	0.09	0.02
Competency	0.08	0.04	0.04	0.37	0.10	0.008
R^2 Total	0.28		0.13		0.21	
Max VIF	1.75		1.74		1.74	

Table 6 shows the results of the follow-up multiple regressions with separate Perceived Personal and Perceived Recognized scores (along with other attitudinal covariates) in predicting the three measures of participation in science experiences. Most importantly, the standardized beta loadings for Personal and Recognized *Science Identity* are of similar size, arguing against a mediated relationship of Personal *Science Identity* through Recognized *Science Identity*. Moreover, when these analyses were repeated on subsets of the data by sex, race/ethnicity, and their intersection (e.g., black women vs. white women), the same pattern of roughly equal contributions of Personal and Recognized identities were observed (See Appendix for regression tables by subgroup). Overall, these results support a coherent Personal/Recognized *Science Identity* across gender and race/ethnicity subgroups.

Table 2.6. Multiple Regressions comparing Perceived Personal vs Perceived External Science Identity Factors. All models include Fascination, Values, and Competency Beliefs as covariates

Science Identity Component	Choice Preferences		Formal Science Experiences		Informal Science Experiences	
	β	p	β	p	β	p
Perceived	0.10	<.001	0.06	0.090	0.20	<.001
Perceived	0.14	0.002	0.10	<.001	0.11	0.001
R^2	0.28		0.14		0.23	
Max VIF	1.97		1.97		1.97	

Finally, moderation models formally tested whether there were differential relationships of science identity with participation in Optional Science Experiences by gender or race/ethnicity. Overall, interactions with gender were commonly observed, and generally consistent across measure of science identity (see Table 7). Interactions with race were rarely observed, once at the level of perceived personal and once at the level of perceived external.

Table 2.7. Statistical significance of interactions between identity and gender or race in predicting optional preferred and actual Science Experiences across Science Identity types

	Choice Preferences			**Formal Experiences**			**Informal Experiences**		
	Internal	External	Overall	Internal	External	Overall	Internal	External	Overall
Identity x Gender	**	**	**	*		**	**	**	**
Identity x Race					*		*		

p<0.05;p<0.001*

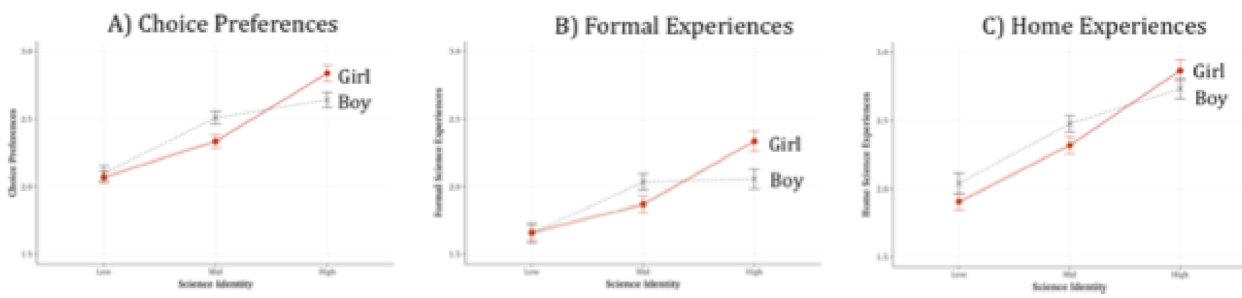

Figure 2.1. Estimated marginal means (with SE bars) of a choice preferences, b formal science experiences, and c home science experiences, predicted by science identity (low, moderate, and high levels) and gender

Given the more consistent pattern of results by gender across identity measures, detailed descriptive statistics are provided for just those interaction effects. Students were binned into three levels of overall *Science Identity* (*binned into equal frequency bins, with 33% of responses in each bin*). The interactions are shown in Figure 2.1.A (Choice Preferences), 2.1.B (Formal Experiences), and 2.1.C (Home Experiences). All three figures show a similar pattern: at moderate levels of Science identity, boys participated more often than girls in optional experiences, whereas at high levels of Science identity, the opposite pattern is observed.

2.6 General Discussion

Understanding student's identity in science is important as it is an important driver of choice in their present and in their future (Barton et al., 2013; Crowley et al., 2015; Hazari et al., 2010). Furthermore, identity is a multicomponent construct through which people internalize experiences, their context, see themselves as members of social groups, and intersect with their personal characteristic (e.g., gender and race). This section revisits each of the primary research questions to discuss the theoretical and practical implications of our findings and how context relates to science identity.

2.6.1 Which Attitudinal Aspects Cohere Within Science Identity?

Many researchers have strongly connected science identity with attitudinal constructs like fascination, values, and competency beliefs (Barton et al., 2013; Barton & Tan, 2010; Brotman & Moore, 2008; Hazari, Sonnert, Sadler, & Shanahan, 2010; Trujillo & Tanner, 2014), and some measures of identity occasional even include items which appear more similar to items typically found in measures of these other constructs (Crowley et al., 2015; Eccles et al., 2015; Trujillo & Tanner, 2014). Critically, the four-factor solution from the EFA analyses revealed that *Science Identity* was psychometrically distinct from the other science attitudinal measures, contrary to the prior conceptualizations of identity as a super-ordinate construct. Moreover, Perceived Personal

Science Identity and the three different Perceived Recognized *Science Identity* elements loaded into a single identity factor. Although some research has argued through qualitative research methods that Perceived Personal and Perceived Recognized factors separate specifically when looking at different ethnic/racial groups (Barton et al., 2013; Rosa & Mensah, 2016), we did not find this separation—in this urban context with middle-schoolers and early high-schoolers, we observed a consistent loading into a single factor across racial/ethnic groups, gender and grade. It is possible that, as students grow older, these factors separate, especially in highly masculine science fields like physics and engineering (Hazari et al., 2013) due to lack of external support and need for a lot of internal resilience. Such possible effects highlight the importance of the context and its likely role on student's internalization of science identity. But, is also important to understand that at least at this age perceived personal and perceived external factors as closely related and these appeared to contribute to students' overall science identities. Furthermore, science identity was the only attitudinal construct that has a strong component influenced directly by the student's context (Perceived Recognized *Science Identity).* Interestingly, at this age there was no evidence of large gaps in students' science identity by any of the examined demographic subgroups or their interaction. It may be that contextual factors commonly associated with students' internalization of negative stereotypes or barriers around gender and race/ethnicity have not become salient at this age in this middle and early high school context.

2.6.2 Is Science Identity Predictive of Student Choices?

Science identity overall was either comparable or a stronger predictor of out-of-school science experiences when compared to other attitudes towards science already associated with making such choices (Dorph, et. al., 2016; Lin & Schunn, 2016). This is an important finding in terms of increasing our understanding of the factors that support students' pathways towards science careers.

Furthermore, although the factor analyses established relatively high covariance of perceived personal and perceived recognized aspects of science identity, these analyses on their own did not establish that both personal and recognized aspects serve similar functions such as the decisions to participate in optional science learning experiences. It was still possible based on those analyses alone, as others have argued (Hazari et al., 2010; Rosa & Mensah, 2016), that perceived external identity influences personal identity, and then personal identity drives participation. However, the follow-up regression analyses revealed that both perceived personal and perceived recognized identities were similarly important in predicting participation in out-of-school science experiences. Moreover, the importance of both aspects in predicting choices were similar across gender, race/ethnicity, and grade. In terms of theory, these results suggest that, at this developmental stage, perceived personal and perceived recognized identities are so closely related that can be measured and understood as a single functional construct. In other words, identity emerges from both views of self and perceptions of how others view the individual, and both elements shape the choices learners wish to make as well as the choices they actually make. More specifically, these perceptions are shaped by students context is highlighted by the coherent and central role of perceived recognized *Science Identity*. This pattern is not only consistent with current understandings of how systemic disadvantages can affect science pathways, but, it may also suggest opportunities for intervention: influential others could be used to change activity patterns and change self-perceptions of identity, leading to further changes in activity.

Finally, although identity mattered (and both aspects of identity mattered) to guide participation in optional science for all subgroups, they did so to differ extents across gender subgroups: for girls, science identity played a greater role in shaping participation in science. Unfortunately, girls also had somewhat lower overall science identities. That is, the groups most dependent upon science identity for participation also had lower overall identities. This pattern partially explains the gap in participation by gender. However, further research is required understand the mechanism underlying the particular patterns that were observed. Most saliently, why was participation lower in girls at moderate levels but greater at high levels of science identity?

2.6.3 Generalizability of the Patterns and Limitations

This study purposely sampled students from diverse public urban schools in one region of the U.S. to understand the nature of science identity and its relationship to personal characteristics (e.g., race and gender) as well as optional science experiences. While the proportion of minoritized youth within the study sample was an overall match to base-rates in US urban public schools, the distribution by more specific subgroups was not (Aschbasher & Roth, 2009). Further, a much larger sample is required to produce truly representative data for urban students in the US, including other regions as well as private, charter, and home-schooled students. Furthermore, a much larger sample would also allow us to draw inferences in other important demographic groups like Latinx students.

Another possible limitation is regarding our choice of grouping of 7th and 9th graders together, as arguably the students could be in very different developmental processes and therefore may internalize science identity differently. However, at both 7th and 9th grade, students experience science for one period per day, and 9th grade is still before students enroll in more advanced science / Advanced Placement (AP) type courses. Additionally, we conducted a variety of validity checks to ensure that the patterns and measures within each of the two grades was similar: 1) a DIF analysis by grade showing measurement invariance; 2) regression analysis separately by grade finding similar patterns; and 3) the Science Identity mean was not statistically different between groups.

Finally, it is important to note that this sample was collected within a formal context. It is possible that patterns of behavior and influence of science identity could look different within informal settings.

2.7 Conclusions and Implications

This study found results consistent with many identity theorists' conceptions of identity as a multicomponent construct (Gee, 2014). The novel contribution to the science identity field highlights the specific multi-component ways in which students endorse science identity in middle school and early high school. At this age in this particular context, across gender and race/ethnicity subgroups, science identity appears to be a cohesive construct conformed by perceived personal and perceived recognized internalizations of science identity. This result is important, because it highlights the importance of students' context on their construction of their science identity. It also creates opportunities for interventions that can have impact overall science identity—via interventions focused on changing perceptions others convey about a students' science identity. Further, although at this age and particular context, there were relatively small differences by gender, race/ethnicity, and age, there was an important finding that science identity has a complex differential function in supporting student's optional science choices by gender. Thus, at this age, developing a strong science identity is especially critical for girls. These findings highlight the importance of looking beyond mean differences across subgroups. These results also demonstrate important findings that quantitative methods can produce to deepen understanding for how attitudinal and identity constructs can have differential effects across subgroups.

2.8 References

Archer, L., DeWitt, J., & Willis, B. (2014). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching*, *51*(1), 1-30. http://doi.org/10.1002/tea.21122

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). “Doing” science versus ‘being’ a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, *94*(4), 617-639. http://doi.org/10.1002/sce.20399

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). “Balancing acts"“: Elementary school girls” negotiations of femininity, achievement, and science. *Science Education*, *96*(6), 967-989. http://doi.org/10.1002/sce.21031

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). “Not girly, not sexy, not glamorous”: primary school girls’ and parents’ constructions of science aspirations 1. *Pedagogy, Culture & Society*, *21*(1), 171-194. http://doi.org/10.1080/14681366.2012.748676

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching*, *50*(4), 564–582. http://doi.org/10.1002/tea.20353

B, C. H., & Angela, J. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187-1218. http://doi.org/10.1002/tea.20237

Barton, A. C., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *Journal of the Learning Sciences*, *19*(2), 187-229. http://doi.org/10.1080/10508400903530044

Barton, A. C., Kang, H., Tan, E., O’Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a future in science: Tracing middle school girls’ identity work over time and space. *American Educational Research Journal*, *50*(1), 37-75. http://doi.org/10.3102/0002831212458142

Braund, M., & Driver, M. (2005). Pupils' perceptions of practical science in primary and secondary school: implications for improving progression and continuity of learning. *Educational Research*, *47*(1), 77-91. http://doi.org/10.1080/0013188042000337578

Brotman, J. S., & Moore, F. M. (2008). Girls and science: A review of four themes in the science education literature. *Journal of Research in Science Teaching*, *45*(9), 971-1002. http://doi.org/10.1002/tea.20241

Brown, B. A. (2004). Discursive identity: Assimilation into the culture of science and its implications for minority students. *Journal of Research in Science Teaching*, *41*(8), 810-834. http://doi.org/10.1002/tea.20228

Cantú, N. (2012). Getting There Cuando No hay camino (when there is no path): Paths to discovery testimonios by Chicanas in STEM. *Equity & Excellence in Education*, *45*(3), 472-487. http://doi.org/10.1080/10665684.2012.698936

Chang, M. J., Eagan, M. K., Lin, M. H., & Hurtado, S. (2016). Considering the impact of racial stigmas and science identity: Persistence among biomedical and behavioral science aspirants. *The Journal of Higher Education*, *82*(5), 564-596. http://doi.org/10.1080/00221546.2011.11777218

Cheryan, S., Plaut, V. C., Handron, C., & Hudson, L. (2013). The stereotypical computer scientist: Gendered media representations as a barrier to inclusion for women. *Sex Roles*, *69*(1-2), 58-71. http://doi.org/10.1007/s11199-013-0296-x

Clark Blickenstaff, J. (2006). Women and science careers: Leaky pipeline or gender filter? *Gender and Education*, *17*(4), 369-386. http://doi.org/10.1080/09540250500145072

Costello, A. B., & Osborne, J. W. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation*, *10*(7), 1-9.

Crenshaw, K. (1991). Mapping the margins: Intersectionality, identity politics, and violence against women of color. *Stanford Law Review*, *43*(6) 1241-1299.

Crowley, K., Barron, B., Knutson, K., & Martin, C. K. (2015). Interest and the development of pathways to science. In *Interest in Mathematics and Science Learning* (pp. 297-313). American Educational Research Association. http://doi.org/10.3102/978-0-935302-42-4_17

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2016). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science*, *12*(3), 258-261. http://doi.org/10.1111/1467-9280.00347

Dorph. R., Cannady, M. A., Schunn, C. D. (2016), How science learning activation enables success for yout in science learning. *Electronic Journal of Science Education,* 20(8), 49-85.

Eccles, J. S., Fredricks, J. A., & Baay, P. (2015). Expectancies, values, identities, and self-regulation. In G. Oettingen & P. M. Gollwitzer (Eds.), *The Jacobs Foundation Series on adolescence* (pp. 30-56). Cambridge, UK: Cambridge University Press.

Emvalotis, A., & Koutsianou, A. (2017). Greek primary school students' images of scientists and their work: Has anything changed? *Research in Science & Technological Education*, *36*(1), 69-85. http://doi.org/10.1080/02635143.2017.1366899

Hazari, Z., Sadler, P. M., & Sonnert, G. (2013). The science identity of college students: Exploring the intersection of gender, race, and ethnicity. *Journal of College Science Teaching*, *42*(5), 82-91. http://doi.org/10.2307/43631586

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M. C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*(8), 978-1003.

Koballa, T. R. (1988). Persuading girls to take elective physical science courses in high school: Who are the credible communicators? *Journal of Research in Science Teaching*, *25*(6), 465-478. http://doi.org/10.1002/tea.3660250604

Kroger, J. (2003). Identity development during adolescence. In G. R. Adams & M. D. Berzonsky (Eds.), *Blackwell Handbook of Adolescence*, (pp. 205-226). Malden, MA: Blackwell Publishing.

Liu, A. S., & Schunn, C. D. (2018). The effects of school-related and home-related optional science experiences on science attitudes and knowledge. *Journal of Educational Psychology, 110*(6), 798-810.

Long, M., Steinke, J., Applegate, B., Lapinski, M. K., Johnson, M. J., & Ghosh, S. (2010). Portrayals of male and female scientists in television programs popular among middle school-age children. *Science Communication*, *32*(3), 356-382. http://doi.org/10.1177/1075547009357779

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education*, *32*(5), 669-685. http://doi.org/10.1080/09500690902792385

McGee, E., & Bentley, L. (2017). The equity ethic: Black and Latinx college students reengineering their STEM careers toward justice. *American Journal of Education*, *124*(1), 1-36. http://doi.org/10.1086/693954

Merolla, D. M., & Serpe, R. T. (2013). STEM enrichment programs and graduate school matriculation: The role of science identity salience. *Social Psychology of Education*, *16*(4), 575–597. http://doi.org/10.1007/s11218-013-9233-7

Lin, P., & Schunn, C. D. (2016). The dimensions and impact of informal science learning experiences on middle schoolers' attitudes and abilities in science. *International Journal of Science Education, 38*(17), 2551-2572. doi: 10.1080/09500693.2016.1251631

Previs, K. K. (2016). Gender and race representations of scientists in *Highlights for Children*. *Science Communication*, *38*(3), 303-327. http://doi.org/10.1177/1075547016642248

Rosa, K., & Mensah, F. M. (2016). Educational pathways of Black women physicists: Stories of experiencing and overcoming obstacles in life. *Physical Review Physics Education Research*, *12*(2), 020113. http://doi.org/10.1103/PhysRevPhysEducRes.12.020113

Schiebinger, L. (2000). Has feminism changed science? *Signs: Journal of Women in Culture and Society*, *25*(4), 1171-1175. http://doi.org/10.1086/495540

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology*, *69*(5), 797-811.

Steinke, J., Lapinski, M. K., Crocker, N., Zietsman-Thomas, A., Williams, Y., Evergreen, S. H., & Kuchibhotla, S. (2016). Assessing media influences on middle school–aged children's perceptions of women in science using the Draw-A-Scientist Test (DAST). *Science Communication*, *29*(1), 35-64. http://doi.org/10.1177/1075547007306508

Stets, J. E., & Burke, P. J. (2000). Identity theory and social identity theory. *Social Psychology Quarterly*, *63*(3), 224-237. http://doi.org/10.2307/2695870

Stets, J. E., Brenner, P. S., Burke, P. J., & Serpe, R. T. (2017). The science identity and entering a science occupation. *Social Science Research*, *64*, 1-14. http://doi.org/10.1016/j.ssresearch.2016.10.016

Tan, A.-L., Jocz, J. A., & Zhai, J. (2015). Spiderman and science: How students' perceptions of scientists are shaped by popular media. *Public Understanding of Science*, *26*(5), 520-530. http://doi.org/10.1177/0963662515615086

Trujillo, G., & Tanner, K. D. (2014). Considering the role of affect in learning: monitoring students' self-efficacy, sense of belonging, and science identity. *CBE-Life Sciences Education*, *13*(1), 6-15. http://doi.org/10.1187/cbe.13-12-0241

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology*, *25*(1), 68-81. http://doi.org/10.1006/ceps.1999.1015

Zhai, J., Jocz, J. A., & Tan, A.-L. (2013). "Am I like a scientist?": Primary children's images of doing science in school. *International Journal of Science Education*, *36*(4), 553-576. http://doi.org/10.1080/09500693.2013.791958

3.0 Science Identity in Competition With Other Possible Topical Identities[1]

3.1 Introduction

A recent report on Women, Minorities, and Persons with Disabilities in Science and Engineering makes clear that science is still far from having an equitable distribution by gender, ethnicities, and disabilities (Foundation & for and Statistics, 2017). In trying to explain differential persistence within science trajectories by demographic factors, many scholars have highlighted having a science identity as particularly important (Archer et al., 2010; Barton et al., 2013). Identity can be generally defined as the composition of self-views that emerge from participation in certain activities and self-categorization in terms of membership in particular communities or roles (Stets & Burke, 2000). Science identity is a *topical identity*, which refers to an identity related to a topic rather than a social or cultural group.

Closely connected to categorization into identities, there are also socio-cultural conditions that shape possible or expected roles of individuals due to personal attributes or characteristics. For example, there are expectations imposed on people due to their gender (Archer et al., 2013) and race (Fordham & Ogbu, 1986). Therefore, an individual's identities are a constant negotiation of their goals, cultural expectations, and the different social identities they chose to endorse. Importantly, one individual has many identities including the possibility of multiple topical

[1] Authors: Paulette Vincent-Ruz, pvincentruz@pitt.edu, Learning Research and Development Center, University of Pittsburgh, Phone: (412) 648-1109, ORCID: 0000-0002-8244-8700. Christian D. Schunn, schunn@pitt.edu, Learning Research and Development Center, University of Pittsburgh, ORCID: 0000-0003-3589-297

identities, henceforth called *identity complexes*. Little is known about which identity complexes tend to occur nor the consequences of endorsing multiple topical identities on later choices and development.

Researching identity complexes is important because before children develop career aspirations, they perceive and internalize ideas about professions, race, and expected social roles from their parents (Archer et al., 2013), the media (Steinke, et al., 2012), and environment (Adams, Gupta, & Cotumaccio, 2014). These pressures may make certain identity complexes more likely to occur overall as well as more (or less) accessible to certain children. The primary objective of the current study is to characterize typical identity complexes and who endorses them among early secondary students. Of particular importance is understanding relative topical complex frequency and their demographic distribution that reflect the overlapping and interdependent systems of disadvantage in science across gender and race (Barton & Tan, 2010; Carlone & Johnson, 2007; Chang, et al., 2011).

3.1.1 Topical Identity Complexes

Topical identity refers to self-classification or perceived recognition as someone that has access and participates in distinctive experiences, practices, and behaviors related to a specific topic.

Topical identities exist at many grain sizes. The ones that have been traditionally studied include discipline-specific topical identities (e.g., math, science, art), sub-discipline level (e.g., physics identity) or research area identities (e.g., high energy physicist). Regardless of the grain-size, particular topical identities are typically studied in isolation (Harrison, Sailes, Rotich, & Bimper, 2011; Kelly-McHale, 2013; Langdon & Petracca, 2010). Indeed, some individuals need to develop a unique topical identity when pursuing elite performance levels. However, the majority of people are likely to have fewer extreme requirements for basic identity development and therefore can develop identities related to multiple topics. An identity complex refers to the bundling of different identities as part of one's core self. Further, this framing recognizes that these different identities may interact with one another and the whole may have consequences for further participation and choices. In this study, we propose a way of studying topical identities at this larger grain size: topical identity complex. Topical identity complexes involve combinations of topical identities within a level (e.g. discipline, subdiscipline); they allow an individual to be multi-faceted and yet not generically everything.

But little is known about the likelihood of nor consequences of endorsing multiple topical identities on later choices and development. Endorsing multiple topical identities could have a synergistic effect around natural clusters like science and math, where the expectations for behaviors and knowledge have a large overlap. Endorsing multiple identities could also have a conflicting effect like art and sports which have little overlap in underlying skills and yet both require of substantial time commitments to reach proficiency. Clashes can also exist if the topical identities are associated with different stereotypical characteristics and behaviors (e.g., introvert or extrovert; physically strong or physically weak). However, having multiple identities could also help people buffer social pressure when endorsing identities that go against cultural expectations. For example, girls that have scientific and artistic identities might use the artistic identity to showcase they do have feminine attributes.

3.1.2 Topical Identity Complexes in Early Secondary School

After primary school, students often transition from the fantasy phase to a phase during which a combination of perceived ability and external messages increasingly influence possible career paths (Auger, Blackhurst, & Wahl, 2005). This increasing role of perceptions of ability and external messages may lead to a narrowing of topical identities (and possible career paths) during the secondary school years. Indeed, from such external messaging, secondary students may endorse a mono-topic identity complex, and likely one that does not involve STEM (e.g., artistic or athletic). However, the environment also includes aspects that could support having multiple topical identities (such as informal learning opportunities), especially ones that include STEM (e.g., STEM+Athletic).

Furthermore, students are required to take science in the early secondary school years, providing opportunities to include science in their topical identity complex despite earlier conceptions built without experience. Specifically, in the American context, early secondary is the specific window of time during which all students learn foundational science content, but it is also before students make elective choices enroll in more advanced science courses. Since identity will likely drive choices in later high school course taking, studying topical identity complexes during this developmental period is important. Further, the use of the topical identity complex as an analytic frame can provide new views on patterns of participation in science, new views on how science identities might grow, and new views of systemic inequities in science. For example, if students have only science or only STEM topics in their topical identity complex, there is no conflict in choices; but if science or STEM typically occur alongside other topical identities, there may be conflict in which choices are made, such as optional course enrollment or after school club participation.

In addition, there may be additional pressures to combine 'unlike' topics. If students have topical identities that generally have negative stereotypes in popular culture (e.g., math and science as 'geeks'), then students might find psychological safety in combining these identities alongside ideas that are more broadly acceptable (e.g., combining science with athletic or artistic identities), particularly if they have demographic identities that are otherwise marginalized in science (e.g., women and some race/ethnicities) (Bagwell, Coie, Terry, & Lochman, 2000; Kahan, Braman, Gastil, Slovic, & Mertz, 2007; Nichols & White, 2014). By psychological safety, we mean being able to show one's self without fear of negative consequences for status or self-image. As a result, our first research question is: *what common topical identity complexes include science in early secondary*? In particular, will there be a STEM-only complex or will science tend to be included in complexes that include non-STEM identities as well?

3.1.3 Additional Key Questions Regarding Identity Complexes

There is an asymmetric relationship between demographic and topical identities: demographic identities tend to be construed long before and independently of any topical identity, but endorsement of topical identities tends to be developed much later and are influenced by demographic identities because of the social component and the unfortunately strong stereotypes in certain topics for demographic associations with who participates in certain experiences (Archer et al., 2012; Chang, et al., 2011; Harrison et al., 2011). Therefore, personal preferences for topical identities may be curtailed by risk perceptions (Kahan, et al., 2007). Based on prior research, it is likely that science identity will be lower in those who are currently under-presented in science (e.g., ethnic minorities and women). However, it is unclear how this will show itself within topical identity complexes. Will the general demographic trends for science identity be equally strong within each topical complex or are some topical complexes relatively more likely among those under-represented in science? In addition, since identities are developing, there may be changes in topical identity complex frequency across grades within secondary science. Therefore, the second research question is: *Are topical identity complexes that include science associated with demographic identities?*

Students are required to take science in the early secondary school years, providing opportunities to broaden identities beyond conceptions built without experience. But these school-based experiences may produce negative reactions for some students. Early informal science experiences have been shown to be an important factor in students' career choices, and many researchers have suggested it as a way to diversify the STEM pool (Barton & Tan, 2010). But there is a chicken-and-egg problem: marginalized populations may be less likely to choose to participate in optional science experiences (Akiva & Horner, 2016). Further, if students have multiple topical identities, it is unclear how these multi-topic identity complexes lead to choices relative to having mono-topic identity complexes. Understanding how students' identities influence their choices is key to the development of interventions, programs, and activities that can increase the diversity of the STEM workforce (Li et al., 2017; Crowley, et al., 2001). This issue leads to the third research question: *In what ways are identity complexes with high science identity related to student's choice preferences and participation in optional science experiences?* Topical identity complexes that include many topics in addition to science may not lead to higher participation in science than complexes that are more narrowly focused on science.

3.2 Research Questions

1. What common topical identity complexes include science in early secondary school?
2. Are topical identity complexes that include science associated with demographic identities (gender, race/ethnicity and grade?
3. In what ways are identity complexes with high science identity related to student's choice preferences and participation in optional science experiences?

3.3 Methods

The primary objective of the study was to identify common identity complexes including and not including science in early secondary students. With the specific goal of understanding relative topical complex frequency and their demographic distribution, quantitative measures of topical identity were obtained and then subjected to latent class analysis to classify individuals into distinct groups based on individual response patterns.

For the secondary goal of testing the consequential validity of identity complexes through examining their relationship to participation in optional science learning experiences, two groups of measures were used: 1) preferences for engaging such experiences; and 2) reports of actual experiences.

3.3.1 Participants

The sample used for analysis is a subset of the ALES15 dataset (Activated Learning Enables Success 2015) that contains information about topical identities, participant demographics, and preferences for/participation in optional science experiences. This dataset was collected in strategically varying public schools in two urban/suburban regions of the United States with different demographic profiles: 1) Pittsburgh, a mid-sized city in the East Coast region with a high proportion of African American students; and 2) the Bay Area, a region in the West Coast with a high proportion of Latino students and recent immigrants. Altogether, there were 20 sixth grade, 45 seventh grade, and 37 ninth grade classes drawn from 23 public schools that represent a range of school configurations (e.g., stand-alone middle schools or high schools vs. 6-12 schools, comprehensive schools as well as topic-specific magnet schools). In terms of demographics, school make-up also varied widely by Race/Ethnicity (Under-represented groups in science: 23-99%) and socio-economic status (students from low income families eligible for Free/Reduced Lunch at school: 26-84%).

Table 1 presents demographic characteristics of each group. Sample size varied across measures due to student absence at different data collection points (across two different points in a school year, separated by at least three months; see Procedures for details). The primary sample of this study, those who completed the identity profile questionnaire and the demographics questionnaire, consisted of approximately 1,200 students. The study was approved by The University of Pittsburgh Institutional Review Board. Students were allowed to opt-out from participating in the surveys. Furthermore, each student was given a passive consent permission slip that explained the research project as well as its implications.

Table 3.1. Within each grade level, mean and SD of participant age (in years) as well as percentages of participants by gender and by race/ethnicity

	Age		% Female	Race/Ethnicity			
Grade	M	SD		% White	% Black	% Asian	% Latinx
6	12.5	0.7	46%	27%	61%	3%	8%
7	13.5	0.6	52%	37%	36%	8%	17%
9	15.4	0.6	50%	21%	55%	7%	16%

3.3.2 Measures

A number of steps were taken to validate all of the instruments. We conducted cognitive interviews (Desimone & Floch, 2004) in which at least 10 students of varying ages engaged in think-alouds to explain their thought process when answering each question. Item wordings were refined to ensure students' thought processes reflected the intended meaning of the items. Second, to support complex statistical analyses, the psychometrics of the instruments needed to be strong (measuring students well across ability levels and age). For all surveys, we conducted Confirmatory factor analyses (CFA), and Item Response Theory analyses (IRT) to ensure validity cross gender, race/ethnicity, and grade. That is, all CFA and IRT analyses were run with the full sample and then by gender, race/ethnicity, and grade to ensure patterns were consistent across subgroups.

3.3.2.1 Identity Profile Questionnaire

The Identity Profile Questionnaire was designed to assess students' endorsement of different topical identity components. The identity items focused on the different components of

STEM as middle and high school students might label them along with the most popular topical identities for those age groups: artistic, musical, and athletic (see Table 2). The scale was adapted from the research of Aschbacher, Li, and Roth (2010) and Hazari, et al., (2010). Students could also select "other" for an identity and write in an open response. There were no commonly occurring specific "other" responses, suggesting the primary topical identities were represented in the instrument. The order of STEM and non-STEM items was purposely mixed to ensure that the discovered topical complexes reflected the content of the items and not simple item order effects. In all, the questionnaire consisted of seven questions with a four-point Likert scale from 1 to 4 with labels at the end points: 1="Not Me" and 4="Exactly Me".

Table 3.2. Percentage of students overall and by grade level endorsing each topical identity

Item	Overall	Grade 6th	 7TH	 9TH
I am a SCIENCE person	41%	48%	39%	36%
I am a MATH person	54%	58%	52%	53%
I am a person who INVENTS or MAKES things	39%	42%	39%	31%
I am a NATURE person	52%	52%	53%	46%
I am an ATHLETIC person	66%	70%	67%	56%
I am a MUSICAL person	53%	47%	54%	57%
I am an ARTISTIC person	53%	49%	54%	55%
Did not endorse any item	3%	3%	2%	2%

This questionnaire was designed with a person-centered approach in mind. In a variable-centered approaches, there is an assumption that the relationship between variables is the product of a homogenous population. In that case, an exploratory factor analysis would often be the method of choice to understand the patterns obtained from these variables. However, given there is the possibility of a categorical presence/absence of endorsement with these items, the underlying assumption of factor analysis of a homogenous, continuously-varying population might be violated (Eye & Wiedermann, 2015). In a person-center approach, the assumption is that the heterogeneity of observed patterns of behaviors may be the product of subpopulations or latent classes (Morin et al., 2011; Sangha et al., 2012).

Table 2 shows the percentage of students that selected answers of 3 or 4="Exactly Me" in each of the items, overall and by grade. All identities were endorsed by a plurality of students overall and at each grade level. The sum across identities is almost 360%; clearly students regularly endorsed multiple identities. The decreasing endorsement of the science identity across grades is consistent with research showing that science-related attitudes often decrease with age (Osborne, Simon, & Collins, 2003; Sorge, 2006).

3.3.2.2 Demographics

Participants provided basic demographic information in a survey that asked them about their gender, date of birth, and race/ethnicity.

- Gender – Students were asked to select among four different options in the question "Which of these bests describes you": 1) boy, 2) girl, 3) Do not identify as girl or boy, 4) prefer not to answer. Students selecting the third and fourth options collectively accounted for 1% of the data. We created a new variable labeled female where 1=girl, 0=boy and removed from the dataset the rest of the students because they were so low in frequency.
- Race – Students were asked to select among six different race/ethnicity categories with which they identified, and they were allowed to choose more than one. Students rarely identified as three or more racial groups or as "other" (less than 1% of the sample). To maximize power of the analysis by race/ethnicity, students were classified by giving priority to the minoritized aspect of their biracial

identity (e.g., if a student identified as white and black, they were classified as black). See Table 1 for Descriptive Statistics.

- Age – Students reported their month and year of birth. We did not collect birth day for improved participant anonymity. Age was calculated using the last day of the month when data collection was finished in the Spring semester as the reference point.

3.3.2.3 Science Choice Preferences

Choice Preferences for optional science learning experiences was measured as a mean across ten items (α=0.85) on a Likert scale (4=YES!, 3=yes, 2=no, 1=NO!). These items provided students with future choices about participating in common optional learning experiences involving science at home (e.g., “Collect rocks, butterflies, bugs, or other things in nature”), at school (e.g., “Be part of a study group for science class”), or in other locations (e.g. "I would like to attend a science camp next summer”). The choices ranged from situations that could happen in the immediate future (e.g., “Watch TV about science topics”) to choices about preferences for the next year (e.g., "Join a science club at school next year"). This measure focuses on the child’s preferences *per se*, rather than a mixture of child preferences, adult preferences, and availability of opportunities that collectively influence the frequency of actual experiences. See Li et al. (2016) for the creation of the construct and Authors (2017) for more details on the validation of this version of the scale.

3.3.2.4 Science Recent Experiences

Across 23 items, students reported on a wide range of recent STEM-related optional experiences they had recently had during the summer (in a fall survey) or fall (in a winter survey).

All items were measured on a 4-point Likert regarding amount of exposure to the experience (4=Many days, 3=A few days, 2=One day, 1=Never). Following prior psychometric work on natural groupings (Authors, 2016), these recent experiences were conceptually grouped by time (summer vs. school year) and by location (related to school, at home, or informal outside the home).

- STEM Camps during the summer – Measured as the maximum value (since long camp experiences can be expensive and therefore competing with other long camp experiences) across three items: a) "I went to a science camp"; b) "I went to a camp about making or engineering"; and c) "I went to a computer programming camp".
- Informal Science Experiences during the summer – Measured as a mean across seven items (α=0.82) that asked about common things students might be able to do on the summer in or near the home (e.g., "I built or took things apart (like motors, computers, clocks, etc.)").
- Formal Recent Science Experiences during the school year – Measured as a mean across seven items (α =0.72) (e.g., "I did an extra-credit research project for science class"). Formal experiences were defined as optional science learning experiences that were school related (i.e., happened in school after class hours or related to science class) but were not just regular homework activities.
- Informal Recent Science Experiences at home during the school year – Measured as a mean of five items (α =0.77). Informal experiences refer to those experiences related to science that were not closely connected to formal curriculum and where students were free to explore the topics at their own pace (e.g., "I read books about science or science fiction").

Table 3.3 shows descriptive statistics and inter-correlations between the optional science preferences and recent experiences scales. Choice Preferences had overall a higher mean than actual participation on science related experiences; for children at this age, it may be more likely that they do not have access to desired experiences than they are taken to experiences they do not want. Furthermore, choices preferences and participation in optional science experiences was correlated but not highly, showing the importance of separately examining each. In general, participation in the various optional science experiences were highly correlated with one another except for the Home Informal experiences, which may be most dependent upon caregiver educational factors.

Table 3.3. Means, standard deviations and intercorrelations of optional science preferences and recent experience scales

Scale	M	SD	Intercorrelations				
			CP	STEM Camp	Summer Informal	School Formal	Home Informal
Choice Preferences (CP)	2.45	0.62	1				
STEM Experiences							
STEM Camp	1.62	1.06	0.20	1			
Summer Informal	1.88	0.66	0.25	0.75	1		
School Formal	1.44	0.78	0.22	0.88	0.80	1	
Home Informal	2.48	0.74	0.37	0.33	0.43	0.35	1

3.3.3 Data Collection Procedure

Students completed paper-based surveys across at two points within a school year, each time as a packet to be completed in one class period by the research team. All but the school-year recent experiences were collected at the first time-point. The demographics survey was given last in the first time-point packet to avoid the effect of stereotype threat on attitudinal survey responses

(Steele & Aronson, 1995). The recent school-year optional science experiences survey was given at a second time-point to enable analyses of identity predicting future events, which provides a better approximation of causality than from measures all collected at the same time point.

3.3.4 Model Building Procedure

Latent Class Analysis (LCA) (Vermunt & Magidson, 2004) was used to reveal different identity complexes using the poLCA package in R (Linzer & Lewis, 2011). LCA is a powerful tool for identifying subgroups through analysis of the structure of relationships among categorical variables. It is similar to exploratory factor analysis (EFA), except that LCA clusters individual respondents into complexes, rather than items into factors (i.e., it is a person-centric grouping technique rather than a variable-centric grouping technique). As with EFA, there are no *a priori* assumptions about number of complexes. For the LCA analyses, the Likert scale responses were converted to a binary where a 0 was assigned to the "Not me" responses (1 & 2) and it was relabeled to "No". A code of 1 was assigned to the "Exactly me" responses (3 & 4) and was relabeled as "Yes". This recoding maximizes sample size per response level and thus the sensitivity of LCA to detect complexes, particularly by demographic subgroups. LCA with small sample sizes can fail to identify a substantively important but low prevalence complexes. Such mischaracterizations have negative consequences for generalizability of results (Collins & Lanza, 2009).

Indeed, running the analysis using all four response levels failed to identify the latent group with the least number of students, although all other results were similar.

To find the optimum number of complexes, the analyst tests different number of complexes and selects the best fitting model using four criteria:

1. Parsimony – Using global fit indices—1) Bayesian Information Criterion (aBIC), which penalizes models with higher number of complexes to account for over-fitting; 2) Akaike Information Criterion (bAIC), which estimates the relative information lost by a given model; 3) And the chi-square goodness of fit (through a likelihood-ratio test) to compare the goodness of fit relative to another model—to identify the best model with the least number of complexes (Cochran, Hruschak, Bacci, Hohmeier, & Tarter, 2017).
2. Entropy – The extent to which the complexes are distinct from one another (Celeux & Soromenho, 1996).
3. Substantiveness – How much meaningful information does an additional complex provide for the analysis (Celeux & Soromenho, 1996).
4. Interpretation – There must be a theoretical basis for the observed complexes (Cochran et al., 2017; Vermunt & Magidson, 2004).

Considering the multiple fit criteria (see Figure 3.1), the LCA revealed that four topical identity complexes provided the optimal fit to the identity data: relatively high entropy and relatively low cAIC, aBIC, and log-likelihood. Note that the model with only five identity theory complexes, close in overall fit statistics and better on Entropy, produced similar complexes to the four-complex model. However, theoretically the five-complex model did not provide additional information about how students endorse these items differently. The difference between the four and five complex model resided on a complex focused on athletic identities. In the five complex model one obtains two athletic focused complexes. In the first athletic complex, students have a 60% chance of endorsing an athletic topical identity and a 9% chance of endorsing a science topical identity. In the second one, students have a 70% chance of endorsing an athletic topical identity and a 26% of endorsing a science topical identity. That is, if we were to choose the model with five complexes, we wouldn't get any additional theoretical or practical insight into students' relationship with different topical identities, only a complex where students are slightly more athletic leaning than the other.

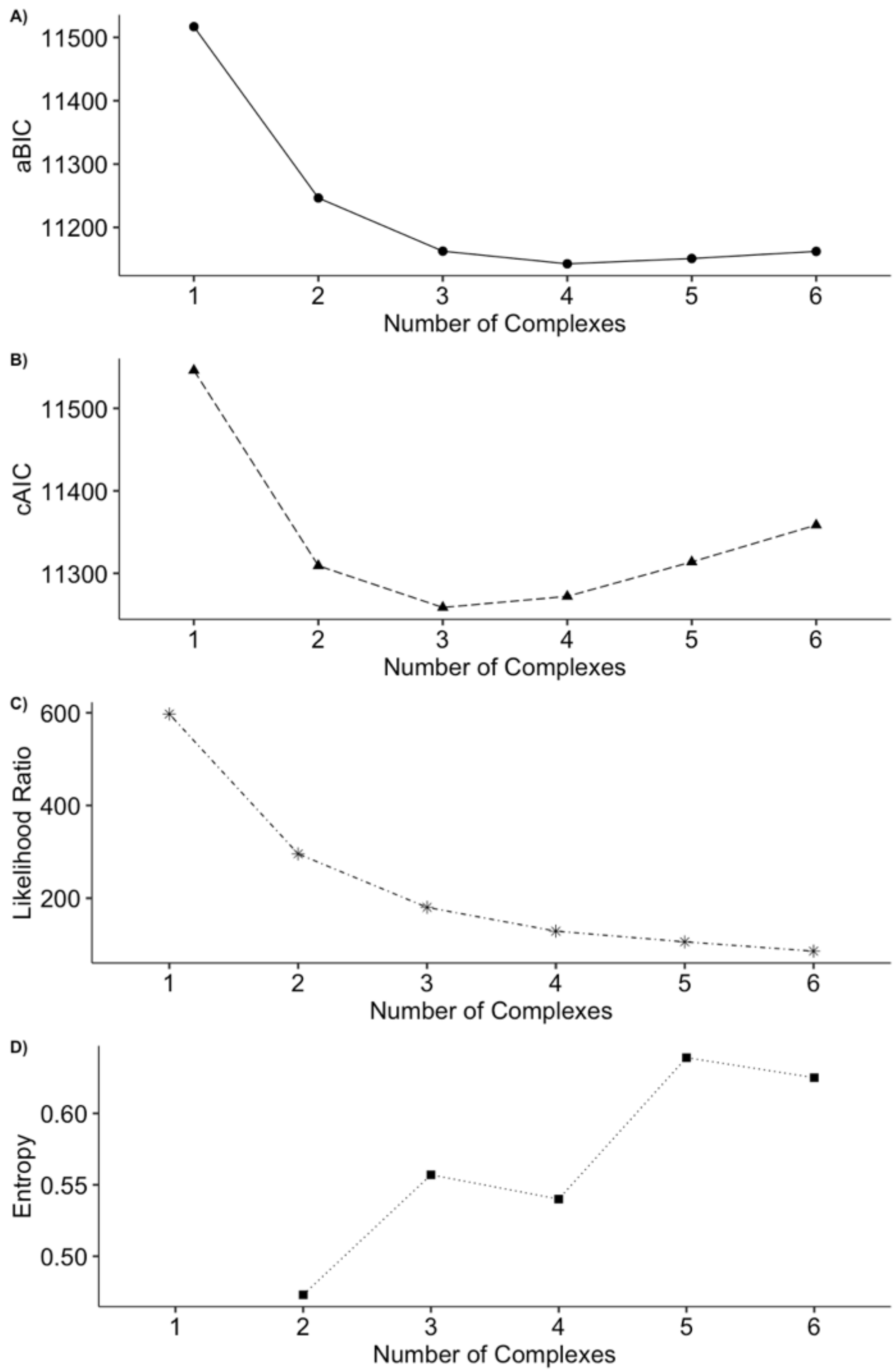

Figure 3.1. Model fit statistics for testing different number of identity complexes. A) aBIC, B) cAIC, C) Likelihood-ratio, and D) Entropy. Lower is better for all but Entropy.

In order to test the effects of gender and race and it is necessary to conduct a Type II Permutational Multivariate Analysis of Variance (PERMANOVA) with the posterior probabilities obtained from the LCA (Anderson, 2008). PERMANOVA and subsequent post-hoc analysis were conducted using the *vegan* package in R (Dixon, 2003). The posterior probabilities in Latent class analysis (LCA) refer to the probability of that observation that is classified in a given identity complex. That is, for each possible complex the students get a probability of belonginess and the total sum across the four possible complexes is 1. Based on this, individuals are classified to the complex with the highest probability. Using posterior probabilities in lieu of the category classification has several advantages: 1) Individuals' posterior probabilities of latent class account for the possible error with which individuals can be assigned to latent classes when they do not fit any latent class perfectly (Lanza, Collins, Lemmon, & Schafer, 2007); 2) Running a multinomial logistic regression (a regression where the complex membership categorical variable is used as the dependent variable) produces biased estimates and incorrect standard errors (Bolck, Croon, & Hagenaars, 2004).

PERMAMANOVA allows testing hypotheses regarding the effect of independent variables (race/ethnicity, gender, and grade) on multiple dependent variables that are correlated with one another (e.g., each of the identity complexes posterior probabilities) rather than assuming the dependent variables are uncorrelated with one another; this approach has greater statistical power. Type II refers to the test of the main effects (of gender, race/ethnicity, and gender). Furthermore, permutational refers to the measure of dissimilarity between the gender, race/ethnicity and grade distributions between identity complexes; the particular measure of dissimilarity used in this case were Bray Curtis distances, which is often used to characterize dissimilarity in population composition (Anderson, 2008). The magnitude of the demographic differences in each identity complex's frequency were computed using Cohen's *d* as a measure of effect size (Lakens, 2013).

3.4 Results

3.4.1 In What Ways is Science Typically Present in Identity Complexes?

The identity component with highest endorsement was "Athletic person," while the lowest identity components were "Science person" and "person who invents or makes things" (as shown in Table 2), reflecting typically-reported emphases on athletics over STEM within US schools (Biddulph, 1954; Guest & Schneider, 2003; Harrison, Sailes, Rotich, & Bimper, 2011; Veliz et al., 2017). However, all identity components were endorsed by a large plurality of students. Importantly, there were enough students endorsing the science identity in particular and STEM identities in general that a science-focused or STEM-focused identity complex could have emerged.

Table 4 presents the make-up of the four complexes provided the optimal fit to the identity data: the average probability of answering yes to each topical identity within each complex. Most saliently, two of the complexes had a narrow topical focus, but none of the complexes focused only on science or only on STEM. Instead, two of the complexes had high levels of science or STEM as part of a multi-topic identity complex.

Table 3.4. Probability of Endorsing each Topical Identity by Topical Identity Complex

Identity Complex	N	Science	Nature	Maker	Math	Athletic	Artistic	Musical
STEM+Athletic+Artistic	167	88%	98%	79%	69%	83%	91%	81%
STEM+Athletic	299	71%	52%	47%	74%	73%	27%	32%
Athletic	408	0%	28%	15%	38%	64%	24%	33%
Artistic	335	30%	53%	36%	43%	55%	91%	82%

Specifically, the four main complexes had the following characteristics:

1. STEM+Athletic+Artistic: This complex had the highest probability of science identity endorsement, but also the highest probability of endorsement of all other identities.
2. STEM+Athletic: This complex represents students with STEM (math, science, nature, and maker) and athletics identities, but not artistic and musical identities.
3. Athletic: Members of this complex had a less than 1% chance of endorsing a science identity and overall tend to identify only with an "Athletic" identity.
4. Artistic: Members of this complex, were only approximately 30% likely to see themselves as having a science identity, instead endorsing musical and artistic identities with very high rates.

The relative frequencies of the four topical identity complexes are shown in Figure 3.2. The first two complexes involve many topical identities (i.e., multi-topic) AND they involved high levels of STEM identity; these were the less common complexes. The last two complexes had levels of only one (or two closely related) topical identity (i.e., mono-topic) AND these did not involve high levels of STEM; these were the two most common complexes.

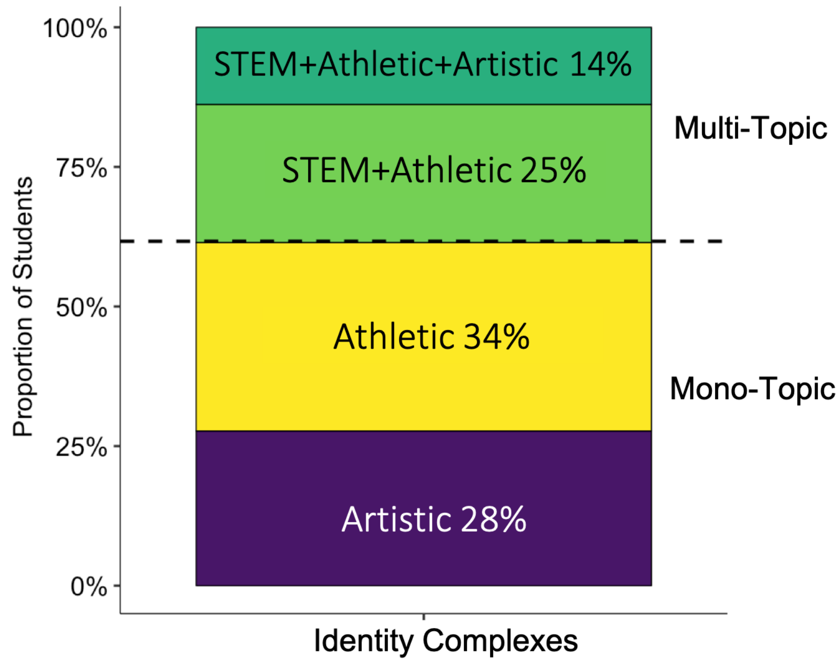

Figure 3.2. Relative frequency of each identity complex

In sum, there was neither a pure Science topical complex nor a pure STEM topical complex, even though almost two thirds of students had complexes that were narrowly focused (on other topics). In other words, students were often narrow in their topical identities, but not commonly in ways that focused on science. Since latent class analysis is sensitive to sample size, we also conducted a simple count of students endorsing only the STEM identities (in any combination). There were 83 such students, representing less than 5% of the sample. These STEM-focused students did not form a coherent complex because the 83 students endorsed different combinations of the science, math, maker, and nature items. For example: just three students endorsed only a Science Identity, and 19 endorsed only a Math identity. Thus, affinities towards STEM came in different forms rather than a unified complex, and all forms were quite rare in this population (e.g., much less common than Artistic-only or Athletic-only complexes).

3.4.2 How are science-related identity complexes distributed across race/ethnicity, gender and grade?

Figure 3.3 presents the mean posterior probabilities of being in each identity complexes as a function of the three key demographic variables. In terms of grade, there was an overall decrease of students being classified on STEM related identity complexes from 6^{th} to 9^{th} grade (Figure 3.3), consistent with the general decrease in the science identity in this data and the general decline in attitudes towards science that are often described in the literature (Osborne, et al., 2003). The identity complexes provide more insight into the nature of the decline. The decline in the STEM+Athletic+Artistic was not statistically significant, while the Athletic STEMer identity complex showed a medium-sized significant decrease (d=0.30, p=0.006). The decline in STEM was matched by an increase in the Artistic identity complex (d=0.36, p=0.006).

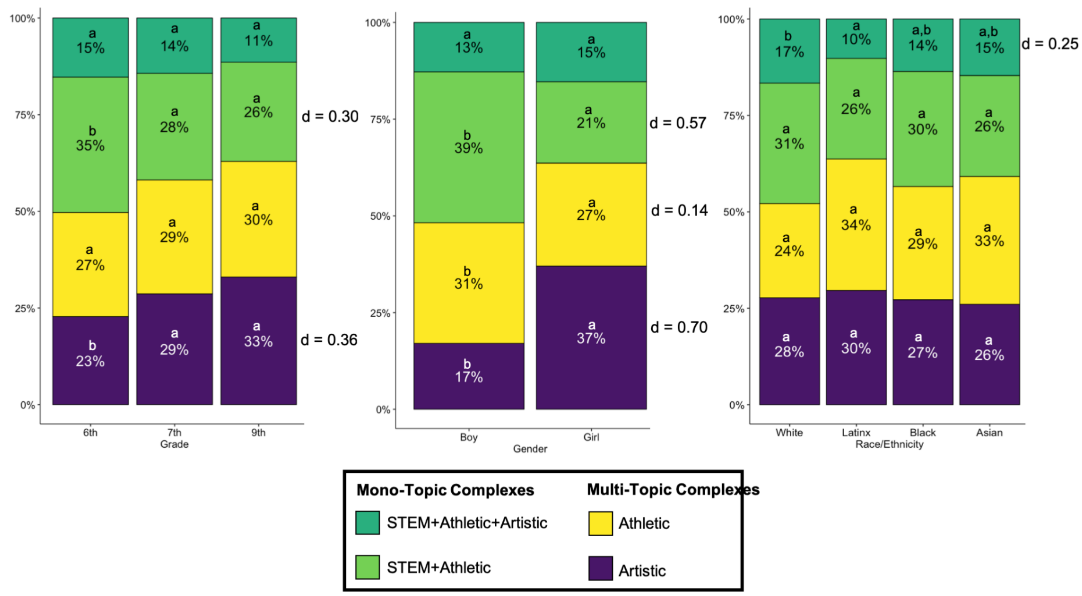

Figure 3.3.[2] Identity Complex distribution across different key variables: A) Grade, B) Gender, C) Race. Cohen's dis reported for statistically significant differences at p<0.01.

Turning to gender (see Figure 3.3), the largest identity complex differences were observed. Girls were overall less likely to be classified into an identity complex related to science, as would be expected by the prior literature. But again, the form of the difference by identity complex is more nuanced. In terms of the STEM+Athletic+Artistic identity complex, the difference between boys and girls is not significant and actually goes in the opposite direction (i.e., girls were higher). Instead, it was specifically within the STEM+Athletic complex that a medium-sized statistically significant effect is observed (d=0.57, p=0.001). The matched higher identity complexes in girls were to be found in the Artistic identity complex (d=0.70, p=0.001). Note there was also a small

[2] Note: When comparing between two demographic categories with a complex (e.g., boys vs. girls for STEM+Athletic+Artistic), statistically significant differences are denoted with different letters (a for the categories within the statistically smaller quantity and b for all the cells with the statistically larger quantity). a,b is use for cases that are in-between, not statistically different from the higher quantity or the lower quantity.

difference in the Athletic identity complex; however, the real pattern is Athletic-related complexes was the large difference in the STEM+Athletic complex.

Finally, the differences by race/ethnicity in probabilities for complexes were less common and smaller. As expected from prior literature (Bentz, & Meskimen, 2001), white students had the highest probabilities in being in one of the two STEM-related identity complexes. But the only significant difference was for the STEM+Athletic+Artistic identity complex suggesting maybe an access issue on the possibility of experiencing many different activities with limited resources. There is a medium size difference between White and Latinx students, where Latinx students were more likely to be in the STEM+Athletic+Artistic identity complex (d=0.25 p=0.01). The rest of the differences were not statistically significant.

3.4.3 Topical complexes and students' participation in out-of-school science experiences

Using Artistic as the reference category, regressions controlling for demographic variables revealed significant associations between identity complexes and optional science learning choices, whether measured by choice preferences or each actual science experience as outcomes (Figure 3.4). Not surprisingly, in all cases, students in both complexes with higher science identity were significantly more likely to want to and actually participate in optional science experiences than students in the complexes with lower science identity (Table 3.5). For example, when compared to the Artistic complex, students in high science identity complexes were more likely to actively prefer these optional experiences and to later have actually experience them. Some of these effects were large: individuals in the STEM+Athletic+Artistic identity complex were much more likely to have informal science experiences in the summer.

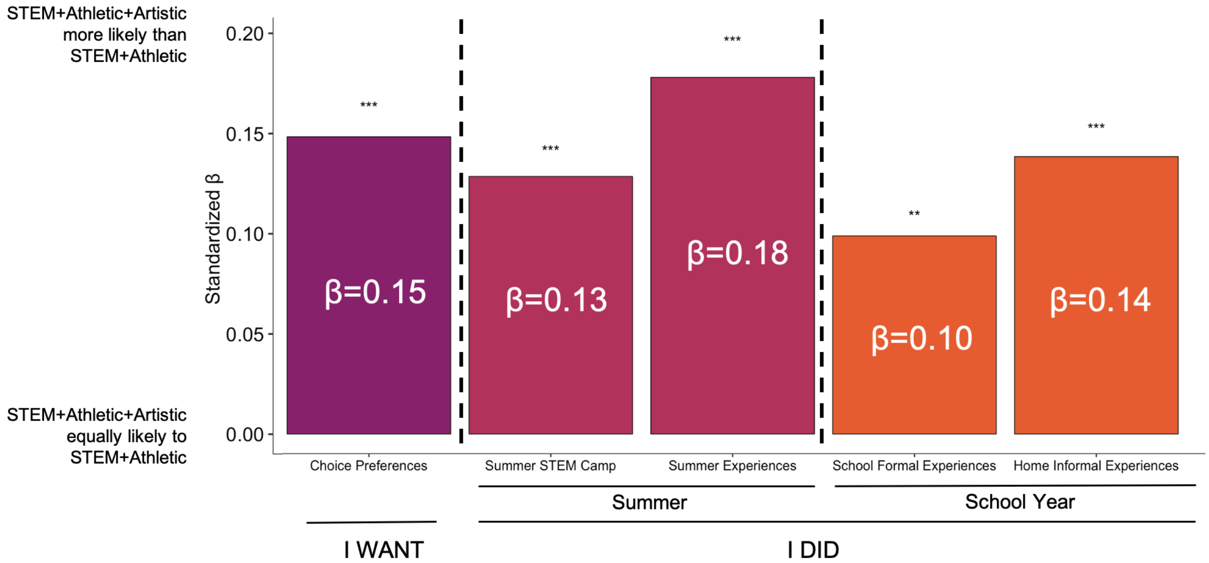

Figure 3.4. Demographic variable associations between identity complexes and optional science learning choices

Table 3.5. Multiple linear regressions of identity complexes predicting Choice Preferences and Optional Science Experiences, with Artistic as the baseline group and controlling for grade, race/ethnicity, and gender effects

	Choice Preferences		**STEM Camp**		**Informal Summer Experiences**		**Formal School Experiences**		**Informal Home Experiences**	
Predictors	*std. Beta*	*p*	*std. Beta*	*p*	*std. Beta*	*p*	*std. Beta*	*p*	*std. Beta*	*p*
STEM+Athletic+Artistic	0.22	**<0.001**	0.18	**<0.001**	0.28	**<0.001**	0.17	**<0.001**	0.21	**<0.001**
STEM+Athletic	0.09	**0.012**	0.07	0.051	0.13	**<0.001**	0.10	**0.012**	0.09	**0.015**
Athletic	-0.11	**0.003**	-0.04	0.243	-0.19	**<0.001**	-0.03	0.495	-0.12	**0.002**
adjusted R^2	0.090		0.046		0.169		0.033		0.090	

More interesting from a topical complexes' perspective is the contrast comparing the STEM+Athletic+Artistic and STEM+Athletic identity complexes: does the All identity involve lower levels of participation in science due to a conflict in time, in available resources, or in commitment? In fact, rather than showing a conflict effect, the reverse pattern was found. As Figure 3 shows, across all optional science experiences, students in the STEM+Athletic+Artistic identity complex were more likely than the STEM+Athletic to want to and to actually participate in them. Interestingly, the effect is equally large in preferences as in actual experiences, suggesting the difference is not just one of students being forced by parents to participate in many forms of activities. The contrast also suggests students are not just falsely listing an unrealistically broad identity because they actually do participate in many activities. However, it is also important to note that these differences were moderate to small—both of these complexes were generally high in optional science participation levels.

3.5 Discussion

Identity has long been considered important to understanding participation or lack therefore in science (Archer et al., 2010; Aschbacher, Li, & Roth, 2010; Barton et al., 2013). This paper explores science identity from a new perspective— science identity as part of a topical identity complex—to provide new insights into who is more likely to endorse a science identity and how science identity in related to choices within a co-occurring competing or synergistic topic identities. Such new insight can support new understandings of how those historically minoritized in science might be more frequently included. We will now revisit each of our primary research questions to discuss the theoretical and practical implications of our findings.

3.5.1 Science Identity Within Topical Identity Complexes

Across a large, diverse sample of learners in urban US early secondary schools, students could be classified into four different topical identity complexes. There were two salient patterns in these results. First, some of these identity complexes matched traditional school cliques with little connection to science that have been previously studied in the literature like jocks (athletes with few other interests) and artists (Barber, Eccles, & Stone, 2001). Collectively, these low science topical identity complexes represented almost two-third of the students, with even higher percentages in under-represented minorities and in girls. Furthermore, these two most common complexes were mono-topical, consistent with the notion that traditional cliques have a lower risk perception (Bagwell, et al., 2000; Kahan, et al., 2007; Nichols & White, 2014). By lower risk perception, we mean that traditional cliques conform with social norms constructed in secondary school, and students at this age are aware that non-conformity has social consequences like exclusion and isolation (Thornberg, 2011). Interestingly, math was relatively high in both of these identity complexes (close to the 50% threshold), even though science was not. This could be explained by the gatekeeper role mathematics has for most educational and economic opportunities (Gresalfi & Cobb, 2006; Moses & Cobb, 2001). That is, it is possible students perceive the need to become members of mathematical communities if they want to have access to future opportunities like college.

Second, despite clear representation as a stereotype in popular media (Kendall, 2011), the latent class analysis did not reveal any kind of pure science or STEM identity complex. Its conspicuous absence may have a number of causes. A very small number of students did endorse only STEM topical identities, but in various unique combinations. That is, even though STEM is usually packaged as a goal for students (Hughes, et al., 2013; Zeidler, 2016), students' topical identities may only align with certain components of STEM. Some students may have career goals that aspire towards traditional science research (Russell, et al., 2007), while others may be interested in more practical applications of science into technology (Diekman, Clark, Johnston, Brown, & Steinberg, 2011) and therefore that will influence their learning choices and in turn their identities. Furthermore, since latent class analysis is sensitive to sample size (Collins & Lanza, 2009), these STEM subgroupings may have been too small to be captured. Finally, it may be that some students do not feel comfortable endorsing science identities or STEM related identities without endorsing at the same time something consistent with social expectations. This pressure may be especially true for girls and racially/ethnic under-represented groups in science (Bucholtz, 1999).

3.5.2 Demographic Variation in Science-Related Topical Identity Complexes

Overall, the observed relative frequencies of topical complexes were consistent with common cultural expectations for both gender and ethnicity (i.e., science-related topic complexes were highest among white males and lowest for females) (Carlone & Johnson, 2007; Chang, et al., 2011). But this study also revealed new patterns regarding the differential ways in which subgroups included science in their identities (e.g., as part of a STEM+Athletic complex for boys) (Kahan, Braman, Gastil, Slovic, & Mertz, 2007; Kendall, 2011). The analyses also revealed the common complexes for each subgroup that did not include science (e.g., athletics for boys and artistic girls), perhaps suggesting topic contexts that are especially likely to support the addition of science (e.g., sports science or STEAM).

Furthermore, this study provided important insights into what additional information is obtained by looking at identity complexes rather than topical identities in isolation. For grade, the decline in the STEM+Athletic complex matched the increase in the Athletic complex as students progressed through early secondary school. This change is consistent with the increasing time commitment that athletics requires of students as they move into late secondary school (Guest & Schneider, 2003; Veliz et al., 2017). And in the US specifically, this time commitment is connected to students' access to athletic scholarships for college (Biddulph, 1954; Harrison, et al., 2011).

In terms of gender, the biggest difference was related to Athletic-related complexes. More importantly, there was an overall difference of boys being more likely to be classified in a science related complex (Archer et al., 2013; Osborne, et al., 2003). However, there was no statistically significant difference in the STEM+Athletic+Artistic complex (with a tendency of girls being higher) while there was a medium-sized difference. The fact that there was such a large difference in the frequency of the Artistic complex suggests that STEAM opportunities could offer a pathway for girls to shift from that complex to the STEM+Athletic+Artistic one (Liao, Motter, & Patton, 2016) rather than Athletic related opportunities

Finally, there was an overall tendency of White students to be more likely to be classified into STEM related identity complexes. The only statistically significant difference was within the STEM+Athletic+Artistic complex, suggesting possibly an access issue for students from less advantaged backgrounds (Akiva & Horner, 2016). These results across ethnicity and gender highlight systems of disadvantage in science across gender (Adams, Gupta, & Cotumaccio, 2014; Archer et al., 2013; Barton et al., 2013; Bucholtz, 1999; Crowley, Callanan, Tenenbaum, & Allen, 2001), where gender at this age is the main driver of differences in identity complexes beyond race and grade.

3.5.3 Identity Complexes and Participation in Optional Science

Replicating previous identity research, students with higher science identities were to have optional science learning experiences (Feldman & Matjasko, 2005; Guest & Schneider, 2003); the current study showed that this relationship is very strong. Turning to the level of topical complexes and participation, it appeared that having multiple topical identities did not appear to create conflict in which experiences students chose to participate (Knifsend & Graham, 2012). In fact, the opposite pattern occurred: students in the STEM+Athletic+Artistic identity complex were more likely to do science than the STEM+Athletic. It may be that these results suggestive of non-competition for participation time occurred because students at this age could still juggle multiple activities. Requirements for many activities may increase with older ages (e.g., sports become more competitive in later high school and therefore more time consuming), and school time becomes more important for their future (e.g., SAT prep, college application processes). Therefore, it is likely that some competition effects will emerge at later ages.

The high participation of the STEM+Athletic+Artistic complex students is a validation of the importance at looking at the relationship of multiple identities. It could have been argued that students falsely endorsed multiple topical identities simply to give responses expected by society or by the researchers. However, if this were the case, there should not have seen a significant relationship between complexes including STEM identities and participation in optional science experiences.

3.5.4 Limitations and Future Directions

This study purposely sampled students from diverse public urban schools in the US to be representative on the dimensions that mattered the most for science identity endorsement (gender, ethnicity). However, a much larger sample is required to produce truly representative data for non-urban students, other regions within and outside the US, as well as including private, charter, and home-schooled students.

A larger sample might also support uncovering relatively rare STEM identities, such as those with and without mathematics, or with and without technology. Such different identity complexes would likely be differentially connected to science-related outcomes (e.g., in medicine, in medicine, in computer science). Larger cross-national samples might also reveal the role of cultural expectations in shaping the types of complexes which include science; athletics may be less central in other countries where competitive athletics is not so strongly represented within the schools themselves.

3.5.5 Implications for Practice

In this study, we found results consistent with general identity theorists' perceptions of identity as a multicomponent construct (Crenshaw, 1991; Stets & Burke, 2000). However, even though researchers studying science identity have indeed included an understanding of learners' characteristics like gender and ethnicity, they have not studied how science identity may compete with other topical identities. Thus, our contribution to the science identity field not only highlights the ways in which students endorse other non-STEM identities at the same time, but it also reveals the ways which these other identities are not detrimental to participation in science. Furthermore, science identities research often uses gender and ethnicity/variables as controls and in isolation, whereas there current study systematically explored both. We found that students with STEM-related identities tended to be White and male, consistent with societal expectations. We also found that students' complex classification tended to be along very gendered ways. However, girls' high endorsement of art identities may serve as a possible introduction to science. STEAM experiences and Maker spaces could introduce girls to the idea of a STEM pathway within a space in which they already feel safe and part of a community (Carlone & Johnson, 2007). This psychological safety aspect can also explain why science identity were found paired with identities that are more socially acceptable in the US like artistic and athletic.

3.6 References

Adams, J. D., Gupta, P., & Cotumaccio, A. (2014). Long-term participants: A museum program enhances girls' STEM interest, motivation, and persistence. *Afterschool Matters*, *20*, 13-20.

Akiva, T., & Horner, C. (2016). Adolescent motivation to attend youth programs: A mixed-methods investigation. *Applied Developmental Science*, *20*(4), 278-293. doi:10.1080/10888691.2015.1127162

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, *94*(4), 617-639.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science, *American Educational Research Journal, 49*(5), 881-908.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). 'Not girly, not sexy, not glamorous': Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society*, *21*(1), 171-194.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching*, *47*(5), 564-582. doi:10.1002/tea.20353

Auger, R. W., Blackhurst, A. E., & Wahl, K. (2005). The development of elementary-aged children's career aspirations and expectations. *Professional School Counseling*, *8*(4) 322-329.

Bagwell, C. L., Coie, J. D., Terry, R. A., & Lochman, J. E. (2000). Peer clique participation and social status in preadolescence. *Merrill-Palmer Quarterly*, *46*(2), 280-305.

Barber, B. L., Eccles, J. S., & Stone, M. R. (2001). Whatever happened to the jock, the brain, and the princess? *Journal of Adolescent Research*, *16*(5), 429-455. doi:10.1177/0743558401165002

Barton, A., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a future in science: Tracing middle school girls' identity work over time and space. *American Educational Research Journal*, *50*(1), 37-75.

Barton, A., & Tan, E. (2010). We be burnin'! Agency, identity, and science learning. *The Journal of the Learning Sciences*, *19*(2), 187 229.

Biddulph, L. G. (1954). Athletic achievement and the personal and social adjustment of high school boys. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *25*(1), 1-7. doi:10.1080/10671188.1954.10624937

Bucholtz, M. (1999). "Why be normal?": Language and identity practices in a community of nerd girls. *Language in Society*, *28*(2), 203-223.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187-1218.

Chang, M. J., Eagan, K. M., Lin, M. H., & Hurtado, S. (2011). Considering the impact of racial stigmas and science identity: Persistence among biomedical and behavioral science aspirants. *The Journal of Higher Education*, *82*(5), 564-596.

Collins, L., & Lanza, S. (2009). The relation between the latent variable and its indicators. *Latent Class and Latent Transition Analysis: With Applications in the Social, Behavioral, and Health Sciences*, 49-76.

Crenshaw, K. (1991). Mapping the margins: Intersectionality, identity politics, and violence against women of color. *Stanford Law Review*, *43*(6) 1241-1299.

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2001). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science*, *12*(3), 258-261.

Diekman, A. B., Clark, E. K., Johnston, A. M., Brown, E. R., & Steinberg, M. (2011). Malleability in communal goals and beliefs influences attraction to stem careers: Evidence for a goal congruity perspective. *Journal of Personality and Social Psychology*, *101*(5), 902-918. doi:10.1037/a0025199

Feldman, A. F., & Matjasko, J. L. (2005). The role of school-based extracurricular activities in adolescent development: A comprehensive review and future directions. *Review of Educational Research*, *75*(2), 159-210. doi:10.3102/00346543075002159

Fordham, S., & Ogbu, J. U. (1986). Black students' school success: Coping with the "burden of 'acting white,'" *The Urban Review, 18*(3), 176-206.

Gresalfi, M., & Cobb, P. (2006). Cultivating students' discipline-specific dispositions as a critical goal for pedagogy and equity. *Pedagogies: An International Journal*, *1*(1), 49-57. doi:10.1207/s15544818ped0101_8

Guest, A., & Schneider, B. (2003). Adolescents' extracurricular participation in context: The mediating effects of schools, communities, and identity. *Sociology of Education*, *76*(2), 89-109.

Harrison, L., Sailes, G., Rotich, W. K., & Bimper, A. Y. (2011). Living the dream or awakening from the nightmare: Race and athletic identity. *Race Ethnicity and Education*, *14*(1), 91-103. doi:10.1080/13613324.2011.531982

Hughes, R. M., Nzekwe, B., & Molyneaux, K. J. (2013). The single sex debate for girls in science: A comparison between two informal science programs on middle school students' STEM identity formation. *Research in Science Education*, *43*(5), 1979-2007.

Kahan, D. M., Braman, D., Gastil, J., Slovic, P., & Mertz, C. (2007). Culture and identity-protective cognition: Explaining the white-male effect in risk perception. *Journal of Empirical Legal Studies*, *4*(3), 465-505. doi:10.1111/j.1740-1461.2007.00097.x

Kelly-McHale, J. (2013). The influence of music teacher beliefs and practices on the expression of musical identity in an elementary general music classroom. *Journal of Research in Music Education*, *61*(2), 195-216.

Kendall, L. (2011). "White and nerdy": Computers, race, and the nerd stereotype. *The Journal of Popular Culture*, *44*(3), 505-524. doi:10.1111/j.1540-5931.2011.00846.x

Knifsend, C. A., & Graham, S. (2012). Too much of a good thing? How breadth of extracurricular participation relates to school-related affect and academic outcomes during adolescence. *Journal of Youth and Adolescence*, *41*(3), 379-389.

Langdon, S. W., & Petracca, G. (2010). Tiny dancer: Body image and dancer identity in female modern dancers. *Body Image*, *7*(4), 360-363.

Liao, C., Motter, J. L., & Patton, R. M. (2016). Tech-savvy girls: Learning 21st-century skills through STEAM digital artmaking. *Art Education*, *69*(4), 29-35. doi:10.1080/00043125.2016.1176492

Moses, R. P., & Cobb, C. E. (2001). *Radical equations: Math literacy and civil rights*. Boston, MA: Beacon Press.

National Science Foundation. (2017). *Women, minorities, and persons with disabilities in science and engineering*. Alexandria, VA: Author.

Nichols, J. D., & White, J. (2014). Friendship cliques: A comparison of the motivational traits of lower/upper track algebra students. *Social Psychology of Education*, *17*(1), 141-159.

Norman, O., Jr, C. R., Bentz, B., & Meskimen, L. (2001). The black–white "achievement gap" as a perennial challenge of urban science education: A sociocultural and historical overview with implications for research and practice. *Journal of Research in Science Teaching*, *38*(10), 1101-1114.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049-1079. doi:10.1080/0950069032000032199

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science*, *316*(5824), 548-549.

Steinke, J., Applegate, B., Lapinski, M., Ryan, L., & Long, M. (2012). Gender differences in adolescents' wishful identification with scientist characters on television. *Science Communication*, *34*(2), 163-199.

Stets, J. E., & Burke, P. J. (2000). Identity theory and social identity theory. *Social Psychology Quarterly*, *63*(3), 224 237.

Thornberg, R. (2011). 'She's weird!'- The social construction of bullying in school: A review of qualitative research. *Children & Society*, *25*(4), 258-267. doi:10.1111/j.1099-0860.2011.00374.x

Veliz, P., Schulenberg, J., Patrick, M., Kloska, D., McCabe, S., & Zarrett, N. (2017). Competitive sports participation in high school and subsequent substance use in young adulthood: Assessing differences based on level of contact. *International Review for the Sociology of Sport*, *52*(2), 240-259. doi:10.1177/1012690215586998

Zeidler, D. L. (2016). STEM education: A deficit framework for the twenty first century? A sociocultural socioscientific response. *Cultural Studies of Science Education*, *11*(1), 11-26.

4.0 Differential Enactment of Science Identity on Career Affinities

Research and policy in science education is has for many decades issued a call to arms in terms of an economic argument about overall STEM-worker shortages (Iammartino, Bischoff, Willy, & Shapiro, 2016; Jang, 2016; Stevenson, 2014; Xue & Larson, 2015). This argument has critical flaws from the perspective of policy, research, and teaching. In brief, the more important issue is lack of equity than overall numbers, the importance is more than simple economic impact, and the treatment of STEM as a whole confuses critical variation (in shortages, cultural expectations, and equity) between science and science-related careers. Here we examine variation by gender in career affinity across science and science-related careers. We test whether that variation in career affinity can be explained in terms of attitudes held in early secondary, especially science identity, that may drive pursuit of each of these careers differentially by gender. That is, whether boys and girls express their science identity differently.

4.1 The Need to Distinguish Science from Science-Related Careers

Many policy documents have referred to the importance of STEM-worker shortages with STEM careers as a monolith. The most famous of these in the US is the policy landmark “A nation at risk” (Gardner, et al., 2001). In another example, (Holdren, Cora, & Suresh, 2013) referred to a need for 1,000,000 more STEM workers in the US by 2023. However, the reality is that the worker shortage presents itself primarily within specific careers and areas (Xue & Larson, 2015). Most saliently, shortages are relatively small in the sciences (a growth of 8% by 2026), and instead the largest shortages are in science-related areas of health (15% growth) and technology (30% growth). Thus, from a workforce shortage perspective, distinctions must be made between science and science-related careers.

In a similar way, many policy documents have called for diversification of STEM overall because of overall STEM worker shortages: one key way to addresses shortages is to draw upon the untapped pools of minoritized groups (Clark Blickenstaff, 2006; VanLeuvan, 2004). It is important to note the problematic nature of treating minoritized groups as individuals who should only be invited into STEM when there is a shortage of white males; instead attention should be given to the clear right for minoritized individuals from participating in well paid (Melguizo & Wolniak, 2011; Olitsky, 2013) and influential positions (Gebbie, Rosenstock, & Hernandez, 2003), as well as the quality of science and engineering innovation (Pless & Maak, 2004), and the quality of health outcomes (Tsugawa et al., 2017) by creating spaces where they can thrive in science and science-related careers. For example, overall health for everyone has been found to improve when female physicians hold important healthcare positions—female physicians are more likely to adhere to clinical guidelines (Kim et al., 2005), are more likely to provide preventive care (Franks & Bertakis, 2003), communicate better with their patients (Roter, Hall, & Aoki, 2002), and have lower mortality rates (Tsugawa et al., 2017).

In any case, there are many reasons for achieving equity in STEM, and, regardless of the reason, STEM must be divided into science and various science-related careers because the marginalization varies substantially across those. For example, aggregate levels of undergraduate degrees in the US are close to parity between women and men in STEM overall, with slightly higher representation in science overall, much lower participation of women in Engineering (e.g., 1:5, National Science Foundation, 2015) and computer science (1:6, National Science Foundation, 2015), and much higher participation of women in health (e.g., 10:1 in nursing and 8:1 on home healthcare positions, Healthcare Advisory Board, 2018, though only 2:5 women are active physicians, Kaiser Family Foundation, 2018). In addition, the underrepresentation of women relative to men in Engineering and computer science can become even more pronounced when focusing on people of color (National Science Foundation, 2015).

Understanding why inequity in STEM participation is observed and therefore creating effective strategies inside and outside the classroom for addressing these outcomes requires understanding this variation across career categories. Overall, the specific nature of shortages and the variation of women preferences by career category suggests studying the causes of inequity in outcomes at the level STEM overall is too course-grained a category. Here we focus more specifically on career interest during early secondary school, one of the important factors found to predict career outcomes in large-scale longitudinal studies (Sadler, Sonnert, Hazari, & Tai, 2001). Is there important variation in this early career interest by gender, does it vary across science and science-related categories, and what underlying motivational factors could explain this variation?

4.2 Early Interest in Science and Science-Related Careers

While seemingly simple, career interest is actually multi-faceted. Career interest can refer to career aspiration (I would like X), career goal (I am trying to be X), or career affinity (I liked careers related to X), and students have different views depending which of those is being asked. Further, students may have different perceptions about the meaning of specific or general career labels (Dorph, Bathgate, Schunn, & Cannady, 2018), such as confusing engineer with building maintenance worker or train operator. Nonetheless, the meaning students attach to these labels, accurate or not, can influence their career-related decisions such as whether to put importance on performance in science class or whether to participate in optional science instruction. For example, the stereotypical engineering career connotation makes women feel like they do not fit-in and that the expectations constrain them (Heyman, Martyna, and Bhatia, 2002). Further, since only some science and science-related careers have low presence in common culture, students in early secondary may not yet know which specific career is of interest despite knowing that they want some kind of career related to science (Dorph et al., 2018). Therefore, in early secondary, studying affinities that students have towards career categories is useful, despite many students not yet having a strong understanding of what specific careers entail or misconceptions of the category labels.

Early career interest can be influenced by many different factors. Specifically, when it comes to science and science-related careers, researchers have found that the major contributors to gender differences in early career interest are: 1) cultural values or pressures (Jacobs, 2005), 2) parental influence (Sonnert, 2009), 3) attitudinal factors (Wegemer & Eccles, 2002), and 4) identity (Hannover & Kessels, 2004). Attitudinal factors in general and identity in particular are especially relevant to science education as those are possible foci of intervention. Early secondary school presents an important developmental period in which to study these factors. At the beginning of secondary, student-teacher relationships change dramatically. Furthermore, it is in secondary school when many students either start studying science formally as part of the curriculum (Speering & Rennie, 1996) or the dosage of science instruction significantly increases (Betancur et al., 2018). Research has also shown that attitudinal factors become increasingly important across grades within secondary school (Rosa & Mensah, 2016; Vincent-Ruz & Schunn, 2017).

Motivational factors that have previously been associated with STEM career preferences (Dorph et al., 2018) include: science fascination (interest, curiosity, and mastery goals for science); science values (endorsing the utility of science for self and society); and science competency beliefs (students' beliefs that they have component competencies of science and can successfully participate in science experiences). Each of these motivational factors have also been found to differ somewhat or substantially in girls and other marginalized youth (P. R. Hernandez, Schultz, Estrada, Woodcock, & Chance, 2013; Wang, 2013).

However, some researchers have argued that identity in particular, a person's recognition that they belong to a social category or group (Hogg and Abrams 1988), should be most strongly associated with career preferences (Hazari et al., 2010; Rosa & Mensah, 2016) because such identification comes with expectations with regards to others and one's behaviors and choices (Stryker, 1980). Further, minoritized individuals report conflict between identifying with science and identifying with their gender and/or racial/ethnic group (Espinosa, 2001). This conceptualization of identity has been found to be predictive of student choices on more proximal choices in time such as free choice learning (Aschbacher et al., 2010; Murdock & Miller, 2003, Vincent-Ruz & Schunn, 2018), generally in a stronger way than other motivational factors (Vincent-Ruz & Schunn, 2018). Therefore, identity should be a strong predictor of career preferences for all individuals, while other factors related to likely enjoyment, value and success likely also matter to an important but lesser extent (Hazari et al., 2010; Holmegaard, Ulriksen, & Madsen, 2014).

But the prediction about the central role of identity in career preferences has not previously been tested in terms of whether identity translates into career preferences for those who are not commonly seen in science and science-related careers. Not only may those who are marginalized in STEM may have lower science identities, they may also be less likely to have science and science-related career goals even when they have a high science identity due to cultural expectations. For example, a female student with a strong science identity may choose her career based on the perceived utility the career has for other personal goals (e.g., interacting with and helping others) (Eccles, 2005). Using that goal as a benchmark, she may shy away from technology careers because she perceives them as isolating and relatively dissociated from communal goals such as helping society and working with others (Hoh, 2009; Diekman et al., 2010). Therefore, it is important to understand that the enacting of identity in the form of a career choice will be constrained by societal factors, particularly their stereotypes about of the kind of people, the work involved, and the values of these fields (Cheryan, et.al., 2015). For example, given the perception of health careers as communal or geared towards helping others (Palumbo, et. al., 2008), we could expect that girls would enact their science identities by choosing health-related careers in the same way that girls may not enact their science identities by choosing technology-related careers.

In sum, this study asks two research questions about the role of science identity in understanding gender differences in career preferences. Despite prior work on the factors influencing career affinities, studies have often lacked datasets that allow them to examine the relative importance of the different factors. Therefore, our first research question is: **RQ1. What are the most important factors that influence career affinity in early secondary school?** To foreshadow the results, science identity is found to be the most important factor. Because the current state and future needs for gender equity highly vary by science, technology-related, and health-related careers and because the motivational factors that drive early career interest may also vary by gender across those career categories, the second question is: **RQ2. Does science identity**

have a differential role for girls versus for boys in supporting science, technology, and health career affinities?

4.3 Methods

4.3.1 Participants

The participants sample is a subset of the ALES15 dataset (Activated Learning Enables Success 2015). This dataset was collected in a diverse range of public urban schools from two different regions in the United States with approval from the University of Pittsburgh and University of California-Berkeley Institutional Review Boards. The full dataset is longitudinal and includes a wide range of demographic, attitudinal, and experience measures, and is available upon request by contacting the Activation Lab (http://activationlab.org). The current study uses the subset of schools that participated in both pre and post data collection points reported in this study. In particular, the current analyses focus on the structure of the career affinity scale and the relationship of the science identity scale to the career affinity scales, which have not been reported elsewhere.

The nineteen schools in this study were recruited to represent different socio-economic levels and distributions of ethnicities: the % of students at school receiving Free/Reduced Lunch ranged from 26% to 84% and the % of students who are Minoritized groups in science ranged from 23% to 99%. Data was collected from 21 sixth grade, 23 seventh grade, and 32 ninth grade classes. Overall, the sample is overall similar to US urban middle school students on key demographic distributions relevant to science education (e.g., sex and race/ethnicity) (Archer et al., 2012), except for a slight over-representation of Blacks and under-representation of Hispanic/Latino and Asians (Kena et al., 2015): 50% White, 25% Hispanic/Latino, 16% Black, and 5% Asian. Participants ages ranged from 10 to 16 years old.

Sample sizes varied across measures due to student absence across data collection points. The primary sample of this study consisted of 1,322 students. The percentage of missing data per item had a mean of 0.2% and was no higher than 4.8% for any item. We therefore did not use data imputation methods since those are typically recommended for datasets with an average of 4% to 15% missing data (Gold & Bentler, 2000). Instead, missing items were dropped from the computation of scale mean scores, and students simply needed to have at least half the items on a scale for a mean to be computed.

4.3.2 Measures

The measures used in this study involved three *Career Affinity* scales, multiple scales of attitudes towards science that are potential predictors of career affinities, and key family context and demographic control variables that have previously been associated with science outcomes.

4.3.2.1 Career Affinities

The career affinities survey captures career preferences even when students may not have settled on a particular career (Dorph, Bathgate, Schunn, & Cannady, 2018), an especially important consideration when dealing with lower secondary students (rather than upper secondary or tertiary students). The survey consisted of seven items on a four-point scale (YES!, yes, no, NO!) asking whether students would like to have a job in science, engineering, mathematics, designing technology, or programming computers, caring for people, or caring for animals (e.g. “In general, would you like to have a job related to: Science"). These seven items were used to create three different affinity scales (Science, Health, and Technology) using the factor scores from structural equation models (see Analysis section for details).

4.3.2.2 Attitudes Towards Science

More generally, attitudes towards science can include ideas, values, beliefs, and perceptions regarding the general enterprise of science, school science, or another context where students interact with scientific knowledge and ideas (Archer et al., 2012; Barton et al., 2013; Liu & Schunn, 2018; Osborne, Simon, & Collins, 2003; Rosa & Mensah, 2016). This study focused upon science identity and three other constructs previously found to be predictors of student choices: science fascination, science values, and science competency beliefs. These scales were developed based upon prior theories and scales, and then subjected to extensive iterative qualitative/quantitative development with student think-aloud interviews, Factor Analysis, and Item Response Theory analyses, including testing for differential functioning by gender, race/ethnicity, and socio-economic status. For this information and prior empirical work using these scales within US urban lower-secondary settings, see: 1) Science Identity (Vincent-Ruz & Schunn, 2018), 2) Science Fascination (Bathgate & Schunn, 2017a), 3) Science values (Bathgate & Schunn, 2017b), 4) Science Competency Beliefs (Vincent-Ruz & Schunn, 2017), and 5) Career affinities (Dorph, et al., 2018). Of particular relevance to the current analyses, prior Item Response Theory analyses were previously conducted to show equal distance between levels on the Likert scales, thereby justifying the use of mean scores. In the current study, scales were constructed using items that showed adequate psychometric properties for the sample.

Science identity. The four-item measure of science identity (Chronbach's α=0.84) is composed of perceived personal and perceived recognized science identity aspects: whether students see themselves and perceive influential others (friends, family, and teachers) to see them as being the kind of person who is associated with science. Ratings were given on a 4-point Likert scale (4=YES!, 3=yes, 2=no, 1=NO!) and are combined into a mean score across the four items.

Fascination. Fascination in science refers to interest and positive affect towards science, curiosity about the natural world, and goals of acquiring and mastering scientific skills and ideas. The scale (α=0.83) was computed as a mean across the five items, each involving one of several four-point Likert scales (e.g. "In general I find science" 4=Very interesting, 3=interesting, 2=boring, 1=Very boring).

Values. Values refers to the importance placed on knowing and being able to do science because of its usefulness in meeting personal goals (e.g., fixing a problem at home) and its utility to society (e.g., solving environmental problems). The scale (α =0.73) was computed as a mean across three items, each involving one of several four-point Likert scales (e.g. "Knowing science is important for" 4=All jobs, 3=Most jobs, 2=A few jobs, 1=No jobs).

Competency beliefs. Competency beliefs are the learner's beliefs about their ability to successfully participate in diverse science learning situations as well as their beliefs about having the core skills of science to have a good performance in specific activities. The scale (α =0.63) was computed as a mean across four items, each involving one of two four-point Likert scales (e.g. "If I were working on a class science project, I could understand the science in books for adults" 4=All, 3=most, 2=some, 1=a little).

4.3.2.3 Family Context and Demographics

Participants provided information about their family context that have previously been associated with science outcomes (e.g., socio-economic status indicators, parental education level, and parental career information) along with other basic demographic information (gender, race/ethnicity, and date of birth).

Home resources and *Family support for learning.* Socio-economic status (SES) is often assessed in research through the convenient indicator of free/reduced lunch status, which is a distal measure of the learning-relevant resources provided in the home. Instead, we included two more direct measures of the socio-economic factors that support science learning. The first such measure is learning-relevant physical resources in the home (α =0.75), which is a mean score across seven items (e.g., Internet, computer, calculator, etc.). The second SES measure focuses on the support the family provides for learning. Family support (α =0.74) consisted of a mean score across five items (e.g., When I work on homework at home, I have someone who can help me with it if I need help).

Parental career topic. Of especially high relevance to student career decisions are the parental careers. Parental career information was collected for each parent. Researchers coded responses to this item into the mutually exclusive categories found in Table 4.1. The categories were created to respond to patterns in STEM-related workforce shortage, levels of required schooling (at least a bachelor or only an Associate's degree), direct vs. indirect inclusion of STEM. Two coders met to discuss the categories, independently coded 200 responses and then met to discuss overlap and disagreement among codes. This procedure was repeated until the inter-rater Kappa reached 0.97.

From this detailed coding, we produced two sets of derived variables used the analyses. The first set was parental career topic, which involved two binary variables: *STEM Career* (STEM professional, STEM middle job/technician, STEM related) of at least one parent, and *Health Career* (health professional and health related) of at least one parent.

Parental career level. The second set of derived variables from the parental career responses was the level of education required for STEM or related careers, since the perceived value of the career may vary by the status and income associated with the career. First, we combined all professional categories (at least one parent with a professional job related to STEM or Health). Second, we combined the technician/middle job data (at least one parent with a technician/middle-job job related to STEM or Health). That is, we created two binary variables: *Professional Job* and *Middle Job*.

Table 4.1. Career goal categories, requirements, and example student responses in each category

Category	Requirements	Examples
STEM jobs (19%)		
STEM professional	Bachelors, masters, doctorate	Scientist, engineer, programmer, astronaut, biotech
STEM technician/middle job	Associate or technical degree; may have BA or advanced degree, but not required	Lab assistant/technician, game designer, computer help, mechanic
STEM-related job	Varies by job	Science teacher, architect, industrial designer; includes high science or technology companies without specifying particular job (e.g. Google, Apple, NASA, science centre)
Health jobs (21%)		
Health professional	Bachelors, masters, doctorate	Doctor, nurse, vet, dentist, pharmacist, psychiatrist; does not include social worker or social services

Table 4.1 continued

Health technician/middle job	Associate or technical degree; may have BA or advanced degree, but not required	EMT, dental hygienist, e-ray tech; includes health locations without listing specific job (e.g. VA hospital, elder care)
Other jobs (89%)	Varies by job	Social services, massage therapy, accountant, artist, humanities

Gender. Students were asked to select among four different options in the question "Which of these bests describes you": 1) boy, 2) girl, 3) Do not identify as girl or boy, 4) prefer not to answer. Students selecting the third and fourth options collectively accounted for 1% of the data. We created a new variable labeled female where 1=girl, 0=boy and excluded the rest of the students because they were so low in frequency.

Race/Ethnicity. Students were asked to select among six different race/ethnicity categories with which they identified, and they were allowed to choose more than one. Students rarely identified as three or more racial groups or as "other" (less than 1% of the sample). For the analysis we created a variable called "Minoritized" where 0 corresponded to white/Asian students and 1 to all the other categories that are minoritized in STEM careers.

Age. Students reported their month and year of birth. Students did not provide birth day for improved participant anonymity. Age was calculated using the last day of the month when data collection was finished in the Spring semester as the reference point.

4.3.3 Data Collection Procedures

Students completed paper-based surveys during science class at two time-points within a school year, each time as a packet distributed and monitored by the research team and to be completed in one class period. All but career affinity was collected at the first time-point (early in the Fall). The demographics survey was given last in the first time-point packet to avoid the effect of stereotype threat on attitudinal survey responses (Steele & Aronson, 1995). The career affinity survey was given at a second time-point (early Spring) to enable analyses of identity predicting future events, which provides a better approximation of causality than from measures all collected at the same time point. There were at least three months between the two time points.

4.3.4 Analysis

The data analysis consisted of three main components, both using Structural Equation Models: 1) determining the best fitting model of career affinity categories (how many different categories, which specific careers belong to each category), 2) examining gender variation in outcomes and inputs within this study population (e.g., establish the phenomenon and possible inputs that produce it), and 3) testing gender-specific models of the relationships of the motivational attitudes to the career affinity categories with and without various control variables.

Validating career affinity categories. To understand the relationship between the career affinity items to career affinity constructs, we ran various Structural Equation Models (SEMs) that made different assumptions about how affinity preferences coalesce into coherent factors. This form of SEM, sometimes called a measurement model, is similar to Confirmatory Factor Analysis (CFA). The key difference between SEM and CFA is that SEM incorporates the relationship among the latent variables as a key part of the analysis and model fit. SEM is used here because it directly represents the correlations among the career affinity factors, and it serves as the foundation for the analyses conducted in the last analysis step. Furthermore, it provides us with information to inform theoretically about our understanding as a field about the relationship of these career affinity variables.

Figure 4.1 presents the four tested SEM models of different groupings of career affinity items to career affinity categories. The best SEM model will be the one that has the best statistical fit while making sense theoretically. Therefore, only conceptually meaningful models were tested. Health was always modeled separately from the rest because despite having overlapping content knowledge, the social messages relating to these careers classify them as different career paths and health careers are often not considered as part of STEM. Model A assumed engineering was related to both Science and Technology affinities. Model B tested whether engineering is predominantly part of Technology affinities while model C tested whether it was predominantly part of Science. Finally, we tested whether a monolithic STEM model would be the best fit for the data.

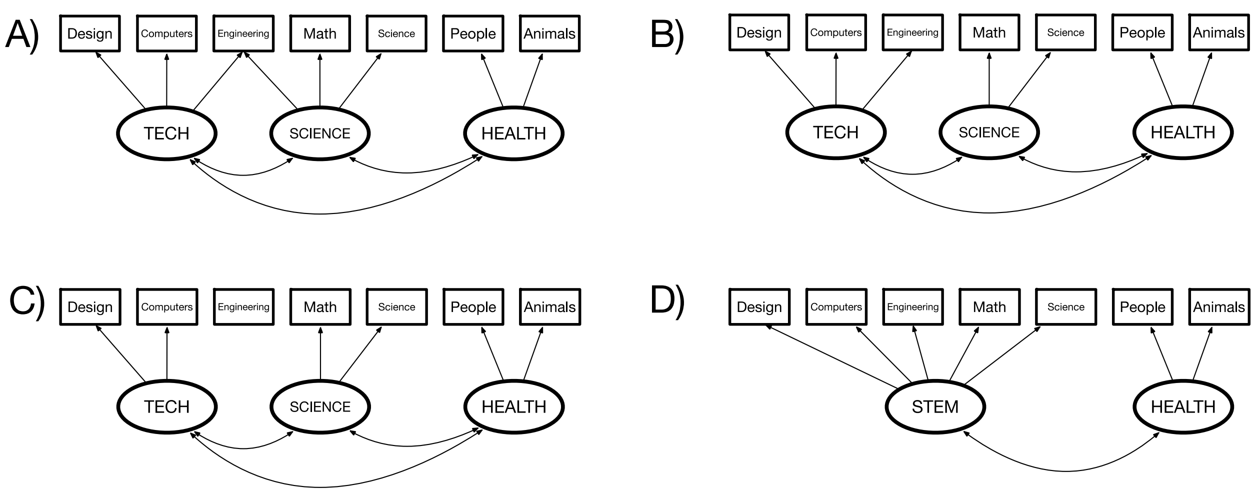

Figure 4.1. Measurement models of the relationship between the different career affinity measures. [3]

[3] Model A) Three factor model with engineering affinity cross-loaded across Science and Technology factors; B) Three factor model in which engineering affinity is only within the Technology factor; C) Three factor model where engineering affinity is only within the Science factor; D) Two factor model that combines all STEM affinities. In all cases, Health career affinities are in their own factor.

We consider three fit statistics that are typically used to assess the SEM models: 1) The Comparative Fit Index (CFI), which tests how well the data the hypothesized unidimensional scale and values of 0.95 or above are considered satisfactory; 2) The Tucker-Lewis Index (TLI), which analyzes the discrepancy between the chi-squared statistic of the hypothesized model and the one of the null model (In the null model, the covariances in the covariance matrix among the latent variables are all assumed to be zero), and ranges from 0 to 1 with values of 0.95 or more considered as satisfactory; and 3) Root Mean Square Error of Approximation (RMSEA), which determines how well the model reproduces the data, and ranges from 0 to 1 with smaller values indicating a better model fit and values of 0.06 or less considered as satisfactory (Osborne & Costello, 2009).

Gender differences in career preferences and potential drivers of career preferences. Having constructed career affinity categories, it was then possible to test the existence and size of gender differences within each category. Simple t-tests and Cohen's *d* were used to test the statistical significance and effect size of the gender differences. For science careers, it was unclear whether there would be gender differences in career affinities at this age. For science-related careers, based upon prior research in degree enrollments and career participation, it was likely that large differences in favors of boys would exist for engineering or technology career affinities and large differences in favor of girls would exist for health career affinities throughout the early middle school to early high school period.

Gender effects were also tested within all the attitudinal and family context variables, again using simple t-tests and Cohen's *d*. Overall gender differences across science and science-related careers could potentially be explained by substantial gender differences in these explanatory variables (formally tested as mediation models on the results section). However, differential gender patterns across different science and science-related careers would require a different form of explanation, which was explored in the next set of analyses.

Relationship career affinities and science identity overall and by gender. In order to test the connections of attitudes to career affinities, SEM models were run. In particular, we used the *sem* function in the *lavaan* package. The settings were set to the "MLR" maximum likelihood estimation with robust (Huber-White) standard errors, which allows for the handling of missing information. The same model fit criteria were used as with the SEM model testing of career categories. Four different models were tested to determine which attitudinal factors predicted each career affinity categories. The models varied which control variables were included. First, we tested a base model that included attitudinal factors, race, family support and home resources. Non-significant attitudinal links were dropped to ensure adequate model fit. Race, family support, and home resources were kept regardless of significance as research has shown these to be critical statistical controls regarding science choices; model fit still was adequate according to the literature recommendations. In the last two models, we added the parental career variables. The second model added only the parental topic variables, but they were not statistically significance. The third model added the parental career level, which appeared to have a stronger influence on career affinities at this age.

Finally, to test whether there was a differential relationship of attitude by gender, multigroup Structural Equation Modeling (MSEM) analyses by gender were conducted, building upon the best fitting overall model.

4.4 Results

4.4.1 Validating Career Affinity Categories

Building upon the pattern of correlations between individual career affinities (See Appendix A for details), the SEM measurement models testing different categorical groupings revealed that while all the models had some support, Model A provided the best fit for both genders. Table 4.2 shows the different fit statistics for each model by gender (see Appendix B, Figure B1 for item loadings). In Model A, there are three career categories (Science, Technology, and Health), and engineering career affinities cross-loaded as part of Science and Technology categories (though more strongly related to the Technology category).

Table 4.2. Fit statistics for the different career affinity measurement models by gender. CFI, TLI and RMSEA used as statistics of model fit. Acceptable values are shown in bold. spilt

	Boys			Girls		
CFA models	CFI	TLI	RMSEA	CFI	TLI	RMSEA
A (Engr. cross-load)	**0.97**	**0.94**	0.07	**0.98**	**0.95**	**0.05**
B (Engr. in tech)	0.94	0.90	0.09	**0.96**	0.94	**0.06**
C (Drop Engr.)	0.94	0.89	0.09	0.93	0.88	0.09
D (STEM)	0.88	0.81	**0.06**	0.91	0.85	0.10

4.4.2 Gender Differences in Predictors and Outcomes

Means on each scale by gender are shown in Table 4.3, excluding parental career which logically could not vary by student's gender. Beginning with career affinities, these preferences at early secondary generally matched current outputs in university degrees. For example, career affinities related to Technology showed a medium-sized gender difference, with boys much more likely to feel an affinity towards these types of careers. Career affinities for Science showed only a small gender difference. Finally, Health careers showed a medium-sized difference in favor of girls.

Table 4.3. Within each gender, mean and SD for the three career affinity factor scores, the four attitudinal variables, and the two family-context variables, along with Cohen's d and t-test statistical significance for each of the gender difference contrasts.

	Boys		Girls		Gender Difference	
Variable	M	SD	M	SD	*p*-value	Cohen's *d*
Career Affinities						
Technology	0.37	1.0	-0.33	0.9	<0.001	-0.70
Science	0.16	1.1	-0.15	1.1	<0.001	-0.28
Health	-0.30	1.0	0.27	1.1	<0.001	0.52
Science Attitudes						
Identity	2.3	0.7	2.1	0.7	<0.001	-0.32
Fascination	2.8	0.5	2.7	0.5	<0.001	-0.26
Values	2.7	0.5	2.6	0.5	0.005	-0.20
Competency Beliefs	2.7	0.4	2.7	0.4	0.15	0.06
Family Context						
Home Resources	3.4	0.5	3.4	0.4	0.27	0.08
Family Support	3.5	0.5	3.5	0.4	0.65	0.03

Turning to the science attitudes and family context variables, three of the attitude variables showed statistically significant but small effects consisting of more positive attitudes in boys. There were no statistically significant family context differences. Overall, differences in Technology and Health career affinity categories were unlikely the result of simple mean differences in science attitudes or family context differences because these differences were all much smaller than those career affinity differences (That is, they don't seem to be explained through a mediation model where gender pressures affects science identity acceptance and in turn that affects career affinity).

The last issue was whether there are important differences in the gender differences in career affinities across grade. Specifically, between 6th graders (transitioning from elementary to secondary school) and 9th graders (transitioning to late secondary school where tracking towards advance science and math courses happen). MANOVA analysis using the factor scores for each career affinity type show that gender has a medium size effect ($p<0.001$, partial-$\eta2=0.18$) while grade only has a small size effect ($p=0.01$, partial-$\eta2=0.01$) (Steyn & Ellis, 2009). The gender differences in technology and health career affinities were relatively stable across these grade levels in early secondary school. The preference for science careers by boys grew across the grades in a statistically significant way, however effect sizes remained small. Appendix B Figure B1 shows the effect size by gender for each career affinity by gender including the confidence intervals of the effect size. To ensure stability of the attitudinal variables we also conducted MANOVA analysis across grade and gender. Interestingly gender differences across science related attitudes increased with age with boys having higher attitudes on average (Appendix B Figure B2). That is, career affinity is more stable, and science related attitudes are more malleable in early secondary school.

4.4.3 Relationship of Attitudes and Parental Careers to Career Affinities

In terms of simple correlations with career affinity, we found that all attitudes towards science are significantly correlated with each of career affinities, but to varying degrees (See Table A2). All of the science attitudes were also correlated with each other (especially Science Identity with Fascination and Fascination with Values), therefore requiring multivariate analyses to tease apart the unique relationships to career affinities. Importantly, none of attitude intercorrelations are strong enough to cause multi-collinearity issues in the multivariate analyses. Family context variables were generally not significantly correlated with career affinity categories (see Table A3), except for very small correlations of the science career with family support, parents' professional job, and parents' middle job. Since some of the intercorrelations among these family context variables are high (see Table A3), separate models needed to be tested in the next step including only subsets of the variables.

The SEMs testing which attitudinal and family context variables were important, unique predictors of career affinities are shown in Table 4.4. The first model, including only attitudinal variables, reveals that Science Identity is the strongest predictor of career affinities above and beyond other attitudinal variables. In the models adding family context variables, Science Identity remains the most important predictor, with small contributions of parental career topic or level. Since parental career level was a stronger predictor than parental career topic, that model formed the base model for the analysis of interactions with student gender, presented next.

Table 4.4. Standardized coefficients (statistically significant cases only) from Structural Equation Models for A) attitudinal variables, B) attitudinal variables and parental career, and C) attitudinal variables and educational level for the relationships with each career affinity factor.[4]

	1)Attitudinal Only			2)Attitudinal + Parent Topic			3)Attitudinal + Parent Professional Level		
Predictors	Tech	Science	Health	Tech	Science	Health	Tech	Science	Health
Science Attitudes									
Identity	0.15*	0.43**	0.09*	0.15*	0.42**	0.10*	0.16*	0.42**	0.11*
Fascination	0.18**			0.18**			0.18**		
Values		0.11*			0.11*			0.11*	
Competency Beliefs									
Parent Career									
Parents STEM				0.11					
Parents Health				-0.14*					
Parents Professional								0.27*	
Parents Middle-Job							-0.24*		
Other Key Contexts									
Race/Ethnicity									
Family Support									
Home Resources									
CFI		0.98			0.96			0.97	
TLI		0.96			0.94			0.95	
RMSEA		0.05			0.05			0.05	

[4] Race/ethnicity and family context variables were included in all models. **p<0.001, *p<0.05. Tested but not statistically significant relationships are suppressed. Gray shading refers to variables not included in a given model.

4.4.4 Differential Effect of Science Identity by Gender

One would expect that differences in career affinities by gender would be mediated by science attitudes. That is, the reason girls have less career affinity towards science careers is because they have lower science attitudes on average. We tested the mediation mechanism with each science attitude using Structural Equation Modeling. Results are presented on Table 4.5. Science Identity and the other attitudinal variables are indeed mediators of the relationship between gender and science career affinity. However, that is not the case for the other career affinities. That is, the gender differences we observe in Technology and Health career affinities are not explained through a mediation mechanism. We hypothesized whether the differences we were observing on career affinities were due to a differential expression of science identity given the gendered expectations surrounding technology and health careers.

Table 4.5. Standardized coefficient of gender in SEM models predicting the different career affinities. 1) Coefficient without mediators, models 2-5) Coefficient of the direct gender effects to career affinities accounting for the indirect effect of the correspondent attitudinal variable.

	1) No Mediator	2) Science Identity	3) Fascination	4) Values	5) Competency Beliefs
Career Affinity					
Technology	-0.34***	-0.31***	-0.31***	-0.33***	-0.34***
Science	-0.14**	-0.02	-0.05	-0.10**	-0.11**
Health	0.36***	0.40***	0.40***	0.37***	0.37***

** p<0.05, ***p<0.001

The MSEM analyses repeating the measurement model and prediction models by gender revealed a number of important similarities and differences by gender. First, we consider the relationships among the career categories. Interestingly, across both genders (and actually for all measurement models that were tested), factor scores for each of the career affinity categories were positively correlated with one another. Thus, Science, Technology, and Health career goals are more synergistic than competing during this developmental period. However, the correlations between career factors varied somewhat by gender. Boys conceptualized all three career affinity factors as closely related to each other (Figure 4.2.A top). In contrast, girls saw Science as related to both Tech and Health career affinities but saw little relationship between Tech and Health career affinities (Figure 4.2.B top). But these career-relatedness differences cannot explain differences in patterns of health and technology career choices by gender.

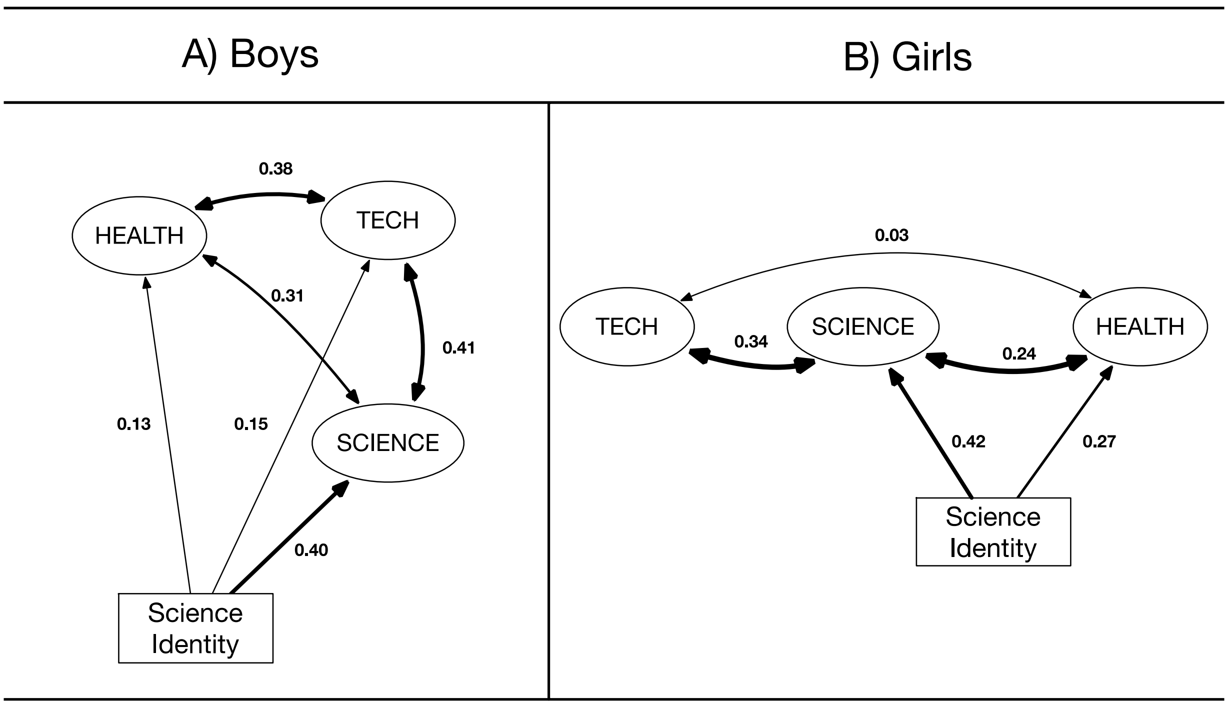

Figure 4.2. Multigroup Structural Equation Models for A) boys and B) girls of the relationship among career affinities factors (top) and of science identity towards different career affinities (bottom).[5]

---

[5] Note that the models include controls for different attitudinal factors (science fascination, science values, and science competency beliefs) that are not shown in the diagrams. Fit statistics: CFI (good > 0.95), TLI (good > 0.95), and RMSEA (good < 0.06)

Instead, the MSEM analyses showed that Science Identity was similarly positively related to Science careers for both boys and girls, but Science Identity was related to Tech careers only for boys (Figure 4.2.A) and to Health careers by a greater extent for girls (Figure 4.2.B). Furthermore, Science Identity was a predictor of career affinities above and beyond other science attitudinal factors, and parental educational level (see Table 4.6).

Table 4.6. Standardized coefficients from Multigroup Structural Equation Models by gender for the relationship of identity (all cases) and other attitudinal controls (statistically significant cases only) with each of the career affinities factors.[6]

	Boys			Girls		
Predictors	Tech	Science	Health	Tech	Science	Health
Science Attitudes						
Identity	0.15*	0.40**	0.13*		0.42**	0.27*
Fascination		0.14*				
Values	0.23**	0.17*		0.19**	0.19*	
Competency Beliefs						
Parental Career						
Parent professional		0.44**		0.50**		
Parent middle-job		-0.39**		-0.60**		

Note. **p<0.001, *p<0.05.

4.5 Discussion

In this research study employing SEM and asking students about their career affinities we found that despite the pervasive messaging of STEM as a monolithic label in media, policy and after school programming (Diekman & Benson-Greenwald, 2018; Glass, Sassler, Levitte, & Michelmore, 2013; Iammartino et al., 2016; Jang, 2016; Prescod, Daire, Young, Dagley, & Georgiopoulos, 2018; Wegemer & Eccles, 2002), students in early middle school have importantly

[6] Model controls for race/ethnicity, family support and home resources.

differentiated career affinities towards basic science and technology. Further, even though health is often treated as a completely separate and competing career outcome we found that career affinities related to health are positively correlated with science career affinities. That is, despite the fact that medical and other health careers are ultimately a different pathway, early secondary students appear to endorse a foundational relationship between them, and indeed there is a foundational relationship at the level of coursework through science-heavy early university-level instruction.

Overall, the current study revealed that health, science, and technology careers had separable affinities that nonetheless were positively rather than competitively related, at this age and when measured as affinities that could be simultaneously endorsed, rather than specific career goals, which are by definition competitive. This synergy is important given that both health careers and technology careers are related to science in terms of foundations and coursework. Further, there are complex pathways by which students often switch from one goal to another based on their experiences in foundational courses. For example, many students select science majors during the undergraduate years as preparation for medical school, and then later switch to STEM careers (Witherspoon, Vincent-Ruz & Schunn, under review; Vincent-Ruz, Grabowski & Schunn, 2018). We know turn to answer each of our research questions.

4.5.1 Factors That Influence Career Affinity in Early Secondary School

A lot of reports on the literature has focused on the relationship between career choice and parental career influence (Gushue & Whitson, 2006; Hernandez, Rana, Alemdar, Rao, & Usselman, 2016; Sonnert, 2009). However, there is less of an understanding on the interplay of this influence with attitudinal factors. We competed attitudinal, parental influence and family background on different models. Across these different analysis attitudinal variables and more importantly science identity were the strongest predictors of career affinity. Surprisingly parent's profession on Health careers didn't have a statistical significance when predicting Health career affinities. Furthermore, in our analysis we compared the influence of parental topic with career professional level. When it comes to STEM careers these two topics are usually confounded as STEM careers are often associated with higher payed jobs (Ashby & Schoon, 2001) However, low socioeconomic status is associated both with less information about possible careers and access to opportunities to develop STEM skills (Diemer & Hsieh, 2001; Leppel, Williams, & Waldauer, 2001). Therefore, determining whether one factor or the other is a better predictor is important for theoretical purposes. Finally, we didn't find significant relationships between family context (home resources, family support) and race with career affinities, again because. The fact that Career professional level was an overall a strongest predictor suggests the mechanism of parental influence might be more related to socio-economic status and access to opportunities than topic. For example, in our sample white and Asian students were more likely to have parents with professional type jobs (p=0.001).

4.5.2 Gender Differences in Career Affinities

The current study also revealed gender differences in relationships between career affinities, which highlights the deeply social ways in which career conceptions are developed. Future research must examine the kinds of experiences and societal messages that shape these career conceptions. Practically, that health and technology career affinities are not seen as related by girls may provide insights into why pathways combining those interests are still male dominated (e.g., bioengineering; Matusovich et al., 2010).

The gender-moderated relationship of science identity to health and technology careers provides important information about functioning of science identity within larger motivational models. Prior work on identity has called for growing identities to achieve equity without considering the mechanisms by which identities are translated into career goals. The lack of a relationship to technology-related careers for girls might be explained by narrow perceptions of technology careers. One possible option could be that girls may shy away from technology careers because they perceive them as isolating and relatively dissociated from communal goals (Hoh, 2009; Diekman et al., 2010). Interventions that change students' perceptions of careers can lead to large changes in career goals (Reynolds et al., 2009). For example, several out-of-school programs have seen success by providing girls with panels and experiences to show that computer science careers involve more than just coding (Graham & Latulipe, 2003).

4.6 Generalizability of the Patterns and Limitations

This study purposely sampled students from diverse public urban schools in one region of the USA to understand the nature of science identity and its relationship to career affinities. While the proportion of minoritized youth within the study sample was an overall match to base-rates in US urban public schools, the distribution by more specific subgroups was not (Aschbasher & Roth, 2010). Further, a much larger sample is required to produce truly representative data for urban students in the USA, including other regions as well as private, charter, and home-schooled students. Furthermore, a much larger sample would also allow us to draw inferences in other important demographic groups like Latinx students.

Finally, in this study we emphasized the difference between boys and girls across career affinities. While this provided and advantage to understand overall patterns of behavior and statistical power has the drawback on emphasizing a conception of gender as categorical and binary rather than as a spectrum. We would like to emphasize the need to work as a field to work on ways to account for the multidimensionality of gender as identity and expression in quantitative analysis.

4.7 Implications

This work brings to the foreground the importance of understanding the process of enacting a science identity in the form of career affinities and choice will be constrained by societal factors for both boys and for girls, particularly their stereotypes about the kind of people, the work involved, and the values of these fields. It also provides an analytic framework that could be productively applied to understanding marginalization more broadly.

Having a particular gender identity has many complexities associated with it. We caution policymakers and other stakeholders to only create interventions emphasizing the communal aspect of technology in order to attract girls into those types of careers. Leveraging only the want to care for others would emphasize the social role of women as caretakers (Camussi & Leccardi, 2001) which has been shown to hurt women's professional careers in the long run (Miller, 2001) Our study suggests general trends on affinities and relationships, however, there are many ways for girls and boys to express their gender identity in ways that don't match these patterns. Therefore, increasing equity in science and science related careers should appeal to the multi-faceted aspects of early secondary school students' multiple identities and on debunking narrow perceptions of what careers are (Lewis, Anderson, & Yasuhara, 2016).

4.8 Conclusions

Prior work has highlighted the importance of parental influence and attitudinal factors shaping career choice. However, there is little information about how these different factors interact with one another. The first contribution of this work highlights science identity as the strongest factor determining career affinities in early secondary school. Furthermore, the literature also suggests strong gender differences on career affinities in early secondary school. Indeed, we found differences consistent with prior reports. However, we provide a new explanation for these differences. Before, high career affinity towards health careers for girls has been explained as a consequence of lack of interest or identity in STEM. However, this work shows that girls with high science identity chose to express this identity through Health career affinities which is more consistent with traditional feminine cultural expectations.

4.9 References

Ashby, J. S., & Schoon, I. (2001). Career success: The role of teenage career aspirations, ambition value and gender in predicting adult social status and earnings. *Journal of Vocational Behavior*, *77*(3), 350-360.

Camussi, E., & Leccardi, C. (2001). Stereotypes of working women: Tpower of expectations. *Social Science Information*, *44*(1), 113-140. https://doi.org/10.1177/0539018405050463

Diekman, A. B., & Benson-Greenwald, T. M. (2018). Fixing STEM workforce and teacher shortages: How goal congruity can inform individuals and institutions. *Policy Insights from the Behavioral and Brain Sciences*, *5*(1), 11-18. https://doi.org/10.1177/2372732217747889

Diemer, M. A., & Hsieh, C.-A. (2001). Sociopolitical development and vocational expectations among lower socioeconomic status adolescents of color. *The Career Development Quarterly*, *56*(3), 257-267. https://doi.org/10.1002/j.2161-0045.2008.tb00040.x

Espinosa, L. (2001). Pipelines and pathways: Women of color in undergraduate STEM majors and the college experiences that contribute to persistence. *Harvard Educational Review*, *81*(2), 209-241. https://doi.org/10.17763/haer.81.2.92315ww157656k3u

Gardner, D. P., Larsen, Y. W., Baker, W., Campbell, A., & Crosby, E. A. (2001). *A nation at risk: The imperative for educational reform*. Washington, DC: United States Department of Education.

Glass, J., Sassler, S., Levitte, Y., & Michelmore, K. (2013). What's so special about STEM? A comparison of women's retention in STEM and professional occupations. *Social Forces*, *92*(2), 723-756. https://doi.org/10.1093/sf/sot092

Graham, S., & Latulipe, C. (2003, February). CS girls rock: Sparking interest in computer science and debunking the stereotypes. *SIGCSE Bulletin*, *35*(1), 322-326. https://doi.org/10.1145/792548.611998

Gushue, G. V., & Whitson, M. L. (2006). The relationship among support, ethnic identity, career decision self-efficacy, and outcome expectations in African American high school students. *Journal of Career Development*, *33*(2), 112-124. https://doi.org/10.1177/0894845306293416

Hannover, B., & Kessels, U. (2004). Self-to-prototype matching as a strategy for making academic choices. Why high school students do not like math and science. *Learning and Instruction*, *14*(1), 51-67. https://doi.org/10.1016/j.learninstruc.2003.10.002

Hernandez, D., Rana, S., Alemdar, M., Rao, A., & Usselman, M. (2016). Latino parents' educational values and STEM beliefs. *Journal for Multicultural Education*, *10*(3), 354-367. https://doi.org/10.1108/jme-12-2015-0042

Holdren, J. P., Cora, M., & Suresh, S. (2013). *Federal STEM education, 5-year strategic plan: A report from the Committee on STEM Education*. Washington, DC: Committee on STEM Education.

Iammartino, R., Bischoff, J., Willy, C., & Shapiro, P. (2016). Emergence in the U.S. Science, Technology, Engineering, and Mathematics (STEM) workforce: An agent-based model of worker attrition and group size in high-density STEM organizations. *Complex & Intelligent Systems*, *2*(1), 23-34. https://doi.org/10.1007/s40747-016-0015-7

Jacobs, J. E. (2005). Twenty-five years of research on gender and ethnic differences in math and science career choices: What have we learned? *New Directions for Child and Adolescent Development*, *2005*(110), 85-94. https://doi.org/10.1002/cd.151

Jang, H. (2016). Identifying 21st Century STEM competencies using workplace data. *Journal of Science Education and Technology*, *25*(2), 284-301. https://doi.org/10.1007/s10956-015-9593-1

Leppel, K., Williams, M. L., & Waldauer, C. (2001). The impact of parental occupation and socioeconomic status on choice of college major. *Journal of Family and Economic Issues*, *22*(4), 373-394. https://doi.org/10.1023/a:1012716828901

Lewis, C. M., Anderson, R. E., & Yasuhara, K. (2016). "I don't code all day": Fitting in computer science when the stereotypes don't fit. *Proceedings of the 2016 ACM Conference on International Computing Education Research*, 23-32. https://doi.org/10.1145/2960310.2960332

Miller, D. C. (2001). Children's policy and women's policy: Congruence or conflict? *Social Work*, *32*(4), 289–292. https://doi.org/10.1093/sw/32.4.289

Pless, N., & Maak, T. (2004). Building an inclusive diversity culture: Principles, processes and practice. *Journal of Business Ethics*, *54*(2), 129–147. https://doi.org/10.1007/s10551-004-9465-8

Prescod, D. J., Daire, A. P., Young, C., Dagley, M., & Georgiopoulos, M. (2018). Exploring negative career thoughts between STEM-declared and STEM-interested students. *Journal of Employment Counseling*, *55*(4), 166–175. https://doi.org/10.1002/joec.12096

Sadler, P., Sonnert, G., Hazari, Z., & Tai, R. (2001). The role of advanced high school coursework in increasing STEM career interest. *Science Educator*, *23*(1), 1-13.

Sonnert, G. (2009). Parents who influence their children to become scientists. *Social Studies of Science*, *39*(6), 927-941. https://doi.org/10.1177/0306312709335843

Stevenson, H. J. (2014). Myths and motives behind STEM education and the STEM-worker shortage narrative. *Issues in Teacher Education*, *23*, 133-146.

Wegemer, C. M., & Eccles, J. S. (2002). Gendered STEM career choices: Altruistic values, beliefs, and identity. *Journal of Vocational Behavior*, *110*, 28-42. https://doi.org/10.1016/j.jvb.2018.10.020

5.0 Critical Use of Quantitative Methodologies

5.1 Summary of Findings

A key theoretical underpinning of identity as an overall concept is that it can only occur because in a given society there are different structures and roles creating contrasting categories from which people must choose (Stets & Burke, 2001). Therefore, despite identity referring to an internal state and process, it cannot be separated from the individual's relationship with the outside world. A process of self-categorization into a group identity creates an accentuation of the perceived similarities between the self and other in-group members while also accentuating differences between self and out-of-group members (Stets & Burke, 2000). As a consequence, a person will choose behaviors, styles of speech, and experiences that will enhance these similarities to these characteristics of the group, which in turn enhances all the attitudes and related affective reactions related to the group. This dissertation presented three empirical studies that both deepened and expanded understanding of science identity, a kind of educationally-relevant identity that is particularly challenging for many students to hold. Furthermore, the three studies provided practice and policy implications for the field of science education.

5.1.1 The Nature of Science Identity

Even though the literature has suggested that science identity is an important factor in determining career pathways in science, it has been less clear about what components are distinctly part of science identity vs. other attitudinal constructs (Sadler, et al., 2001; Hazari et al., 2010). In my first empirical paper, I conceptualize science identity as an interplay of perceived internal and perceived external aspects and show that in early secondary school these two aspects of identity are closely connected and dependent on each other. Furthermore, I provide strong quantitative evidence to show how it is separate from other attitudinal constructs that are dominant in the literature, like fascination/interest/intrinsic value, extrinsic value, or competency beliefs/self-efficacy. Therefore, this paper contributes to the field by theoretically clarifying the nature of the construct while also providing clear empirical evidence for that conceptualization.

This empirical investigation of this conceptualization took a quantitative route for both measurement and cross-validation of the construct structure. Given the amount of work already completed using qualitative methodologies, I decided to advance the conceptualizations of science identity using advanced quantitative methods, a much less explored area. However, it is the deep existing understanding provided by the qualitative literature that served as a foundation for this conceptualization and measurement development, so the qualitative work on identity should be considered synergistic rather than competitive with the quantitative work on identity. Further, the now-validated quantitative measure can be scalable to larger populations which then creates opportunities to unearth new patterns related to the internalization of science and uncover systematic areas of inequity in experiences that support science identity development or enactment of such an identity inside and outside of educational environments.

5.1.2 Identity Complexes as a Way to Study Endorsement of Multiple Identities

Topical identities, like science identity and math identity, have been traditionally studied in isolation (Harrison, Sailes, Rotich, & Bimper, 2011; Kelly-McHale, 2013; Langdon & Petracca, 2010), where in my second empirical paper, I created and applied a new framework for studying their interaction as well as effects of such interactions on student choices. My theoretical contribution is in introducing identity complexes. This concept directly represents the many identities individuals hold, including the possibility of multiple topical identities. It also builds on the theory that an individual's topical identities are a constant negotiation with their goals, cultural expectations, and the different social identities they chose to endorse, which then shape the combinations of topical identities that are observed and their association with demographic-based identities. Furthermore, my contribution to the science identity field not only highlights the ways in which students endorse other non-STEM identities at the same time, but it also reveals the ways which these other identities are not detrimental to participation in science.

5.1.3 The Gendered Relationship of Science Identity to Science and Science-Related Career Affinities

Science identity has been strongly linked to career choice through retrospective interviews (Rosa & Mensah, 2016), and this connection serves as a strong justification for research on science identity—the 'so what' of the construct. However, given that this kind of evidence relies on memories of subjective states from long ago which are likely to reconstructed to be consistent with current identities, it is difficult to really establish causality of this relationship. Science identity was also found to be an important factor in students' persistence and learning in science (Barton & Tan, 2010; Hazari et al., 2010). However, there was still some remaining ambiguity about what specific role science identity played in science-related careers.

My third empirical paper provided three key contributions to the literature. First, as a more conceptual contribution, I revealed the ways in which STEM(M) career affinities are related to one another in early secondary school. This worked revealed that STEM is actually too broad of a categorization for capturing the nuance of affinities. It also revealed that health careers affinities are actually positively rather than negatively associated with science career affinities, contrary to prior claims.

Second, of both practical and theoretical value, this study revealed that science identity is still a malleable (and therefore intervenable) factor that is nonetheless very important for predicting career affinities. The prior literature has focused on the role of parental career and socio-economic status in these choices, but these are not things that educators can change. It is quite useful to find a malleable factor that a strong driver of large consequential decides like career choices.

Third, this study provided evidence that even though science identity mediates the relationship between gender and science career affinities, more importantly, the study reveal that the mechanism for science-related careers is quite different by gender and by type of science-related career. This finding highlights the deeply social/contextual nature of the translations of identity into career, rather than a fixed psychological law. It also directs areas of intervention beyond only attending to identity but also to conceptualization of career categories (i.e., supporting identity development is not enough to address large differences in career aspirations).

5.2 Limitations and Critical Use of Quantitative Methodologies

A central underlying goal of this dissertation is to address the issue of equity in science, with a particular focus on patterns of marginalization through the lens of science identity that emerge in early secondary school and are consistent with the lack of representation and power of minoritized populations in science careers. Therefore, I now take up an unspoken question surrounding these empirical studies: Can quantitative methods, long critiqued for their inability to capture the nuance of everyday experience, support and further an equity agenda in science identity and science education overall?

Several scholars have started questioning what it means to do critical quantitative methodologies (Crawford, 2018; Garcia, López, & Vélez, 2017; Gillborn, Warmington, & Demack, 2017; Huber, Vélez, & Solórzano, 2017). In this section, I want address some of the issues prior work has raised and build upon them to provide support for future scholars wanting to use quantitative methodologies to further equity and justice agendas. This section focuses on four salient issues regarding the use of quantitative methodologies and their amenability to further equity and justice agendas: 1) Categories as Social Constructs, 2) Taking statistical analysis at face value, 3) Quantification of Systemic Oppression, 4) Interpretation of Statistical Coefficients, 5) Using experiential knowledge.

5.2.1 Categories as Social Constructs

Key results in these studies involved the strong role gender played in the way students experience and make choices due to their science identities. However, is important to point out that the use of gender in these studies relied on a binary operalization of gender. Defining gender as a binary erases the existence of trans and non-binary people (Frohard-Dourlent, Dobson, Clark, Doull, & Saewyc, 2017; Nicolazzo, 2014). During the construction of the demographic data survey, rather than relying on district-provided binary data, we constructed a gender survey following the guidelines of prior work (Broussard, Warner, & Pope, 2018), which allowed for non-binary responses as well as allowing students to define their gender, rather than using sex as would likely be provided by the school districts. In my dissertation studies, trans and non-binary youth were a small percentage of the sample, approximately 1%. Therefore, the quantitative methods chosen by these studies could not be used to meaningfully study their experiences and make meaningful conclusions about their science identity. Furthermore, conceptualizing gender as several distinct categories might not be nuanced enough. Some researchers argue that gender is better conceptualized as a spectrum rather than distinct categories (Kuper, Nussbaum, & Mustanski, 2001). Further, dimensional conceptualizations are amenable to quantitative methods pending big enough sample size. Therefore, science educators and quantitative researchers should collaborate with trans-scholars to develop measurements that capture the nuance and complexity of gender.

5.2.2 Statistical Analyses Have No Inherent Value

To address this issue, I want to specifically draw attention to the LCA methodology presented in the second study (Chapter 3) and why this approach was chosen over other options suggested by the literature. Particularly, I chose a probability regression approach (Clark & Muthén, 2001) instead of a, three-step approach as is often recommended (Vermunt, 2001). In this approach, each individual is allowed fractional class membership in all possible identity complexes and may have non-zero values for multiple classes (e.g., a 70% change of being in the Athletic group and a 20% chance of being in the Artistic group). It is from these probabilities that the effects of different covariates are assessed (e.g., are girls more likely than boys to be in the Athletic STEMer category?). However, that was not the original approach I took; instead I first used the commonly recommended, three-step approach in which covariates are part of the LCA model calculation (Clark & Muthén, 2001). This approach makes the covariates part of the information used by the algorithm to estimate class probabilities, and it has been argued that such an approach. This approach was created after noticing a classify, analyze approach (regressing on the categories as mutually exclusive) created bias on the standard errors (Clark & Muthén, 2001). However, there is no evidence that this approach is inherently better than the probability regression approach. When using the three-step approach, I observed something interesting. In LCA, people that do not exactly fit one of the classes will be classified according to the closest match. With many features and complex patterns that human identity will typically involve, many students will not exactly fit one of the clusters. When using the three-step approach, people that did not match any of the identity complexes tended to be classified where the majority of people of their gender and race were distributed. That is, because using covariates is part of the algorithmic decision process and the probability estimation failed to give a clear-cut classification, the algorithm was strongly influenced by tendencies within gender and race combinations. From a statistical perspective, the final classification had good statistical fit and without second thought from a numbers perspective the model looked correct. However, this process greatly magnified stereotypical patterns for both genders. For example, without including covariates in the classification process, girls had a mean probability over 90% in the Artistic category, whereas with the covariate information, this probability for girls was 37%. When I was writing about the results, I was taken aback by the very large difference in classification rates, and the ways in which it did not match what I saw in more simple frequency counts of responses. This instance highlights the importance of not taking quantitative analysis at face value just because the numbers are "mathematically correct." Instead, the researcher has to be conscious of whether the results make theoretical sense and weight the advantages and limitations of each methodological approach not only when making decisions of which one to use but also when it comes to analyzing and interpreting the results.

5.2.3 Interpretation of Statistical Coefficients and Experiential Knowledge

In line with a perspective of social construction within quantitative methods ((Huber, Vélez, & Solórzano, 2017)), there is a need for critical interpretation of statistical coefficients, the dominant numbers within quantitative methods. Often times, when it comes to the measurement of learning, negative coefficients are associated with a deficit perspective. That is, the models are interpreted as minoritized groups to living to expectations compared to their peers. Though interpretation informed by the experiential knowledge of marginalized groups, I interpret these results in light of systemic disadvantages. As an example, from prior research, black students get lower scores on standardized testing not because they are less capable but because they attend segregated schools that have less resources to provide adequate instructions (Owens, 2018). A good example of this interpretational stance in my dissertation occurs within Chapter 4. In my study of the relationship of science identity to career affinities, I first observed that girls were less likely to have a career affinity within the technology cluster. Instead of just reporting this likelihood, I explained this relationship as a consequence of differential enactment of scientific identity. This is consistent with experiential knowledge reported both from retrospective case studies and interviews with your girls regarding socialization and femininity in technology contexts (Archer et al., 2001; Betz & Sekaquaptewa, 2001; Wegemer & Eccles, 2002).

5.2.4 Centrality of Systemic Oppression and Lived Experiences

Critical theory is centered on the principle that racism, race, and its intersections (with gender, class, etc.) are an endemic part of society (Garcia et al., 2017; Gillborn et al., 2017). However, their effects may be invisible within biases of measurement, sample selection, sample retention, etc. For example, in my dissertation studies, it was not possible to conduct intersectional analysis beyond the comparison between white and Black students. This is because the other racial/ethnic categories on the sample were not big enough to accommodate moderation analysis from a statistical power perspective. Another example comes from Chapter 4. Qualitative work in the literature suggests that women shy away from Technological careers due to messaging that these careers are not "feminine" and that girls should strive to femininity first (Archer et al., 2001). That is, patriarchal expectations push girls away from these types of careers. However, in my studies I didn't have a specific measure about message perception or whether girls have heard pushback from family or counselors when expressing their want to study this. These considerations therefore beg the question of how to interpret results based upon experiential knowledge and acknowledgement of systemic inequities. A possible solution for this is mixed-methods studies, so we can cross-validate what we observe quantitatively with qualitative data, in addition to allows deeper exploration into these topics. In the case of science identity, mixed-methods studying the process of internalization of identity could strengthen the work produced in this dissertation.

Specifically, I suggest future qualitative investigations of the ways in which the internalization process is affected by interactions among personal, social, and cultural factors. Personal factors emphasize an individual's autonomy and engagement with experiences as being coherent with their desires separate from community expectations (Bathgate, 2016; Hewitt, 1989). Social factors refer to the classification of the individual with relation to other people, social categories, or roles (Turner, Hogg, Oakes, Reicher, & Wetherell, 1987), for example, whether one is part of the science community or not (Kozoll et al., 2002). Cultural factors refer to the "imposed" selves based upon people with shared history and cultural expectations held in common (Hall, 1990). For example, even before children develop science related aspirations, they perceive and internalize ideas about science, race, gender, and expected social roles from their parents (Archer et. al., 2013), the media (Steinke, et. al., 2012), and environment (Adams, Gupta, & Cotumaccio, 2014).

5.3 Conclusions

Through the three empirical studies of my dissertation, I argue for the centrality, power dynamics, and complexity of science identity and why its study is critical in education. Science Identity is shown to be a useful lens in particular educational fields where we have failed to support minoritized populations and their educational pathways in science and science related careers. There are three important contributions from this work. First, I have clarified the conceptualization of science identity in early secondary school as a combination of personal and social factors. Second, I drew attention to the ways in which students can have multiple topical identities not related to science and a framework for understanding these *topical complexes.* Finally, I highlighted the importance of science identity for student choice in terms of career affinities for both science and science-related careers. The three papers further highlighted important differential relationships by gender and race/ethnicity.

5.4 References

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2001). "Balancing acts''': Elementary school girls' negotiations of femininity, achievement, and science." *Science Education*, *96*(6), 967-989. https://doi.org/10.1002/sce.21031

Betz, D. E., & Sekaquaptewa, D. (2001). My fair physicist? Feminine math and science role models demotivate young girls. *Social Psychological and Personality Science*, *3*(6), 738-746. https://doi.org/10.1177/1948550612440735

Broussard, K. A., Warner, R. H., & Pope, A. R. (2018). Too many boxes, or not enough? Preferences for how we ask about gender in cisgender, LGB, and gender-diverse samples. *Sex Roles*, *78*(9–10), 606–624. https://doi.org/10.1007/s11199-017-0823-2

Clark, S. L., & Muthén, B. (2001). *Relating latent class analysis results to variables not included in the analysis*. Retrieved from: https://www.researchgate.net/publication/237346694_Relating_Latent_Class_Analysis_Results_to_Variables_not_Included_in_the_Analysis

Crawford, C. E. (2018). The one-in-ten: Quantitative Critical Race Theory and the education of the 'new (white) oppressed.' *Journal of Education Policy*, 1-22. https://doi.org/10.1080/02680939.2018.1531314

Frohard-Dourlent, H., Dobson, S., Clark, B. A., Doull, M., & Saewyc, E. M. (2017). "I would have preferred more options": accounting for non-binary youth in health research. *Nursing Inquiry*, *24*(1). https://doi.org/10.1111/nin.12150

Garcia, N. M., López, N., & Vélez, V. N. (2017). QuantCrit: Rectifying quantitative methods through critical race theory. *Race Ethnicity and Education*, 1-9. https://doi.org/10.1080/13613324.2017.1377675

Hazari, Z., Potvin, G., Lock, R. M., Lung, F., Sonnert, G., & Sadler, P. M. (2022). Factors that affect the physical science career interest of female students: Testing five common hypotheses. *Physical Review Special Topics - Physics Education Research*, *9*(2), 020115. https://doi.org/10.1103/physrevstper.9.020115

Huber, L., Vélez, V. N., & Solórzano, D. (2017). More than 'papelitos:' A QuantCrit counterstory to critique Latina/o degree value and occupational prestige. *Race Ethnicity and Education*, 1-23. https://doi.org/10.1080/13613324.2017.1377416

Nicolazzo, Z. (2014). "Couldn't I be both Fred and Ginger?": Teaching about nonbinary identities through memoir. *Journal of LGBT Youth*, *11*(2), 171-175. https://doi.org/10.1080/19361653.2013.878860

Owens, A. (2018). Income segregation between school districts and inequality in students' achievement. *Sociology of Education*, *91*(1), 1-27. https://doi.org/10.1177/0038040717741180

Sadler, P., Sonnert, G., Hazari, Z., & Tai, R. (2001). The role of advanced high school coursework in increasing STEM career interest. *Science Educator*, *23*(1), 1-13.

Stets, J. E., & Burke, P. J. (2001). Identity theory and social identity theory. *Social Psychology Quarterly*, *63*(3), 224-237. https://doi.org/10.2307/2695870

Wegemer, C. M., & Eccles, J. S. (2002). Gendered STEM career choices: Altruistic values, beliefs, and identity. *Journal of Vocational Behavior*, *110*, 28-42. https://doi.org/10.1016/j.jvb.2018.10.020