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Identifying a typology of high schools based on their orientation toward STEM: A latent class analysis of HSLS:09

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Abstract

The purpose of this study is to investigate the extent that there is a typology of high schools based on their orientation toward science, technology, engineering, and mathematics (STEM), as well as the extent to which school-level demographic variables and student high school outcomes are associated with subgroup membership in the typology, by analyzing data from a large nationally representative sample of high schools ($n = 940$) from the High School Longitudinal Study of 2009 (HSLS:09) using latent class analysis (LCA). We used a three-step LCA approach to identify significantly different subgroups of STEM-oriented high schools, what covariates predict subgroup membership, and how subgroup membership predicts observed distal outcomes. We find that there are four significantly different subgroups of STEM-oriented high schools based on their principal's perceptions: *Abundant* (12.3%), *Support* (23.3%), *Bounded* (10.1%), and *Comprehensive* (54.3%). In addition, we find that these subgroups are associated with school demographics, such as the percent of students eligible for free and reduced-price lunch, school locale, and control (public or private). Subgroup membership is also associated with student outcomes, such as postsecondary program enrollment and intent to pursue a STEM degree.

KEYWORDS

high schools, multivariate analysis, STEM education

1 | INTRODUCTION

The purpose of this study is to investigate the extent that there is a typology of high schools based on their orientation toward science, technology, engineering, and mathematics (STEM) from a large nationally generalizable data set, the High School Longitudinal Study of 2009 (HSLS:09) from the National Center for Education Statistics (NCES). During the 20th century, the United States shifted much of its educational focus to science and technology due to the Soviet Union's launch of Sputnik in 1957 (Thomas & Williams, 2010). STEM continues to drive innovation in the U.S. economy and is at the forefront of maintaining economic competitiveness and stability. However, there is uneasiness about the capability of the United States to meet the needs of the projected workforce trends that include a STEM worker shortage; although, some would debate that the STEM worker shortage is manufactured (Atkinson & Mayo, 2010; Berliner & Biddle, 1995; Berliner & Glass, 2014). Given the growing concerns about economic and workforce trends in the United States, effective interventions for K-12 STEM education are continuously being developed. These interventions include the development of STEM-related programs such as STEM-focused high schools. STEM-focused high schools are specialty high schools with a primary focus on STEM subjects (Atkinson & Mayo, 2010). These schools are often regarded as one of the most viable methods for improving K-12 STEM education as outlined in various reports (Atkinson & Mayo, 2010; Gonzalez & Kuenzi, 2012; Means, Confrey, House, & Bhanot, 2008; President's Council of Advisors on Science & Technology, 2010). They are also viewed as a means for advancing students through the STEM pipeline by supporting and developing student interest and motivation in pursuing STEM careers (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2007; National Research Council, 2011; Subotnik, Tai, Rickoff, & Almarode, 2010).

STEM-focused high schools have piqued the interest of policymakers, education researchers, district leaders, teachers, parents, and students concerned with improving and having access to better K-12 STEM education. STEM-focused high schools have a range of characteristics that distinguish them from comprehensive high schools such as their mission, which outlines a commitment to produce more STEM degree pursuers and workforce entrants, and the educational opportunities accessible to their students through a stimulating and advanced STEM curriculum (Means et al., 2008; National Research Council, 2011). Research on STEM-focused high schools is necessary to answer questions about their effectiveness and to identify characteristics attributable to their success. If it is determined that specific types of STEM-focused high schools produce the desired student outcomes outlined in the goals for U.S. STEM education in comparison to other high school models, then we can develop exemplars of successful STEM education for districts seeking to improve the quality of STEM teaching and learning.

Research and policy reports on STEM-focused high schools, especially from the National Research Council, suggest a typology that includes three school models: selective STEM school, inclusive STEM schools, and STEM-focused career and technical education (CTE; Means et al., 2008; National Research Council, 2011; Tofel-Grehl & Callahan, 2016, 2014). Research on the effects of STEM-focused high schools is varied. Results suggest that STEM-focused high schools, in some cases, have a positive effect on student learning and STEM outcomes (Bottia, Stearns, Mickelson, & Moller, 2018; Means et al., 2017; Means, Wang, Wei, Iwatani, & Peters, 2018; Means, Wang, Young, Peters, & Lynch, 2016; Wiswall, Stiefel, Schwartz, & Boccardo, 2014), in other cases do not have a significant effect on student learning and educational opportunities (Eisenhart et al., 2015), or in yet other cases produce inconclusive results (Gnagey & Lavertu, 2016). In addition, many research studies on STEM-focused high schools are limited in their generalizability by the research design as many of these research studies use case-study design methods (Eisenhart et al., 2015; Lynch et al., 2017; Lynch, Peters-Burton, & Ford, 2015; Peters-Burton, Lynch, Behrend, & Means, 2014), or small sample sizes with some studies having less than 10 sampled school (Bruce-Davis et al., 2014; Eisenhart et al., 2015; Franco & Patel, 2017; Gnagey & Lavertu, 2016; Weis et al., 2015).

Indeed, what remains to be explored in this domain is the prevalence of a typology of STEM-oriented high schools and a better understanding of their distinguishing features. In addition, the merit of research on this topic is building the relevance of policy-level recommendations for improving STEM education and the development of new

STEM-focused school models, as well as getting closer to determining whether or not one STEM-focused high school model is more effective in delivering STEM education and what students these school models best serve.

Thus, in this article, we extend the research on STEM-focused high schools by investigating the extent that there is a typology of STEM-oriented high schools using a nationally generalizable data set, the High School Longitudinal Study of 2009 (HSLS:09). To do this we use latent class analysis (LCA) and find that there are four significantly different subgroups of STEM-oriented high schools in the United States: *Abundant* (12.3%), *Support* (23.3%), *Bounded* (10.1%), and *Comprehensive* (54.3%). We also find that school demographic variables, such as the percent of students eligible for free and reduced lunch, and school locale, and control (public or private) significantly predicts the likelihood of subgroup membership. School subgroup membership is also associated with student outcomes, such as the likelihood of enrolling in a bachelor's degree program, and intend to major in a STEM field.

2 | LITERATURE REVIEW

The STEM acronym and concept was first popularized by the National Science Foundation (NSF) in the 1990s as a way to group the disciplines of science, technology, engineering, and mathematics (Sanders, 2009). In general, STEM education encompasses teaching and learning in those academic disciplines. At the same time, there are different interpretations of STEM, STEM education, and what is considered a STEM career field. For instance, in the educational context, an integrated definition of STEM has become more prominent. Kelley and Knowles (2016) define integrated STEM education as "the approach to teaching the STEM content of two or more STEM domains, bound by STEM practices within an authentic context for the purpose of connecting these subjects to enhance student learning" (p.3). Also, what constitutes a STEM field varies across organizations. NSF's definition of STEM includes the social sciences, whereas it is excluded from the definition used by the Department of Homeland Security (Gonzalez & Kuenzi, 2012). Bybee (2010) and English (2016) point out that inconsistency in definitions presents the issue of inequitable STEM discipline representation in STEM education policy, programs, and practices. In like manner, definitions of what constitutes a STEM-focused high school has not reached a consensus among researchers (Tofel-Grehl & Callahan, 2016, 2014). This presents challenges around evaluating the effectiveness of these school models (LaForce et al., 2016).

In the below review of the literature, we review the STEM education literature generally related to STEM-focused high schools, the research on different types of STEM-focused high school models, and discussions of other frameworks developed for STEM-focused high schools.

2.1 | STEM-focused high school models

National Research Council's Committee on Highly Successful Schools or Programs for K-12 STEM Education organized a workshop to identify highly successful K-12 STEM schools and programs. To do this, a set of example schools were examined at the workshop. These schools were identified based on research that provided evidence in support of claims of success. The workshop participants included a number of educational researchers and school administrators. Four broad categories of schools and programs were identified: (a) selective STEM schools, (b) inclusive STEM schools, (c) schools with STEM-focused CTE, and (d) STEM programs in comprehensive schools (National Research Council, 2011). In addition, they suggest that these schools and programs have the potential to meet the comprehensive goals of STEM education, which are to increase the number of students pursuing advanced degrees and careers in STEM, STEM literacy for all students, and the participation of women and minorities in the STEM workforce.

2.2 | Selective STEM high schools

Selective STEM high schools have existed since the 20th century and their development was largely driven by educational, economic, and political trends (Thomas & Williams, 2010). Many are member schools of the National Consortium for Secondary STEM Schools (NCSSS). Like STEM school models in general, there is an element of variation within selective STEM schools. Selective STEM high schools can be: (a) residential schools; (b) a school-within-a-school; or (c) part-time programs providing advanced coursework (Means et al., 2008; National Research Council, 2011; Scott, 2012; Tofel-Grehl & Callahan, 2014). These schools are also likely to be found in cities (Rogers-Chapman, 2014). Features of selective STEM high school environments include combinations of: (a) a focus on one or more STEM disciplines, (b) high admissions standards, (c) well-trained teachers, (d) advanced coursework, (e) research experiences for students, (f) community partnerships, (g) STEM-focused teacher professional development, (h) additional graduation requirements, (i) high amounts of instructional technology, (j) mentorships or internships, and (k) high engagement among students and teachers. Also, selective STEM high schools allow students to have tailored learning experiences based on their STEM interest (Atkinson & Mayo, 2010; Thomas & Williams, 2010).

Selective STEM high schools are primarily characterized by their selective admissions standards. These high schools target students who have high aptitude and interest in STEM (Atkinson, Hugo, Lundgren, Shapiro, & Thomas, 2007; Means et al., 2008; National Research Council, 2011; Scott, 2012; Subotnik et al., 2010; Subotnik, Tai, Almarode, & Crowe, 2013). Hence, they view their students as having the most potential for improving the STEM worker shortage (Atkinson & Mayo, 2010; Atkinson et al., 2007). Whereas some students seek admission into a selective STEM high school because of their interest in STEM, others are seeking academically challenging environments (Subotnik et al., 2013). Unfortunately, students may be denied admission into these selective STEM high schools if they do not perform well enough on competitive admissions examinations. As a result, they miss out on the rigorous STEM environments these schools offer (Means et al., 2008; Tofel-Grehl & Callahan, 2016). One critique of selective STEM high schools is their lack of racial and economic diversity. The student body often consists of a high percentage of Asian and White students and disproportionately lower numbers of Hispanic and Black students (Atkinson & Mayo, 2010).

Although common elements across selective STEM high schools have been described in the literature (Means et al., 2008; National Research Council, 2011), there are often variations in the student experience. For instance, Tofel-Grehl and Callahan (2014) sought to determine the universal and distinctive features of selective STEM high schools using a qualitative research design and a sample of six selective STEM high schools in the United States. The schools were selected based on four criteria: school model, geographic region, admissions criteria, and enrollment size. They found that selective STEM high schools collectively offer a variety of STEM courses, research opportunities for students, and professional development for teachers. However, these features can also distinguish selective STEM high schools based on the resulting student experiences as Tofel-Grehl and Callahan (2016) found in a related study. Using the same sample of selective STEM high schools in their 2014 study, they categorized schools based on the intensity of the STEM experience offered to students. Schools fells into two groups, high and low STEM intensity. The authors suggested variations in the student experience at selective STEM high schools can result from how the school's goals and mission are carried out.

Research on student performance and outcomes has indicated the advantage of attending a selective STEM high school. In their investigation of whether selective STEM high schools improve student mathematics and science performance and close achievement gaps, Wiswall et al. (2014) found that minority-White gaps are lessened in selective STEM high schools relative to non-STEM high schools. However, gender gaps, as well as Asian–White gaps, are larger in selective STEM high schools relative to non-STEM schools. Subotnik et al. (2013) investigated the likelihood that graduates of selective STEM high schools completed STEM-related majors in college. Their findings suggest that students who attend selective STEM high schools are more likely to complete a STEM major in college compared to students with similar abilities who did not attend a selective STEM high school.

In addition, the odds of completing a STEM major in college were higher for selective STEM high school attendees who engaged in internships, mentorships, or research during high school.

2.3 | Inclusive STEM high schools

The second STEM-focused high school model is inclusive STEM high schools. Like selective STEM high schools, they are focused around one or more STEM discipline, have expert teachers, offer advanced coursework, have a high use of technology, and are likely to be found in cities (National Research Council, 2011; Rogers-Chapman, 2014). Inclusive STEM high schools can also take the form of a stand-alone school, school-within-a-school, or a part-time program (Lynch et al., 2015; Means et al., 2008). Unlike selective STEM high schools, inclusive STEM high schools do not have selective admissions criteria and particularly aspire to provide equitable opportunities for students from underrepresented groups.

Although we have highlighted features of inclusive STEM schools, there is little consensus in the literature on what inclusive STEM high schools actually are. This makes school evaluation efforts to determine effectiveness difficult. A study by LaForce et al. (2016) speaks to this point and aims to address this gap in the literature. They sought to examine inclusive STEM high schools, their specific components, and their intended outcomes. Twenty inclusive STEM high schools were selected across the United States and a theoretical model detailing the critical elements of inclusive STEM high schools was developed. A qualitative approach was used to review school written materials, model articulation interviews, and follow-up interviews. The study consisted of two analysis phases to establish a school model and derive critical components of inclusive STEM high schools. A total of 76 critical components were identified and grounded theory was used to determine the eight essential elements that comprise the critical components for inclusive STEM high schools. The eight essential elements are: (a) Personalization of Learning, (b) Problem-Based Learning, (c) Rigorous Learning, (d) Career, Technical, and Life Skills, (e) School Community and Belonging, (f) External Community, (g) Staff Foundations, and (h) External Factors. The authors mentioned that in their theoretical model many of the elements do not relate specifically to STEM.

Inclusive STEM high schools are development focused and this focus aligns with one priority for improving K-12 STEM education, that is, to boost the participation of students from underrepresented groups in STEM (National Research Council, 2011). Accordingly, inclusive STEM high schools help address issues of social equity in STEM by targeting enrollment efforts toward students from low socioeconomic status (SES) and minority backgrounds (Means et al., 2008; National Research Council, 2011; Rogers-Chapman, 2014). This is done in direct support of decreasing the gender, race, and socioeconomic inequalities prevalent in STEM. Inclusive STEM high schools seek to develop STEM talent and participation in STEM among students from underrepresented groups by preparing students for college-level STEM coursework (Lynch et al., 2017, 2015; Means et al., 2008; Peters-Burton et al., 2014).

Attending an inclusive STEM high school can improve STEM participation, interest, and academic achievement. Means et al. (2016) conducted a study to examine student high school outcomes from inclusive STEM high schools and comparison schools with similar students in North Carolina using propensity-score weighting and hierarchical modeling. They found that students in inclusive schools were more likely to take advanced STEM courses, have an interest in STEM degrees and careers, and participate in informal STEM activities than students in non-STEM high schools. Means et al. (2018) compared postsecondary education records of seniors from 23 inclusive STEM high schools and with seniors from 19 non-STEM high schools in Texas. Using propensity score weighting, they found that students who attended an inclusive STEM high school were three times more likely to enroll in a bachelor's degree program 2 years after high school than students from non-STEM high schools.

However, some studies have found the impact of attending an inclusive STEM high school can be negligible. Erdogan and Stuessy (2015a) examined the college readiness of graduates of inclusive STEM high schools compared to traditional high school graduates in Texas using descriptive and multigroup analysis. There were no statistically significant differences found between students in inclusive STEM high schools and traditional high school reading, math, and science standardized test scores. However, there was evidence that student demographics influence the success and experience of students attending inclusive STEM high schools. Gnagey and Lavertu (2016) studied the effect of six inclusive STEM high schools on academic achievement during the first 2 years of high school by estimating student growth models to compare student achievement in inclusive STEM high schools and traditional public schools in Ohio. They found that attendance during the first 2 years of high school in inclusive STEM high schools can sometimes have a negligible or negative effect on academic achievement, especially in non-STEM courses. In some schools, there were achievement gains in science courses but it came at the expense of nonachievement in non-STEM courses.

There is evidence in the literature that the STEM education experience in inclusive STEM high schools can be limited. Specifically, inclusive STEM high schools are less likely to offer advanced STEM coursework than selective STEM high schools (Means et al., 2008). In addition, the demographic composition in STEM high schools can affect the learning experiences of students at these schools. Some of these effects can be direct or indirect and can also vary by a student's gender, race, and SES. Bottia, Mickelson, Giersch, Stearns, and Moller (2018) investigated the relationship between high school racial composition and student STEM learning opportunities and how it affects the likelihood that a student would complete a STEM major. Using hierarchical logistic models and longitudinal data from students who completed their secondary education in North Carolina and postsecondary studies in North Carolina public universities, the authors found a negative association between declaring and completing a STEM major and attending a school with a predominately white student body, suggesting that high schools' racial composition can have an effect on short-term and long-term STEM outcomes. Thus, whereas attending an inclusive STEM school may not provide access to the same coursework and curricula opportunities as other STEM school models, the learning environment offered in these spaces is associated with students from underrepresented groups in STEM to build STEM social capital (Lynch et al., 2017; Means et al., 2017; Spillane, Lynch, & Ford, 2016)

2.4 | STEM-focused CTE

The last type of STEM-focused schools are schools with STEM-focused CTE. They seek to prepare students for college, inform students of the more real-world applications of STEM by preparing them for STEM-related careers, and increase engagement to prevent students from dropping out of school (National Research Council, 2011). In CTE programs, students focus on building skills for careers in fields in growing industries such as health services and information technology (Dougherty, 2016). In a study using student-level data from the Arkansas Research Center (ARC), Dougherty (2016) found a positive impact on student enrollment in CTE courses in terms of their education and employment outcomes. In addition, the impact of STEM-focused CTE programs for students with disabilities has been investigated by Gottfried, Bozick, Rose, and Moore (2016). Their findings suggest that STEM-focused CTE programs do not increase the likelihood that a student with disabilities will major in a STEM field. Evidence of the impact of STEM-focused CTE is an area of research that remains relatively unexplored.

2.5 | Alternative frameworks

In addition to the framework developed by the National Research Council (2011) for STEM-focused high schools, other frameworks have been developed. Erdogan and Stuessy (2015b) developed a conceptual framework of effective learning environments of STEM-focused schools. This conceptual framework is referred to as "collaborative actions of the community" and comprises components of STEM-focused high schools. The three components in this framework are: (a) Actors, (b) Contextual Factors, and (c) Actions. This framework provides a system for describing and understanding the dynamic nature of STEM-focused schools. Means et al. (2008) developed a conceptual framework for describing STEM-focused high schools consisting of three components: program design, implementation practices, and student outcomes. Elements of program design include goals, partnerships, curriculum and pedagogy, governance and academic structure, and student recruiting and selection.

Implementation practices focus on how a program is carried out in a particular setting. It includes support, teacher recruitment and professional development, and assessment practices. Last, outcomes include near-term outcomes, long-term outcomes, and postsecondary transition.

As demonstrated above, the research on STEM-focused high schools is mixed and limited. There remain many questions in the literature regarding the value of the STEM-focused high school experience (Thomas & Williams, 2010). Research on STEM-focused high schools is often limited due to small sample size, high use of case-study methods, and internal program evaluation. Also, the promotion of STEM-focused high schools has not been backed by research evidence of its effectiveness (Wiswall et al., 2014). Moreover, the effect of STEM-focused high schools using large-scale data is largely unknown (Subotnik et al., 2010).

The classification of STEM-focused high schools identified in the National Research Council's (2011) report is nonexhaustive, meaning that other models of STEM-focused schools may exist that do not fall into this classification scheme. In the literature, there is much variation in how STEM fields and schools are defined (LaForce et al., 2016). STEM-focused high schools are often identified based on self-identification and their mission statements (Tofel-Grehl & Callahan, 2016, 2014), whereas some STEM-focused high schools have adopted a STEM label without the academically intensive STEM-focused program (Eisenhart et al., 2015). The research in this area has also been unclear as to what essential features truly differentiates STEM-focused high schools from other comprehensive schools (Tofel-Grehl & Callahan, 2014).

The feasibility of an expansion of STEM-focused high schools is critiqued to a great extent because of the funding challenges placed on school districts to develop and sustain these schools (Atkinson et al., 2007; Gnagey & Lavertu, 2016; National Research Council, 2011; Thomas & Williams, 2010). Whereas STEM-focused high schools are valued for providing STEM exposure to students there may be other high schools that provide advanced learning opportunities in STEM to students in similar ways.

3 | THEORETICAL FRAMEWORK

In our study, we aim to empirically identify significantly different types of high schools based on their STEM orientation. This type of research, typology subgroup studies, can be conducted using LCA to determine the prevalence of homogeneous subgroups within a heterogeneous sample (Collins & Lanza, 2010; Henry & Muthén, 2010; Jung & Wickrama, 2008). LCA is a person-centered statistical method that allows us to empirically assess whether or not there are multiple distinct subgroups within the larger group. Through this method, we can categorize subjects based on a set of observed characteristics and learn how prevalent subgroups are. In addition, through LCA we can evaluate what predicts subgroup membership as well as the consequences of subgroup membership. Other studies within STEM education have made use of LCA that has led to finding categories of students' expectancy-value profiles in the ninth grade (Andersen & Chen, 2016), concept classes related to students' understanding of acid-based chemistry (Romine, Todd, & Clark, 2016), profiles of school trust (Smetana, Wenner, Settlage, & McCoach, 2016), subgroups of students' math attitudes and self-efficacy (Dang & Nylund-Gibson, 2017; Ing & Nylund-Gibson, 2013, 2017; Zhao & Bowers, 2017), and subgroups of teachers' technology use in schools (Graves & Bowers, 2018). There have been calls in the literature to conduct research that continues to develop classification schemes for STEM-focused high schools to better differentiate between school models (Tofel-Grehl & Callahan, 2014). Developing a new typology of STEM-oriented schools is important for identifying school types that are common and recognizing and classifying those that are in contrast with more commonly known models. In addition, National Research Council's classification does not tell us the prevalence of each STEM-focused high school model, which affects our ability to determine how generalizable their classification is. What has not been examined in the literature to date is the extent to which there is a typology of STEM-oriented high schools that is empirically defined using a nationally generalizable data set and the prevalence of each school type. Therefore, we aim to address the following research questions: (a) To what extent are there significantly different types of high schools based on their orientation toward STEM? (b) To what extent are high school demographics and high school outcomes associated with membership in these subgroups of schools?

4 | METHOD

4.1 | Data and sample

This study is a secondary analysis of the restricted-use data from the High School Longitudinal Study of 2009 (HSLS:09). HSLS:09 is a nationally representative longitudinal study of approximately 21,000 grade 9 students in 940 high schools (Ingels et al., 2013). In this study, the National Center for Education Statistics (NCES) follows students throughout their secondary and postsecondary education years, the workforce and beyond. Special emphasis is given to students' decision making related to STEM courses, majors, and careers. So far, students have been surveyed in grade 9 in the 2009 base year, in 2012 when the students were in grade 11, in 2013 for a postsecondary update, and in 2016 when students may be continuing through postsecondary education.

Given its special emphasis on STEM, HSLS:09 provides an opportunity for researchers to explore issues and ideas in STEM education using large-scale data. When we consider other studies available through the NCES Longitudinal Studies Program, HSLS:09 is the most appropriate fit for our research questions. In addition, HSLS:09 is the most recent national-level secondary school student data available at the time this study was conducted. We examined the full sample of schools who participated in HSLS:09 (n = 940). Due to confidentiality requirements, all sample size numbers are rounded to the nearest tens place.

For our study, we used responses from the base-year school administrator survey. The school administrator survey consists of five sections that cover topics on the school characteristics; student body; faculty; science and mathematics courses offered; and the school administrator's background, goals, and beliefs. In addition, we used sample member responses from the 2013 Update and aggregated to the school level. The 2013 Update survey provides information on student sample members' high school completion status, applications, and registration at postsecondary institutions, financial aid and enrollment cost, and employment.

The sampling weights from the base year (W1SCHOOL) and 2013 update (W3STUDENT) of HSLS:09 were applied to the LCA so the results are nationally generalizable to all regular public and private schools in the 50 United States and District of Columbia with grades 9 and 11 in 2009 (Ingels et al., 2013).

TABLE 1 Descriptive statistics for indicator variables for STEM-focused high schools

Variable	N	Min	Max	Mean	*SD*	HSLS:09 Variable
Holds math or science fairs/workshops/competitions	810	0	1	0.39	0.49	A1MTHSCIFAIR = 1
Partners w/ college/university that offers math/science summer program	810	0	1	0.46	0.50	A1MSUMMER = 1
Pairs students with mentors in math or science	810	0	1	0.35	0.48	A1MSMENTOR = 1
Requires teacher prof development in how students learn math/science	810	0	1	0.58	0.49	A1MSPDLEARN = 1
Requires teacher prof development in increasing interest in math/science	810	0	1	0.41	0.49	A1MSPDINTRST = 1
School offers calculus AP (BC) on-site	810	0	1	0.37	0.48	A1ONCLCAPBC = 1
School offers advanced chemistry, chemistry II, AP, or IB on-site	810	0	1	0.57	0.50	A1ONADVCHEM = 1
School offers advanced physics, physics II, AP, or IB on-site	810	0	1	0.44	0.50	A1ONADVPHYS = 1
School offers computer science AP (AB) on-site	810	0	1	0.07	0.25	A1ONCMPSCIB = 1

Abbreviations: SD, standard deviation; STEM, science, technology, engineering, and mathematic.

TABLE 2 Descriptive statistics for covariates for STEM-focused high schools

Variable	N	Min	Max	Mean	*SD*	HSLS:09 variable
Private	820	0	1	.19	.39	X1CONTROL = 2 or 3
School urbanicity						
City	820	0	1	.28	.45	X1LOCALE = 1
Town	820	0	1	.13	.33	X1LOCALE = 3
Rural	820	0	1	.23	.42	X1LOCALE = 4
School demographics						
Above median % Free or reduced-price lunch	800	0	1	.50	.50	A1FREELUNCH
Above median % Hispanic	800	0	1	.46	.50	A1HISPSTU
Above median % Black	800	0	1	.48	.50	A1BLACKSTU

Abbreviations: SD, standard deviation; STEM, science, technology, engineering, and mathematic.

4.2 | Variables included in the analysis

In this study, we focused on measures related to STEM-focused high school environments and student outcomes at the secondary level. We selected indicator variables related to elements of STEM-focused high school environments based on National Research Council's (2011) framework for STEM-focused high school models (see Table 1). We chose covariates related to school demographic and social context factors highlighted in the literature as being associated with students' experience in STEM-focused high school (see Table 2). We selected distal outcomes that relate to academic milestones students typically reach en route to a STEM career (see Table 3).

4.3 | Informal STEM activities and professional development

HSLS:09 base year administrator survey includes questions related to informal STEM and professional development activities used to raise students' interest and achievement in mathematics or science (Ingels et al., 2013). There is a total of 12 items related to this topic. We used five of these items based on how closely they related to characteristics of STEM high schools mentioned in the literature (Means et al., 2008; National Research Council, 2011). We determined that it would be best not to include all items related to informal STEM and professional development activities for building student interest and motivation in STEM because of concerns regarding statistical power (Dziak, Lanza, & Tan, 2014). The items we used include the following practices: hold school-wide math or science fairs, workshops, or competitions; partner with community colleges or universities that offer math or science summer programs or camps for high school students; pair students with mentors in math or science; require teacher professional development in how students learn math or science; require teacher

TABLE 3 Descriptive statistics of distal outcomes for STEM-focused high schools

Variable	N	Min	Max	Mean	*SD*	HSLS:09 variable
Mean overall GPA	820	0.19	3.79	2.96	0.39	X3TGPATOT
% High school diploma	820	0	100	95.85	9.71	X3HSCOMPSTAT = 1
% Enrolled in bachelor's degree program	820	0	100	43.44	24.50	S3PROGLEVEL = 1
% Considering STEM major	820	0	100	21.07	14.98	S3FIELD_STEM = 1
% Offered Pell grant	820	0	100	42.61	19.67	S3CLGPELL = 1

Abbreviations: SD, standard deviation; STEM, science, technology, engineering, and mathematic.

professional development in increasing student interest in math or science. Administrators were asked to report whether or not these practices were present in their school. All responses to these items are scored 0 for no and 1 for yes.

4.4 | Coursework

HSLS:09 base year administrator survey also includes questions related to mathematics and science courses offered. Coursework is vital for building students' interest in STEM (Sadler, Sonnert, Hazari, & Tai, 2014; Wang, 2013). At the same time, student participation in advanced coursework in STEM high schools is often voluntary (Sadler et al., 2014). In past studies, STEM coursework exposure has been measured by the number of units taken (Redmond-Sanogo, Angle, & Davis, 2016; Wang, 2013), but because we are concerned with STEM education at the school level we focus on what is offered at each school. We operationalized exposure to STEM coursework based on rigorous mathematics and science course taken as defined in a pipeline developed by Burkam and Lee (2003). In their study, they developed foreign language, science, and mathematics course-taking pipeline classifications. Other studies in STEM education have used these classification schemes (Ashford, Lanehart, Kersaint, Lee, & Kromrey, 2016; Tyson, Lee, Borman, & Hanson, 2007). We focused on the highest rigor of STEM courses offered on-site at the schools. We used the following dichotomously coded STEM coursework variables: AP Calculus, BC; AP Computer Science, AB; AP or IB Advanced Chemistry or Chemistry II; AP or IB Advanced Physics or Physics II. All responses to these items are scored 0 for no and 1 for yes.

4.5 | Covariates

Our choice of covariates was influenced by literature on STEM-focused high schools that noted the influence of school racial composition of student experiences (Bottia et al., 2018), that the location of STEM-focused high schools is geographically uneven, and that access to STEM-focused high schools are stratified based on race, ethnicity, and socioeconomic status (SES; Rogers-Chapman, 2014; Scott, 2012; Subotnik et al., 2013). As a result, we included the following covariates related to school demographic factors: dichotomously coded variables for whether or not a school is above the median percent of students eligible for free or reduced-priced lunch, above the median percent of the racial composition of the student body, school locale, and control (e.g., public vs. private).

4.6 | Distal outcomes

School-level analysis using HSLS:09 data is only appropriate with base-year data (Ingels et al., 2013), but we wanted to investigate the potential outcomes of attending different STEM-oriented schools identified in our typology. To develop measures of STEM school effectiveness outcome data is needed and because we are performing a school-level analysis we found it most appropriate to use school-level outcomes. As a result, we determined that we would create school-level outcome measures by taking student-level outcomes measures from the HSLS:09 2013 Update and aggregate to the school level. We selected outcomes for our analysis based on academic milestones students typically reach en route to a STEM career and evidence of postsecondary support (Bowers & Zhou, 2019). Evidence of postsecondary support for students' entrance into STEM has been previously characterized in the literature as the receipt of financial aid (Crisp, Nora, & Taggart, 2009; Wang, 2013; Wolniak, 2016). Taking this into consideration, we used student-level variables from the HSLS:09 2013 Update on whether or not the sample member graduated with a high school diploma; overall high school GPA; enrollment in a bachelor's degree program; received a Pell grant during the first year of postsecondary enrollment; and intent to major in STEM. Continuous distal outcomes variables were aggregated to the mean values for each school (e.g., GPA). Categorical distal outcomes were aggregated to the percentage of students in each school having a response in the category of interest (e.g., enrolled in a bachelor's degree program as their postsecondary program level).

4.7 | Missing data

All indicators in our baseline model have proportions of missing data below 10%. We followed recommendations from Strayhorn (2009) to account for missing data and used Full Information Maximum Likelihood (FIML) as suggested in the literature (Asparouhov & Muthén, 2014; Collins & Lanza, 2010; Enders, 2010). Cases with missing data across all indicators, $n = 120$, were omitted from all statistical procedures, reducing the study sample size to $n = 820$ for the enumeration model. The amount of missing data varied across all covariates, ranging from 0% to 4%. Cases with any missing data on covariates, $n = 40$, were dropped from the analysis, reducing the sample size to $n = 780$ when we included covariates in our model. For the distal outcomes, at the student-level, many of the variables had missing data over 40% before they were aggregated to the school level. The sample size was $n = 820$ when we added distal outcomes to our model.

Table 1, Table 2, and Table 3 summarizes the HSLS:09 variable labels, variable coding, and descriptive statistics for all indicator variables, covariates, and distal outcomes.

4.8 | Analytic approach

We used LCA to investigate whether or not there were significantly different types of schools based on their STEM orientation. LCA is a statistical method that is an extension of mixture modeling used to identify distinct subgroups within a population (Asparouhov & Muthén, 2014; Collins & Lanza, 2010; Jung & Wickrama, 2008; Masyn, 2013; Nylund-Gibson & Masyn, 2016; Samuelsen & Raczynski, 2013). In LCA, subgroups within the model sample are identified based on their similarities or differences on a set of indicator variables. We chose to apply LCA in the present study because it allows us to take a “person-centric” approach rather than “variable-centered” approach. Also, it allows us to focus on the schools as our research questions here are centered on schools. Last, school-level analysis as it relates to STEM-focused high schools has largely used qualitative methods in past literature (LaForce et al., 2016; Lynch et al., 2017; Scott, 2012; Tofel-Grehl & Callahan, 2014).

For our study, we used the three-step approach for estimating LCA models following recommendations in the literature (Asparouhov & Muthén, 2014; Masyn, 2013; Nylund-Gibson & Masyn, 2016; Vermunt, 2010). The three-step procedure is used to estimate the relationship between a latent class variable and a set of covariates or distal outcomes. In the first step, the latent class model “C” is estimated from a set of dichotomously scored indicator variables. This is done through an iterative approach where the model is fit to a k-class model and compared to the fit of a k-1 class model. In the second step, a “most likely class” variable is created to assign each member of the model sample to the class with the highest likelihood of membership. In the final step, auxiliary variables (covariates and distal outcomes) are tested whereas class membership is preserved. We used the R3STEP and BCH functionality to perform our covariate and distal outcome testing following recommendations in the literature (Asparouhov & Muthén, 2018; Muthén & Muthén, 1998-2015). Figure 1 shows the structural equation model tested for this study. All analysis was done using Mplus version 7.4 (Muthén & Muthén, 1998–2015). The Mplus code used for the analysis is included in the Appendix.

Model fit can be assessed using a number of methods. This includes using a set of information criterion or likelihood ratio tests to assess model fit, and interpretability and classification quality (i.e., entropy) to assess model usefulness (Jung & Wickrama, 2008; Nylund, Asparouhov, & Muthén, 2007; Vermunt, 2010). Some researchers suggest the Bayesian Information Criterion (BIC) for correctly identifying the appropriate number of latent classes in the model (Nylund et al., 2007). Another recommendation is the Lo-Mendell-Rubin (LMR) adjusted likelihood test to evaluate the model fit (Jung & Wickrama, 2008). Based on the suggestions in the literature, we decided to rely on the LMR test, BIC, entropy values, and theory to evaluate model fit.

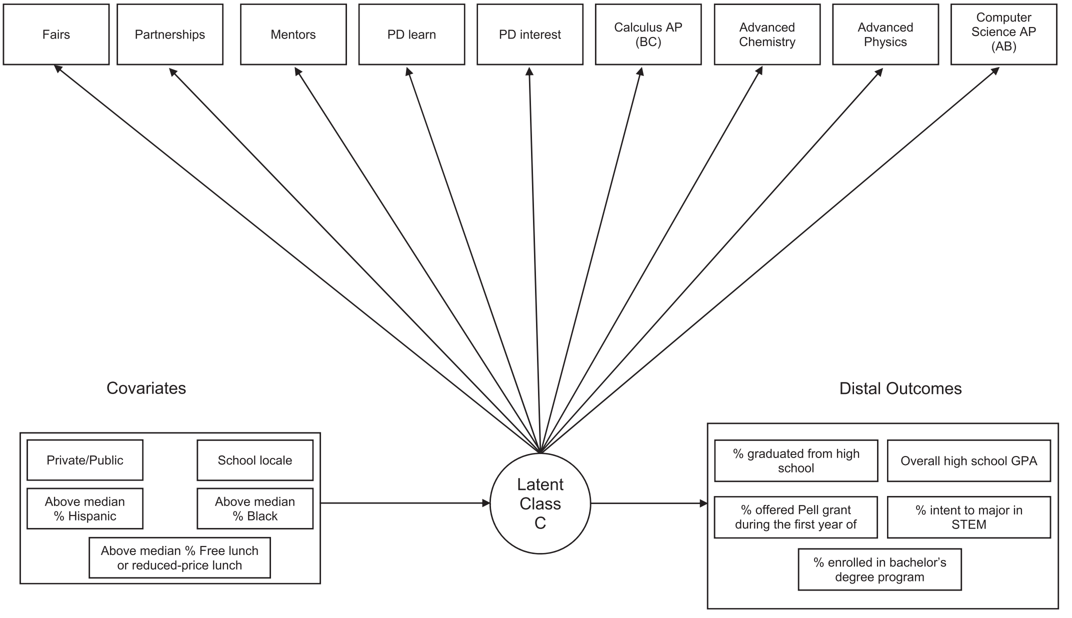

FIGURE 1 Latent class analysis model for STEM high school typology. STEM, science, technology, engineering, and mathematics

5 | RESULTS

In this study, we used LCA with data from the High School Longitudinal Study of 2009 (HSLS:09) to determine to what extent there are significantly different types of high schools based on their orientation toward STEM. In this section, we present our model fit statistics and then describe the four different subgroups of schools based on their STEM orientation. We conclude this section by reviewing which covariates significantly predict school subgroup membership and the association between high school outcomes and subgroup membership.

We tested a set of iterative models to identify the best model fit. Following the recommendations from the literature, we started with the two-class model and proceeded to subsequent models until the model fit statistics (BIC and LMR statistic) indicated the best model fit (Jung & Wickrama, 2008; Masyn, 2013; Muthén, 2004). Table 4 presents the model fit statistics for each estimated model. The first nonsignificant *p*-value of the LMR test occurred at the three-class model ($p = .345$), implying that the two-class model is the best fit according to the LMR test. The first positive change in the BIC occurred between the four-class (BIC = 7594.798) and five-class models (BIC = 7597.037), demonstrating that the four-class model is the best fit with the lowest BIC. Guided by our model selection, theory reviewed above, and that the current literature in LCA fit statistics indicates that BIC is superior to LMR (Nylund et al., 2007; Nylund-Gibson & Masyn, 2016), we selected the four-class model for interpretation.

TABLE 4 LCA results and fit statistics for STEM high schools

Model	AIC	BIC	−Log likelihood	LMR test for k-1 classes	*p*	Entropy
Two Classes	7683.017	7772.540	3822.508	607.048	.006	0.864
Three Classes	7465.413	7602.053	3703.706	234.116	.345	0.855
Four Classes	**7411.040**	**7594.798**	**3666.520**	**73.281**	**.519**	**0.841**
Five Classes	7366.162	7597.037	3634.081	63.925	.777	0.859

Abbreviations: AIC, Akaike Information Criteria; BIC, Bayesian Information Criteria; LMR, Lo-Mendell-Rubin Adjusted Likelihood Ratio Test; STEM, science, technology, engineering, and mathematics.
Bold values are the best fit model.

TABLE 5 Average latent class probabilities for most likely class membership (row) by latent class (column)

Latent class	Abundant	Comprehensive	Support	Bounded
Abundant	**0.872**	0.015	0.020	0.093
Comprehensive	0.007	**0.970**	0.008	0.015
Support	0.050	0.097	**0.853**	0.000
Bounded	0.084	0.046	0.000	**0.870**

Bold values are the best fit model.

The four-class model fit the data well with fit statistics of AIC = 7411.040, BIC = 7594.798, −Log likelihood = 73.281, and entropy = 0.841. The classification probabilities for latent class memberships reported in Table 5, shows the probability of a school belonging to a particular group being placed in that group. The off-diagonal elements in Table 5 show that the model fits the data well with all classes at 0.85 or higher.

We identified four significantly different groups of high schools based on their orientation toward STEM. We named the four groups of high schools *Abundant*, *Comprehensive*, *Support*, and *Bounded*. An indicator plot for the four groups of high schools is provided in Figure 2. The indicator plot portrays the response patterns of each group for the nine indicator items. As the first result from this study, for the first time in the literature using a large nationally generalizable sample of high schools, we show empirically that there is a four-group typology of high schools in their orientation toward STEM.

The *Abundant* group represented 12.3% of high schools (Figure 2; solid gray line). They are typified by high responses across all indicator variables. This group had the highest proportion of schools who indicated that they offer informal STEM learning opportunities for their students, such as mentorships and school-wide science and mathematics fairs. They also provide support for teachers in terms of professional development opportunities. Schools in this group also offer a wide range of rigorous STEM coursework. They were one of two groups of schools to indicate that they offer advanced computer science coursework.

The largest group, with 54.3% of the high schools, is the *Comprehensive* group (Figure 2; dashed gray line). This group appears to be most reflective of traditional high schools, with generally low responses across all of the indicators. Schools in this group indicated that they do not offer advanced STEM coursework, and a very small proportion require STEM-related professional development for their students and provide informal STEM experiences to raise student interest and achievement in STEM.

The LCA model also identified a group of schools that appear to be looking to build capacity in STEM education. At 23.3% of high schools, the *Support* group (Figure 2; dotted black line) had the highest proportion of schools who required teacher professional development to increase student interest and achievement in STEM. However, this group had very low proportions of schools that offered advanced coursework, and a moderate proportion offering informal STEM experiences to their students.

The smallest subgroup of schools is the *Bounded* group that comprises 10.1% of high schools (Figure 2, solid black line). This group can be contrasted with the *Support* group as they have the highest proportion of schools that offer advanced STEM coursework, but the lowest proportion of schools who required teacher professional development to increase student interest and achievement in STEM. This group also has a moderate proportion of schools offering informal STEM experiences to their students.

We present the relationship of the covariates to subgroup membership by reporting the means and odds ratios for the covariates in Table 6. The *Comprehensive* group was used as the reference category and odds ratios are reported for significant differences. Additionally, as odds ratios below 1.0 are difficult to interpret, we invert the odds ratios. Compared to public schools, private schools are 4.76 (1/0.21) times less likely to be in the *Abundant* group than the *Comprehensive* group ($p < .001$). With suburban schools as the reference category, schools located in towns are 7.14 (1/0.14) times less likely to be in the *Abundant* group than the *Comprehensive* group ($p = .008$). With suburban schools as the reference category, schools located in rural areas are 8.3 (1/0.12) times less likely to be in

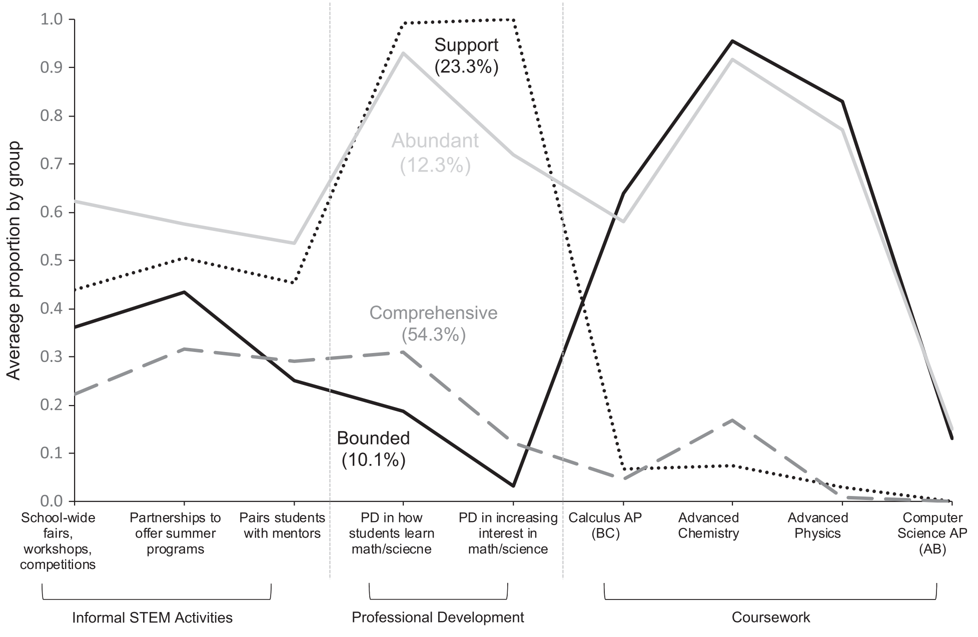

FIGURE 2 Indicator plot of LCA results by subgroup. LCA, latent class analysis

the *Abundant* group than the *Comprehensive* group ($p < .001$). When the percentage of students receiving free or reduced-priced lunch is above the median, schools are 3.57 (1/0.28) times less likely to be in the *Abundant* group than the *Comprehensive* group ($p = .003$). When the percentage of Hispanic students in a school is above the median, schools are 2.39 times more likely to be in the *Abundant* group than the *Comprehensive* group ($p = .015$). When the percentage of Black students in a school is above the median, schools are 2.32 times more likely to be in the *Abundant* group than the *Comprehensive* group ($p = .043$).

Compared to public schools, private schools are 3.22 (1/0.31) times less likely to be in the *Bounded* group than the *Comprehensive* group ($p = .017$). With suburban schools as the reference category, schools in towns are 12.5 (1/0.08) times less likely to be in the *Bounded group* than the *Comprehensive* group ($p = .001$). With suburban schools as the reference category, schools in rural areas are 5 (1/0.20) times less likely to be in the *Bounded group* than the *Comprehensive* group ($p = .005$). The results did not present any evidence of a significant relationship between the tested covariates and membership in the *Support* subgroup.

Lastly, we examine the relationship between school subgroup membership and distal outcomes. The findings are reported in Table 7. There was a significant difference in the mean high school GPA between schools in the *Abundant* group (2.95) and *Comprehensive* group (3.08; $p = .026$). There was a significant difference in the percent of students enrolled in a bachelor's degree program by 2013 between schools in the *Bounded* group (50.88%) and *Support* group (33.01%; $p = .001$); between the *Bounded* group (50.88%) and *Comprehensive* group (36.52%; $p = .002$); between the *Support* group (33.01%) and *Abundant* group (51.16%; $p = < .001$); and between the *Abundant* group (51.16%) and *Comprehensive* group (36.52%; $p = < .001$). There was a significant difference in the percent of students enrolled in postsecondary education in 2013 who intend to declare a STEM major between schools in the *Support* group (15.42%) and *Abundant* group (24.36%; $p = .005$); and between the *Abundant* group (24.36%) and *Comprehensive* group (18.09%; $p = .020$). There were no significant differences in the percent of students receiving a high school diploma and the percent of students offered financial aid for their first year of postsecondary education between schools in any of the groups.

TABLE 6 Means and odds ratios for covariates with comprehensive schools as the reference group

	Abundant (12.4%)			Comprehensive (54.3%)		Support (23.2%)			Bounded (10.1%)		
Variable	**Mean**	**OR**	***p***	**Mean**	**OR**	**Mean**	**OR**	***p***	**Mean**	**OR**	***p***
Private (vs. public)	0.16	0.21***	<.001	0.22	–	0.12	0.81	0.806	0.25	0.31**	0.017
School urbanicity											
City	0.33	0.50	.166	0.22	–	0.26	0.39	0.236	0.37	1.00	1.000
Town	0.04	0.14**	.008	0.21	–	0.19	0.44	0.226	0.06	0.08**	0.001
Rural	0.14	0.12***	<.001	0.33	–	0.27	0.41	0.108	0.15	0.20**	0.005
School demographics											
Above median % free lunch	0.44	0.28**	.003	0.53	–	0.72	4.50	0.080	0.34	0.42	0.124
Above median % Hispanic	0.58	2.39*	.015	0.36	–	0.44	0.76	0.586	0.50	1.94	0.178
Above median % Black	0.60	2.32*	.043	0.41	–	0.44	1.05	0.917	0.48	0.63	0.334

Abbreviation: OR, odds ratio.

*$p < .05$.

**$p < .01$.

***$p < .001$.

TABLE 7 Means and *p*-values for distal outcomes

Variable	Abundant (12.4%)/1	Comprehensive (54.3%)/2	Support (23.2%)/3	Bounded (10.1%)/4	*p*-Value 1 vs. 2	*p*-Value 1 vs. 3	*p*-Value 1 vs. 4	*p*-Value 2 vs. 3	*p*-Value 2 vs. 4	*p*-Value 3 vs. 4
Mean high school GPA	2.95	3.08	3.08	3.03	.026	.070	.258	.995	.393	.443
% of students with high school diploma	96.93	94.13	97.40	97.68	.264	.652	.500	.232	.175	.792
% of students enrolled in a bachelor's degree program	51.16	36.52	33.01	50.88	<.001	<.001	.958	.459	.002	.001
% of students who will be considering a STEM major	24.36	18.09	15.42	20.93	.020	.005	0.224	.477	.384	.112
% of students offered a Pell grant for their first academic year of postsecondary education	42.83	44.13	48.00	40.89	.643	.235	0.569	.398	.351	.124

Note. Significance tests are Pearson's χ^2.

6 | DISCUSSION

The purpose of this study was to empirically identify a typology of high schools based on their orientation toward STEM from a nationally representative sample of high schools using LCA. In addition, our aim was to determine what school-level factors predicted school subgroup membership and subgroup membership's effect on student outcomes. By using LCA, we were able to empirically identify a four-group typology of schools based on their orientation toward STEM: *Abundant*, *Comprehensive*, *Support*, and *Bounded*. In this discussion, we first discuss the overall findings of the four different subgroups of schools, followed by a discussion of how the findings apply to the current research on STEM-focused schools. Finally, we discuss the limitations of the study, followed by implications and concluding remarks.

6.1 | Summary of overall findings

Four different types of high schools based on their orientation toward STEM emerged. High schools in the *Abundant* subgroup offer a wide range of advanced coursework to their students, STEM-focused professional development for their teachers, and use a variety of informal STEM practices to increase their students' interest in STEM. The *Abundant* subgroup is noteworthy for having the highest proportion of schools that offer advanced computer science and is one of only two subgroups that offer computer science at all. Students in these high schools are much more likely to enroll in a postsecondary bachelor's degree programs and to consider a STEM major in college. However, whereas schools in the *Abundant* subgroup appear to fit the ideal STEM high school with strong levels of STEM student and teacher support along with multiple high-level STEM course offerings, a central finding of this study is that the *Abundant* subgroup is only 12.3% of high schools. In addition, we find access and equity issues, as schools in the *Abundant* subgroup have the second lowest mean for being above the median percentage of students receiving free or reduced-price lunch. They are also much less likely to be located in town and rural areas than the *Comprehensive* subgroup. However, schools in the *Abundant* subgroup have the highest mean for being above the median percentage of Hispanic and Black students of the student body. Schools in the *Abundant* subgroup also have the highest percentage of students who go on to enroll in a bachelor's degree program and consider a STEM major in college.

Opposite to the *Abundant* subgroup is the *Comprehensive* subgroup. As the majority of high schools (54.3%), this group appears to be the most traditional type of high school that does not focus on STEM specifically, reporting that they offer very limited advanced coursework, with small proportions offering calculus and advanced chemistry, and generally have lower tendencies of implementing practices to increase student interest in STEM and requiring STEM professional development for teachers.

In comparison, the *Support* subgroup is 23.3% of high schools. Schools in this subgroup are distinguished by their high propensity for requiring teachers to participate in STEM-related professional development but are much less likely to have advanced STEM course offerings for their students. There was no evidence of a significant relationship between the tested covariates and school membership in the *Support* subgroup. Schools in the *Support* subgroup had the highest percentage of students who received a Pell grant for their first year of postsecondary education.

Finally, the *Bounded* group is 10.1% of high schools. Schools in this subgroup are the most likely of all the subgroups to offer advanced STEM coursework but have moderate to low levels of school efforts and professional development for increasing student interest in STEM. Similar to the findings for the *Abundant* subgroup, schools in the town and rural areas are less likely to be in the *Bounded* subgroup than in the *Comprehensive* subgroup.

These findings add to the STEM-focused high school literature in four main ways. First, this study is the first to identify the extent that there may be different types of high schools in the United States based on their STEM orientation, identifying four different types of high schools. Second, our study's findings provide a description of differences between the four types of schools in the ways that they are focused offering informal STEM activities, offering teacher professional development in STEM, and advanced coursework in STEM fields. Third, by using a nationally representative sample, our results are generalizable to all regular public and private high schools in the 50 United States and District of Columbia with grades 9 and 11 in 2009 (Ingels et al., 2013). And fourth, this study brings us one step closer to building a definition of what constitutes a STEM-focused school and describes other categories of STEM-focused school models not addressed in the literature previously.

6.2 | Application of the typology of STEM-oriented schools and current research

STEM education policy documents report that there is a typology of STEM-focused high schools in the United States (Means et al., 2008; National Research Council, 2011). Our findings align with the work of the National Research Council (2011). In their report on successful education in the STEM disciplines, they uncovered four different types of STEM schools and programs: (a) selective STEM schools, (b) inclusive STEM school, (c) schools with STEM-focused CTE and (d) STEM programs in comprehensive schools. In addition, they focused on mathematics and science disciplines, not because of a belief that engineering and technology education is not important, but the education research in those disciplines are not as established (National Research Council, 2011). In our study, we focus on mathematics and science for similar reasons and due to the limitations of our selected data set.

There are similarities between the four-group typology presented by the National Research Council and the findings from our typology analysis. First, the majority of the sample schools used in our analysis best described themselves as a regular, nonmagnet or charter, school. For that reason, we suggest that our four groups are likely derivations of STEM programs in comprehensive schools. At the same time, we do note some similarities between our four groups and the other broad National Research Council categories. There are similarities between selective STEM schools and two of our subgroups, *Abundant* and *Bounded*. The *Abundant* subgroup is most aligned with selective STEM schools in terms of their emphasis on advanced STEM coursework, STEM-focused teacher professional development, and informal STEM activities such as mentorships for students, and community partnerships. These characteristics have been noted in the literature several times as attributes of selective STEM schools (Atkinson et al., 2007; Means et al., 2008; National Research Council, 2011; Thomas & Williams, 2010). The *Bounded* subgroup is also similar to selective STEM schools in regard to advanced coursework.

Schools in the *Abundant* and *Bounded* subgroups also are similar to inclusive STEM schools in terms of academic rigor, and additionally, the *Abundant* subgroup also exemplifies inclusive STEM schools by offering STEM-related professional development and informal activities (National Research Council, 2011; Rogers-Chapman, 2014). Our finding that schools in the *Abundant* subgroup have the highest percentage of Hispanic and Black students makes this subgroup comparable to inclusive STEM schools because inclusive STEM schools aim to reduce achievement gaps among racial groups and eliminate issues of equity and access to a quality STEM education by eliminating selective admissions criteria (Lynch et al., 2015; Means et al., 2008). Although, we were unable to account for admission criteria in our analysis due to limitations with the selected data set.

Another commonality with our findings and previous research is the importance of STEM school location and racial and economic composition. Our results show evidence that school locale is a significant predictor of school subgroup membership. As mentioned previously, the location of STEM high schools could provide a narrative for the racial and economic disparities in STEM (Rogers-Chapman, 2014; Scott, 2012; Subotnik et al., 2013). Atkinson and Mayo (2010) critiqued selective STEM high schools around issues of access and equity. In our study, schools in town and rural areas are less likely to be in the *Bounded* subgroup than the *Comprehensive* subgroup, and schools in town and rural areas are less likely to be in the *Abundant* subgroup than the *Comprehensive* subgroup. Schools in both of these subgroups have a higher likelihood of being located in suburban areas.

Last, there are similarities in our study's finding and extant literature related to measuring the success of different STEM school models. In their study, Subotnik et al. (2013) investigated the benefits of attending selective STEM schools and found that these students were more likely to complete a STEM degree in college. Likewise, students in schools in the *Abundant* and *Bounded* subgroups are more likely to consider a STEM major in college. The mean values in the *Abundant* (51.16%) and *Bounded* (50.88%) subgroups of the percentage of students enrolled in a bachelor's degree program are significantly different from the *Comprehensive* and *Support* subgroups. Means et al. (2016) found in their study that attending inclusive high schools increased the likelihood of having an interest in a STEM degree, which is similar to the effect we found when testing the relationship between subgroup membership and distal outcomes for the *Abundant* and *Bounded* subgroups.

There are many ways our study's findings are different from prior literature. First, the literature states that access to selective STEM schools is layered based on race and ethnicity, with fewer opportunities available for students from underrepresented groups (Rogers-Chapman, 2014; Scott, 2012; Subotnik et al., 2013). Our *Abundant* subgroup had the highest mean above the median percentages of Hispanic and Black students in the student body, which demonstrates the equity and access issues among racial groups are not entirely present. Thus, our finding is a deviation from what is stated in the literature and was a surprising finding given that our *Abundant* subgroup offers the richest STEM education experience. In addition, the *Support* subgroup had the highest mean above the median percentages of students on free or reduced-price lunch in the student body. Both of these subgroups had the highest proportions of schools who offer STEM-focused professional development and, in some cases, serve historically underserved populations more often. Whereas these outcomes appear promising, we are unable to confirm what access these students have to the STEM opportunities in their schools.

Second, there is no direct alignment between our subgroups and the National Research Council's STEM-focused school and program categories. For example, our *Comprehensive* subgroup has a very small proportion of schools offering advanced coursework or other STEM-related opportunities for students and teachers, which differs from National Research Council's (2011) "STEM programs in comprehensive schools" category where schools would provide these opportunities. Partial cause for this is on account of our inability to measure a school's STEM emphasis according to what is described in the extant literature and available in our selected data set. Other reasons include variations in definitions in STEM schools and fields, and previous studies identifying STEM schools based on self-identification before testing the merits of their claims of offering a STEM-focused program (LaForce et al., 2016; Tofel-Grehl & Callahan, 2016, 2014). In addition, we are unable to make comparisons between our subgroups and STEM-focused CTE because we were unable to account for specialized CTE programs in our analysis. This reiterates that the National Research Council's categorizations for STEM-focused schools and other frameworks (Erdogan & Stuessy, 2015b; Means et al., 2008) presented in the literature are not comprehensive.

In general, our study is similar to the NRC's report in that our intent was to identify and examine categories of STEM-oriented schools. However, the present study is distinct in that we investigate the prevalence of different types of schools based on their STEM-orientation using a nationally generalizable sample of regular public and private schools. Whereas HSLS:09 did ask sample member high schools in the base-year about their school's special focus, the subsample of schools focusing on mathematics or science was too small ($n = 10$) to use for analysis with any multivariate clustering technique. In addition, our point was not to derive categories from a sample of schools who already self-identify as STEM-focused or have a STEM-focused mission, but rather to generally determine how much variation exists among schools concerning their emphasis on STEM education. This distinguishes our study from past research on STEM-focused schools and programs in that we wanted to use a data set that allowed us to glean the advanced STEM education experiences students are receiving that may be out of the confines of a specialized high school, especially within the context of public education. A core finding of this study is that it is useful and important to consider what schools say they do and offer, versus just their slogans and missions. Our study provides evidence that guiding our data selection and analysis by what schools say they offer and do produces results that are somewhat divergent from what has been highlighted in the extant literature.

7 | LIMITATIONS

There are a number of limitations to our study. First, although we used a nationally representative sample of high schools, we had limitations on the number of indicators we could include in our LCA due to our relatively small sample size (n = 820) and concerns about statistical power (Dziak et al., 2014). In addition, there were limitations to the student-level data. For our study, the range of students per school used for the aggregation to generate our distal outcomes was 10–40. The mean number of students was 13.80 and the median was 13.00. Because of the severity of the proportion of missing data at the student-level coupled with the fact that HSLS:09 on average sampled 27 students per school (Ingels et al., 2013), we encourage caution in interpreting the distal outcome results and encourage future research to investigate this topic further. Second, there were many elements of STEM-focused high schools that we could not include in our LCA model because our data set was limited. For example, at the school level, HSLS:09 does not provide information on school admission standards and information about classroom instruction as it relates to STEM. Whereas STEM can be broken down into four disciplines, much of the research on STEM-focused high schools concentrate on science and mathematics. This limitation was also prevalent in our data set as most of the variables related to STEM focused on science and mathematics. This is not surprising, as science and mathematics have more established positions in the secondary school curriculum. However, efforts should be made to research the place of technology and engineering in STEM education as to not overlook the valuable contribution these fields make in a student's STEM education experience. Third, the scope of our analysis was limited due to a lack of survey items in HSLS:09 that focus on non-STEM coursework and professional development in non-STEM areas. Thus, we were unable to truly assess whether or not some schools were more likely to offer more advanced STEM coursework and professional development in STEM areas in comparison to advanced non-STEM coursework and professional development in non-STEM areas. Lastly, the information in HSLS:09 is subject to reporting biases because they are self-reports by school administrators and are not a guaranteed reflection of what practices actually take place in the school. For example, school administrators may be less aware of student mentorship practices if such school-wide initiatives are implemented at the classroom level.

8 | CONCLUSIONS AND IMPLICATIONS

In conclusion, this study presents a new typology of STEM-oriented high schools and reiterates the effects of varying definitions of STEM and STEM education. The resulting typology offers four distinct groups of schools based on their STEM orientation that are generalizable to all regular public and private schools in the 50 United States and District of Columbia with grades 9 and 11 in 2009. Also, we find that the subgroups have many similarities and differences to other STEM school typologies presented in the extant literature. Because we decided to guide our study based on what schools say they do and offer, we highlight how this changes the narrative of what it means to be a STEM-focused school. For example, our study shows that some schools provide greater emphasis on professional development, whereas others are primarily focused on course offerings. STEM education is not a unidimensional construct and this study highlights the inequitable representation of the STEM disciplines, such as technology and engineering. This helps to advance the establishment of the T and E in STEM and development of accountability policies (National Research Council, 2011). Our study has strong implications for future studies on STEM-focused school types. First, in addition to contemplating the character of STEM school models, future research should also consider the context in which the schools are operating and its impact on student success and STEM outcomes. This is important largely because context influences school resources and policies. Second, further research should focus on the importance of teachers, especially as it relates to curriculum and instruction, in STEM schools models (National Research Council, 2011).

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APPENDIX

Mplus Code

```
TITLE: STEM HS LCA HSLS:2009
DATA: FILE="STEM HS LCA.dat";
VARIABLE:
NAMES=SCH_ID W1SCHOOL SCIFAIR SUMMER MENTOR PDLEARN PDINTRST
CLCAPBC ADVCHEM ADVPHYS CMPSCIB PRIVATE CITY TOWN RURAL MEDLUNCH MED-
HISP MEDBLACK MEANGPA PCTHSDIP PCTBACH PCTSTEM
PCTPELL;
MISSING=ALL(9999);
IDVARIABLE=SCH_ID;
WEIGHT=W1SCHOOL;
USEVARIABLES=SCIFAIR SUMMER MENTOR PDLEARN PDINTRST CLCAPBC
ADVCHEM ADVPHYS CMPSCIB;
CATEGORICAL=SCIFAIR SUMMER MENTOR PDLEARN PDINTRST CLCAPBC
ADVCHEM ADVPHYS CMPSCIB;
CLASSES=c(4);
AUXILIARY=(R3STEP) PRIVATE CITY TOWN RURAL MEDLUNCH MEDHISP MEDBLACK;
AUXILIARY=MEANGPA(BCH) PCTHSDIP(BCH) PCTBACH(BCH) PCTSTEM(BCH)
PCTPELL(BCH);
ANALYSIS:
TYPE=MIXTURE;
```

```
PROCESSORS=8 (STARTS);
MITERATION=5000;
STARTS=3000 300;
STITERATIONS=100;
PLOT:
TYPE=PLOT3;
SERIES=SCIFAIR SUMMER MENTOR PDLEARN PDINTRST CLCAPBC
ADVCHEM ADVPHYS CMPSCIB(*);
SAVEDATA:
SAVE=CPROBABILITIES;
FILE=4 CLASS CPROBS.dat;
FORMAT=FREE;
ESTIMATES=4 CLASS MIXEST.dat;
OUTPUT:
TECH10 TECH11;
```