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Impacts on Secondary School Students of Hands-On Environmental Measurement Projects Mentored by College Students (Evaluation)

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Abstract

A unique program partners university students to mentor rural secondary students with a goal toward building science and engineering identity and supporting learning. High school students in STEM courses at rural schools complete open-ended inquiry-based projects using air or soil quality monitors. In Spring 2025 the program was integrated into 28 STEM classes across 11 schools, with about 574 secondary students mentored by 30 engineering college students receiving course credit for their engagement. The program has been growing and improving since 2013 based on feedback from the program coordinators, classroom observations, surveys of the college mentors, and focus groups with the college mentors. Spring 2025 was the first year that significant evaluation data were available from the secondary school students. Students at 7 schools completed a pre-retrospective / post survey. Science identity increased on the post-survey among students at 6 of the schools, with gains in science interest at 6 schools, performance competence at 4 schools, and recognition at 4 schools. Engineering interest and confidence to learn engineering increased at only 3 schools. Gender differences were found, with female students lower than male students in their overall science identity (small effect size) and engineering interest (large effect size). There was generally strong agreement among the high school students that the university mentors helped them be successful in their air or soil quality projects. The results demonstrate that the program which leveraged place-based inquiry learning projects mentored by engineering college students increased the science identity of many of the secondary students. Program changes are in-progress in attempts to bolster engineering interest and confidence.

Introduction

Outreach partnerships between colleges and K-12 education offer potential benefits to both groups of students. A unique community engagement program that encompasses multiple rural schools pairs college students with secondary STEM classrooms. Secondary students use university-provided environmental monitoring equipment in locally relevant inquiry projects. College students take a for-credit mechanical engineering course where they learn about environmental monitoring, mentoring projects, and teaching. The majority of the program evaluation activities for the past 10 years have focused on examining the experiences of and benefits to the college student mentors. This paper explores the impacts on secondary students. The paper first provides an overview of the motivation for the program and background on student identity. This is followed by a description of the program and the evaluation survey that was used with the K-12 students. The evaluation results are then presented and discussed. Implications for future changes in the program conclude the paper.

Background

Rural students are underrepresented in college and STEM majors. Among the class of 2024 high school graduates, 53.2% from rural schools immediately enrolled in college, compared to 63.4% from suburban schools and 49.5% from urban schools [1]. This represented a decrease from 54.8% immediate college enrollment among rural high school graduates in 2023 and 53.9% in

2022. More specifically, STEM participation rates in college among students from rural areas lags other groups [2]. These numbers highlight a missed opportunity. Rural communities need STEM-prepared professionals [3] and the nation can benefit from STEM professionals with rural backgrounds [4]. For example, individuals with rural backgrounds often have a deep connection to the land and natural resources, as well as a collaborative mindset. Rural students also frequently encounter STEM issues in their daily lives and can bring this intuition and these skills to higher education [5]. These assets represent Rural Cultural Wealth (RCW) that can support the journeys of rural students in STEM majors in college [6]. However, because rural high school students often shift away from STEM without intervention [4], activities that help interest rural students in college and STEM are important. These activities may include project-based learning and exposure to local STEM career opportunities [6]

While rural environments impart a number of assets, there are also well documented challenges. There are often fewer opportunities for advanced STEM courses and STEM extracurricular activities which can limit students' preparation for admission to highly selective colleges and scholarship opportunities [2]. Rural life might also look different on a college application, since work is with family and may not look like urban "community service" or leadership. Cost and distance to college pose additional challenges [7],[8]. There may also be a lack of role models for STEM careers [9].

A growing body of research explores the importance of disciplinary identities in K-12 learning (e.g., [10]) for developing students' sense that school learning is relevant to and consequential for everyday life [11],[12],[13] and for encouraging future aspirations and pathways, including pursuit of and persistence in academic degree programs [14],[15],[16]. Project-based and inquiry-based learning such as that used in this initiative have been shown to foster disciplinary identities in science [17] and engineering [18]. Place-based [19] and community-connected approaches to engaging youth in consequential science and engineering have been shown to both foster learning and identity development among rural elementary and middle school students [20],[21].

The conceptualization of identity used in this project is drawn from sociocultural approaches (e.g., [22]) and practice theory (e.g., [23]), which view identities as culturally informed, dynamic, and constantly unfolding through participation in practices. This backdrop informs the notion that all humans have *trajectories of identification* [24],[25],[26] that refer to the experiences of individuals as they travel through space and time, and across the borders of different "communities of practice" [27]. Individuals experience multiple trajectories of identification over time corresponding to communities of which they are a part. Trajectories of identification directly influence learning pathways [28], through the ways that people interact within communities, and how people connect their pasts, their present lives, and the futures they imagine.

We utilize an adaptation of a STEM identity survey [29] that is based on identity research in science education [30] and engineering education [31],[32]. The survey includes three key subconstructs, interest [33], performance-competence [34], and recognition [35],[36]. Interest reflects intrinsic enjoyment and a desire to engage with STEM content. Performance-competence is the extent that students feel they can successfully learn and understand STEM subjects and also demonstrate STEM skills such as through homework assignments. Recognition is being seen by others including teachers, peers, and family as being capable in STEM. Godwin et al. [31] used survey items to explicitly measure physics identity and math identity using items mapped to interest, recognition, and performance-competence subconstructs. Dou and Cian [29] measured STEM identity in these same 3 subconstructs. We adapted survey items to measure science identity across the 3 subconstructs and engineering interest. More details on the survey are provided in the section "Evaluation Survey for Secondary Students."

Because women continue to be underrepresented in STEM fields, developing STEM identity among women is particularly important, and it has been showed to be fostered through positive social recognition [37],[38]. In a large study of high school students, a gender gap was found in the engineering identity of male and female students, with lower interest, attainment value, and self-efficacy among female students [39]. STEM interest was slightly lower among female compared to male high school students, among a group that was primarily African American [40]. Studies have also found lower physics identity among female compared to male college students [34].

Questions: Given this background, we were interested in evaluating the extent to which a unique outreach program that embedded place-based inquiry projects mentored by college students in rural STEM secondary classes would impact the STEM identity of the secondary pupils. Given the complexity of the program which partnered with multiple schools, different classes, and unique teachers, the differences in the effectiveness of the program in fostering STEM identity at these different schools was of interest. We also wanted to evaluate if there were differences between female and male pupils in the impact of our program on their STEM identity.

Program Description

From the perspective of secondary school partners, the SCENIC program consists of three key elements: curriculum, equipment, and mentors. The inquiry-based curriculum embeds air or soil quality monitors (equipment) that students can use in local projects of personal interest. College students have been trained to teach the curriculum and mentor the secondary students on their projects. Teachers at the schools determine how best to integrate the curriculum into one or more of their STEM courses and provide support for their pupils as they conduct their personal projects. The program is led by two faculty at the University of Colorado Boulder – one with expertise in education and the other with expertise in environmental engineering monitoring equipment. The education expert is the primary contact person with the secondary schools and typically travels to each partner location about once per year. More recently the program has added rigorous evaluation and research components, including two additional faculty members, graduate students from the School of Education, and an external evaluator associated with a current NSF grant (EEC #2318489).

From the university perspective, STEM college students are recruited to participate in a 3-credit course that spans two semesters (1 credit in fall, 2 credits in spring). The course is offered through mechanical engineering (the home department of the two lead faculty) and is cross-listed at the senior undergraduate level and the graduate level. The course can serve as a technical elective for engineering students. In the fall semester, students learn how to teach the curriculum, use the environmental monitoring equipment, and conduct independent projects similar to those that the secondary students will conduct in the spring. The college students are formally prepared to serve as project mentors for secondary pupils enrolled in STEM courses in high school or middle school (and are thus called 'mentors'). These college student mentors are paired and matched with a partner secondary teacher. The mentors travel to the secondary rural school (anywhere from a 1 to 6 hour drive from the University) once in the fall semester to begin to understand the local context, run an icebreaker activity and meet their partner class. In the spring semester these mentors teach the curriculum at the partner schools and mentor the inquiry-based learning projects, with approximately monthly in-person trips to the partner school and some "virtual visits" to classes using videoconferencing.

The class includes sections that are focused on air quality or soil quality. The curriculum itself includes 5 lessons [41],[42]. The first two lessons are different for air and soil. Lesson 1 objectives provide background content and hands-on activities to engage the students in either air or soil quality content and to learn the capabilities of the appropriate environmental monitor. Lesson 1 activities occur inside. Lesson 2 activities typically occur outside and take a deeper dive into active learning, measuring tailpipe emissions for the air quality section and building structures to counter erosion in the soil quality section. Lesson 3 is similar for both sections and is focused on brainstorming an idea for a hands-on student project. This lesson includes activities to connect air or soil quality to everyday examples in a student's life such as hobbies (e.g., biking and particulate matter from cars or hiking and trail erosion). Students are also shown examples from other projects. The secondary students generally work in teams of 2 to 4 and brainstorm ideas for their inquiry projects assisted by the college mentors. Lesson 4 is focused on data collection with the monitors and analysis of the collected data including data visualization. Lesson 5 is focused on communicating their results and displaying them in a poster. The curriculum wraps up with a poster symposium at the secondary school where secondary students present their posters to their fellow classmates, college mentors, teachers and invited community members.

The key collaboration is generally between individual teachers and the university program leads (who are also the co-instructors of the university course). The program began as part of a Sustainability Research Network (SRN) funded by the National Science Foundation (NSF) with 1 partner school in 2013 using the air quality (AQ) curriculum. Over time the number of partner schools grew, with changes each year. The soil quality (SQ) curriculum was added in 2021. The inquiry curriculum has been integrated into secondary courses including environmental science (including AP / IB versions), chemistry, physics, math, and specialty electives like river systems and global science. These courses were most commonly offered to high school students, with about 1 course per year serving middle school students. Many of the secondary schools and teachers continue to use the curriculum over a number of years. The program includes online professional development activities for the cohort of teachers who participate, mentored by the university faculty and graduate students. The format leverages the shared expertise of the group, including teachers who have previously used the curriculum sharing their experiences and insights.

Study Year

In the fall 2024 / spring 2025 academic year the participants included 11 rural secondary schools (10 high schools, 1 middle school), 13 different secondary STEM teachers (12 who had previously taught the curriculum), and 28 classes (e.g., Environmental Science, Chemistry).

The basic characteristics of the rural secondary schools are summarized in Table 1. Not all of the schools are officially categorized as rural by the NCES [43], with a number whose geographic context is described as a town. We have broadly described our partner schools as rural, aligned with the literature which indicates that the concept of rural is socially constructed and varies across classification systems [44],[45]. In addition, some of these schools were in the rural and town categories when they initially joined the program (some more than 10 years ago); schools are able to remain participating partners regardless of changes in regional population impacting geographic context classifications.

Table 1. Partner K-12 Schools in 2025

DEID School	Type	Grade levels at the School	Geographic context (NCES) +	Student number ^	% FRL eligible ^	Graduation rates, %	College going rates, %
HS1	Public	9-12	Town, distant [32]	616	52	91	*~49*
HS2	Public	9-12	Town, remote [33]	910	60	88	*~49*
HS3	Public	PK-12	Rural, remote [43]	~125	28	83	*~47.5*
HS4	Public	9-12	Rural, remote [43]	278	53	93	*~47.5*
HS5	Public	9-12	Rural, distant [42]	1069	51	89	*~47.5*
HS7	Public	9-12	City, midsize [12 *]	1987	73	90	*~60*
HS8	Public	9-12	Rural, remote [43]	217	59	84	*~47.5*
HS9	Public	9-12	Rural, remote [43]	450	49.9	96	*~47.5*
HS10	Public	9-12	Rural, distant [42]	40	45	~90	*~47.5*
HS11	Public	10-12	Suburban, midsize [22]	1273	29	93	59
MS6	Public	PK-8	Rural, remote [43]	252	57.5	N/A	N/A

\+ NCES Locale Codes [43]:

- Rural outside urban cluster: (42) distant 5-25 miles, (43) remote >25 miles
- Town inside an urban cluster (<50,000) and distance from urbanized area: (32) distant 10-35 miles from urbanized area; (33) remote = more than 35 miles from urbanized area;
- Suburb, midsize (22): outside principal city but inside an urbanized area with population 100,000 to 250,000.
- City, midsize (22): inside an urbanized area; 100,000-249,000 population;

* When the High School opened it was located on the outskirts of a town of ~30,000 people, surrounded by rural farmland and cornfields. It was considered a "rural school" or "out of town" before urban growth surrounded the campus.

^ NCES data [46], Colorado State Department of Education (SchoolView) [47], or U.S. News Best High Schools profiles [48]

Note that the State of Colorado estimates that for rural schools ~47.5% of students attend college; estimates for towns are ~49%, suburban ~55%, and urban ~60%. These estimates were used for all schools except one that published its own data.

Among the classes, 25 used the air quality (AQ) curriculum and 3 used the soil quality (SQ) curriculum. Each teacher was provided with 2-4 air or soil quality monitors for their use, depending on the number of students involved. The teachers retained these monitors for the months that they engaged with the program. In total across all of these classes, about 574 secondary students participated in the curriculum. In general, each teacher was partnered with 2-3 college students, depending on number of secondary students in their classes. In total, 30 college students participated. Among the college students, 29 were engineering majors and 1 in another STEM discipline. College student ranks included undergraduate students (n=24, juniors to fifth year seniors) and graduate students (n=6).

Evaluation Methods

Historically, the project has conducted a variety of evaluation activities. This has included feedback from the college student mentors via focus groups conducted during class at the end of the spring semester and individual surveys. Standard student evaluations of teaching are administered by the campus each semester and provide anonymous feedback. The faculty leading the team routinely meet to share insights, with a weekly teaching team meeting that includes the teaching assistant for the college course (typically a graduate student who previously took the course as a student) and a graduate student from the school of education (who periodically conducts observations of the college course and some of the K-12 classes). The program added an external evaluator in 2023 who interviewed 4 faculty leaders associated with the program, K-12 teachers, and conducted a few visits to K-12 partner classes. Some earlier evaluation (and research) results have been published [49],[50],[51].

In spring 2025 the program added evaluation of the K-12 students. After participating in the inquiry projects and presenting their posters at the concluding symposium, secondary students at 7 of the participating schools were invited to complete an online pre-retrospective / post survey as part of the program evaluation process. The survey included primarily 6-point Likert-type items and two open-ended questions, as well as demographic questions (see Appendix with the evaluation survey). A series of 11 items measured science identity (including 3 sub-constructs), with a smaller number of items measuring engineering interest and confidence. More specific information on the survey is described below.

A summary of the secondary school evaluation context is shown in Table 2. The timing and methods that teachers used to encourage their students to take the survey varied. There were responses from 197 secondary students. A few students (n=7) only filled out the pre-retrospective survey items or the post items but not both. HS7 was removed from the school-level analysis due to the low number of respondents (n=7, only 6 completed both the pre and post items) and response rate (16%). Among the other 6 schools response rates ranged from 40% to 73%. (Note that HS4 ended up with only 1 college student mentor in Spring semester.)

Table 2. K-12 classes who partnered in evaluation activities in Spring 2025

School	N survey responses	N students	Response rate, %	SQ or AQ?	# classes	Class Name(s)	Yrs prior teacher experience w/ curriculum
HS1	26	46	57	AQ	2	Enviro Science	More than Five Years
HS2	20	40	50	AQ	2	River	Less than Five Years
HS3	22	30	73	AQ	2	Earth Science	Less than Five Years
HS4	15	25	60	SQ	1	Enviro Science	More than Five Years
HS5	79	196	40	AQ+SQ	8	Chemistry, River	More than Five Year
MS6	28	40	70	AQ	2	General Science	More than Five Years
HS7^	7	45	16	AQ	1	Enviro Science	More than Five Years

^ *removed from statistical analysis across schools due to low n and response rate*

Evaluation Survey for Secondary Students

The impact of the program on participating secondary students was evaluated using a survey at the end of the term. Most survey items prompted students to report their attitudes as they remembered them prior to the program and again at the time of the survey, using a retrospective pre–post design. Retrospective pre-post (RPP) surveys were first introduced in the late 1970s to address the weaknesses of traditional pre-test and post-test surveys for self-report measures such as attitudes and beliefs. Howard and Dailey [52] introduced the technique of administering retrospective pre-test and post-test items simultaneously at the end of an intervention to reduce response-shift bias. Such bias can be a problem when the interpretations by participants of the meaning of terms and questions in a survey might be different pre-intervention from what they are post-intervention, precisely because the intervention is targeted at the constructs underlying those terms and items. Little et al. [53] provide evidence for the increased "sensitivity to change" of RPP surveys compared to traditional approaches (p.181). Similar to traditional pre/post survey designs, nonresponse bias remains a concern in RPP designs whereby students with more negative attitudes or poorer experiences are less likely to respond resulting in overly positive estimates of program impacts [54],[55]. Biases particular to RPP include problems with recall of the past (especially among children) and implicit theories of change that might cause people to inflate their estimates of improvement over time [56]. Although RPP surveys are not widely used in educational research, there are a few examples. In a study about makerspace experiences among youth aged 11 to 18, Hamidi et al. [57] concluded that RPP surveys were better measures of effects on students' STEM interests and skills because at the beginning the youth "lacked a clear frame of reference."

The largest portion of the survey measured students' STEM identity using a series of 6-point Likert-type RPP items [see Appendix]. The identity items were adapted from [31], [30], and [29]. Prior work has operationalized student identity at varying levels of specificity, including discipline specific identities (e.g., science, physics, mathematics, or engineering identity) as well as broader STEM identity. Because our programs were implemented within high school science courses and enrolled students from a range of science classes, we elected to assess science identity to maximize face validity. Although the survey instrument of Dou and Cian [29] was originally developed to measure STEM identity, we were concerned that a composite STEM framing could mask meaningful variation across disciplines, such as students with strong science identity but weaker mathematics or engineering identification. Framing items explicitly around science was therefore judged to more accurately reflect students' classroom context and the construct most directly targeted by the intervention. Items from [29] were used verbatim, with the sole modification of replacing the word *STEM* with *science*. The original instrument in [29] demonstrated robust reliability and validity, including evidence from confirmatory factor analysis, internal consistency reliability (Cronbach's alpha), and factor loadings. Our survey has 11 total items to measure science identity, including the sub-constructs of interest with 2 items, performance competence with 4 items, and recognition by others with 4 items.

The program also hopes to spur student identity development in engineering, but at this stage the subconstruct of engineering interest is most relevant (2 survey items) and confidence to learn engineering (1 survey item). We don't expect that secondary students at these rural schools have enough significant experience with engineering to make the performance items relevant nor any way to meaningfully judge engineering recognition items, so these identity elements were not surveyed. One item specifically asked about students' confidence in using engineering equipment to measure air or soil quality. There were also survey items to measure perceptions of the role of the college student mentors and place-based application of science/engineering. The survey included two open-ended items. Students were provided with a link to take the evaluation survey online in Qualtrics. The data were exported from Qualtrics into Excel.

To analyze the survey results, a variety of statistical tests were conducted. Overall science identity was represented by the average across the 11 survey items. The identity sub-constructs also represent per-person averages across the multiple survey items. Simple paired t-tests of the retrospective pre/post responses to compare the means were conducted in Excel. These tests were conducted both across the entire pool of student responses and among the responses from individual schools. Statistically significant differences were inferred for p values less than 0.05. Unpaired t-tests compared male to female responses. To indicate effect size, Cohen's D was calculated with values greater than 0.80 representing a large effect, 0.50-0.80 indicating a moderate effect, and 0.20 to 0.50 a small effect. To explore potential variation in medians across the six schools, non-parametric tests were conducted in IBM SPSS v31, including the independent samples Kruskal-Wallis test followed by post-hoc pairwise comparisons that are equivalent to Dunn's test (sig.) and then applying the Bonferroni corrections to control for Type I error (adj. sig.); results are shown in the Appendix. Significant differences were inferred when the paired test sig. was 0.10 or lower; the Bonferroni adj. sig. values are shown for completeness. However, the Bonferroni correction is widely recognized as overly conservative and increases Type II errors [58].

The intent of this study was not to develop or conduct a comprehensive psychometric validation of a new survey instrument, but rather to evaluate program impacts using items aligned with established identity constructs. Face validity was supported by adapting items from previously published surveys that had undergone rigorous validity and reliability testing, combined with review by the research team, which includes expertise in STEM education and assessment. Internal consistency reliability of the resulting scales was examined using Cronbach's alpha values calculated in IBM SPSS v31. All of the retrospective pre and post responses for the same item were combined. Because students skipped various items, the number of cases included in each analysis varied and are reported. The Cronbach's alpha values indicated strong reliability of the scales: science interest (2 items, n 384, α 0.840), science recognition (4 items, n 383, α 0.851), science confidence (4 items, n 374, α 0.891), science identity overall (11 items, n 364, α 0.934), engineering interest (2 items, n 352, α 0.930), engineering interest + confidence (3 items, n 350, α 0.926). Item correlations are also shown in the Appendix, with moderate to strong relationships between the items in the same constructs. Additional forms of validity evidence (e.g., confirmatory factor analysis or convergent validity testing) were beyond the scope of the present study and were not necessary for the intended descriptive and comparative analyses.

Results from the Secondary Student Evaluation Survey: Quantitative Items

There were 190 students who completed all of the retrospective pre / post items. Paired tests found that overall science identity (averaged across the 11 survey items) increased among 57% of the students (average gain 0.5 Likert points), did not change among 31%, and decreased among 12% (average –0.3 Likert points). The largest changes were in the science interest sub-scale, with an average gain of 0.9 among 39% of the students and loss of –1.0 among 5% of the students. There were similar changes in the science performance and recognition sub-scales (average gains 0.6-0.7 and average losses –0.5).

Box-and-whisker plots of the average overall science identity scores among the students on the pre-retrospective items and post items for 6 different schools are shown in Figure 1 (this includes all survey responses, not just the pre-post pairs). There was a wide range of individual pre-retrospective science identity scores, with a low of about 1.1 for a student at HS2 to a high of 6.0 (the top of the scale) for a student at HS5. The Kruskal-Wallis omnibus test did not find significant differences in the median pre or post overall science identity scores across the 6 schools (see detailed statistical results in Appendix).

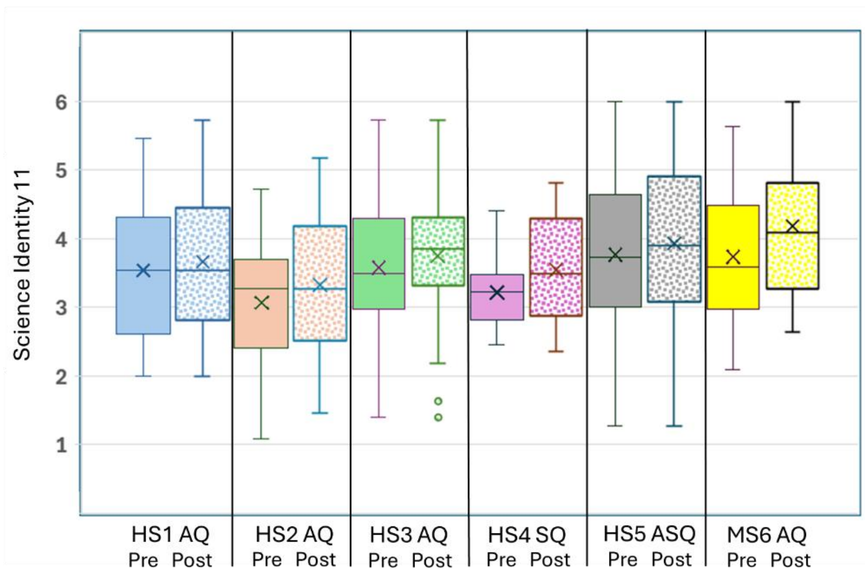

Figure 1. Science identity scores among the secondary students, showing the pre-retrospective and post ratings side-by-side for each of the 6 schools.

The mean pre and post science identity results at each school and associated paired pre-post statistical test results are summarized in Table 3. The mean science identity increased on the post-survey among students at all of the schools compared to pre-retrospective ratings, with moderate effect sizes of 0.53 to 0.79 at 5 schools and a small effect size of 0.46 at HS3. There were gains in the identity sub-scales of science interest (6 schools, 5 with moderate effect size, differences in amount of change among schools), science performance competence (4 schools, 3 with moderate effect size), and science recognition (4 schools, 2 with moderate effect size). The highest averages were in the performance competence sub-scale, followed by interest, and the lowest in recognition (with the exception of HS3 where these sub-construct scores were all similar).

Table 3. Mean pre-post of science identity and engineering interest scores at six schools

School	Overall Science Identity (11 items)	Science Interest (2 items)	Sci Performance Competence (4 items)	Science Recognition (4 items)	Engineering Int+Conf (3 items)
HS1	3.54 - 3.66 ^{**D}	3.7 - 3.9 ^{*D}	3.9 - 4.1 ^{*d}	3.1 - 3.2 ^{*D}	3.6 - 3.7 ^{d}
HS2	3.07 - 3.33 ^{*D}	3.3 - 3.7 ^{*D}	3.4 - 3.7 ^{*D}	2.7 - 2.9 ^{d}	3.3 - 3.9 ^{*D}
HS3	3.57 - 3.75 ^{*d}	3.6 - 3.9 ^{*D}	3.6 - 3.8 ^{d}	3.6 - 3.7 ^{d}	3.2 - 3.4 ^{d}
HS4	3.22 - 3.55 ^{*D}	3.4 - 3.9 ^{*D}	3.8 - 4.1 ^{D}	2.8 - 3.1 ^{*D}	3.7 - 3.7 ^{D}
HS5	3.77 – 3.94 ^{**D}	4.0 - 4.1 ^{*d}	4.2 - 4.4 ^{**D}	3.3 - 3.4 ^{*d}	3.6 - 3.8 ^{**d}
MS6	3.74 - 4.19 ^{**D}	3.7 - 4.3 ^{**D}	4.0 - 4.4 ^{*D}	3.6 - 3.9 ^{*d}	3.8 - 4.3 ^{*D}

per school pre vs. post: paired t-test, * $p<0.05$; ** $p < 0.001$; ^{D} Cohen's D >0.5, ^{d} Cohen's D > 0.2

Engineering interest + confidence (EngIC, averaged across 3 items) differed on the retrospective pre and post items (paired t-test p <0.001, n 176), with 30% of the students increasing (average gain 0.76), 67% of the students not changing, and 2% decreasing (average 0.29 lower). A box-and-whisker plot of the average of the three engineering interest and confidence items per school is shown in Figure 2. Engineering interest was generally more variable than science identity among the students, with the most noticeable difference compared to science identity for HS3 (green boxes in Figure 1 vs. Figure 2). The average engineering interest and confidence to learn engineering increased on the post compared to the pre survey at only 3 schools (HS2, HS5, and MS6, as shown in Table 3). The amount of change in EngIC3 varied across schools (see Appendix).

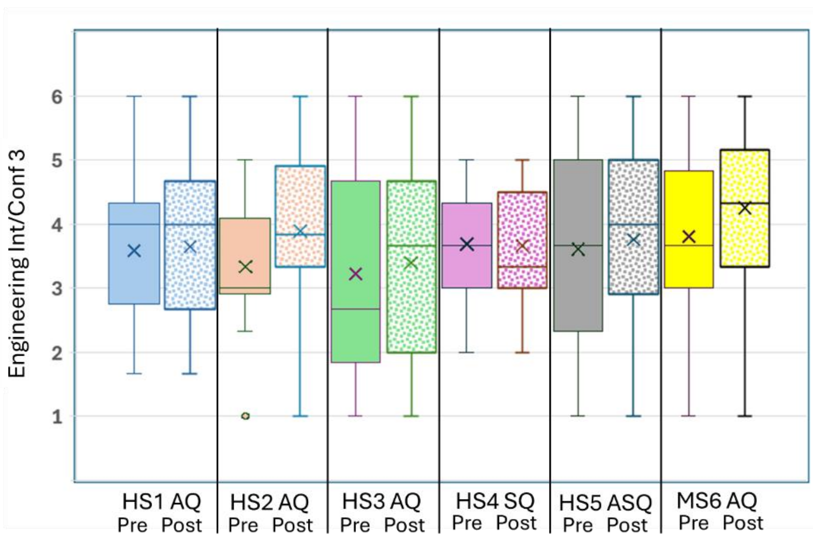

Figure 2. Engineering interest/confidence scores (averaged) among the secondary students, showing the pre-retrospective and post ratings side-by-side for each of the 6 schools.

The reasons the schools differed in science identity and engineering interest/confidence changes are not yet known. At some schools the curriculum was integrated into electives, so the students in those courses may have been more interested in STEM subjects. The K12 teachers and college student mentors likely had significant effects. Qualitative information is needed to understand the reasons for these differences.

The results from the additional survey items for program evaluation by school are summarized in Table 4. Confidence to use engineering equipment to monitor air or soil quality increased at 5 of the schools. The lack of gain at HS4 is significant and perhaps correlated with the low rating for "The university mentors helped me be successful in my air quality or soil quality project". This school only had a single college student mentor in the spring semester, while all of the other schools had 2 to 4 mentors. In addition, the soil quality monitors are newer compared to the air quality monitors and there have been fewer iterations of the SQ curriculum. These challenges are likely reflected in these ratings (note that at HS5 one course used the soil curriculum and the other the air curriculum; the survey did not ask students to identify which curriculum they used).

Table 4. Average survey item responses at 6 schools (6-point scale)

Survey Item	HS1	HS2	HS3	HS4	HS5	MS6
Confident to use engrg equipment to monitor air or soil quality pre * / post	3.5 / 4.0^	2.8 / 3.6^	3.0 / 3.7^	3.9 / 4.1	3.3 / 3.8^	4.0 / 4.5^
I understand the role of going to college in pursuing a career in engineering	3.9	4.1	3.8	3.1	4.1	3.7
University mentors helped me be successful in my air or soil quality project	4.8	4.5	4.6	3.9	4.6	4.6
University mentors helped me think about pursuing a college degree in eng or science	3.4	3.9	3.6	3.2	3.4	4.0
Confidence can use science and eng to answer questions about issues in your local community *	3.3	2.8	3.1	2.6	3.5	3.7
Confidence can use science & eng to solve problems in your local community	3.2	2.7	2.9	2.6	3.4	3.7
How important is it to you to measure air or soil quality in your own community	3.1	3.1	3.5	3.5	3.5	3.4

* Kruskal-Wallis test across 6 schools, sig < 0.10; ^ paired retrospective pre-post t-test at the school, $p < 0.05$

Survey responses among male and female students were compared; results are summarized in Table 5. Female students were lower than male students in their overall science identity (small effect size), including lower recognition ratings. The interest in engineering among female students averaged much lower than the male students (1.4 Likert-points lower, large effect size), in contrast to similar science interest among male and female students. On average, the male students had a slightly higher interest in engineering compared to science while female students had a higher interest in science than engineering. The gains on the post responses compared to pre were similar among both male and female students (data not shown). Both male and female secondary students had similarly strong agreement that the university mentors helped them be successful in their air or soil quality projects.

Table 5. Comparison of evaluation survey results by student gender, mean for each gender and statistical parameters shown

Construct (n Survey Items)	F pre / post	M pre / post	F v M t-test p Pre / Post	F v M Cohen's D Pre / post
Science identity (11)	3.3 / 3.6^	3.7 / 4.0^	0.027 * / 0.019*	0.35 S / 0.38 S
Science interest (2)	3.5 / 3.8^	3.7 / 4.1^	0.20 / 0.075 $^{+}$	0.20 S / 0.28 S
Science recognition (4)	2.9 / 3.1^	3.4 / 3.6^	0.017*/ 0.019*	0.38 S / 0.37 S
Science performance competence (4)	3.7 / 4.0^	4.0 / 4.3^	0.053^{+}/ 0.057 $^{+}$	0.31 S / 0.30 S
Engineering Interest (2)	2.7 / 2.9^	4.1 / 4.3^	<.001** / <.001**	1.13 L / 1.10 L

Construct (n Survey Items)	F pre / post	M pre / post	F v M t-test p Pre / Post	F v M Cohen's D Pre / post
Confidence in ability to learn engrg (1)	2.9 / 3.2	4.1 / 4.3	<.001** / < .001**	0.99 L / 0.85 L
Confident to use engrg equipment to monitor air or soil quality	2.7 / 3.5	3.8 / 4.1	<0.001** / 0.008*	0.89 L / 0.43 M
Below items current opinion				
I understand the role of going to college in pursuing a career in engineering	3.5	4.2	0.001 *	0.53 Moderate
university mentors helped me be successful in my air or soil quality project	4.5	4.7	0.32	0.16
university mentors helped me think about pursuing a college degree in eng or science	3.1	3.8	<0.001**	0.56 Moderate
Confidence can use science and eng to answer questions about issues in your local community	3.0	3.5	0.024 *	0.36 Small
Confidence can use science & eng to solve problems in your local community	2.8	3.5	0.001 *	0.51 Moderate
How important is it to you to measure air or soil quality in your own community	3.4	3.4	0.79	0.04

^ paired pre-post t-test p value < 0.05; * male and female responses differed p < 0.05, ** p < 0.001, + p < 0.10
Cohen's d indicates L = large, M = moderate, S = small effect

Results from the Student Evaluation Survey: Qualitative Items

There were two questions on the survey that invited open responses. The research team used a process of emergent, non-exclusive coding, which was led by a graduate student with checks by other members of the team. (Rigorous inter-rater checks not completed.)

The first open-ended question asked, "How did your experience in the Air Quality InQuiry (AQIQ) or Soil Quality InQuiry (SQIQ) project affect any of your responses above?" There were 15 codes among the responses (plus a code for an irrelevant answer, e.g., IDK). Generally, the answers supported the quantitative responses, both among students who had indicated no changes and gains in their pre-retrospective / post responses. Table 6 provides the most commonly identified themes, with an example quote, and the number of student responses coded to this theme. A number of these themes map to ideas of identity including increased confidence and/or interest; e.g., "The Air Quality Inquiry project affected my responses above positively as it helped me to understand and like science more." Some student responses indicated positive or negative identification with and/or interest in science and/or engineering prior to the project. More students directly mentioned science in their response (n=48) compared to engineering (n=20). Some students linked these initial leanings to the reason for no change in their attitudes; e.g., "The project had not affected my responses above because I had already not had an interest in engineering and knew what I wanted to do in the future." A handful contrasted an initial dislike with a change in perspective. While the majority of the responses were positive, some were mixed (e.g., "My experience was good and it fun exciting and in the same time scared to make a mistake."), and a few were negative (e.g. "This project was just difficult because I had many other things going on outside of school that made me miss school. As well as the topic wasn't something I was super interested in and my group members weren't very helpful. So I was not very engaged into the project meaning I wouldn't want it to be my career in the future.") The open-ended responses provided helpful context to the numerical responses.

Table 6. Themes in open-ended survey responses on the effect of the AQIQ/SQIQ project

Code	Example Quote from student response	N
No effect	It didn't	54
Increased scientific knowledge and understanding	My experience in the AQIA project opened my eyes to a type of science I had never been taught before. I have learned biology and physics but never how it impacts our Earth.	36
Increased scientific confidence / how to do it	I think that the AQIQ did help me in science because I am more confident in my research skills and collecting my own data	23
Fun / enjoyable / general positive	It [showed] me how fun science really was. At first I didn't really enjoy research projects but this one was different. We actually went out in our community and did research of whatever we wanted it.	22
Perspective into a science / engineering career / college	My experience in the AQIQ project affected a couple of my responses, it showed me a better understanding of engineering in college.	10
Increased interest in science	The AQIQ changed my perspective on science because at first I hated science and thought it was one of the most boring subjects, but after doing these projects I believe that science can be fun.	11
No change in science / engineering interest	The AQIQ project did not affect any of the answers I have provided. This is because I had a big interest in science and engineering before it and I still do.	3
Decreased interest in science / eng	It made me dislike science and engineering more.	2
Have a positive interest in science / engineering	engineering is something I already have wanted to do.	11
Have a negative interest in science / engineering	I am not really a science person it's just not something that really interests me	11
Positive sci / eng identity	They had no effect I've already been a science dude.	3
Negative sci / eng identity	I am not really a science person	7
Career / college plans in science or engineering	In my opinion it really didn't change any of my choices. I've always been a big science and engineering person and I'm very excited to see where I can go with it.	4
Career / college plans not in science or engineering	I had a good understanding before but its not something that truly interests me for a career or overall.	5

The second open-ended survey question asked students to comment on any way that the university mentors contributed to their experience with the AQIQ or SQIQ project. The most common theme related to the mentors helping the students understand the project and explaining the instructions (n=58), e.g., "They helped me understand the machines and how to read the data." Other responses were somewhat more generic about receiving guidance from the mentors (n=24), e.g., "They helped give me direction to what we could do with our project and how open it could be." Many of the responses were unspecifically positive (n=31), e.g., "They were absolutely amazing! They were helpful, and kind, and I have much respect for them, for driving down to help us do these projects." Those answers conveyed a sense of "good" but not really why or how they were good. There were 11 responses that referred to the mentors making the curriculum fun. Just a few responses (n=6) said "they didn't" [contribute].

Suggestions for Future Work

The results show that the curriculum could improve on communication of engineering elements. As a result, the poster template provided to the students has been edited. Students are being encouraged to think about problem solving and practical implications (a key characteristic of engineering) rather than merely scientific curiosity in their projects. The student posters from spring 2026 can be examined and compared to earlier years to look for evidence of engineering (building on [59]). Attention to engineering aspects might be particularly impactful for female secondary students, as they averaged significantly lower initial interest and confidence in engineering compared to both these aspects of science identity and compared to male peers.

It is currently unclear to what extent the variations found at different schools are due to the local context, science teacher, the specific college student mentors, or other factors. Interviews with the teachers are planned in Spring 2026. We also hope that more high school students participate in the Spring 2026 evaluation. We are also considering conducting focus groups with the secondary students. This will provide information that might illuminate important implementation differences among the schools and specific classes. Triangulation among the multiple sources of evaluation data should lead to richer insights. A greater understanding of these issues can be integrated into continued improvement of the program. A deeper dive into the data around female student identity can include elements such as the gender mix in the class, gender of the science teacher, and gender of the college student mentors. This aligns with some previous studies which have found that teacher gender may impact the STEM identity, confidence, and interest among female students [60],[61],[62],[63].

Some small changes to the evaluation survey are being implemented in Spring 2026. The first open-ended question ("How did your [project] experience affect any of your responses above") was located right after the Likert-item "I understand role of college for engineering". It is unclear if students thought about ALL of their previous responses on the science identity items when they answered this question. The survey now asks this open-ended question right after the science identity items and repeats it after the engineering items. The evaluation survey has also added an item regarding whether the secondary students found the project overall to be a positive learning experience and why or why not. Future work can also deepen the exploration of the validity and reliability of the survey, including confirmatory factor analysis and congruence between open-ended responses and numerical responses.

Conclusion

A unique partnership between university faculty and graduate students has been delivering hands-on inquiry-based curriculum to secondary school classes in rural schools. The program has been growing since 2013, reaching a stable number of participating schools each year (about 11) across the state over the last three years. In 2024/2025 the place-based curriculum reached about 574 secondary students mentored by 30 college students partnered with 13 teachers and 28 classes. This is the first year that significant evaluation data from the secondary students were available. These data were largely gathered from 6 of the partner schools. The retrospective pre/post evaluation survey demonstrated that the program increased the science identity of 57% of the secondary school students. The science identity gains were statistically significant with a moderate effect size at 5 schools and small effect size at 1 school. Among the 3 science identity constructs, gains in science interest were larger than performance or recognition. Impacts on engineering interest+confidence were more modest, with gains at only 3 schools. Comparing male and female students, the overall science identity was stronger among male students, primarily due to the higher science recognition among male compared to female students.

Engineering interest and confidence were significantly higher among male compared to female students.

Open-ended comments supported the quantitative findings, suggesting that many students found that the program increased their knowledge of science, interest in science and/or engineering, found the program fun, and had increased confidence. It also confirmed that some students started with strong or weak science and/or engineering identity and interests.

Other evaluation measures for the program found that on average the secondary students recognized the helpful role of the college mentors for their project success (average ~4 somewhat agree). Open-ended comments communicated the idea that the mentors taught the students practical skills (e.g., how to use the equipment), were supportive, and made the experience fun. The place-based elements of the project were somewhat less prominent. On average students were only slightly confident in their ability to use science and engineering to answer questions about issues in their local community or solve problems in their local community. Measuring air or soil quality in their own community averaged slightly important among the students. Female students averaged lower than male students on all confidence-related items on the survey.

The program continues with a strong interest from rural partner schools and the return of most of the teachers each year. At present, the number of partner schools and classes is in a good balance with the size of the college course and the teaching and mentoring capacity of the group. Therefore, there are not plans to expand the size of the program. A few schools tend to rotate in every other year while others are annual participants. The group is committed to continuing to improve the quality of the program. Its curriculum meets learning objectives appropriate for the secondary science courses where it is being integrated. This includes strong ties to practices in the Next Generation Science Standards (NGSS) [64] including asking questions and defining problems; planning and carrying out investigations; analyzing and interpreting data; engaging in argument from evidence; and obtaining, evaluating, and communicating information. The learning activities are designed to be engaging and fun for the students, strengthening their confidence in science. We also hope that participation in the curriculum builds STEM identity more broadly, helping students to identify how pursuing STEM majors in college, including engineering, will meet their goals and benefit their communities.

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Appendix: Survey Instrument

The mapping of the items to Dou and Cian [29, supplemental], highlighting in red when we replaced the word STEM in their item with science or engineering.

Q1 Please enter your name. ______________________ *{will be used to confirm parental consent in the future}*

Q2 What is the name of your High School? [select among drop-down menu of de-identified options]

For the following questions, please reflect on your interests and experiences BEFORE and AFTER doing the AQIQ or SQIQ project and provide answers in the "Before" and "After" rows accordingly.

Q3 I see myself as a science person [DC1]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q4 Topics in science are exciting to me [DC4]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q5 I am interested in learning more about science [DC5]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q6 My teachers see me as a science person [DC2]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○

After AQIQ/SQIQ	○	○	○	○	○	○

Q7 My friends/classmates see me as a science person [DC3]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q8 My family sees me as a science person [DC6]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q9 Others ask me for help in science [DC7]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q10 I feel confident in my ability to learn science [DC8]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q11 I can do well on tests and exams in science [DC9]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ (1)	○	○	○	○	○	○
After AQIQ/SQIQ (4)	○	○	○	○	○	○

Q12 I understand concepts I have studied in science [DC10]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q13 I feel confident conducting scientific research.

	Strongly disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)

Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q14 Topics in engineering are exciting to me [DC4]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q15 I am interested in learning more about engineering [DC5]

	Strongly Disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q16 I feel confident in my ability to learn engineering [DC8]

	Strongly disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q17 I feel confident using engineering equipment to monitor air quality or soil quality.

	Strongly disagree (1)	Disagree (2)	Somewhat Disagree (3)	Somewhat Agree (4)	Agree (5)	Strongly Agree (6)
Before AQIQ/SQIQ	○	○	○	○	○	○
After AQIQ/SQIQ	○	○	○	○	○	○

Q18 I understand the role of going to college in pursuing a career in engineering
Strongly Disagree (1), Disagree (2), Somewhat Disagree (3), Somewhat Agree (4), Agree (5), Strongly Agree (6)

Q19 How did your experience in the Air Quality InQuiry (AQIQ) or Soil Quality InQuiry (SQIQ) project affect any of your responses above?

____

____

Q20 The university mentors helped me be successful in my air quality or soil quality project
Strongly Disagree (1), Disagree (2), Somewhat Disagree (3), Somewhat Agree (4), Agree (5), Strongly Agree (6)

Q21 Having the university mentors involved helped me think about pursuing a college degree in engineering or science
Strongly Disagree (1), Disagree (2), Somewhat Disagree (3), Somewhat Agree (4), Agree (5), Strongly Agree (6)

Q22 Please comment briefly on any way that university mentors contributed to your experience with the AQIQ or SQIQ project.

____

Q23 How confident are you that you can use science and engineering to answer questions about issues in your local

community?
Not at all confident (1), Somewhat confident (2), Slightly confident (3), Moderately confident (4), Very confident (5), Extremely confident (6)

Q24 How confident are you that you can use science and engineering to solve problems in your local community?
Not at all confident (1), Somewhat confident (2), Slightly confident (3), Moderately confident (4), Very confident (5), Extremely confident (6)

Q25 How important is it to you to measure air or soil quality in your own community?
Not at all important (1) Somewhat important (2) Slightly important (3)
Moderately important (4) Very important (5) Extremely Important (6)

Q35 The following questions are optional and will be used to compare the experiences of different groups

Q26 What is your gender identity? Female (1), Male (2), Other/please specify (3) ____________________

Q27 Which social categories do you identify with? (please check all that apply)
White or European American (1) Black or African American (2) Hispanic or Latino (3) Asian American (4) American Indian or Alaska Native (5) Native Hawaiian or Other Pacific Islander (6) Other, please specify: (7) ____________

Q28 What is the highest degree or level of schooling completed by a parent or guardian?
Less than a high school diploma, High school degree or equivalent (e.g., GED),
Some college, no degree, Associate degree (e.g., AA, AS), Bachelor's degree (e.g., BA, BS),
Master's degree (e.g., MA, MS, MEd), Professional degree (e.g., MD, DDS, DVM), Doctorate (e.g., PhD, EdD)

Q29 What is the zipcode of your hometown? __________________

Item correlations among survey responses

Output from SPSS is included in the figure below.
Highlighted in yellow are the two science interest items; peach the science confidence items; blue science confidence items; green the engineering items.

Correlation Matrix

		Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
Correlation	Q3	1	0.709	0.750	0.610	0.664	0.676	0.493	0.628	0.592	0.610	0.618	0.469	0.371	0.459
	Q4	0.709	1	0.745	0.511	0.516	0.528	0.378	0.580	0.620	0.626	0.607	0.498	0.390	0.425
	Q5	0.750	0.745	1	0.574	0.614	0.638	0.407	0.622	0.532	0.595	0.627	0.517	0.409	0.487
	Q6	0.610	0.511	0.574	1	0.726	0.617	0.523	0.521	0.475	0.481	0.522	0.509	0.408	0.460
	Q7	0.664	0.516	0.614	0.726	1	0.698	0.573	0.526	0.510	0.466	0.513	0.431	0.349	0.396
	Q8	0.676	0.528	0.638	0.617	0.698	1	0.520	0.555	0.561	0.484	0.524	0.420	0.350	0.400
	Q9	0.493	0.378	0.407	0.523	0.573	0.520	1	0.569	0.613	0.521	0.525	0.323	0.205	0.306
	Q10	0.628	0.580	0.622	0.521	0.526	0.555	0.569	1	0.724	0.685	0.686	0.452	0.361	0.569
	Q11	0.592	0.620	0.532	0.475	0.510	0.561	0.613	0.724	1	0.753	0.643	0.407	0.332	0.456
	Q12	0.610	0.626	0.595	0.481	0.466	0.484	0.521	0.685	0.753	1	0.670	0.459	0.361	0.470
	Q13	0.618	0.607	0.627	0.522	0.513	0.524	0.525	0.686	0.643	0.670	1	0.481	0.359	0.490
	Q14	0.469	0.498	0.517	0.509	0.431	0.420	0.323	0.452	0.407	0.459	0.481	1	0.866	0.771
	Q15	0.371	0.390	0.409	0.408	0.349	0.350	0.205	0.361	0.332	0.361	0.359	0.866	1	0.771
	Q16	0.459	0.425	0.487	0.460	0.396	0.400	0.306	0.569	0.456	0.470	0.490	0.771	0.771	1
Sig. (1-tailed)	*Q3*		*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
	Q4	*0.000*		*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
	Q5	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
	Q6	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
	Q7	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
	Q8	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
	Q9	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
	Q10	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
	Q11	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
	Q12	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*	*0.000*
	Q13	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*
	Q14	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*
	Q15	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*
	Q16	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	

Summary of non-parametric statistical tests across 6 schools, Kruskal-Wallis (KW) omnibus test statistic and post-hoc paired comparisons where sig. and adj. sig. were below 0.1, adj. sig. includes the Bonferroni correction for multiple tests. Change represents the post minus pre score calculated for each student paired response

Construct, n items, pre or post or change	KW test Asymptotic sig. (2-sided test)	Differences in Pairwise comparisons sig. < 0.1	Differences in Pairwise comparisons adj. sig. <0.1
Sci Identity 11 pre	0.116	HS2-MS6, HS2-HS5, HS4-HS5	*None*
Sci Identity 11 post	0.115	HS2-MS6, HS2-HS5, HS4-MS6, HS1-MS6	*None*
Sci Identity 11 change	0.232	HS3-MS6, HS1-MS6, HS5-MS6	*None*
Sci Interest 2 pre	0.319	HS4-HS5, HS2-HS5	*None*
Sci Interest 2 post	0.502	*None*	*None*
Sci Interest 2 change	0.054 *	HS2-HS5, HS5-MS6, HS1-HS2, HS1-MS6	*None*
Sci Recognition 4 pre	0.104	HS2-HS5, HS2-MS6, HS2-HS3, HS4-MS6, HS4-HS3	*None*
Sci Recognition 4 post	0.087 *	HS2-HS3, HS2-MS6, HS3-MS6, HS1-MS6, HS5-MS6	*None*
Sci Recog 4 change	0.322	HS3-MS6, HS3-HS4	*None*
Sci Performance 4 pre	0.026 *	HS2-MS6, HS2-HS5, HS3-HS5,	HS2-HS5
Sci Perf 4 post	0.077 *	HS2-MS6, HS2-HS5, HS3-MS6, HS3-HS5,	*None*
Sci Perf 4 change	0.556	*None*	*None*
Engrg IntC 3 pre	0.724	*None*	*None*
Engrg IntC 3 post	0.457	HS3-MS6	*None*
Engrg IntC 3 change	0.008 *	HS1-MS6, HS1-HS2, HS3-MS6, HS2-HS3, HS5-MS6, HS2-HS5, HS2-HS4	HS1-HS2, HS2-HS3, HS2-HS5
Individual survey items where responses differed among the schools			
Q17 Confident using eng equipment pre	0.049 *	HS2-HS4, HS2-MS6, HS3-HS4, HS3-MS6, HS5-MS6	*None*
Q23 Confident use sci / eng to ans ?s in local community	0.052 *	HS4-HS5, HS4-MS6, HS2-HS5, HS2-MS6	*None*

* Asymptotic Sig. (2-sided test) in omnibus Kruskal-Wallis < 0.10