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Mentoring Correlates to Characteristics of University K12 Outreach Programs: Survey Findings (Fundamental)

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Abstract

Effective mentorship between faculty and undergraduate students has been recognized by the National Academies as an avenue to address issues of diversity and identity in Science, Technology, Engineering, and Mathematics (STEM). Mentoring relationships may also form in other contexts, such as between undergraduates and K-12 students in K-12 STEM outreach programs. A survey was administered to university faculty / staff who coordinate K-12 STEM outreach programs to obtain a pool of respondents and facilitate interview selection in a larger phenomenographic study. This paper presents the results from the survey, and focuses on developing a better understanding of mentoring in K-12 STEM outreach programs through the research question, Do K-12 STEM outreach program characteristics differ between programs that are and are not believed to foster mentoring relationships between university and K-12 students? The survey yielded useful responses from 61 program coordinators representing 131 K-12 STEM outreach programs. Tests for association between individual program characteristics and program coordinators' beliefs about mentoring in their program(s) and a binomial logistic regression model were carried out using IBM SPSS 26. The most significant program characteristics were found to be having the goal "Improve K-12 student learning in STEM," the program time (i.e., Day, Summer, Academic Year OR Year), and the level of cohort experience among college students. A discussion as to why these characteristics differ between programs that are and are not believed to foster mentoring relationships is included, and future qualitative work in the larger study will provide more insight.

Background

With the ever-growing need for educated scientists and engineers in the workforce, there exists a necessity for the recruitment and retention of females and individuals from underrepresented racial/ethnic minorities (URM) including Black/African American, Hispanic/Latinx, and Native Americans in Science, Technology, Engineering, and Mathematics (STEM). Increasing diversity in STEM is a desirable asset; diverse groups show more engagement in active thinking and stronger academic skills [1]. Additionally, diversity in engineering "makes teams more creative, solutions more feasible, products more usable, and citizens more knowledgeable" [2, pp. 73–74]. There have been mild upward trends in engineering bachelor's degrees awarded to URM and women over the past decade; however, the numbers are still low. In 2019, URM students obtained only 20.8% of awarded bachelor's degrees in engineering, and women represented 22.5% of awarded degrees [3]. The trend of underrepresentation of women and racial / ethnic minorities extends to the science and engineering (S&E) workforce. The National Science Board [4] reported that the 2017 S&E workforce was 29% women, which is only a mild increase from the 1993 composition of 22.9% women. And while Black / African American and Hispanic / Latinx US citizens comprise approximately 12 and 15% of the US residential population, respectively, both groups combined make up less than 16% of the total S&E workforce [4].

The National Academies [1] lists understanding the role of mentoring as a priority area of inquiry for addressing issues of diversity and identity in STEM. Mentoring is generally viewed as a reciprocal relationship between a more experienced person (e.g., the mentor) and an inexperienced person (e.g., the mentee) in a specific field and may involve psychosocialemotional and / or instrumental support [5], [6]. In these understandings, mentoring is a potentially hierarchical relationship where both parties benefit. Definitions of mentoring differ across the literature, as do attributes of effective mentoring [7]–[11]; however, common themes exist [12]. Recently, the National Academies [8] presented a "starting point" definition of mentoring to provide guidance with the goal of promoting diversity in science, technology, engineering, mathematics, and medicine (STEMM):

> Mentorship is a professional, working alliance in which individuals work together over time to support the personal and professional growth, development, and success of the relational partners through the provision of career and psychosocial support. [8, p. 2]

Many studies have focused on the benefits to mentees, both at the K-12 youth and undergraduate levels [5], [6], [13], [14]. Previous research of effective faculty mentorship in undergraduate research found that undergraduate mentees self-reported gains in research, skills, productivity, and retention in STEMM [8]. Estrada et al. [15] found that when combined with quality mentorship, research experiences positively impacted URM students' science efficacy, identity, and values. Beyond undergraduate research settings, effective mentorship has been shown to impact the science identity and deep interest in science of female undergraduate students, and these gains were higher for students mentored by faculty than those without faculty mentors [5]. However, undergraduates themselves may participate as mentors in other contexts, such as in K-12 STEM outreach programs.

Few studies have specifically examined benefits to undergraduate student mentors. Surveys by Monk et al. [14] found that mentors improved their science communication skills and found mentoring high school students to be a rewarding experience. Lim et al. [6] corroborated these results, finding that undergraduate peer mentors gained interpersonal and teaching skills. A recent study by Huvard et al. [16] examined undergraduate mentors across peer inreach and K-12 outreach programs, and found that in both programs, mentors "demonstrated evidence of strengthened metacognition and science identity" [16, p. 14].

STEM outreach has been broadly defined as, "The act of delivering STEM content outside of the traditional student / teacher relationship to STEM stakeholders (students, parents, teachers…) in order to support and increase the understanding, awareness, and interest in STEM disciplines" [17, p. 10]. University-run K-12 STEM outreach programs can vary in format, from one-day competition-based events held on college campuses to weekly afterschool clubs at community centers. Interviews with program coordinators from the authors' pilot study [18] found that many programs with various program times can be present at a single university, such as a week-long camp during the summer and an afterschool STEM club during the academic year. Programs can also focus on one discipline or cater to STEM more broadly.

Often, programs include a program coordinator(s), a faculty and / or staff member(s) at the university who is knowledgeable about the programs' goals and operation. Program coordinators manage the program; though their responsibilities vary across programs, they might organize and train employees / volunteers and / or select curricula / activities to align with program goals. Common goals include sparking interest in STEM, building STEM-oriented competencies, and attracting students to STEM careers [17]. Additionally, some K-12 STEM outreach programs purposefully target populations that are historically underrepresented in STEM. Such programs utilize these common goals to provide pathways for K-12 students to develop a sense of belonging in the STEM community and can promote persistence of URM in STEM [19], [20]. Programs that target K-12 girls can impact the future composition of the S&E workforce by mitigating bias in STEM [21]. K-12 STEM outreach programs can also impact K-12 students' interest in and identification with STEM [22], [23]. For example, a study by Wei & Hill [23] found that students became more enthusiastic about STEM and that girls' " implicit perception that they can be engineers" increased [23, p. 13].

Regardless of format, focus, and benefit to K-12 students, many universities select promising undergraduate students to facilitate their outreach programs, with undergraduates benefiting alongside K-12 students [24]. Through their interactions with K-12 students, knowledgeable and experienced undergraduates are thought to potentially form mentoring relationships with comparatively less knowledgeable and inexperienced K-12 students. Given the potential benefits to undergraduate mentors, the authors are interested in examining mentoring as it manifests in K-12 STEM outreach programs facilitated by universities.

Research Question

This paper presents the analysis of a survey that was situated within a larger study that seeks to examine undergraduate STEM identity development in relation to mentoring in K-12 STEM outreach programs. A first step towards achieving this larger goal is to better understand if and how mentoring occurs in these programs. To this end, the survey analysis presented here focuses on the research question:

> Do K-12 STEM outreach program characteristics differ between programs that are and are not believed to foster mentoring relationships between university and K-12 students?

The program characteristics of interest include goals, K-12 to university student ratio, duration, "cohort" experience among students, etc.

Methods

This paper focuses on one part of a larger research study: a pre-interview survey given to coordinators of university-run K-12 STEM outreach programs. The larger study involves semi-structured interviews and follows a phenomenographical methodology, requiring a variety of experience be represented in the research participants. To select a variety of programs and participants for interviews, the authors first needed to collect a pool of potential participants and gather information about their K-12 STEM outreach programs. The survey achieved this goal. This study was approved by the university's Institutional Review Board (IRB) for humans subjects research (Protocol #20-0041); all participants provided consent before beginning the survey.

Survey Development

Prior to developing the survey, interviews were conducted with eight program coordinators of K-12 STEM outreach programs at the University of Colorado Boulder in a pilot study on mentoring and identity [18]. Interview questions probed at program goals, duration, college student engagement, mentoring, and identity. Building on these interview topics, the survey included questions on program goals, discipline, duration, number and composition of college students, and mentoring. The majority of these questions were multiple choice / select options, with some open-ended responses. Table 1 provides examples of some multiple choice / select questions that probe into a program's goals, undergraduate diversity, and mentoring. The complete survey is included in the Appendix.

Table 1. Selection of Survey Questions

Question Number	Question
Q4	What are the goals of the program? (Select all that apply) □ Spark K-12 students' interest in STEM □ Build K-12 students' confidence in STEM-oriented competencies □ Increase diversity of students enrolling in STEM higher-education majors and careers □ Improve K-12 student learning in STEM □ Improve college student learning in STEM □ Other: ___
Q8a*	About what percentage of the undergraduate student participants typically are female? (Select only one) ○ 0 ○ 1 - 25% ○ 26 - 50% ○ 51 - 75% ○ 76 - 100%
Q8b*	About what percentage of undergraduate participants are typically from racial / ethnic groups underrepresented in science, technology, engineering, and mathematics (i.e., not White or Asian)? (Select only one) ○ 0 ○ 1 - 25% ○ 26 - 50% ○ 51 - 75% ○ 76 - 100%
Q10	Do you believe that your program fosters mentoring relationships between K-12 students and college students? (Select the most appropriate answer) ○ Yes ○ Maybe / Unsure ○ No
Q10a**	Please expand on how your program fosters mentoring relationships. (Select all that apply) □ Explicit training of college students on mentoring □ Many face-to-face interactions between K-12 and college students □ Open communication between K-12 and college students □ Other: ___
*Q8a and Q8b are only shown if program coordinators indicate that undergraduates participate in their program. **Q10a is only shown if "Yes" is selected in Q10.	

Since universities often include many K-12 STEM outreach programs, program coordinators were given the opportunity to describe up to four programs. The authors communicated throughout the survey development process, to ensure that questions were clearly worded and that answer options were appropriate for each question type (e.g., multiple choice to select more than one program goal). After these negotiations, the survey was shared with a program coordinator from the pilot study to check for comprehensiveness, before finalizing the survey for distribution. The final survey required about 5 minutes to complete and included 13 questions, with 9 questions being repeated for each program described.

Participant Recruitment

Target participants were coordinators of at least one K-12 STEM outreach program run through a university. The authors reached out to potential participants through direct emails and announcements through divisions of the American Society for Engineering Education (ASEE). Since ASEE members may have more focus on engineering outreach rather than other STEM disciplines, the combination of methods was to ensure that non-engineering specific programs were represented in the survey. Surveys were distributed through Qualtrics; invitation emails included a brief overview of the purpose of the larger study (studying STEM identity and mentoring K-12 STEM outreach programs) and informed potential participants that they may choose to participate in the interview portion of the larger study. There was no incentive given for participating in the survey; it was assumed that university faculty / staff program coordinators would view participating in research as a form of service to the STEM education community.

Program coordinators were recruited between February 20, 2020 and May 19, 2020 via direct email and through ASEE division newsletters and listservs; Table 2 includes a summary of survey distribution.

Table 2: Summary of Survey Distribution

Recruit	Description	Date Initial Invitation	Date Reminder	# Contacted	# Completed Responses	Response Rate (%)
Wave 1	Authors in ASEE PEER, Recipients of NSF Advancing Informal STEM Learning and Engineering Research Center awards	2/20	3/3	36	8	22.2
ASEE Community Engagement Division	Emails sent to division listserv	3/10	-	777	22	2.83
ASEE Educational Research & Methods division	Announcement included in bi-monthly newsletter	3/15	4/1	1416	2	0.14
Wave 2	Coordinators at 32 Hispanic Serving Institutions (HSIs) and 21 Historically Black Colleges and Universities (HBCUs)	4/29	5/12	112	29	25.9
ASEE Pre-College Engineering Education division	Announcement included in newsletter	5/19	-	929	0	0

The Waves of individual recruitment included a few cases of emailing multiple program coordinators from the same university. This decision was made to 1) reach out to multiple separate programs with different coordinators operating through the same university, and 2) offer redundancy when a single K-12 STEM outreach program website listed multiple contacts / coordinators.

Survey invitation emails were sent out near mid-day Mountain Time, to ensure that respondents might receive the invite in either morning or early afternoon their local time, and reminders were sent approximately two weeks after the initial invitations [25], [26].

Survey Respondents

Between the survey open date on February 20, 2020 and the survey close date on July 7, 2020, 85 program coordinators responded, 43 from the Waves and 42 from anonymous links sent to ASEE divisions. Of these respondents, 83 consented to participate in the survey and 61 provided useful responses (identified as ‘completed’ responses in Table 2 above). Program coordinators were given the option to describe up to four K-12 STEM outreach programs; a “useful” response requires that they fully described at least one program, meaning that most questions appeared to be answered (not skipped) and that Q10 inquiring about mentoring in the program was answered.

The overall survey response rate was 1.87%. Participants emailed directly in Wave 1 and Wave 2 yielded a much higher group response rate than email solicitations through ASEE newsletters and listservs. This difference may have been due to the personal nature of the direct emails; they included mention of the participants’ names, universities, and the name(s) of identified K-12 STEM outreach program(s). The response rate may have also been affected by the COVID-19 pandemic, which caused major disruptions in higher education, starting around mid-February 2020.

Program coordinators represented 46 distinct colleges and universities and provided information on 131 K-12 STEM outreach programs, with 34 program coordinators describing more than one program. Table 3 summarizes characteristics of survey respondents and Table 4 of programs. The total number of institutions in Table 3 reflects the number known to the authors, including from direct emails and respondents who supplied their affiliations when agreeing to participate in the interview phase of the research. Program coordinators could select multiple options for university characteristics and program disciplines, and they always had the option to leave questions blank. The final columns of Table 4 indicate the number of programs that included “Increase diversity of students enrolling in STEM higher-education majors and careers” as a goal. They also show the number of programs that appear to target specific groups of K12 students (e.g., Women, URM). This information was extrapolated from the names of the programs. For example, a (fictitious) program called “STEM for Girls” would be thought to target women. Program coordinators were not required to provide the name of their program, and the authors only include counts for programs that obviously target a certain group.

Table 3: Summary of Survey Respondents

	Total #	# Public	# Private	# Community College	# Bachelor’s Awarding	# Masters Awarding	# Doctorate Awarding
Institutions	46	30	18	2	4	7	32
People	61	38	21	2	4	8	42
Programs	131	83	46	2	7	24	90

Table 4: Summary of Program Characteristics

Total # Programs	Program Time	Disciplines Represented	# Diversity Goal	Target Demographics
131	41 Summer	31 Biology	103	11 Women / Girls
		37 Chemistry		
		55 Computer Science / Computer Programming		
	41 Academic Year	30 Earth / Environmental Science		
		92 Engineering		
		42 Mathematics		2 “Underrepresented groups”
	30 Day	13 Medicine		
		45 Physics		
	6 Year	58 STEM (general)		1 Students with Disabilities
		19 Other		

Program coordinators provided examples of 85 multidisciplinary programs. The median number of disciplines per program was 2 (range: 1 to 10). As expected from recruiting program coordinators through engineering-focused grants, publications, and listervs, the most common discipline was Engineering. Among programs with engineering, the median number of additional disciplines was 2.5 (range: 0 to 9), and the most common co-occurring discipline was Computer Science / Computer Programming.

Table 5 provides information on college student participants in the 131 K-12 STEM outreach programs. The authors note that in many programs, undergraduates seem overrepresented in groups who are typically underrepresented in engineering (2019 engineering bachelor’s degrees included only 22.5% women and 20.8% URM [3]). Since this information was gathered to inform the interview phase of the research, which aimed to include diverse undergraduate participants, the prevalence of women and URM was seen as an advantage for the larger study.

Table 5: College Student Participant Characteristics

# Include Graduate Students	# Include Undergrads	Are Undergrads paid?	Diversity, % of undergrads	# programs with % Female undergrads	# programs with % URM* undergrads
57	112	54 Yes	76 – 100	22	15
			51 – 75	33	15
		36 No	26 – 50	45	30
			1 – 25	12	49
		22 Varies	0	0	3

*Coordinators asked for percentage of undergrads “typically from racial / ethnic groups underrepresented in STEM (i.e., not White or Asian)”

Survey Data Analysis
Data were deidentified and analyzed in MS Excel and IBM SPSS 26. Chi-Squared contingency tests were run to test for association between various independent categorical variables and mentoring. Mentoring was set up as a dependent ordinal variable with three levels: "Yes," "Maybe / Unsure," and "No." In cases where the assumptions of the Chi-Squared test were violated (more than 20% of cells with an expected frequency of less than five), the Mentoring variable was collapsed into two categories, "Yes" and "Maybe / Unsure OR No." Since independent numerical variables did not meet assumptions of normal distribution, tests of association between mentoring and numerical variables were run using the nonparametric Kruskal-Wallis test to compare the means of independent variables across the three levels of mentoring. As a check on the results, any test that could be run with Mentoring as three categories was repeated with Mentoring as two categories.

Following tests of individual variables, logistic regression models were run to observe the level of relationship between Mentoring and the independent variables that were found to be significant from the individual tests. Both binomial and ordinal logistic regression tests were run; however, only results from the binomial regression model are presented in this paper. The three levels of Mentoring were originally chosen to assist in the selection of programs for inclusion in the interview phase of the research. Given that the original intention of the survey was not to parse out characteristics between more nuanced levels of Mentoring, collapsing Mentoring into two levels of "Yes" and "Maybe / Unsure OR No" provides acknowledgement of the variation of perspectives on mentoring present within the program coordinators and it prevents conclusions being drawn from programs that *might* include mentoring compared to those that are more definitively thought to foster mentoring. Therefore, using the binomial regression model with only two categories of mentoring best answers the research question without overstepping the ability of the data. Additionally, utilizing two categories for Mentoring resulted in a more even distribution of programs across the categories, yielding more robust findings.

The results from binomial logistic regression show if there are significant mutual changes between variables of interest (Mentoring and various program characteristics) and provide insight into how a change of program characteristic affects Mentoring (i.e., if an "increase" in a program characteristic is associated with an "increase" of Mentoring from "Maybe / Unsure OR No" to "Yes.") This type of modeling provides direction on how programs can leverage their characteristics to foster mentoring relationships.

Results
The following summarizes results from survey responses and statistical analyses. For all tests, the significance level was set at $\alpha = 0.05$. The authors are aware of the possibility of a Type II error, where the null hypothesis is falsely rejected; therefore, cases where the p-value is between 0.05 and 0.1 are also identified. The authors also note where the p-value is less than 0.01.

Mentoring
Program coordinators were asked, "Do you believe that your program fosters mentoring relationships between K-12 students and college students?" Table 6 provides a summary of their

answers, the coding schema, and the responses collapsed into the two Mentoring categories used in some individual tests and in binomial logistic regression modeling.

Thirty-four program coordinators described two to four K-12 STEM outreach programs. Among these, 21 rated their programs across different categories of Mentoring (e.g., A coordinator with two programs rated one program as "Yes" and another as "No"). This shows that most program coordinators who described more than one program provided a range of anticipated mentoring across their multiple programs.

Table 6: Mentoring Question Survey Responses

Response	Coding	Frequency	Percent
Yes	2	77	58.8
Maybe / Unsure	1	30	22.9
No	0	24	18.3
Yes	1	77	58.8
Maybe / Unsure OR No	0	54	41.2

For the 77 programs that were in the "Yes" category, program coordinators were given an additional sub-question to probe into how their program fosters mentoring relationships. The most common method of fostering mentor was "Many face-to-face interactions between K-12 and college students" (n = 73), followed by "Open communication between K-12 and college students" (n = 66). Curiously, the method with the lowest representation was "Explicit training of college students on mentoring" (n = 31). Seven program coordinators wrote in "Other" ways their programs foster mentoring, including teambuilding ("They stay with the same group all week and interact with the students") and expansions on training / support for college students ("Graduate student coordinator trains undergraduate mentors and helps resolve any issues"). Programs with "Maybe / Unsure" or "No" responses to fostering mentoring may include these methods; however, the survey instrument did not display the sub-question for those responses.

Individual Tests with Program Characteristics

Based on the pilot study and previous literature, various program characteristics were thought to potentially impact the degree to which a program fosters mentoring. Table 7 provides a list of characteristics as independent variables, a short description of each characteristic, and the valid percentage of responses in each coded category (calculated using only the responses to the associated survey question as the total, which may have been less than the 131 total survey responses).

Written-in "Other" program goals were not made into independent variables due to their small quantity (n = 33).

To develop variables for the characteristic of Program Duration, write-in survey responses were separated into two variables reflecting the total number of contact hours between K-12 and college students and the timing of the program and were coded qualitatively. For coding contact hours, "day" was coded as 8 hours, "residential" programs were coded as 12 hours per day, "week" was assumed to be 5 days, and there were assumed values of 15 weeks per semester and

30 weeks per academic year. Additionally, the variable of program time was initially coded into four categories. The category of "Year" included programs with both summer and academic year components; however, only 6 programs fell into this category and it was combined with "Academic Year" to provide a large enough sample size for inclusion in analysis.

The variable corresponding to the program characteristic of Student Ratio was obtained from a multiple-choice response to select a possible range of ratios (see survey Q7 in the Appendix). To respect the range and for ease of data analysis, the average ratio was calculated (e.g., range "6:1 to 10:1" averaged to "8:1" and variable value set to 8) and the variable K-12Uni_Ratio was created as a non-continuous numeric variable.

Table 7: Program Characteristics & Independent Variables

***Program Characteristic* / Independent Variable**	**Description**	**Code**	**% Valid Reponses**
Program Goals			
Goal_SparkInt	Coded "1" if the goal "Spark K-12 students' interest in STEM" was selected; coded "0" otherwise	0	11.5
		1	88.5
Goal_BuildConf	Coded "1" if the goal "Build K-12 students' confidence in STEM-oriented competencies" was selected; coded "0" otherwise	0	15.3
		1	84.7
Goal_Diversity	Coded "1" if the goal "Increase diversity of students enrolling in STEM higher-education majors and careers" was selected; coded "0" otherwise	0	21.4
		1	78.6
Goal_K-12Learn	Coded "1" if the goal "Improve K-12 student learning in STEM" was selected; coded "0" otherwise	0	32.8
		1	67.2
Goal_UniLearn	Coded "1" if the goal "Improve college student learning in STEM" was selected; coded "0" otherwise	0	74.8
		1	25.2
Program Duration			
Contact_Hrs	Estimated number of total contact hours between K-12 and college students		
Com_Prgm_Time	Categories reflecting timing of programs, including "Summer," "Academic Year OR Year," and "Day" coded as "0," "1," and "2," respectively	0	34.7
		1	39.8
		2	25.4
Student Ratio			
K-12Uni_Ratio	Averaged ratio of K-12 to college students		
Salary			
Ugrad_Paid	Responses of "No," "Varies," and "Yes" coded as "0," "1," and "2," respectively	0	32.1
		1	19.6
		2	48.2
Graduate Students			
Grad_Students	Responses of "No" and "Yes" coded as "0" and "1," respectively	0	56.5
		1	43.5
Cohort Experience			
Foster_Cohort	Responses "Little to None," "Moderate Extent," and "Large Extent" coded as "0," "1," and "2," respectively	0	20.6
		1	53.4
		2	26.0

Tests of association between categorical variables and Mentoring were run using Chi-Squared contingency tests with the null hypothesis that the variables were independent. For both numerical variables (Contact_Hrs and K-12Uni_Ratio) the Shapiro-Wilk test yielded p-values << 0.001; therefore, assumptions of normal distributions were not met, and the non-parametric Kruskal-Wallis test was used to compare the means of these independent variables across Mentoring categories.

Table 8 reports the results of these tests. It includes which format of Mentoring variable was tested; Mentoring-3 indicates that the test could be run with all three levels of mentoring, and Mentoring-2 shows the collapse of the variable into two categories where the assumptions of the Chi-Squared test were violated (e.g., too few responses in some categories). Tests with p-values that rejected the null hypotheses are indicated.

Table 8: Results from Individual Variable Tests

Categorical Variable	**n**	**Dependent Variable**	**Pearson Chi-Square**	**df**
Goal_SparkInt	131	Mentoring-2	0.435	1
Goal_BuildConf	131	Mentoring-2	8.068**	1
Goal_Diversity	131	Mentoring-3	3.035	2
Goal_K-12Learn	131	Mentoring-3	5.050	2
		Mentoring-2	3.976*	1
Goal_UniLearn	131	Mentoring-3	2.249	2
Com_Prgm_Time	118	Mentoring-3	19.845**	4
Ugrad_Paid	112	Mentoring-2	13.633**	2
Grad_Students	131	Mentoring-3	4.135	2
Foster_Cohort	131	Mentoring-3	21.268**	4
Numerical Variable			**Kruskal-Wallis H**	**df**
Contact_Hrs	119	Mentoring-3	16.747**	2
K-12Uni_Ratio	128	Mentoring-3	7.803*	2
*p<0.05. **p<0.01.				

When Mentoring-3 could be tested, the authors also tested the same variable with Mentoring-2 as a check on the results. Most of these additional tests returned the same results and are not shown in Table 8, with the exception of the categorical variable Goal_K-12Learn. The disagreement between tests with Mentoring-3 and Mentoring-2 may indicate a Type II error, where the null hypothesis was falsely rejected in the Mentoring-3 test for association. The authors note that the p-value for the Chi-Squared test of Goal_K-12Learn and Menoring-2 was 0.046, which is just on the borderline of being significant at $\alpha = 0.05$.

The program characteristics found to have significant associations with Mentoring included having the goal of "Build K-12 students' confidence in STEM-oriented competencies," the program time, whether undergraduate students were salaried, and the level of cohort experience among college students. The program characteristics of having the goal "Improve K-12 student learning in STEM" had a significant association with Mentoring-2 only. The program characteristics found to have significantly differing means across categories of Mentoring included the estimated total number of contact hours between K-12 and college students and the average ratio of K-12 to college students.

Binomial Logistic Regression

Following the individual tests, a binomial logistic regression model was run using the independent variables that were shown to be significant from the individual tests. The borderline-significant independent variable Goal_K-12Learn was also included in the model because it was significant when tested with Mentoring-2, the dependent variable in the model. Of the 131 programs, 99 were included in the model. This reduction was due to the requirement that each program description include information about all the program characteristics included as independent variables. Some program coordinators elected to skip survey questions regarding a certain characteristic, or some programs did not include undergraduates, leading to the question about undergraduate salary being left blank.

A baseline model, without any independent variables, provided a predictive capacity that was correct 65.7% of the time. The fitted model with independent variables improved on this, reaching 78.8% percentage correct. The Hosmer and Lemeshow Goodness of Fit test yielded a χ^2 of 3.685 with 8 degrees of freedom and a p-value of 0.884, indicating that the model is a good fit for the data. The model had a Nagelkerke R-square value of 0.390.

Table 9 provides the results of the binomial logistic regression model for each variable, or program characteristic, in the model. SPSS separated the categorical variables into dummy variables for each of their categories, following the coding schemes in Table 7. This set the category coded "0" as the reference category for these variables. To provide clarity, the survey responses corresponding to the separated categorical variables are also included in Table 9.

Table 9: Results from Binomial Logistic Regression Model

Variable	**Corresp. Survey Response**	**β**	**Standard Error**	**Wald χ^2**
Goal_BuildConf(1)	Has the goal	0.916	0.785	1.361
Goal_K-12Learn(1)	Has the goal	1.010	0.574	3.095*
Com_Prgm_Time	Summer			5.080*
Com_Prgm_Time(1)	Academic Year OR Year	-1.523	0.727	4.386**
Com_Prgm_Time(2)	Day	-1.628	0.833	3.816*
Ugrad_Paid	No			2.425
Ugrad_Paid(1)	Varies	0.075	0.781	0.009
Ugrad_Paid(2)	Yes	0.963	0.683	1.987
Foster_Cohort	Little to None			5.019*
Foster_Cohort(1)	Moderate Extent	1.163	0.828	1.974
Foster_Cohort(2)	Large Extent	2.152	0.977	4.848**
Contact_Hrs	-	0.004	0.006	0.346
K-12Uni_Ratio	-	-.0.44	0.041	1.153
Constant	-	-1.110	1.257	0.779
*p<0.1. **p<0.05.				

The Wald χ^2 test tests the null hypothesis that the regression coefficient (β) is zero. A significant p-value from this test rejects the null hypothesis, indicating that β, and its associated variable, is significant to predict Mentoring. The value of β indicates the influence that a given variable has on Mentoring; the higher the value, the stronger the influence. Categorical dummy variables set at “0” are the reference categories; they do not have β values and instead serve to act as a base of comparison for the other dummy variables of that program characteristic. For example, comparing Com_Prgm_Time(2), or “Day,” with its negative β to the reference Com_Prg_Time, or “Summer,” shows the model is less likely to predict a Mentoring category of “Yes” for a Day program than for a Summer program.

In all, there were three program characteristics found to be statistically significant factors in the logistic regression model: having the goal “Improve K-12 student learning in STEM,” the program time, and the level of cohort experience among college students.

Limitations

The perceptions of the program coordinators about mentoring relationships may or may not be accurate. Additionally, program coordinators’ definitions of mentoring vary, as the authors found in a pilot study with coordinators at the University of Colorado Boulder [18]. Some individuals may be more “optimistic” in their perceptions of mentoring while others may be more conservative. Following leverage-saliency theory [27], the survey invitation language and consent information at the start of the survey may have resulted in over-representation of responses among individuals who believe their programs foster mentoring relationships; therefore, the results of this study should be cautiously interpreted to broadly represent K-12 STEM outreach programs in general. The authors also recognize that survey Q10a, which asked for coordinators to expand on how their program fosters mentoring, was not shown when coordinators responded “Maybe / Unsure” or “No” about their belief that their program fosters mentoring. This may have prevented “triggering” program coordinators to change their perceptions of mentoring in their programs (if they interpreted the choices in Q10a as methods to foster mentoring); however, not showing Q10a helped to ensure that the perceptions of mentoring were the program coordinator’s alone, without interference from the imposed perceptions of the authors.

The authors also recognize that their positionality affected the research. Schill is a white woman who had favorable experiences in K-12 STEM outreach as a graduate student; survey questions written by Schill may have unintentionally been presented in such a way that attracted coordinators of programs similar to Schill’s experience. Bielefeldt is a white woman who has participated in K-12 outreach activities as a faculty member, but not to a significant degree.

Additional limitations stem from the COVID-19 pandemic. The large distractions of initial shutdowns and moves to remote learning alongside email overload in March-May 2020 during the survey solicitation period may have lowered response rates. Additionally, there is the potential that K-12 STEM outreach program coordinators were laid off and / or their programs discontinued during this time.

Discussion

Of the program characteristics tested, having the goal “Improve K-12 student learning in STEM” (Goal_K-12Learn), the program time (Com_Prgm_Time) and the level of cohort experience among college students (Foster_Cohort) were significant in both individual tests for association and in the binomial logistic regression model.

The characteristic of having the goal "Improve K-12 student learning in STEM" was borderline significant in its individual test with Mentoring as two categories and was not significant in its individual test with Mentoring as three categories. This demonstrates that this program characteristic might not have as strong as an influence on mentoring as the other characteristics that were significant across both organizations of Mentoring; however, this goal still may be leveraged to promote mentoring in K-12 STEM outreach programs. A program with this goal might encourage interactions where college students work closely with K-12 students to help them understand STEM, thus setting the groundwork for building mentoring relationships. Additionally, the very action of teaching and helping to learn disciplinary knowledge has been identified as an attribute of effective mentorship [11], and preliminary analysis from the larger study this survey is situated in has found that some undergraduates consider teaching to be part of mentoring. Having the goal "Improve K-12 student learning in STEM" may facilitate teaching, and therefore facilitate mentoring.

The characteristic of program time was coded into three categories, "Summer," "Academic Year OR Year," and "Day." Its significance in the statistical tests is consistent with preliminary data from the authors' pilot study [18], where program coordinators indicated that Day programs were typically seen as including less mentoring than week-long summer camps at the same university. It is interesting that the other variable for Program Duration, the estimated total number of contact hours, was not found to be significant in the logistic regression model. The difference between program time and contact hours, and therefore the possible explanation for program time's significance, concerns the distribution of interactions between K-12 and college students. For example, a program might contain 8 hours of contact time; however, there is a difference between a program that sets all these hours into one Day-long event and another that spreads them across a week-long Summer camp. Time is viewed in the literature as an important aspect of mentoring, relating to components of effective mentorship such as building trusting and honest relationships and reflection [8], [11], [28]. The spread of contact hours across a longer program time might relate to the difference in significance of these characteristics. College students may get to know their K-12 mentees on a deeper level when they see them over a longer period; this might facilitate lasting mentoring relationships that can positively affect both the college students and K-12 students.

The characteristic of college cohort experience was left up to program coordinator interpretation. From initial interviews with program coordinators, activities that foster a cohort experience include co-leading K-12 student groups with another college student, attending weekly meetings to discuss the program, and participating in social activities outside of the program. A program with many of these activities might provide more support for building mentoring relationships with K-12 students than a program with little to no cohort experience. College students might feel comfortable discussing their mentoring practices and reflecting on their experiences during the program with their cohorts, thus potentially engaging in peer mentorship to assist in challenges and celebrate successes in K-12 mentoring relationships. Additionally, this finding in particular may demonstrate how mentoring can address issues of diversity in STEM. Many programs in this study included a high percentage of women and undergraduates from racial / ethnic groups underrepresented in STEM; being in a cohort and mentoring K-12 students might provide opportunities for counterspaces that contribute to college student persistence in STEM

[29]. However, the authors note that this is only a contemplation, and that the larger *how* and *why* program characteristics relate to mentoring and impact diversity is beyond the scope of this paper.

The motivations of college students to participate in programs with a longer time and in programs that foster cohort experiences might also differ from those in shorter or less-cohort-fostering programs. College students in a week-long Summer camp might aim to develop mentoring relationships, knowing that they will see the same K-12 students daily, while a student volunteering at a single Day event might not. Similarly, a college student intending to join a K-12 STEM outreach program known to foster a cohort experience might be more open to developing relationships with other participants, including K-12 students.

Other program characteristics were significant in individual tests, but not in the fitted model. These included having the goal “Build K-12 students’ confidence in STEM-oriented competencies” (Goal_BuildConf), whether undergraduates received a salary (Ugrad_Paid), the estimated total number of contact hours between K-12 and college students (Contact_Hrs), and the average ratio of K-12 to college students (K-12Uni_Ratio). The shift from an individual test with up to 131 programs to the 99 programs represented in the binomial logistic regression model may have affected the significance of a given characteristic in the regression model. The representation of programs with the goal of building K-12 students’ confidence was reduced the most; nearly 25% of programs with this goal were not included in the regression model. The characteristic of undergraduate salary was reduced the least and only 12% of programs were excluded: two programs where undergraduates are not paid, seven where pay varies, and four where undergraduates are paid.

There were also program characteristics that were not significant in the analyses. These include most of the program goals (Goal_SparkInt, Goal_Diversity, and Goal_UniLearn) and the program’s inclusion of graduate students (Grad_Students). Given that mentoring may play a role in solving prevalent issues of diversity in engineering, it is interesting that having the goal to “Increase diversity of students enrolling in STEM higher-education majors and careers” was not significant. This finding along with the other null results are important in that they provide an avenue for future research that examines why these characteristics were not associated with Mentoring in the survey sample.

Conclusion

The survey focused on in this paper was part of a larger study on mentoring and STEM identity development in K-12 STEM outreach programs. This paper presented survey analysis to answer the research question, Do K-12 STEM outreach program characteristics differ between programs that are and are not believed to foster mentoring relationships between university and K-12 students? Results suggest “Yes,” and Table 10 provides a summary of the tested program characteristics in descending order from the group of characteristics most likely to impact mentoring to those least likely.

Table 10. Summary of Study Results

Results from Statistical Analyses	Program characteristic
Significant in both individual tests and binomial logistic regression	Having the goal, “Improve K-12 student learning in STEM” *
	Program Time, separated into categories of “Summer,” “Academic Year OR Year,” and “Day”
	Cohort Experience, how much college students feel they are part of a “cohort” or group
Significant in individual tests only	Having the goal, “Build K-12 students’ confidence in STEM-oriented competencies”
	Salary, if undergraduates are paid
	Contact Hours, the estimated number of total contact hours between K-12 and college students
	Student Ratio, the average ratio of K-12 to college students
Not significant in tests	Having the goal, “Spark K-12 students’ interest in STEM”
	Having the goal, “Increase diversity of students enrolling in STEM higher-education majors and careers”
	Having the goal, “Improve college student learning in STEM”
	Graduate Students, if graduate students participate in the program
*Significant only with Mentoring as two categories, “Yes” and “Maybe / Unsure OR No”	

Mentoring relationships have the potential to benefit both K-12 and college students. Given the range and variety of K-12 STEM outreach programs at universities, results from this study can widely impact these programs. The authors recognize that not all K-12 STEM outreach programs aim to foster mentoring relationships between K-12 and college students, and that programs with varying levels of mentoring are capable of significantly impacting both K-12 and college student views on and competencies in STEM. However, should a program aim to foster mentoring relationships, the results of this study indicate that the program characteristics of having the goal to improve K-12 learning, the program time, and the college student cohort experience may have a significant relationship to mentoring in K-12 STEM outreach programs. Programs may incorporate the goal “Improve K-12 student learning in STEM” through deliberately having college students teach K-12 students. Programs might encourage a cohort experience among college students by arranging time for students to debrief and discuss their experiences with K-12 students; they may seek to spread out the timing of their interactions, such that K-12 and college students see each other over a longer period.

Future Work

The analyses presented here indicate that the characteristics of having the goal “Improve K-12 learning in STEM,” program time, and college cohort experience may be significant to fostering mentoring relationships within K-12 outreach programs; however, it does not answer further questions of why these characteristics are significant. This survey was intended to provide a pool of potential participants for the interview phase of a larger research study; therefore, future work building on this survey includes interviews with K-12 STEM outreach program coordinators and undergraduate student participants. This will give the authors the opportunity to compare perceptions of mentoring across coordinators and students. It will also provide a qualitative follow-up to inquire as to how various program characteristics impact mentoring, such as asking program coordinators if and how their descriptions of “cohort experience” connect to K-12 mentoring. Future work also includes further examination of mentoring in programs with the goal "Improve K-12 student learning in STEM," since the significance of this characteristic proved inconsistent in individual tests.

Future work also includes delving into interactions between program characteristics. It may be interesting to see how the two Program Duration variables (total number of contact hours and program time) relate to each other when looking at their associations with mentoring. The authors are also curious about the interactions between characteristics of ratio of college:K-12 students and contact hours; a program that is only a few hours long might foster more mentoring relationships than a longer program if the college students are each interacting with fewer K-12 students.

Future work could also look deeper into the program characteristics that were found to be significant in individual tests only; interviews with students and program coordinators may shed light on how these characteristics affect mentoring (or not) and provide an explanation for the lack of significance in the binomial regression model. There is also merit to further examining the null results of this study, especially given the surprising result that having graduate students was not a significant program characteristic. One program coordinator indicated that having a graduate student coordinator train undergraduate mentors helped foster mentoring relationships in their program; there is the possibility that mentoring in other K-12 STEM outreach programs not represented in this survey also benefit from graduate students, and future work would target programs with both undergraduate and graduate students to better explore this characteristic.

Initial tests, which are beyond the scope of this paper, found that there is an association between undergraduate diversity demographics (% Female Undergraduates and % URM Undergraduates) and Mentoring; future work could delve into this association and its relationship to other program characteristics. Breaking from the focus on mentoring, data from the survey can be analyzed to examine college student diversity in K-12 STEM outreach programs. Given the large pool of data gathered and the imminent need for addressing issues of diversity and inclusion in STEM, programs specifically targeting increasing diversity in STEM can be the target of future analysis. This includes focusing on programs that had the goal of increasing diversity in STEM and / or target certain groups of students and examining the representation of women and URM undergraduates across programs.

This study also provided essential feedback on the survey as an instrument to examine K-12 STEM outreach programs and mentoring. Some survey wording may have been confusing, resulting in program coordinators skipping questions. The authors have determined that the program goals question could have been more robust, since busy program coordinators might have indicated different goals if they were provided as options, rather than left to the program coordinators to write in themselves. The authors intend to use the future interviews with select program coordinators as a modest check on the accuracy of the survey instrument for examining mentoring; program coordinators' answers to mentoring questions in their interviews will be compared to their survey responses.

The survey data analyzed in this paper contributes to the developing understanding of mentoring in K-12 STEM outreach programs. With this base, future research can further dive into K-12

STEM outreach programs, so that these vital programs can support both their K-12 and their college student participants.

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Appendix

Program Coordinator Survey

Q1: [CONSENT TEXT] Do you consent to participate in this survey?

- ○ Yes, I consent
- ○ No, I do not consent

Q2: If you direct multiple K-12 STEM education and outreach programs, describe attributes for ONE of the programs first. Then you will be given an opportunity to describe up to three additional programs.
How many programs do you direct? (Please enter a number up to four. Ex: 1, 2, 3, 4)

____

[Q3-Q11 repeat for the number of programs indicated in Q2]

Q3 Please provide information about Program [1 / 2 / 3 / 4]. Name of your Program: [optional],

____

Q4 What are the goals of the program? (Select all that apply)

- □ Spark K-12 students' interest in STEM
- □ Build K-12 students' confidence in STEM-oriented competencies
- □ Increase diversity of students enrolling in STEM higher-education majors and careers
- □ Improve K-12 student learning in STEM
- □ Improve college student learning in STEM
- □ Other: ____

Q5 What discipline(s) are the primary focus of the program? (Select all that apply)

- ◻ Biology
- ◻ Chemistry
- ◻ Computer Science / Computer Programming
- ◻ Earth / Environmental Science
- ◻ Engineering
- ◻ Mathematics
- ◻ Medicine
- ◻ Physics
- ◻ STEM (general)
- ◻ Other: ____

[If "Engineering" is selected in Q5, then Q5a is displayed]

Q5a Engineering Discipline: [optional]

____

Q6 What is the total duration of time that a single cohort of K-12 students engages with your program? [Examples: 1 hour per week over 15 weeks; 8 hours over one day; 5 hours per day over one week]

____

Q7 What is the approximate ratio of K-12 students to college students? (Select only one)

- ○ 5:1 or less
- ○ 6:1 - 10:1
- ○ 11:1 - 20:1
- ○ Greater than 20:1

Q8 How many undergraduate students participate in the program? (Select only one)

- ○ 0
- ○ 1 - 15
- ○ 16 - 30
- ○ 31 - 60
- ○ Over 60

[If Q8 is answered and "0" is not selected, then Q8a, Q8b, and Q8c are displayed]

Q8a About what percentage of the undergraduate student participants typically are female? (Select only one)

- ○ 0
- ○ 1 - 25%
- ○ 26 - 50%

- 51 - 75%
- 76 - 100%

Q8b About what percentage of undergraduate participants are typically from racial / ethnic groups underrepresented in science, technology, engineering, and mathematics (i.e., not White or Asian)? (Select only one)

- 0
- 1 - 25%
- 26 - 50%
- 51 - 75%
- 76 - 100%

Q8c Are undergraduate participants paid? (Select only one)

- Yes
- No
- Varies

Q9 Do graduate students participate in your program?

- Yes
- No

[If “Yes” is selected in Q9, then Q9a is displayed]

Q9a About what percentage of college student participants are graduate students? (Select only one)

- 0
- 1 - 25%
- 26 - 50%
- 51 - 75%
- 76 - 100%

Q10 Do you believe that your program fosters mentoring relationships between K-12 students and college students? (Select the most appropriate answer)

- Yes
- Maybe / Unsure
- No

[If “Yes” is selected in Q10, then Q10a is displayed]

Q10a Please expand on how your program fosters mentoring relationships. (Select all that apply)

- ◻ Explicit training of college students on mentoring
- ◻ Many face-to-face interactions between K-12 and college students
- ◻ Open communication between K-12 and college students
- ◻ Other: ____

Q11 To what extent does your program foster a cohort experience among the college student participants? (Select the most appropriate answer)

- ○ Large extent
- ○ Moderate extent
- ○ Little to none

Q12 Please provide some information about your institution. (Select all that apply)

- ◻ Public
- ◻ Private
- ◻ Community College
- ◻ Doctoral Awarding
- ◻ Master's Awarding
- ◻ Bachelor's Awarding

Q13 The research team will select program coordinators to invite to participate in two elements of this research study: (1) an interview, and (2) contacting university students who participated in your program between 2018 and 2020 on behalf of the research team. The interview would last about 45-75 minutes and will be conducted remotely. If you consent to contact university students, a scripted email to send to students will be provided for you.

To be considered for participation in this study to support research on STEM identity development in K-12 STEM education and outreach programs (with $45 compensation), please provide your contact information.

- ○ College / University Name: ____
- ○ Program Name(s): ____
- ○ Name: ____
- ○ Email: ____