Deeper Learning Opportunities and STEM Career Orientation in Out-of-School Time (OST) STEM Enrichment Programs

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Abstract

This study analyzes Deeper Learning (DL) opportunities and the correlation between multiple DL measures on STEM (science, technology, engineering, and math) career orientation in out-of-school time (OST) STEM programming. Additionally, this study examines the presence and validity of the American Institutes for Research (AIR) DL measures in OST STEM enrichment program evaluation, and DL's ability to help address equity issues in STEM education for diverse learners. For analysis, this study examined longitudinal data (pre- and post-surveys) using confirmatory factor analysis (CFA) and design-based multilevel structural equation modeling (MSEM) from a large-scale OST STEM enrichment program with multiple sites across the state of Texas (22) that serves middle and high school students who participated for seven weeks over the summer in 2019 (n = 1,447). Results showed that the AIR-DL measures were suitable for use in OST STEM enrichment programming and that DL opportunities measured through critical thinking, communication and collaboration, and real-world connections had positive effects on STEM career orientation, especially for women and underrepresented minority students. Implications for theory, practice, and future research are briefly discussed.

Keywords: STEM enrichment, Deeper Learning, out-of-school (OST), STEM career orientation, multilevel structural equation modeling (MSEM)

Introduction

As the United States continues to struggle filling the high demand for STEM professionals, it faces a critical challenge on how best to educate and prepare women, racial/ethnic minorities (Latinx/Hispanics, Blacks, Native Americans, hereafter referred to as underrepresented minorities [URMs]), and low-socioeconomic status (low-SES) students for STEM careers (National Science and Technology Council [NSTC], 2018; National Center for Science and Engineering [NCSES], 2021). To make STEM learning more accessible to underrepresented students, and ultimately encourage them to pursue STEM education and careers, out-of-school time (OST) STEM enrichment programs have become popular across the U.S. (National Research Council [NRC], 2015). However, given the unique academic, motivational, and social needs and challenges of women and URMs (Cheryn et al., 2017; Wang & Degol, 2017; Jong et al., 2020; Park-Taylor, 2022), there are often equity issues that make STEM education ineffective for these populations (Dawson, 2017; After School Alliance, 2020; Wallace Foundation, 2022). To help ensure OST STEM programs address equity issues, there is clearly a necessity for quality assessment that can provide the appropriate insight into educational processes and outcomes taking place in OST STEM with diverse learners.

Deeper Learning (DL), a modern and comprehensive structure for learning that puts the student at the center of the learning process (Bitter and Loney, 2015), is auspicious for use in OST STEM enrichment programs because of its effectiveness with all learners (Rickles et al., 2019). Not only does DL show promise for addressing disparities in STEM instruction but it also provides the means to measure educational processes and outcomes for diverse learners. Drawing on DL and the student measurement survey developed by the American Institutes for Research (AIR) (AIR, 2016), this study analyzes the presence and validity of AIR-DL measures in a large-scale OST STEM enrichment program and if and to what extent DL opportunities link to students' interest in pursuing a STEM career.

Theoretical Perspective and Relevant Literature

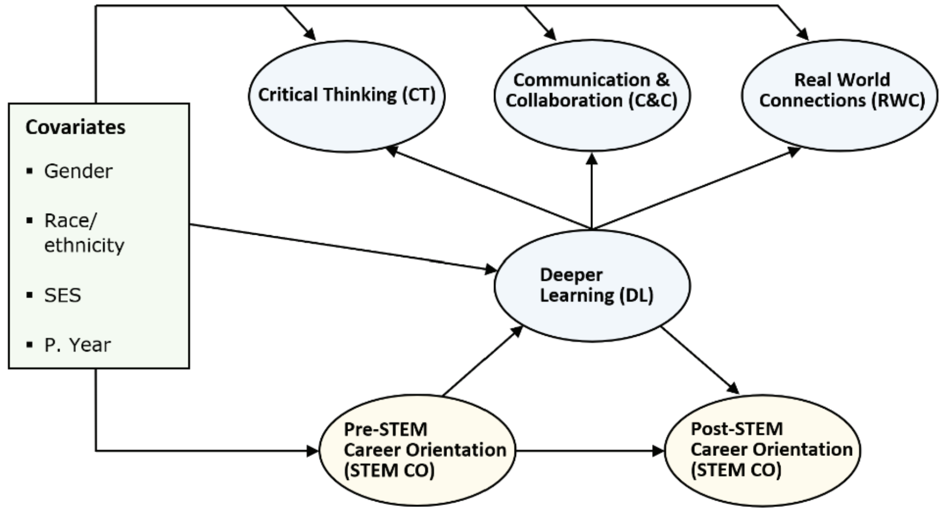
OST STEM Enrichment Programs

In the U.S., millions of students attend OST programs, as they have become a source for positive youth development and enrichment (Smith, 2007; Vandell, 2013; After School Alliance, 2014). Specifically, OST STEM enrichment programs have become popular and, when well structured, show signs of positive outcomes (Allen et al., 2019; Chan et al., 2020). However, OST STEM enrichment programs are often not well structured nor provide the cognitive engagement necessary to meet the needs and challenges of non-traditional STEM students (i.e., women and URMs; Thoman et al., 2015; Tang & Zang, 2020). Most OST STEM enrichment programs are small scale (mostly local programs with small participant numbers), short in duration (a few days in length), and are not demographically diverse (NRC, 2015; Saw et al., 2019). Additionally, evidence on the effectiveness of OST STEM programs is limited, not robust, and inconsistent (NRC, 2015), creating a need for a more comprehensive program structure that is measurable.

Deeper Learning in OST STEM Enrichment

One promising framework for rigorously assessing OST STEM enrichment programs is Deeper Learning (DL), which builds on a concept of learning and acquiring 21st century knowledge and skills in relevant and meaningful ways (Hewlett Foundation, 2013; Huberman et al., 2014). DL posits that learning is inherently unique to each student and, by embracing students' unique backgrounds and intrinsic motivations, learning will become more desirable, part of students' identity, and promote deeper cognitive connections (NRC, 2012a; Farrington, 2013; Noguero et al., 2015). Composed of synergistic components, such as critical thinking, communication and collaboration, and real-world connections, evidence shows that students of all backgrounds and levels can achieve greater learning outcomes when DL is implemented in a rigorous academic environment (Bitter et al., 2014; Zeiser et al., 2014; Ottmar, 2019; Agger & Koenka, 2020). Designed to be measurable for effective implementation and assessment (Conley & Darling-Hammond, 2015), DL has been tested in the regular-time setting (DL network schools) and has shown promising results toward equity and performance outcomes (Martinez & McGrath 2014; Vander Ark & Schneider, 2014; Bitter & Loney, 2015; Mehta & Fine, 2019). DL also has the potential for being an effective structure for use in OST STEM enrichment, leading to increased learning outcomes and desire—particularly for women, URMs, and low-SES students—to obtain a STEM career.

Of the many DL concepts/measures, critical thinking (CT), communication and collaboration (C&C), and real-world connections (RWC) are examined in this study. Together, these three measures capture the cognitive, intrapersonal, and interpersonal domains of DL. Modifying the DL student measures developed by the AIR (2016), particularly CT, C&C, and RWC, which have been validated in DL network schools (regular-school setting), we aim to determine the presence of DL and its validity as a measure in an OST STEM enrichment program and analyze its association with STEM career orientation. In this study, CT refers to students' ability to use multiple sources of information and tools to solve problems and C&C refers to students' ability to share complex ideas in writing and spoken form, listen, receive feedback, and provide feedback in meaningful ways (Huberman et al., 2014). RWC are the ability of students to learn and apply what they learn to practical settings and application relevant to them and their community (NRC, 2012b; Bradley & Hernández, 2019). Figure 1 is a visual display of the theoretical framework of this study.



Note. SES = socio-economic status, P. Year = program year/level.

Figure 1. A Theoretical Framework for the Association Between DL and STEM Career Orientation in OST STEM Enrichment Programs

Research Questions

Since research on DL is relatively new and largely limited to studies conducted in regular-school settings, with none to date being conducting in an OST setting, our study first seeks to determine whether AIR-DL measures of CL, C&C, and RWC were also valid and reliable within an OST setting. Furthermore, we explore whether and to what extent DL opportunities differ across student subgroups in OST enrichment programs. Lastly, we test whether and to what extent DL opportunities in OST settings are associated with students' STEM career orientation. Three specific research questions (RQs) are examined in this study:

RQ1, Measurement. Are AIR-DL measures valid and reliable for assessing DL opportunities in OST STEM enrichment programs?

RQ2, Equity. Do DL opportunities reported by students vary by demographic groups in OST STEM enrichment programs?

RQ3, Effectiveness. How do DL opportunities in OST STEM enrichment programs relate to student STEM career orientation?

Study Context: The Prefreshman Engineering Program (PREP)

This study used data collected from a multi-site OST STEM enrichment summer program. The Prefreshman Engineering Program (PREP) runs across the state of Texas in the United States and was founded in 1979. PREP prepares middle and high school students for success in advanced STEM studies and focuses on recruiting women, URMs, low-SES, and students who would be the first in their family to attend college. Offered to students in grades 6th through 11th, PREP takes place for seven weeks in the summer over four summers (28 weeks total) with progressing levels of STEM curriculum and learning activities that students must take in consecutive order (i.e., students must start and complete year 1 to progress to year 2) (Table 1). Located on a college or university campus, PREP uses an academically rigorous project-based learning curriculum taught by certified teachers who are encouraged to be innovative and creative with teaching methods. Additionally, each PREP year provides equal class time for less formal learning components, providing students the opportunity to explore their own learning in a structured environment and apply what they learn intrinsically (see All Years in Table 1). In summer 2019, there were 22 PREP sites located across 14 geographically diverse cities in Texas, including rural and small towns, large suburban and urban areas, from West Texas, North Texas, Central Texas, and down to the US and Mexico border.

PREP was an ideal setting for conducting this study as it has a large (statistically significant) and diverse population (i.e., women, URMs, and low-SES) and is conducted over a significant time span of seven weeks each summer for four summers (28 weeks total), enabling valid and reliable collection of data. Additionally, PREP is structured in a way that makes it aligned with DL components. Specifically, PREP provides the framework (academic rigor) needed to test the AIR-DL components in. Content mastery in coursework 1 and 2 and research and study align with the DL measure of critical thinking. Communication and collaboration are integral parts of each PREP component, requiring students to work in groups and with near-peer mentors on projects, presentations, and reports. Because students have agency when picking project topics and can conduct research aligned with their intrinsic interests, students can internalize knowledge and see themselves in STEM professions. Additionally, PREP has career awareness seminars, field trips, lab tours, and other real-world connection opportunities specific to each site that join all learning elements together in a way to make content mastery directly applicable to each student. Like DL, the PREP curriculum is designed to work synergistically, supporting, and bolstering its various components to create a cohesive developmental process.

Program Level	Coursework 1	Coursework 2	
Year 1 (6th grade)	Logic and its Application to Math	Introduction to Engineering	
Year 2 (7th grade)	Algebraic Structures	Introduction to Physics	
Year 3 (8th grade)	Probability and Statistics	Introduction to Technical Writing	
Year 4 (9th grade)	Introduction to Computer Science	Advanced Science/Engineering	
All Levels/ Years	• PBL group projects • Career seminars	• 1-1 and group mentoring • Tutoring	• Lab tours • Field trips

Table 1. PREP Structure and Curriculum

	Mean		SD		Min.	Max.
	Pre	Post	Pre	Post		
Independent Variable						
Creative/Critical Thinking (CT)						
I was challenged to create new ideas	-	3.88	-	.96	1	5
I was encouraged to think of creative solutions to problems	-	3.96	-	1.00	1	5
I was encouraged to come up with different ideas	-	3.95	-	1.02	1	5
I was asked to come up with new ways to do things	-	3.83	-	1.09	1	5
Communication & Collaboration (C&C)						
I worked with other students on projects during class	-	4.18	-	.93	1	5
I worked on projects with my classmates outside of class	-	2.71	-	1.50	1	5
I worked in groups of two or more students	-	4.18	-	1.00	1	5
I needed to work with others to do well in PREP	-	3.44	-	1.31	1	5
Real-World Connections (RWC)						
I worked with real-world examples at PREP	-	3.64	-	1.12	1	5
I searched for information for a PREP project from sources outside the classroom	-	3.43	-	1.34	1	5
I worked on helping solve real-world problems	-	3.33	-	1.31	1	5
I connected what we were learning at PREP to life outside the classroom	-	3.38	-	1.32	1	5
Dependent Variables						
STEM Career Orientation (STEM CO)						
Studying in a STEM degree program in college	3.30	3.24	.72	.77	1	4
Working as a STEM professional in the future	3.10	3.11	.83	.87	1	4
Building a career in STEM fields in the future	3.20	3.14	.79	.84	1	4

Note. SD = standard deviation, Min. = minimum, Max. = maximum

Table 2. Summary Statistics on DL and Outcome Measures (*n* = 1,447)

Methods

Data Source and Sample

Data for this study were collected in collaboration with PREP in the summer of 2019 by student surveys. 2019 PREP pre- and post-participant surveys were administered by most sites digitally using Qualtrics. If digital administration was not feasible, sites administered paper-based versions. The pre-survey was administered within the first week of programming (week 1) and the post-survey was administered in the last week of programming (week 7). Both pre- and post-surveys contained circa 80 questions and took approximately 20 minutes to complete (with approx. one third of the questions being demographic/background questions and non-cognitively demanding). A total of 1,447 participants completed both pre- and post-surveys and are analyzed in this study.

Measures

The three DL measures (CT, C&C, and RWC) were assessed in the post-survey to determine each's presence and association with STEM career orientation. Each DL measure (independent variable) was assessed by 4 items with a 5-point Likert scale ranging from 1 (never) to 5 (always) (AIR, 2016; Ottmar, 2019; Rickles, 2019). When needed, the wording for certain items was modified so that it referenced PREP. The outcome variable for this study—STEM career orientation (STEM CO)—was assessed pre- and post- by 3 items with a 4-point Likert scale (modified from Brown et al., 2015; Rozek et al., 2017). Participants answered by expressing their level of interest with each item ranging from 1 (not at all interested) to 4 (extremely interested) While there was no statistically significant difference in STEM CO before and after the program, the two pre- and post-survey measures were valid and reliable for modeling the changes in STEM CO (increase or decline) associated with DL among participants between the two timepoints. The wording and summary statistics for all items are listed in Table 2 (full survey items are listed in the Appendix).

Demographics

Demographic variables, including gender, race/ethnicity, SES, and PREP year were collected in the pre-survey (see Table 3). For gender, other than "female" and "male," "prefer not to respond" or "I don't know" were combined into "other genders". For race/ethnicity, the URM group includes Latinx/Hispanic, Black or African American, American Indian or Alaska Native, and Native Hawaiian or Pacific Islander, whereas the non-URM group includes White and Asian. This study used parental education as a proxy for students' family SES. Participants were categorized into three groups based on their parents' highest level of education: (1) low-SES (associate degree or below), (2) middle-SES (bachelor's degree), and (3) high-SES (graduate or professional degree).

Gender		
Female	757	52
Male	635	44
Other Genders	55	4
Race/Ethnicity		
Underrepresented Minorities (URM)	1138	79
Non-URM (White and Asian)	231	16
Other Races	78	5
Socioeconomic Status (SES)		
Low-SES	437	30
Middle-SES	338	23
High-SES	427	30
No Response	245	17
PREP Year		
Year 1	600	41
Year 2	293	20
Year 3	356	25
Year 4	198	14

Note. n = sample size.

Table 3. Demographic Characteristics of Sample (*n* = 1,447)

Data Analysis

To answer RQ1, our DL measures were validated using a second order CFA model where the CT, C&C, and RWC factors were loaded on a higher DL factor. This was done for three reasons: (1) this study is one of the first to test DL measure in an OST setting, (2) the wording of AIR-DL questions needed to be adjusted from the regular-school setting to the OST setting, and (3) the number of AIR-DL items had to be reduced because of the limited administration time of the 2019 PREP post-survey. To determine goodness of data-model fit, a combination of fit indices were used, including the root mean square error of approximation (RMSEA), comparative fit index (CFI), and standardized root mean square residual (SRMR). Factor loadings above .50 were considered adequate and above .70 desirable (Muller & Hancock, 2008).

Following CFA, to answer RQ2 and RQ3, design-based multilevel structural equation modeling (MSEM) was employed to test (1) the demographic differences in DL and (2) the relationships between DL opportunities and STEM career orientation (STEM CO) (while controlling for demographic characteristics and PREP year). The design-based MSEM approach was used to handle the nested data structure (i.e., students clustered within sites) because student-level measures were of interest (Muthén & Muthén, 1998-2017; Wu & Kwok, 2012). Application of the root mean square error of approximation (RMSEA), comparative fit index (CFI), and standardized root mean square residual (SRMR) were performed to ensure the data fit the model. An RMSEA ≤ .08, CFI ≥ .95, and SRMR ≤ .10 are considered an acceptable fit (Schermelleh-Engel et al., 2003). Descriptive statistics were conducted in STATA 16.1 and CFA and MSEM were conducted in MPLUS 8.6 (Muthén & Muthén, 1998-2017).

Results

RQ1: Reliability and Validity for DL Measures

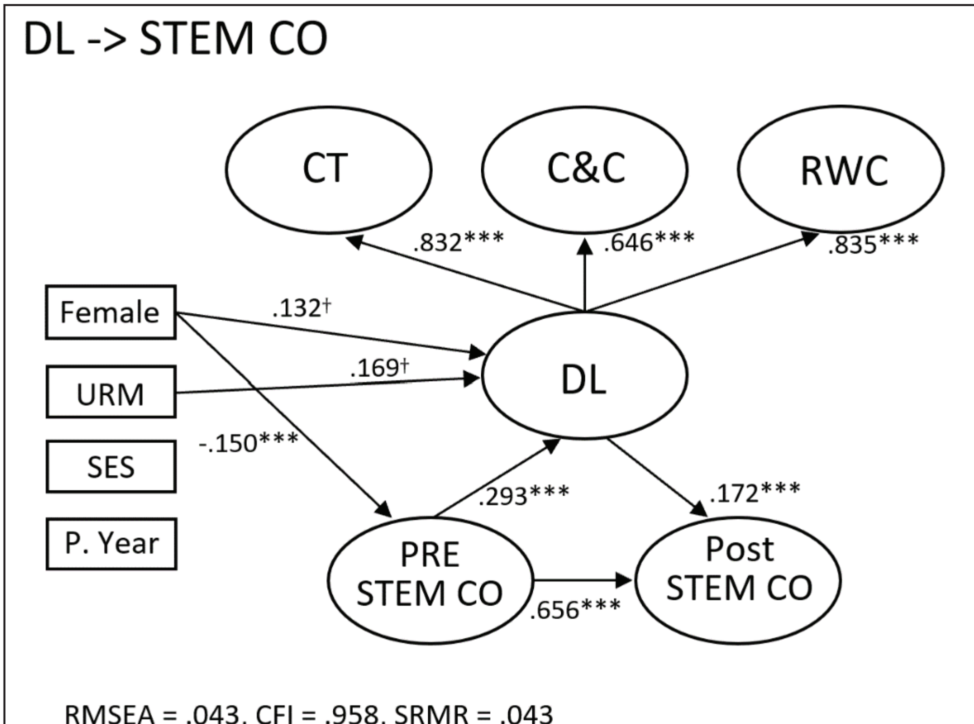
CFA results, as reported in Table 4, provide evidence that AIR-DL and STEM CO measures are valid in an OST setting (RQ1), with most factor loadings above the .70 threshold. Although two of the four factor loadings for C&C were below .50, these factors were considered acceptable given the C&C constructs loaded approximately 0.645 on the second-order DL factor. Findings for the second-order CFA yielded acceptable fit with an RMSEA of .073, a CFI of .961, and SRMR of .061. Additionally, calculated Cronbach's alphas for all first- and second-order factors, including CT, C&C, RWC, STEM CO, and DL, range from 0.71 to 0.93, indicating that these measures are reliable when assessed in OST STEM enrichment programs (Table 4).

RQ2: Demographic Differences in DL

MSEM results provide suggestive evidence that DL may differ for demographic groups. Both women and URM participants reported marginally significant higher opportunities of DL than their male and White/Asian peers, 0.132 and 0.169 standard deviations, with a p-value of .055 and .054, respectively (see Figure 2).

	Factor Loading		Cronbach's Alpha	
	Pre	Post	Pre	Post
Cognitive/Critical Thinking (CT)				.928
I was challenged to create new ideas	-	.818		
I was encouraged to think of creative solutions to problems	-	.911		
I was encouraged to come up with different ideas	-	.914		
I was asked to come up with new ways to do things	-	.856		
Communication and Collaboration (C&C)				.706
I worked with other students on projects during class	-	.828		
I worked on projects with my classmates outside of class	-	.451		
I worked in groups of two or more students	-	.756		
I needed to work with others to do well in PREP	-	.449		
Real-World Connections (RWC)				.863
I worked with real-world examples at PREP	-	.811		
I searched for information for a PREP project from sources outside the classroom	-	.681		
I worked on helping solve real-world problems	-	.828		
I connected what we were learning at PREP to life outside the classroom	-	.812		
STEM Career Orientation (STEM CO)			.912	.932
Studying in a STEM degree program in college	.836	.864		
Working as a STEM professional in the future	.891	.922		
Building a career in STEM fields in the future	.918	.934		
Deeper Learning Opportunities (DL)				.773
Critical Thinking (CT)	-	.829		
Communication and Collaboration (C&C)	-	.645		
Real World Connections (RWC)	-	.839		

Table 4. Second-order Confirmatory Factor Analysis and Reliability Test Results (*n*=1,447)



Note. Latent construct = oval; observed variables = rectangle. All variables were controlled for background characteristics (see Table 2). Values are standardized path coefficients. R^2 for CT = DL OPPORTUNITIES IN OST STEM ENRICHMENT PROGRAMS 15 .693; R^2 for C&C = .417; R^2 for RWC = .698; R^2 for DL = .097; R^2 for Pre-STEM CO = .020; R^2 for Post-STEM CO = .526. RMSEA = Root Mean Square Approximation, CFI = Comparative Fit Index, SRMR = Standardized Root Mean Square Residual. †p < .10, *p < .05, **p < .01, ***p < .001. N = 1,447.

Figure 2. Association Between DL and STEM CO

RQ3: Association between DL and STEM Career Orientation

MSEM results provided further evidence that DL opportunities were significantly positively associated with participants' post-program STEM career orientation (0.172 standard deviations with a p-value significance of .001), controlling for demographic characteristics and pre-program STEM career orientation. Findings of the MSEM yielded good model fit with an RMSEA of .043, a CFI of .958, and SRMR of .043 (Figure 2).

Conclusion

Our study contributes to the literature on DL and OST STEM education in several respects. This study is the first to analyze the relationships among multiple measures of DL opportunities and STEM career orientation with a diverse student sample from a large scale, academic-based OST STEM enrichment summer program. It is also the first study to offer strong empirical evidence on the validity and reliability for DL opportunities— critical thinking, communication and collaboration, and real-world connections—in an OST setting (RQ1). Additionally, our findings from the design-based MSEM shows a marginally significant tendency that women and URMs had higher opportunities for DL than their non-URM peers (RQ2) and provides promising evidence that OST programs may address equity gaps in STEM education by enhancing DL opportunities among underrepresented groups. Lastly, we found that DL opportunities in OST STEM enrichment programs are significantly positively associated with student STEM career orientation, controlling for key demographic characteristics and prior measure on STEM career orientation (RQ3).

Discussion

Given that students spend a significant part of their time in OST, OST has been identified as a time to provide important enrichment (NRC, 2015). STEM enrichment in OST appears to be beneficial as it can lead to long-lasting positive effects on STEM education (Dabney et al., 2012). STEM enrichment programs aiming to make substantive progress toward increasing female and URM's STEM career orientation could begin by incorporating and enhancing DL opportunities. Additionally, because DL is designed to be measurable for educators and students (Conley & Darling-Hammond, 2015), practitioners could use adaptations of the AIR-DL measures as a guide to assess both program processes and student experiences. It is important to note that DL is intended to be implemented in a rigorous academic environment and the inclusion of DL opportunities alone, without an academic program base, might not lead to positive results. When coupled with academic rigor (e.g., PBL in PREP), fostering communication and collaboration via various activities such as group projects and real-world connections could not only provide students with opportunities for hands-on learning but also fosters personal and shared experiences that fortifies learning.

Limitations and Recommendations for Further Research

There are several limitations to this study which future research should address. First, all measures in this study were self-reported and only immediate outcomes were tested. Findings for this study have limited generalizability as they were only gathered from students in Texas and all students were largely STEM motivated and had the access to OST STEM enrichment programs. To increase generalizability, data should be gathered from a larger and more diverse sample. Additionally, non-self-reported outcome measures such as test scores and teacher ratings should be incorporated. There are important student characteristics that could also be collected, such as English language proficiency, participation in other OST programs, parental occupations and involvement, geographic location (e.g., rural v urban), etc., that could provide more in-depth understanding of student unique backgrounds and attitudes toward STEM. Lastly, this study only examined three measures on DL opportunities and one STEM motivational factor. To shine more light on the effectiveness of DL within OST, future research should analyze additional measures on DL opportunities and student motivation. By doing so, key elements of DL can further be identified that exist in STEM enrichment for women and URMs, helping ensure that these students are able to meet the challenges of the 21st century and beyond.

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We have no known conflicts of interest to disclose. Correspondence concerning this article can be sent to Ryan Culbertson at ryaculbe@ttu.edu or Guan Saw at guan.saw@cgu.edu.

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Table 1A

Deeper Learning Questions Assessed in Post-survey

During this summer, how often have you felt any of the following ways **in your STEM classes/activities in PREP?** (*Circle your answer to each item*)					
	Never	Sometime	About half of the time	Most of the time	Always
I was challenged to create new ideas	1	2	3	4	5
I was encouraged to think of creative solutions to problems	1	2	3	4	5
I was encouraged to come up with different ideas	1	2	3	4	5
I was asked to come up with new ways to do things	1	2	3	4	5
I worked with other students on projects during class	1	2	3	4	5
I worked on projects with my classmates outside of class	1	2	3	4	5
I worked in groups of two or more students	1	2	3	4	5
I needed to work with others to do well in PREP	1	2	3	4	5
I worked with real-world examples at PREP	1	2	3	4	5
I searched for information for a PREP project from sources outside the classroom	1	2	3	4	5
I worked on helping solve real-world problems	1	2	3	4	5
I connected what we were learning at PREP to life outside the classroom	1	2	3	4	5

Note. Modified from AIR (2016).

Table 2A

STEM Career Orientation Questions Assessed in Pre- and Post-survey

How interested are you in the following regarding your **STEM educational and career plans**? (*Circle your answer to each item*)				
	Not at all interested	Not interested	Interested	Extremely interested
Studying in a STEM degree program in college	1	2	3	4
Working as a STEM professional in the future	1	2	3	4
Building a career in STEM fields in the future	1	2	3	4

Note. Modified from Brown et al. (2015) and Rozek et al. (2017).