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How Does an Industry-aligned Technology-rich Problem-based Learning (PBL) Model Influence Low-income and Native Hawaiian Student's STEM Career Interest?

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ABSTRACT

The need to increase students interested in pursuing careers in science, technology, engineering, and mathematics (STEM) is growing. The current study delivers results of an Upward Bound program focused on advancing students' interest toward STEM fields and careers. Project STEMulate, funded by the National Science Foundation's ITEST program, used Problem-Based Learning (PBL) in challenging students to engage in solving hands-on, real-world authentic problems in their communities. Project STEMulate takes structured PBL one step further by collaborating with local STEM Industry Partners for contextual learning and STEM pipeline development. The results revealed a raised interest in STEM, and a correlation between: 1) students' career interest and their science ability and motivation, and 2) their Science Self-Efficacy and PBL ratings associated with their interest in STEM careers. These results highlight the significant potential of PBL instructional strategies to increase students' attitudes toward and interest in future STEM careers.

Keywords: Problem-Based Learning, STEM, Underrepresented Minority High School, Native Hawaiian Students, Science Self-Efficacy, Science Education, STEM Camps, Youth

INTRODUCTION

The goal of this three-year ITEST project (2017-2020), Project STEMulate, was to motivate and advance the interest, knowledge, and skills of underrepresented Native Hawaiians and low-income, first-generation college-bound students in STEM by providing technology-rich STEM curricula that actively engages them in real-world

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problem solving and learning. To achieve this next practice of PBL, the project focused on five key components: (1) adaptation, implementation, and testing of a technology-rich, problem-based high school STEM curriculum; (2) professional development and training of 27 teachers; (3) extension of learning through academic-year internships adhering to the PBL model; (4) formative and summative evaluation to refine curriculum; and (5) development of a STEM workforce pipeline. This paper reports on the second year of project's impact on its college-bound first generation Upward Bound students.

REVIEW OF LITERATURE

Whether or not the United States is still globally competitive in STEM fields has been a major concern. With the ever-growing concern for the future of the U.S. economy and workforce, and the short supply of STEM graduates (Johnson, 2018), attention is focused on increasing the number of K-12 students to complete their education with degrees in STEM fields and pursue a STEM career. Many researchers have found that fewer minorities entering STEM fields. In exploring the causes and searching for targeted interventions helpful in escalating student interest in STEM – particularly for minorities – many researchers have begun to examine the STEM pipeline. For the near future, increasing the number of students interested in STEM fields and retaining that interest until they have completed a STEM degree is the key. This exploration has encompassed the examination of an educational pathway that starts in early education, extends into college graduation with a STEM degree, and leads to a career in STEM. However, because of the progressive loss and dropout of capable students from STEM disciplines, many refer to this as a "leaky pipeline" (Dasgupta & Stout, 2014; Resmini, 2016; Van den Hurk, Meelissen, & Van Lagen, 2019).

The Significance of STEM Proficiency

After the Soviet Union launched Sputnik, the world's first space satellite, STEM became a major concern in the United States (Herman, 2019). Thus, during that time, the proposition of STEM education reform arose in response to the mounting risk for national security (Bybee, 2013). The decline in STEM proficiency had been reflected in U.S. students' math and science test scores since the 1980s in comparison to other industrialized countries, and in students' decreased desire for STEM subjects. The National Science Foundation (NSF, 2010) revealed that many academically capable students were not pursuing STEM majors. For example, from 1985-2009, although the number of college students doubled, the number of students graduating with a math or science degree increased by only 3%. According to the Programme for International Student Assessment (PISA), a global benchmark for measuring STEM proficiency in the world, U.S. 8th graders ranked 36th in math and 19th in science, out of 79 in 2018 (OECD, 2019). Many such concerns, and the overall low performance of U.S. students led to the conception and founding of many programs, policies, and grants offered by the National Science Foundation or the America Compete Act of 2007. Identifying and implementing effective educational interventions that enhance K-12 STEM education may be a way to increase the number of students interested in STEM majors and careers. All students should have opportunities to participate in formal and informal STEM learning that prepares them for post-secondary success. One recent survey of college students disclosed that 78% decided to pursue STEM-related majors and careers in high school, whereas only 21% indicated having made that decision earlier (Microsoft Corporation, 2011).

Underrepresentation of Minorities in STEM Fields

Women and minorities (such as African American, Hispanic American, Hawaiian and Pacific Islanders, low income, etc.) have been clearly underrepresented in STEM fields and careers (Conklin, 2015; Morrison, Roth-McDuffie & French, 2015). This setback has endured and created more difficulties given the current national needs. Research confirms there was a time when STEM careers were considered “nontraditional” for women and minorities, creating many barriers and a lack of support for these individuals in their pursuit of STEM careers (Betz & Hackett, 2006; Stout, Dasgupta, Hunsinger, & McManus, 2011; Walton & Cohen, 2007). Various concerns about the decline of U.S. students' interest in STEM have increased the level of national funding for schools and universities to explore best practices for increasing recruitment and retention of women, minorities, and low-income participants in STEM fields.

The Need for Increasing Interest in STEM

Research on the pipeline to STEM fields and careers indicates that early exposure to inquiry, reasoning, and problem-solving skills in STEM stimulates student learning and interest in pursuing an eventual STEM-related degree (Dejarnette, 2012). In search of an explanation for what ignites and retains students’ interest in STEM, a number of varied programs have been envisioned and developed from K-12 to college and at the graduate level, and several have explored strategies for attracting students to STEM. Some programs (such as Project STEMulate) have been implemented through funding from federal agencies or corporate entities. Goals have been varied, covering a wide range of purposes such as assessing how to retain college students in their STEM field, how to motivate and encourage middle or high school students to enroll in STEM programs, or how to provide K-12 teachers with STEM education and professional development. Meanwhile, other researches (Mathers, Goktogen, Rankin, & Anderson, 2012) emphasized the hands-on experiences that will engage and inspire students toward STEM careers. Although some researchers emphasized an earlier start on the educational pathways toward STEM fields and have identified elementary school students as the best targets mainly because they have more time to build a superior competence in STEM

(Alumbaugh, 2015; Cantu, 2011; Isabelle & Valle, 2016), others have concentrated on middle and high school students (Tai, Liu, Maltese, & Fan, 2006). High school is a critical time for providing positive experiences that engage students in STEM activities since it is the time when they are beginning to consider possible career pathways (Hansen, 2011).

Toward STEM Literacy

STEM literacy is also seen as critical for personal decision making and living a productive and engaged life (NRC, 2011, p. 5). To become a productive and contributing members of today's society, all students must succeed in STEM (Ceballos, 2014; Lacey & Wright, 2009). Thus, to foster STEM interests in high school students, Beier and Rittmayer (2009) offered several recommendations in their review of motivational factors in STEM. The main recommendation was to create an open learning environment where: (1) students are in charge of and creating their own learning; (2) there are opportunities for hands-on learning in STEM for students to build their self-confidence; (3) students' achievement is recognized and valued; (4) influential others including students' parents and role models are involved to boost their perceptions; (5) the materials used are targeted to increase achievement, self-concept, and interest in STEM of both girls and boys; and (6) students are divided into small groups based on their STEM capability. These recommendations match with recommendations suggested for PBL. Some of the paths for motivating and encouraging more minorities and women into STEM include providing curricular and extra-curricular STEM-related opportunities to students in the form of after-school clubs, STEM schools, STEM Days or STEM Summer Camps.

PBL and STEM

Problem-Based Learning (PBL) is an instructional strategy that enhances student learning by integrating well with other disciplinary subjects, teaching students how to dig deeper, think analytically, and probe and solve problems (Hallermann, 2013). PBL encourages collaboration and working in teams. It involves "real-world tasks, builds 21st century 4 C's competencies, and has an open-ended question while emphasizing student independence and inquiry to create a product" (Larmer, 2013, p. 3). PBL, although developed in the medical field, is well suited for STEM learning with its emphasis on self-directed and student-centered learning, making it an appropriate instructional approach for the present project. The key components of PBL according to Barrows (1996) are: (1) learning is student centered; (2) learning occurs in small groups; (3) teachers are facilitators or guides; (4) problems form the original focus and stimulus for learning; (5) problems are a vehicle for development of problem-solving skills; and (6) new information is acquired through self-directed learning.

PBL engages students in research and inquiry, communication, collaboration, creativity, critical thinking, and team-work (Ertmer & Simons, 2006; Hmelo-Silver, 2004). It is a student-centered approach that supports the instructional demands for STEM education.

It is depicted as an instructional strategy consistent with the principles of constructivism, driven by stimulating, open-ended questions and collaborative learning (Nariman & Chrispeels, 2016). Learning in a PBL environment happens in small student groups where meaning is negotiated in a collaborative team setting (Barrows, 1996). In such an environment, the problem acts as an impetus for learning, and knowledge acquisition happens through self- and team-directed quests and questioning. The teacher's role is that of a facilitator, enabler, or activator, scaffolding learning instead of directing it (Fullan, 2013; Hattie, 2009). Active learners are engaged in authentic tasks and real-world problem-solving activities (Savery & Duffy, 1995). Students in a PBL environment retain information better and longer mainly because they are actively engaged in their learning.

PBL Effectiveness

PBL effects have been reviewed extensively. For example, PBL positively impacts self-efficacy and the confidence a person feels in STEM fields (Baran & Maskan, 2010); it activates students' intrinsic motivation, self-efficacy, and conceptual knowledge (Massa, Dischino, Donnelly, & Hanes, 2009); it enhances at-risk female middle school students' self-efficacy (Cerezo, 2015); it increases students' engagement and satisfaction in STEM subjects and makes students more interested in pursuing STEM careers (Baran & Maskan, 2010; Berk et al., 2014; Mergendoller, Maxwell, & Bellisimo, 2006); it encourages students to continue their coursework instead of dropping it (Dominguez & Jamie, 2010); and it enhances learning for socioeconomically disadvantaged and ethnically diverse students (Cuevas, Lee, Hart, & Deaktor, 2005; Lynch, Kuipers, Pyke, & Szesze, 2005). The latter is particularly relevant to the goals of Project STEMulate.

Meta-analyses findings indicate that PBL excels over traditional learning methods in teaching critical thinking, communication, collaboration, and applying knowledge to real-world situations (Darling-Hammond et al., 2009; Strobel & van Barneveld, 2009; Walker & Leary, 2009). Although PBL can be used with students of any age and skill level (Lockhart & Le Doux, 2005), results of several high school PBL studies indicate that PBL is equally or more effective than traditional instructional approaches (Mergendoller, Maxwell, & Bellisimo, 2006; Savery, 2006), especially for low-income students (Cuevas, Lee, Hart, & Deaktor, 2005; Gallagher & Gallagher, 2013). STEM-focused PBL summer programs also have been shown to increase STEM career aspirations (Zhe et al., 2010; Lam et al., 2005). The University of Akron Upward Bound Math-science (UBMS) program (a 6-week residential program with classes in math, science, and composition, similar to the UHMC UBMS program), changed from a lecture-based to inquiry-based approach (Lam et al., 2005). Over the following 5-year period, results showed significant increases in GPA, decreased anxiety towards math and science, and increased STEM self-efficacy. A majority of participants entered a STEM degree program following high school graduation.

STEM for Hawaiian Students

The National Science Foundation (2017) revealed that although the number of students in community college is on the rise in Hawai`i, students registered in STEM fields are still very low. Levine (2015) offers 10 hypotheses exploring causes for the lack of Pacific Islanders in STEM careers. However, he emphasizes that the problems begin long before students reach the college admittance level because roughly 40% of school children do not complete primary school, and only 20% graduate from high-school. Further complicating matters, students with Hawaiian ancestry have more economic barriers to education as presented in Hawai`i Papa O Ke Ao, a 2012 report to the University of Hawai`i Board of Regents (2012) and by Tran et al. (2010).

With the goal of raising Hawaiian students' interest in STEM, project STEMulate sets to create, implement, and evaluate an innovative and industry-aligned STEM curriculum explicitly designed for Native Hawaiian and other underrepresented, low-income, potential first- generation-to-college high school students. Prior researchers have pointed to the positive effects PBL summer camps have on raising students' interest in science and mathematics, and the likelihood they will pursue STEM-related college majors and careers (Han, Capraro, & Capraro, 2015; Han, Rosli, Capraro, & Capraro, 2014; Lou, Liu, Shih, & Tseng, 2011; Lou, Shih, Diez, & Tseng, 2011; Robinson, Dailey, Hughes, & Cotabish, 2014). Project STEMulate was adapted, implemented, and tested a PBL setting based on the successful Pacific Institute for the Mathematical Sciences Industrial Problem-Solving (PIMS) Workshop's postsecondary model.

This model provides for the basis of the 'next-practice' of PBL by creating an opportunity for students to learn about scientific methods and how to research and find solutions to genuine real-world problems that are relevant in their local community, and by fashioning a value for the PBL rating for each student that later will be correlated with the students' science ability and motivation, etc. through a regression analysis.

THEORETICAL FRAMEWORK

This research draws upon constructivism, a learning theory rooted in the work of John Dewey (1933/1998), Jean Piaget (1972), and Lev Vygotsky (1978, 1986). Constructivism advocates for learning to be an active process of knowledge construction, and not a passive memorization process. PBL is an instructional strategy that stimulates students by activating their prior knowledge. Students are then provided with opportunities to build new knowledge and to elaborate on their own knowledge (Schmidt, 1983). In PBL, a real-world, relevant problem starts the learning. Teamwork drives problem-solving, and in small groups, students brainstorm various solutions and decide which one will best help them solve the problem. Later, students engage in critical thinking and problem-solving to explain the phenomena at the root of the given problem (Schmidt & Moust, 1998). It is through group discussion and exploration of the problem that a link is created between previous and new knowledge. Therefore, the quality and relevance of problems presented to students and their lives is the key. The success of PBL relies on providing a problem that scientists and engineers might face in the real world (Lockhart & Le Doux, 2005). Larmer (2013) argues that the most powerful, engaging, and effective problems for students are those with the most real-world impacts. King, Newmann, and Carmichael (2009) also agree that PBL must have a real-world context and impact outside the classroom.

Another theory guiding this research is social cognitive career theory (SCCT) as articulated by Lent, Brown, & Hackett (1994), and driven from Bandura (1986). SCCT suggests that self-efficacy and interest play unique roles in career choice (Armstrong & Vogel, 2009; Betz & Borgen, 2010; Byars-Winston, Estrada, Howard, Davis, & Zalapa, 2010; Donnay & Borgen, 1999; Lent et al, 2010; Silvia, 2003; Tracey, 2010; Tracey & Hopkins, 2001). Individuals, according to SCCT, develop interest in activities in which they believe they can perform well. Furthermore, previous research has shown that self-efficacy is positively related to student academic performance, and self-efficacy in science impacts student selection of science-related activities that will both help them succeed in and maintain interest in science (Britner & Pajares 2006; Parker et al. 2014; Richardson et al. 2012). As a result, the personal, academic, and career goals which individuals set for themselves are consistent with their interest, their self-efficacy, and the outcomes they expect to achieve (Sheu et al., 2010). In other words, individuals develop interests primarily on the basis of their beliefs about their self-efficacy and their outcome expectations. If they believe that they can do something well, it encourages them to further partake in that activity. Thus, SCCT hypothesizes that career interests and personal goals involve a process that includes performance, self-efficacy, and outcome expectations.

METHOD

This study draws on a subset of data collected as part of a larger three-year project (NSF ITEST # 1657625). The impact of the project on students' career interests, attitudes, and motivation was assessed via a multi-method evaluation of various sources of data including: (1) the Career Interest Questionnaire (CIQ) (Tyler-Wood, Knezek, & Christensen, 2010); (2) surveys of all participants regarding science self-efficacy, and science motivation; and (3) a survey of students' reactions to and reflection about the PBL environment.

Context of the study

This study focused on high school students who participated in the five-week Upward Bound (UB) summer academy on three islands: Maui, Oahu, and the Big Island (Hilo) with 52% identifying as Native Hawaiian or Pacific Islander. UB program directors on each site identified students to participate in Project STEMulate with the goal of establishing a comparison group comprised of students who had a similar summer experience with traditional courses in math, science, and technical writing.

The aim of project STEMulate, following the PIMS model, is to create an alignment and mutually valuable link with the STEM-industry in Hawai`i. Each year, local STEM industry partners are invited to present one of their current real-world problems for students' teams to explore and resolve, and to present the results of their research back to the STEM industry partner at the end of the program. The problem presented to students in this study came from Hawai`i's EPSCoR (the Established Program to Stimulate Competitive Research) namely, its 'Ike Wai Project (from the Hawaiian words for knowledge and water)[1]. With the reduced rainfall in Hawai`i (18% over a 30-year period from 1978 to 2007); increased drought (75% of Hawai`i's land area was "Abnormally Dry" in 2013); the change in land use (for example half of Hawai`i's original watershed forests being destroyed), and increased global warming, Hawai`i is recognized to have entered a period of increased insecurity regarding its long-term water security (Hawai`i Community Foundation, 2019). Considering the issue of diminishing fresh water supply facing every island in Hawai`i, the 'Ike Wai mission is to ensure Hawai`i's future water security. Students were presented with recent concerns on the limits of Hawai`i long-term fresh water supply, and the need for understanding Hawaiian water sources. Students were encouraged to explore the topic, through research, offer solutions and present their solution to the STEM industry partners, UB administrator and instructors, and the project STEMulate team.

Procedure

For this mixed method study, multiple data sources were used to enhance data credibility (Creswell, Hanson, Plano Clark, & Morales, 2007; Yin, 2009, 2012). Survey data was collected, converted into Microsoft Excel files, then coded for input into SPSS 26.0 for further analysis such as correlation, confirmatory factor analysis, linear regression, multivariate regression, etc. To ensure confidentiality, each student was assigned a numerical ID.

Participants

In total, 116 students participated in the study. Fifty-eight students participated in Project STEMulate (the STEMulate group), and 58 students served as the comparison group. All students consented to participation in this study. Of STEMulate group, 65% were females and 20 35% males.

Interestingly, the majority of the student population (55%) considered themselves a mix of two or more races. Of those who only selected one race to identify themselves, 29% selected Asian and 9% considered themselves Native Hawaiian/Hawaiian/Pacific Islander, with a small percentage selecting African American (1%), Caucasian (2%), or Hispanic (4%).

		Ethnicity
	Asian	29%
	Native Hawaiian/Pacific Islander	9%
	Hispanic	4%
	Caucasian	2%
	Black/African	1%
	2 or more races	55%
Total		100%

Table 1. Participants' Ethnicity.

The participants ranged in age from 13-19 where 26% of them were 15 years old. The UB program is offered to students from rising 9th to rising 12th grade. Thirty-seven percent of the participants were in rising 9th and 12th grade.

Research Questions

The project's goals were to: (1) determine if an industry-aligned, technology-rich STEM PBL curriculum model that is adapted for diverse and underrepresented populations can effectively stimulate STEM interest and learning for today's high school students, and lead to productive participation in the STEM-related workforce of the future; (2) advance knowledge into the experiences that engage and prepare students for the 21st century; and (3) develop a STEM workforce pipeline. Specific research questions were as follows:

RQ1. Could an industry-aligned, technology-rich STEM PBL curriculum model raise STEM interest in high school students?

RQ2: Is there any correlation between students' perception of PBL and their Science Self-Efficacy (SSE), and Science Motivation (SM) ratings?

RQ3: Is there any correlation between Career Interest (SCI) and their Science Self-Efficacy and motivation?

RQ4: Is there a relationship between students' PBL rating and their desire for STEM careers (SD)?

Measures and Instruments

Five different measures were used in this study. This included surveys on science self-efficacy, science motivation, STEM career interest, STEM career desire, and perceptions of PBL. The selection of these measures was based on earlier reviews of the effects and impacts of these measures. All the measures used are listed in Table 2.

	T1	T2
Science Self-Efficacy (SSE)	Yes	Yes
Science Motivation (SM)	Yes	Yes
STEM Career Interest (SCI) Perceptions of PBL (PPBL)	Yes	Yes
STEM Desire (SD)	Yes	Yes

Table 2. Common and Unique Scales Used at Time 1 (T1) and Time 2 (T2).

Science Self-Efficacy (SSE). The overall scales average is derived from a 7-item scale defining students' self-confidence in their science abilities and skills. Science efficacy items were partially adapted from the STEM Career Interest Survey, Science Section (Kier, Blanchard, Osborne, & Albert, 2013). Each item was measured on a 5-point Likert scale anchored by "strongly disagree" and "strongly agree." The science efficacy scale achieved high internal consistency in both pre and post (Pre $\propto$= 0.74; Post $\propto$= 0.81). This scale consisted of items such as "I like my science classes," and "I complete my science homework."

Science Motivation (SM). The overall scales average is derived from a 4-item scale defining students' motivation toward learning science. Science motivation items were adapted from the ROSE Questionnaire (Schreiner & Sjøberg, 2004). Each item was measured on a 5-point Likert scale anchored by "strongly disagree" and "strongly agree" and achieved high internal consistency in both pre and post (Pre $\propto$= 0.81; Post $\propto$= 0.83). This scale consisted of items such as "learning science in a real-life context is stimulating," and "learning science has made me more critical."

STEM Career Interest (SCI). The overall scales average is derived from a 12-item scale defining students' career interest. For this scale, the Career Interest Questionnaire (CIQ) (Tyler-Wood, Knezek, & Christensen, 2010) was adopted. Each item was measured on a 5-point Likert scale anchored by "strongly disagree" and "strongly agree" and achieved high internal consistency in both pre and post (Pre $\propto$= 0.91; Post $\propto$= 0.94). This scale consisted of items such as "I would enjoy a career in science," and "I will make it into a good college and major in an area needed for a career in science."

Desire for STEM Career (SD). An SD score was created to capture students' desire and willingness on attaining STEM careers. Students were presented with 11 items related to STEM careers. Each item was measured on a 5-point Likert scale anchored by "strongly disagree" and "strongly agree" and achieved high internal consistency in both pre and post (Pre ∝= 0.84; Post ∝= 0.90). This scale consisted of items such as "school science has improved my decision-making," and "I would like to get a job in technology."

Perceptions of PBL (PPBL). This scale was adapted from the LaForce, Noble, and Blackwell (2017) scale. This was a 9-item scale that was only asked of the STEMulate group at the end of the summer program. Each item was measured on a 5-point Likert scale anchored by "never" and "always." It achieved a high internal consistency (∝= 0.996), and consisted of the items such as "the STEMulate course made us do research to look for background information," and "it was relevant to our daily lives."

Data Analysis

Rios-Aguilar (2014) framework for the critical quantitative scholarship provided the expanded structure for this study. The proposed framework is based on the premise principles that interact between research questions, theory, method/research practices, and policy/advocacy. In other words, Rios-Aguilar (2014) emphasized to go beyond developing research questions and pay closer attention to factors influencing research practices such as considering intentions about the uses of the study to advocate for equal opportunities for all students. For this study, selecting the multi-method evaluation to calculate and report the effect of this program on students, particularly underserved and underrepresented Hawaiian students provided outline for the implementation, data collection and analysis that could be used in the similar program implementation.

FINDINGS

In this section, the primary measures are taken to calculate, compare, and contrast students’ STEM dispositions, science abilities and motivations. Descriptive statistics and general group mean trends were graphically represented when possible. In addition, linear regression and a few series of multivariate regression analysis were conducted to examine the association between student’s perception of PBL, their STEM career aspiration, and their science ability and motivation. The results revealed that student ratings of PBL were associated with interest in pursuing a career in STEM. Results also highlighted the significant potential of PBL for increasing students’ STEM attitudes and interest in future STEM careers. To determine the regression analysis, the first task was to calculate various scales used in this study and show their distributions.

Student Desire for STEM Career (SD)

Students' desire for STEM was measured after the intervention. On a scale of (1) Strongly disagree to (5) Strongly agree, those with low aspiration scale totals (0 through 3) were assigned an SD score of 0, and those with high aspiration scale totals (4 and 5) were assigned a SD score of 1. Figure 1, showing SD distribution, indicates that over 91% of the STEMulate group had a high aspiration for STEM careers compared to 78% of the comparison group (see Figure 1).

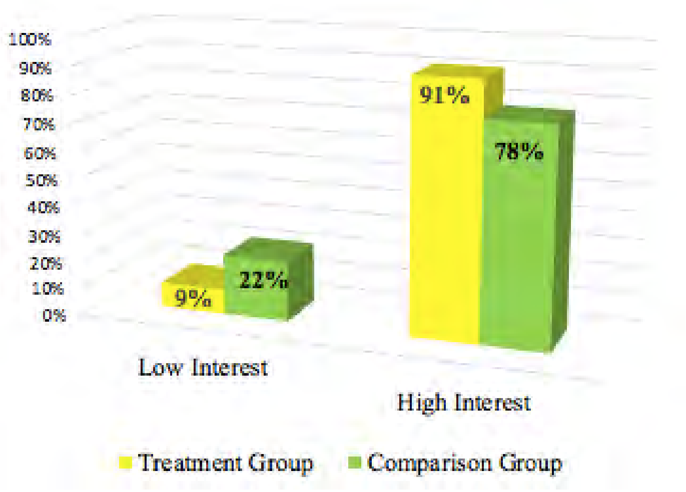

Figure 1. SD Distribution.

Student Science Self-Efficacy (SSE)

Students SSE was measured at the beginning and the end of the summer academy. On a scale of (1) Strongly disagree to (5) Strongly agree, those with low SSE scale totals (0 through 3) were assigned an SSE score of 1, and those with high SSE scale totals (4 and 5) were assigned an SD score of 5. Fig. 2 shows that the SSE scale ranged from Low to High. A confirmatory factor analysis of the measures in the SSE scale indicated that it was bidimensional and reliable, and the factor analysis was statistically significant (KMO = .780, $p < .001$). These results suggest that after the STEMulate, 38% of the STEMulate group had a relatively high SSE compared to only 21% of the comparison group.

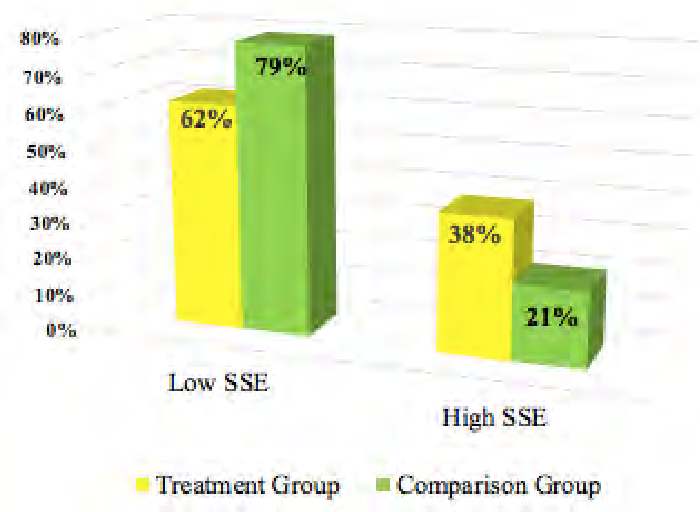

Figure 2. SSE Scale Distribution.

Student Science Motivation (SM)

Students SM was measured at the beginning and end of the summer academy. On a scale of (1) Strongly disagree to (5) Strongly agree, those with low SSE scale totals (0 through 3) were assigned an SSE score of 1, and those with high SSE scale totals (4 and 5) were assigned a SD score of 5. The distribution of the range of SM scale (Low to High) is shown in Fig. 3. A confirmatory factor analysis of the measures in the SM scale indicated that it was statistically significant (KMO = .808, p < .001). These results suggest that after the STEMulate, 45% of the STEMulate group had a relatively high SM compared to only 23% of the comparison group.

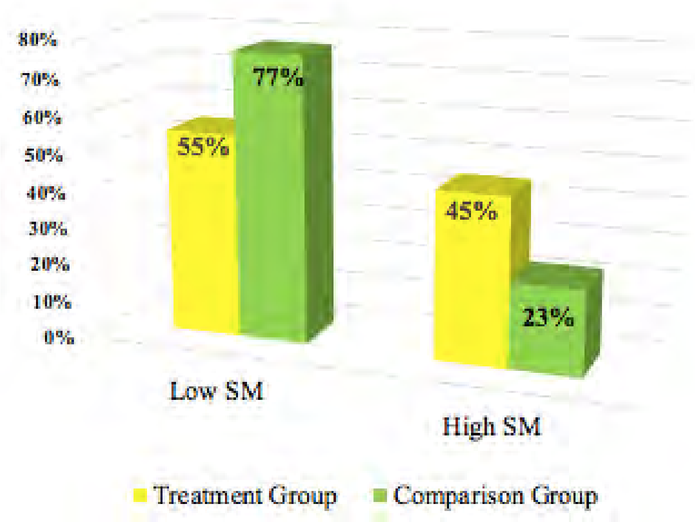

Figure 3. SM Scale Distribution.

The Perception of PBL (PPBL)

The 8 items of the perceptions of PBL were subjected to principal components analysis (PCA) using SPSS Version 26. Upon the completion of exploratory factor analyses (principal components analysis) with all 9 items loading at 0.4 or above, the results revealed this factor to account for 98% of the variance. The parallel analysis (O'Connor, 2000) also supported a one-factor solution. Thus, a one-factor scale ($\propto$= 0.996) average for the PBL rating was used in all analyses.

STEM Career Interest (SCI)

STEM Career Interest (SCI) has three subscales that measure student perception of a supportive environment for pursuing a career in science (Interest), their desire in pursuing educational opportunities that would lead to a career in science (Intent), and their perceived importance of a science career overall (Importance). A number of parallel analyses were conducted to determine the extent to which the SCI documents the effects of Project STEMulate on students' career attitudes. First, the internal consistency of the

SCI for the pre- and post-survey was calculated (see Table 3). The Cronbach's alpha for the pre- and post-surveys was reported for both STEMulate and comparison groups. The range of the Cronbach's alpha for this study was very high, .91 to .94 for both pre- and the post-survey data, compared to the Cronbach's alpha levels reported in the literature that ranged from .70 to .93. Nevertheless, although the internal consistency of the SCI subscales was higher than what was reported in the literature for the support and education subscale, it was very low for the career (Importance) at both pre and post.

		STEMulate Group	Comparison Group
Support (Interest) 3 Items	Pre	.88	.83
	Post	.89	.89
Education (Intent) 5 Items	Pre	.91	.93
	Post	.94	.94
Career (Importance) 4 Items	Pre	.53	.55
	Post	.92	.70
Total (12 Items)	Pre	.92	.91
	Post	.94	.94

Table 3. Internal Consistency Reliabilities for STEM Career Interest Subscales at both Pre and Post Time.

The mean of the subscales (see Table 4) ranged from 2.94 to 4.18 across the subscales. Importance ratings were the highest of the three subscales for each group. Although the comparison group showed a higher mean at all the subscales for the pre-data, their average dropped on the post-data. For both groups, higher Intent is provided compared to Interest ratings. Although the comparison group provided slightly higher ratings than the STEMulate group in all the subscales of the pre-survey, the STEMulate group had a higher rating in all the post subscales.

		STEMulate Group		Comparison Group	
		M	SD	M	SD
Support (Interest)	Pre	3.09	1.14	3.19	1.06
	Post	3.13	1.19	2.94	1.13
Education (Intent)	Pre	3.14	1.10	3.29	1.14
	Post	3.25	1.19	3.05	1.15
Career (Importance)	Pre	4.05	0.63	4.11	0.65
	Post	4.18	0.66	3.96	0.80

Table 4. Means and Standard Deviations for Pre-Post SCI subscale scores by Groups.

Second, was a traditional pre-post analysis to document whether students' career attitudes improved as a result of Project STEMulate. Repeated-measures ANOVAs were conducted to determine the impact of the program on STEM career attitudes. The within-subjects factor was average SCI score at two levels (pre and post). The repeated-measures ANOVA for the STEMulate group was not significant (Wilks K = .970, $F(1, 42) = 1.288$, p = .26, partial η^2 = .03). The repeated- measures ANOVA was also not significant for the comparison group (Wilks K = .977, F (1, 36) = .855, p = .361, partial η^2 = .023). SCI was a useful tool to provide empirical evidence in documenting the impact of the technology-enhanced program of Project STEMulate program, particularly with regard to intent to pursue a STEM career.

RESULTS

The first research question (RQ1) explored the correlation between the perception of PBL, Science Self-Efficacy (SSE), and Science Motivation (SM). As Table 5 displays, there is a high positive statistical correlation between SSE and SM, *r* (116) = .77, p <.001. There is a positive and significant correlation between SD and SSE, *r* (162) = .69, p <.001. Findings showed a positive and significant correlation between SD and SM, *r* (112) = .73, p <.001, and another positive and significant correlation between SD and SCI, *r* (112) = .71, p <.001. Furthermore, PPBL shows minor significant correlation with SSE and SCI.

	SM	SSE	SCI	PPBL	SD
SM	1				
SSE	.77**	1			
SCI	.79**	.79**	1		
PPBL	-.20*	-.16	-.19*	1	
SD	.73**	.69**	.71**	-.20*	1

*p < .05. **p < .01 (2-tailed)

Table 5. Students Science Self-Efficacy, Science Motivation, STEM Career Interest, Perceptions of PBL, and STEM Career Desire: Correlations and Descriptive Statistics (N = 116).

The results of the above analysis support RQ2, indicating that an industry-aligned, technology-rich STEM PBL model raised students' career interests. To determine whether SSE and SM were correlated with career interest (SCI) (RQ3) a simple linear regression was calculated.

Science Self-Efficacy. A simple linear regression was calculated to predict SCI based on SSE. The results, F (1, 114) = 187.04, p <.001, were found to be significant with an adjusted R^2 = .618.

Science Motivation. A simple linear regression between students' SM and SCI. The results, F (1, 114) = 191.36, p <.001, were significant with an adjusted $R^2 = .623$.

These results from initial regression analyses supported RQ3, indicating that students' SSE and SM significantly predicted their interest in pursuing a STEM career (p < .001). The overall saturated model explained 62% of the variance in students' SCI. In other words, industry-aligned, technology-rich STEM PBL curriculum model raised STEM interest in high school students.

Research question (RQ4) explored the relationship between students' perception of PBL rating and their desire for STEM careers (SD).

STEM Career Interest. A simple linear regression was calculated to predict students' career interest based on their perceptions of PBL rating. A significant regression equation was found, F (1, 55) = 6.229, p = .016, with an adjusted $R^2 = .085$.

STEM Desire. A univariate analysis of variance was conducted on students' SD. The STEMulate group scored significantly higher than the comparison group (STEMulate M = 3.72, SD =.76, Comparison M = 3.47, SD = .66), F (1, 147) = 6.87, p = .010, $\eta^2 = .0384$. The effect size was small. These findings suggest that STEMulate participants had significantly greater STEM aspiration than the comparison group.

The results from the analysis of variance (ANOVA) on students' SD suggested that STEMulate groups had a significantly greater STEM aspiration and the simple linear regression analyses supported RQ4, indicating that the STEMulate group students' perception of PBL rating significantly predicted their interest in pursuing a STEM career (p = .04). However, this affect was small as the overall saturated model explained only 8.5% of the variance in students' SCI.

Science Self-Efficacy, Career Interest, and STEM Desire

The initial regression analyses results indicated that students' ratings of PBL significantly predicted their aspiration in pursuing a STEM career (p < .001), and the association stayed significant even after controlling for science ability beliefs and intrinsic motivation (p = .007). With a multiple regression analysis, the overall regression model was significant, F (3, 53) = 65.13, p <.001, $R^2 = .58$. The overall saturated model explained 58% of the variance in students' STEM aspiration.

The Coefficient table shows the amount of unique variance that each variable brings. For example, from the table we can say that the amount of variance that SSE score accounts for, predicts, or explains, the SCI is unique to itself and is significant. i.e., SSE explains something that SM and PBL do not.

DISCUSSION

Learning does not simply happen by listening to the lectures in the classroom, rather by experiences students acquire upon active participation (Montessori, 1946). The results of this study align with constructivism. Promoting student's free exploration, constructivism upholds that students construct new understandings and knowledge, integrating with what they have previously learned, and thus for knowledge acquisition to happen through a process of action, reflection, and construction (Brau, 2020). The course environment and the PBL setting stimulated and activated students' prior knowledge and provided them with opportunities to take an active role in knowledge construction by exploring a real-world problem that was relevant to their lives. Many different criteria are essential for a good PBL problem. Although constructivism is not free of limitation, according to Jonassen (1993) it helps students to gain the highest complexity of knowledge possible.

A special feature of this study was for students to explore an authentic problem suggested by the STEM industry partner. Research shows that at high school, STEM industry involvement has enhanced student's engagement and interest in STEM careers for low-income, first-generation students. The alignment with the STEM industry in Hawai`i further provided opportunities for contextualizing knowledge by providing students with a real-world industry problem. Since the freshwater shortage problem given to students had the most real-world impacts, it was very engaging and geared students into action (Larmer, 2013). The problem was presented in a very simple format to match students' prior knowledge level while at the same time motivating them to further explore it. The PBL problem was suitable for analysis and further discussion and showed a clear connection to potential future professions. These criteria matched with four criteria suggested by Majoor et al. (1990) as vital considerations in constructing a problem. Also, it matched other criteria for clarity of its goal, as well as being open, relevant, and concrete (Schmidt, 1983).

Project STEMulate curriculum also aligned with Kim et al. (2006) who reviewed and synthesized the literature across various disciplines that pinpointed five main attributes of an effective PBL problem: the case should be realistic, instructional, engaging, relevant, and challenging. Additionally, Azer's (2007) criteria for generating trigger images for PBL were evident in the problem presented to students, because the problem was highly authentic, innovative, creative, engaging and was specifically chosen to guide students to STEM careers. These results offer solutions to challenges that the educational system is encountering, particularly in the United States. To deliver for a future STEM workforce, all students must be provided with opportunities that prepare them for the careers of the future.

The present study and its curricula demonstrate that the design for the near-future PBL settings needs to be completely student-centered with problems that are relevant to students' local living environment, realistic to their learning and the impact it can have on their living, while being challenging enough to provoke students to think differently when problem-solving so they can find out-of-the-box solutions. For example, with the value of fresh water for the islands of Hawai`i, it seemed imperative to bring students' focus to a relevant local problem.

> Fresh water is the lifeblood of society. As an island people, we inherently understand that the quantity and quality of available fresh water in our Islands directly impacts our health, our economy, our fisheries, our capacity for food production, the health of our native ecology, Native Hawaiian cultural practices, and other elements of our quality of life. However, recent findings have raised concern among scientists, farmers, and others about the long-term fresh water security of our Islands (Hawai`i Community Foundation, 2019).

It is also important that, at the same time, students are exposed to and learn from the local industry and companies that can inspire them to envision a similar future career for themselves. For a balanced planning of future PBL settings, a comprehensive understanding of the learners' motivation is needed to promote engagement in their learning, to foster the motivation to learn more deeply, and to support the workforce pipeline by informing instructors on guidelines for providing a motivationally supportive learning climate.

The Upward Bound program provided an ideal environment to research the effectiveness of industry-aligned PBL curriculum for low-income first-generation and geographically-isolated students. This program taught students how to be self-directed in their own learning while having access to three teachers who were ready to provide support and guidance. Also, by bringing students to the university campuses, this program exposed students to college student life. These findings align with those of Hutchins and Akos (2013) which indicated that geographically-isolated students face limited exposure to STEM careers. Involvement with STEM industries increased awareness and realistic expectations of local STEM opportunities (Hutson, Cooper, & Talbert, 2011).

Middle and high school students' career knowledge, interest, and intentions vary widely, with many factors influencing them. Some research shows that students start to make decisions about their future careers as early as middle school (Tai et al., 2006). In this study, factors under review were STEM career aspiration, science self-efficacy, and science motivation in a PBL environment. Present findings align with Compeau (2016), Nugent et al. (2015), and Zhang and Barnett (2015) which indicate that science self-efficacy and PBL are significant factors for high school students' aspiration of STEM careers. Research shows that the constructs of science ability beliefs and motivation are highly related to each other, as students who consider their learning outcome to be within their control tend to be more motivated (Bandura, 1997). This study's findings raised the understanding of the development of positive student attitudes toward future STEM careers. Prior research has demonstrated the significant role that motivation and ability beliefs play in student success (Tai et al., 2006; Wang, 2013). The impact has been depicted in many instructional approaches incorporated in educational systems (e.g., problem-based learning, social modeling, cooperative learning, social persuasion, motivational feedback, inquiry-based instruction, differentiation, etc.) and is strengthened by the results from our study.

The unique effect of PBL on STEM aspiration was statistically significant. In this study, PBL's direct effect on STEM career aspiration was observed even after controlling for STEM attitudes. As the findings suggest, higher PBL ratings predict higher aspiration for STEM. This is in alignment with findings from LaForce et al. (2017) regarding the importance of the quality and implementation of PBL.

To support development of a future STEM workforce, all students need to be provided with opportunities that prepare them for the careers of the future. The present study and its curricula demonstrated that the design for the near-future PBL settings highly benefits from being completely student-centered with problems that are relevant to students' local living environment (as supported by the constructivist practices) and realistic to their learning as seen in the results of the pre-post survey collected. Moreover, it can have an impact on their lifestyle and wellbeing through self-efficacy as it has increased and improved their science self-efficacy, and is challenging enough to provoke students to think differently when problem-solving so they can find out-of-the-box solutions.

This research was based on student self-reported data, but further research should collect data from other perspectives such as team members, facilitators, teachers, and mentors to triangulate all input for a more comprehensive understanding. Despite limitations of this study, the results exhibit a connection between student perceptions of PBL and their aspiration for future STEM careers. This result can go beyond the high school and secondary level as the preparation to increase and enhance the future STEM workforce is the main objective. Summer STEM activities are but one channel through which a future STEM workforce can be increased and enhanced. Given the benefits of creating a PBL environment where students can participate in hands-on learning and considering the number of students attending the summer STEM activities and camps, it is important to carefully plan summer activities that support students' self-directed learning and ultimately expand their interest in STEM careers. The findings on the qualities of PBL which support Hawaiian students' interest may be applied in any classroom whether it is during the regular school time or the summer programs.

Educational Importance of this Study

The significance of this study is how engagement in the PBL industry-aligned Project STEMulate helped underrepresented Native Hawaiian and/or socio-economically disadvantaged first-generation college-bound students to develop skills needed for success at the university and higher education. According to social cognitive career theory, self-efficacy and interest play unique roles in career choice. Students' science self-efficacy is positively related to their career interest. Students with higher self-efficacy showed a higher interest in STEM careers. The focus on a local-community problem presented by the STEM industry partner was the key. Hawaiian students pondered the problem of the limited supply of fresh water, an issue hitting home with many students, and they came up with real solutions that could actually help solve the problem. Those with a higher self-efficacy developed the belief that they could do something meaningful with a learned skill and this made their participation in the activity more profound. In other words, the SCCT hypothesis was confirmed. Students with higher self-efficacy performed better and saw STEM as a career option for them, where they would be able to succeed in setting goals and reaching for outcomes.

Practical significance of Project STEMulate surfaced in Year 1 when the UB directors utilized findings to introduce changes in their program. One major modification was to make Project STEMulate available to all UB students and not just for UB math and science students. The introduction and implementation of PBL, for example, has prompted UB directors to look beyond the scope of the 5-week summer camp. Therefore, now that Year 3 is also completed, the UB directors are considering ways to provide the PBL professional development to their future instructors and to keep that as part of their programs. In other words, Project STEMulate has provoked future exploration of innovative change in the UB program. This paper contributes to research on improving instructional practices and integration from a model of PBL like Project STEMulate as a way to facilitate deeper learning for students. It contributes to understanding classroom and instructional changes needed if students are to construct new knowledge.

Concluding Remarks

Prior research has clearly demonstrated the important role that motivation and ability beliefs play in student success. As supported by the literature, a PBL environment engages students in a process that supports their learning through enhanced critical thinking and the use of multiple modes of instruction (Loyens & Rikers, 2011). Project STEMulate set out to identify a coherent set of experiences that effectively and efficiently support student competency, motivation, and persistence to enter the STEM-related workforce. Findings suggest that industry-aligned technology-rich STEM PBL curricula can successfully build interest, motivation, and capacity for underrepresented high school, low-income, and geographically isolated students. By having students explore solutions to an industry-aligned problem, by going on field-trips that helped them understand the severity of the problem in their local area, and by presenting their solutions to the STEM industry partner, students developed an idea of productive participation in the STEM workforce and learned about the significance of various STEM careers. The outcomes establish a pipeline between underrepresented high school students, postsecondary education, and STEM employers. Also, more specifically, Project STEMulate created a team of university instructors, UB administrators and staff, local STEM industry partners, trained instructors and mentors, and the dynamics of this team contributed to the program effectiveness.

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[1] For more information on this industry STEM partner, please visit http://www.hawaii.edu/epscor/