Received: 22 January 2018 | Revised: 2 April 2018 | Accepted: 9 April 2018

DOI: 10.1002/tea.21465

RESEARCH ARTICLE

WILEY | JRST

The effect of authentic project-based learning on attitudes and career aspirations in STEM

Margaret E. Beier[1] | Michelle H. Kim[1] | Ann Saterbak[2] | Veronica Leautaud[1] | Sandra Bishnoi[1] | Jaqueline M. Gilberto[1]

[1] Department of Psychology, Rice University, Houston, Texas

[2] Department of Biomedical Engineering, Duke University, Durham, North Carolina

Correspondence
Margaret E. Beier, Department of Psychology, MS-25, Rice University, 6100 Main St, Houston, TX.
Email: beier@rice.edu

Funding information
Howard Hughes Medical Institute

Abstract

Can engaging college students in client-centered projects in science, technology, engineering, and mathematics (STEM) coursework increase interest in STEM professions? The current study explored the effectiveness of project-based learning (PjBL) courses on student attitudes, major choice, and career aspirations in STEM. Framed in expectancy-value and social cognitive career choice models, we examined the effect of engaging in at least one authentic, project-based course during the first four semesters of college on student STEM attitudes and career aspirations in a quasi-experimental study with a sample of ($N = 492$) natural science and engineering students. STEM self-efficacy and subjective task value variables (STEM attainment, intrinsic and utility value of STEM courses, and relative cost associated with engaging in STEM courses) were examined as mediators of the relationship between classroom project-based experiences and STEM career aspirations. Gender and underrepresented minority status were also examined. We found that engaging in at least one project-based course during the first four semesters affected student perceptions of STEM skills, perceptions of the utility value of participating in STEM courses, and STEM career aspirations. Furthermore, we found that the effect of project-based courses on STEM career aspirations was mediated by STEM skills and perceptions of course utility. The effect of PjBL was not moderated by race or gender. We highlight areas of future research and the promise of PjBL for engaging students in STEM professions.

KEYWORDS

expectancy value theory, career aspirations, project-based learning, social cognitive career theory, STEM education

1 | INTRODUCTION

The past decade has seen an increased focus on inquiry-based instructional approaches to quell student attrition in science, technology, engineering, and mathematics (STEM) disciplines and to increase participation of underrepresented minority students and women in STEM (National Academy of Sciences [NAS], 2013). Challenges to improve STEM curricula at all levels of education reflect a concern that the United States remain globally competitive in STEM (NAS, 2010, 2011). Retention at the undergraduate level has been addressed in recent years by incorporating active learning strategies like project-based learning (PjBL) into STEM curricula (Freeman et al., 2014; Thomas, 2000). Research supports the effectiveness of active learning for student engagement and performance in STEM fields (Freeman et al., 2014), likely because these approaches provide mastery experiences that increase student familiarity with professional activities and positively affect student attitudes and motivation (Eccles & Wigfield, 2002; Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Lent, Brown, & Hackett, 1994).

PjBL is an active learning approach focused on student participation in a project as the central component of the curriculum (Thomas, 2000). The purpose of this study is to examine the effect of PjBL on postsecondary student attitudes and career interest in STEM. We use expectancy value theory (Eccles & Wigfield, 2002) and social cognitive career theory (SCCT; Lent et al., 1994) to frame the study, which examines STEM attitudes and career aspirations for students who have either taken a PjBL course (or courses) or who have not taken a PjBL course by the end of the fourth semester of postsecondary study.

1.1 | Project-based learning

PjBL is a type of experiential learning that engages students to develop their own understanding of a domain by applying its methods and principles; as such, it is a form of active learning (Thomas, 2000). Active learning strategies are understood to be student-centered, inquiry-based instructional approaches in contrast to more passive approaches such as attending a course lecture. Active learning is effective for improving student learning and performance in STEM: A meta-analysis of 225 studies across STEM disciplines (biology, chemistry, computer science, engineering, geology, math, physics, and psychology) showed a benefit of active learning approaches relative to passive lectures on outcomes such as exam performance. The results of this meta-analysis were compelling – the effect was as large as a half standard-deviation improvement in exam performance across STEM fields, class sizes, and course levels (Freeman et al., 2014).

PjBL is often confused with problem-based learning, which describes curricula designed around specific problems, usually instructor derived, that might or might not be similar to problems a professional might encounter in their jobs (Strobel & van Barneveld, 2009; Walker & Leary, 2009). PjBL is a specific type of problem-based learning that is centered on a specific and authentic, open-ended, client-based project (Thomas, 2000). Both PjBL and problem-based learning curricula can be designed around complex problems that allow students to operate relatively autonomously to construct solutions through investigation (e.g., prototypes or presentations). PjBL is distinct from problem-based learning, however, in that it is learning that is a function of engaging in client-based authentic projects; problems derived by the instructor would not be considered PjBL. PjBL has five defining characteristics, aptly summarized by Thomas (2000) as follows:

1. The project-based component is central to the course curriculum. As stated by Thomas, in PjBL, "projects are the curriculum" (emphasis in original; Thomas, 2000, p. 2). PjBL can be compared

to approaches in which projects provide examples or practice and approaches that offer an extra project to enrich classroom learning. Neither the use of projects as examples nor their use for extra credit qualify as PjBL because these approaches do not reflect the centrality of the project in a PjBL course.

2. PjBL courses provide a means to direct students toward constructing their own understanding of the central principles of a discipline. For instance, students must struggle with the key concepts and the projects must be somewhat ill defined.
3. PjBL activities involve constructive investigation. Students must participate in a goal-directed process of inquiry, knowledge building, and problem resolution. If the project simply requires the application of already learned knowledge, then it is not PjBL.
4. PjBLs are student-driven to a degree; they are not instructor-scripted or pre-packaged activities. They are open-ended in that they do not have a predetermined outcome. As such, students have a high degree of responsibility, autonomy, and unsupervised work time when engaging in the projects.
5. PjBL projects are authentic in terms of the topics, the context in which the work gets done, and the tasks that students carry out. In the current study, we focus exclusively on courses that include authentic projects and we do not consider courses built around instructor-developed projects.

Although there is relatively little research directly assessing the effects of PjBL, the studies that have been conducted suggest that PjBL approaches positively affect student performance and retention across elementary, secondary and postsecondary levels (Boaler, 1998; Holmes & Hwang, 2016; Thomas, 2000; Torres, Saterbak, & Beier, 2016). Torres et al. (2016) found that students who chose an elective PjBL course on engineering design were more likely to persist on to earn a degree in engineering than students who did not elect to take such a course. Research also suggests that—even though it may take time away from course lectures—PjBL does not detract from learning the course content. Boaler (1998) examined the effects of PjBL versus a lecture-based course in a quasi-experimental design. At the end of a term, students were equivalent in their ability to answer multiple-choice content questions on a final exam, but the PjBL learners were more flexible in adapting their knowledge to conceptual questions and new problems than were the lecture learners. In summary, the benefits of PjBL seem to mirror those associated with active learning in terms of increasing retention and performance (Boaler, 1998; Freeman et al., 2014; Torres et al., 2016). Less is known, however, about the effects of PjBL on student attitudes toward STEM.

2 | THE EFFECT OF PJBL ON STUDENT ATTITUDES

Research suggests that PjBL approaches positively affect student interest and self-efficacy (Bilgin, Karakuyu, & Ay, 2015; Brown, Lawless, & Boyer, 2013; Holmes & Hwang, 2016). Lima et al. (2014) conducted interviews with multiple stakeholders—students, educators, and engineering professionals—to assess attitudes about PjBL. Results of this research suggest that PjBL is generally positively received. Students valued the opportunity to practice the engineering profession and exposure to the engineering production process afforded by PjBL. Instructors and engineering professionals noted that PjBL taught students' skills associated with communication and project management that students would not normally acquire in engineering courses. Surveys of attitudes about PjBL tend to echo these findings – that is, students enjoy the experience of participating in authentic projects and find value in the projects associated with PjBL courses (Sababha, Alqudah, Abualbasal, & AlQaralleh, 2016; Tseng, Chang, Lou, & Chen, 2013; Zastavker, Ong, & Page, 2006). However, less research has focused on the effect of PjBL on student career aspirations in STEM.

Authentic client-based PjBL should be especially influential in the development of career interests for postsecondary students given that PjBL experiences straddle educational and professional realms, mirroring what students may encounter as young professionals (Guile & Griffiths, 2001; Lima, Mesquita, & Flores, 2014). Moreover, engaging in client-based PjBL in courses allows students to work on authentic projects in professional settings outside of high-stakes work environments, where mistakes might be detrimental to professional advancement. Although apprenticeships are not the same as PjBL, they involve experience with professionals and careers. Therefore, research on apprenticeships can inform predictions about how PjBL will affect career aspirations. Sadler, Burgin, McKinney, and Ponjuan (2010) reviewed the literature on science apprenticeships for secondary and postsecondary students and in-service teachers. They found that engaging in apprenticeships had significant benefits for student performance and career aspirations and concluded that apprenticeships increase student self-efficacy (a person's belief in their ability to accomplish a task, Bandura, 1982) by providing students with direct experiences engaging as professionals within a domain. This self-efficacy, in turn, affected student career aspirations (Eccles & Wigfield, 2002; Lent et al., 1994). Similarly, we expect PjBL to positively affect student self-efficacy and career aspirations.

The limited research that has been conducted directly examining the effect of PjBL on student self-efficacy and career interest generally supports these expectations. A study of science educators found, for instance, that teachers engaging in PjBL had more self-efficacy for teaching compared to a lecture-based control group (Bilgin et al., 2015). Helle, Tynjälä, Olkinuora, and Lonka (2007) found that student intrinsic motivation (a student's enjoyment of a topic) for course subject matter increased significantly over the course of a semester when students engaged in PjBL, but only for students who were low on self-regulation (e.g., those who had difficulty focusing and monitoring their own performance in class). Another quasi-experimental study demonstrated the complexity of the relationship between PjBL and student attitudes. Atadero, Rambo-Hernandez, and Balgopal (2015) examined student self-efficacy, perceptions of utility value, performance goals, and learning for a PjBL section versus a lecture section of a college-level statistics course. They did not find a significant effect of PjBL on student self-efficacy, but they did find that students who engaged in PjBL showed a stronger relationship between self-efficacy and perceptions of course utility (the more efficacious students perceived the course as more useful relative to less efficacious students).

Although these studies are suggestive of the positive effect of PjBL on self-efficacy and career interest in postsecondary contexts, the results are mixed and more research is needed (Atadero et al., 2015; Bilgin et al., 2015; Helle et al., 2007). The present study examines the effect of PjBL on student attitudes and career aspirations across STEM disciplines by employing a quasi-experimental design with a relatively large sample of students who have either taken at least one PjBL course and students who have not.

3 | THEORETICAL MODELS OF ACHIEVEMENT AND CAREER CHOICE

We used expectancy-value models of achievement (Eccles & Wigfield, 2002) and social-cognitive career theory (SCCT; Lent et al., 1994) to frame our investigation. Both are based on social-cognitive theory (Bandura, 1991) and describe how mastery experiences such as participating in a PjBL positively affect student self-efficacy (Bandura, 1982) and the value that students assign various activities (Eccles & Wigfield, 2002). Expectancy-value models developed out of educational psychology and consider a broad array of outcomes related to achievement-focused behaviors and motivation relevant in education (e.g., choosing to participate in STEM classes, engaging in the material during class). By contrast, SCCT developed out of vocational psychology and focuses on outcomes related to career choice.

Expectancy-value models consider motivation as the direction, intensity, and persistence of behavior (Eccles & Wigfield, 2002). Central to expectancy-value models is the idea that motivation is a function of the value that an individual assigns an outcome such as obtaining a STEM degree or a career in a STEM field, and the expectation that exerting effort in an activity, such as performing well in a particular course, will increase the likelihood of attaining that valued outcome. As such, expectations about the relationship between effort and performance are central to motivation in expectancy-value models. Expectations reflect a person's self-efficacy for performance in a domain (i.e., it reflects a person's belief that he or she can successfully perform a task, Bandura, 1982).

In addition to the value an individual assigns to an outcome and his or her expectations of achieving that outcome, Eccles and her colleagues posit four types of subjective task value that influence motivation for academic activities (Eccles, 2005; Eccles & Wigfield, 2002): (i) attainment value, which is the extent to which an activity aligns with a person's self-concept (i.e., a person's perceptions of his or her general abilities and competencies; Gniewosz, Eccles, & Noack, 2015); (ii) utility value, which is the usefulness of the activity for attaining a specific outcome; (iii) intrinsic value, which is the extent to which participating in an activity is enjoyable to a person; and (iv) relative cost, which reflects the negative aspects of participating in the activity – that is, the opportunity costs in terms of time away from other activities and the negative emotions that might result from task engagement under some circumstances. Furthermore, expectancy-value models describe the experiences outside of school that should influence both expectancy judgments like self-efficacy and the value that students place on achievement-based activities such as socioeconomic background, demographics, and gender. In expectancy-value models, person-factors like gender and status as an under-represented minority (URM) student are thought to influence goals and perceptions that may serve to facilitate or hamper academic achievement.

In the expectancy-value model, educational experiences such as PjBL would influence student self-efficacy and the subjective task value associated with academic achievement (Eccles & Wigfield, 2002) because PjBL provides mastery experiences that are related to the course topic and professional activities. Mastery experiences are one of the central determinants of self-efficacy. Positive experiences within a domain will serve to increase self-efficacy; and failures will serve to decrease it (Bandura, 1982). Furthermore, in expectancy-value models, self-efficacy, and subjective task value are thought to mediate the relationship between PjBL experiences and achievement-orientated outcomes.

The outcome of interest in the current study is related to vocational choice. As such, we integrated expectancy-value theory with social cognitive career theory (SCCT; Lent et al., 1994), which explicitly examines antecedents of career choice. SCCT describes how career interests, defined as patterns of likes and dislikes regarding occupations and career-relevant activities, are influenced by a person's attitudes, self-perceptions, and environmental affordances such as exposure to professions and role models (Lent et al., 1994). The SCCT model includes three levels, which pertain to three interrelated outcomes: interest development, career choice, and performance. The current study is focused on the development of career interest early in one's academic career (i.e., within the first two years of college) and thus we focus on the development of career interest and career choice. Similar to expectancy-value models, SCCT posits that mastery experiences affect student career aspirations through self-efficacy. Lent et al. also suggest that experiences influencing expectancies are perhaps most salient in the formative years such as at the beginning of college, when vocational interests are still somewhat fluid and crystallizing (Holland, 1976; Lent et al., 1994; Lent, Brown, & Hackett, 2000).

Like expectancy-value models, SSCT highlights the role of environmental supports. In particular, SCCT highlights the importance of race and gender and environmental byproducts of these factors such

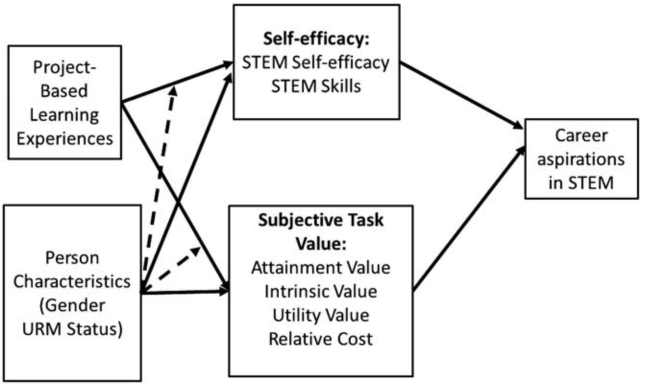

FIGURE 1 A model of career interest incorporating elements of expectancy value theory (Eccles & Wigfield, 2005) and social cognitive career theory (Lent et al., 1994)

as the availability of resources relevant to career choice (Lent et al., 2016, 2000). Personal attributes can affect experiences and self-perceptions in myriad ways. For example, underrepresented minorities and women will have fewer role models that reflect their own race and gender in STEM disciplines (NAS, 2010, 2011). This lack of representation can negatively affect student self-efficacy and engagement in the classroom (Lent et al., 2000). Furthermore, societal expectations and stereotypes about race and gender can undermine student self-perceptions in STEM fields, negatively affecting performance (Eccles, Wong, & Peck, 2006; Lent et al., 2000), and activating stereotype threat (Steele & Aronson, 1995).

The current project integrated constructs relevant in both expectancy-value theory and SCCT to examine the effect of PjBL on career interest in STEM. Although the theoretical models are similar in terms of their basis in social cognitive learning theory (Bandura, 1982), very few researchers have integrated these theoretical models. One exception is Parr and Bonitz (2015), who posited that self-efficacy and subjective task value would mediate the effects of student demographic characteristics on student retention in high school. They found support for the effect of demographic characteristics and SES on student retention, but little support for the role of self-efficacy and subjective task value. They did not, however, examine these variables in the context of an intervention – such as PjBL. Similar to Parr and Bonitz (2015), we use an integrated model of expectancy-value theory and SCCT to examine the effects of PjBL on career aspirations as mediated by self-efficacy and subjective task value. A model reflecting the integration of these theories is shown in Figure 1 (Eccles & Wigfield, 2002; Lent et al., 1994).

In the current study, self-efficacy is operationalized with two variables: (i) STEM self-efficacy, which is the extent to which a person feels he or she can achieve good grades in STEM classes, and (ii) STEM skills efficacy, which is the extent to which a person feels confident in executing specific skills trained within a STEM curriculum. We operationalized subjective task value with four variables modified to be focused on STEM: (i) attainment value, which assesses how important a person's self-perception as a scientist or engineer is to his or her self-concept, (ii) intrinsic value, which is the extent to which a person derives personal pleasure from engaging in STEM courses, (iii) utility value, which is the extent to which a person perceives engaging in STEM to be useful for attaining a future goal, and (iv) relative cost, which is the extent to which a person believes that engaging in STEM detracts from other areas of their life and/or development.

Rather than examine the effects of PjBL in one course or topic as have other researchers (Atadero et al., 2015), the current study examined the effect of PjBL across natural science and engineering curricula on STEM career aspirations at a single university. The sample is composed of second-year college students in STEM fields, which reflects a critical period in developing career interests (Helle, Tynjälä, & Olkinuora, 2006; Lent et al., 1994). The outcome of interest is career aspirations in STEM, but we also assess retention by examining whether students declare a STEM major at the end of their fourth semester. Students enrolled at the university where this research was conducted are required to select a major at the end of their fourth semester. Our hypotheses were:

> H1: STEM students who take at least one PjBL STEM course during their first four semesters in college will have (i) higher STEM self-efficacy and STEM skills efficacy, and (ii) more positive subjective task value ratings (higher attainment, intrinsic, and utility value, and lower perceived cost) related to STEM.

> H2: PjBL will affect STEM career aspirations such that students who have taken at least one PjBL during their first four semesters in college will have higher career aspirations in STEM compared to students who do not take PjBL courses.

> H3: Students who take at least one PjBL during their first four semesters of college will be more likely to select a STEM major at the end of their fourth semester compared to students who do not take at least PjBL course.

> H4: The effect of PjBL on STEM career aspirations will be mediated by STEM self-efficacy and STEM subjective task value.

Expectancy-value theory and SSCT also posit that person-characteristics, such as gender and URM status, will influence self-efficacy and subjective task value, which in turn will influence STEM career aspirations. Indeed, research supports the idea that URM students and women are more likely than non-URM students and men to leave STEM disciplines and that some of the factors contributing to leaving are based on pre-college experiences and preparation (Chang, Sharkness, Hurtado, & Newman, 2014; Parr & Bonitz, 2015). We examined gender and URM status as direct indicators of self-efficacy (STEM self-efficacy and STEM skills efficacy) and the STEM subjective task value variables (attainment value, intrinsic and utility value, and perceived cost; Figure 1). In general, we expected that women and URM students would have lower self-efficacy and lower ratings of subjective task value than other students as has been shown in prior research (Andersen & Ward, 2014; Halpern et al., 2007; Zastavker et al., 2006).

Although we expected PjBL to positively affect self-efficacy and subjective task value for all participants, we were also interested in whether the effect of PjBL would be augmented for women and URM students given that these students would have relatively less exposure to efficacy-enhancing experiences relative to men and non-URM students before entering college. That is, we were interested in knowing whether PjBL experiences would be more salient for these students. Research suggests that PjBL does significantly positively affect women and URM students (Holmes & Hwang, 2016), but has not found that the effect of PjBL varies by gender or URM status. In the current study, we further examine whether URM status or gender moderate the effect of PjBL on self-efficacy and subjective task value (shown as dashed lines in Figure 1). We pose the following hypothesis:

> H5: PjBL will be more effective for affecting attitudes for women and URM students than it is for other students.

4 | METHOD

4.1 | Participants

To ensure that our sample was composed of students who had an interest in STEM upon matriculation, we used archival data to establish the characteristics of matriculants who indicated an interest in completing a degree in STEM. The study was conducted at a small private southern university in the

TABLE 1 Sample characteristics

	No APBL	APBL	Overall
Overall cohort	246	246	492
Gender			
Female	111	111	222 (45.1%)
Male	135	135	270 (54.9%)
URM			
Not URM	197	197	394 (80.1%)
URM	49	49	98 (19.9%)
Entering School			
Engineering	127	127	254 (51.6%)
Natural Science	119	119	238 (48.4%)

United States. The university is highly selective with an acceptance rate between 10% and 15% with just under 4,000 undergraduate students (50% women). Over half of the degrees awarded (51%) during the 2016–2017 school year were in the natural sciences and engineering divisions.

STEM starters were identified as those students who indicated a preference for majoring in a STEM discipline on their college application (i.e., they enrolled in either the School of Natural Science or the School of Engineering) and attempted or earned credit for at least two courses (6 credit hours) in STEM from either (a) their first semester courses and/or (b) incoming AP credit in STEM. Participants were matriculants from Fall, 2014 ($n = 266$) and Fall, 2015 ($n = 226$) who completed the survey at the end of their fourth semester. Spring, 2016 survey data were used for Fall, 2014 matriculants and Spring, 2017 survey data were used for Fall, 2015 matriculants. There were no significant differences on the study variables (e.g., self-perceptions, STEM skills, or career aspirations) by matriculation date.

4.2 | Design

Because students were not randomly assigned to condition, this study engages a quasi-experimental design where enrollment in PjBL (yes or no) is the quasi-experimental variable. At the university where this research was conducted, engaging in a PjBL course during the first four semesters is elective. Because students who elect to take PjBL may differ from students who do not elect to take these courses, we matched the PjBL and non-PjBL samples on gender, ethnicity, entering division (School of Natural Science or School of Engineering), and number of STEM AP credit hours taken during high school. Data from a total of $N = 492$ STEM starter students were included in this study. Half of them ($n = 246$) had taken at least one PjBL course during their first four semesters in college; the other half ($n = 246$) had not taken a PjBL during this same period. Table 1 shows characteristics of the students in PjBL and non-PjBL groups.

4.3 | Procedure

Data were collected via the Survey of All Students (SAS) as part of a larger longitudinal study of student retention. The SAS is an electronic survey administered to all undergraduate students at University X during the final month of each semester. Measures for this study were embedded in a section of the SAS given only to students who indicated a preference for majoring in the Engineering or Natural

Sciences divisions on their college applications. Data were collected in compliance with the university's institutional review board. After the SAS was completed, students who met the criteria for STEM matriculants were included in the study.

4.3.1 | PjBL courses

A description of the PjBL courses included in this study is provided in Table 2. Generally, projects in PjBL courses were completed in student teams that varied in size from 2 to 5 students. The projects varied in format and topic, but each project was in service to an open-ended problem as stated by a client external to the university. Course projects are derived through meetings with potential project partners, who are community partners, research faculty, physicians, and others (business leaders). In these meetings, faculty discuss the purpose of the course and ask about problems, needs, or opportunities in that project partner's workplace. Example questions include "what do you wish you had in your intensive care unit?" or "what would improve your ability to work with this animal?" If the problem is identified and found to be appropriate for the type and level of the course, the instructor will summarize the problem statement in a written document. Students complete the project during the course, which includes interacting with the project partner several times during the semester. At the end of the course, students complete artifacts related to the project (e.g., a physical prototype, computer code, novel

TABLE 2 PjBL class descriptions

Course	Course description	Sample projects
Appropriate design for global health	Students apply the engineering design process to address healthcare disparities in low-resource settings *Target student*: Freshmen and sophomore students interested in global health	• Low-cost thermometer (Client: Queen Elizabeth Central Hospital in Malawi) • Low-cost anemia reader (Client: Queen Elizabeth Central Hospital in Malawi)
Introduction to engineering design	Students learn and apply the engineering design process to solve meaningful problems drawn from the community and around the world *Target student*: Freshman students interested in earning engineering degrees	• Giraffe hay feeder (Client: Houston Zoo) • Modified wheelchair (Client: Patient at Shriners Hospital)
Introduction to scientific research challenges	Students learn the process of scientific research by investigating an open-ended research challenge posed by local laboratories or companies *Target student*: Freshman students interested in earning science degrees	• Vinegar production (Client: Local restaurant) • Understanding the role of jim lovell (*lov*) genes in the respiration of drosophila (Client: Bioscience faculty member)
Experimental biosciences	Students practice scientific research by investigating an open-ended biologically-related research challenge posed by faculty *Target student*: Freshman or sophomore students interested in bioscience degrees	• Conditions for optimal expression and purification for a phusion-like DNA polymerase (Client: Bioscience faculty member)

assay, genetic construct, and so on). For natural sciences, projects included wet lab biological or chemical experiments in which a problem/question is posed to students who are tasked with devising a hypothesis and aims and deriving experiments that can prove/disprove the hypothesis. In engineering, projects are also formed around a stated problem, need, or opportunity and students devise a solution to the problem by going through the engineering design process. In engineering, the project team often develops a physical prototype.

Although students have the opportunity to learn about the format of the course before registering, through course descriptions in the general announcement, course advertisements, from other students, and through course evaluations that are made available to all students at the university where this research was conducted, students may or may not know the format of PjBL courses before registering for them (recall that participation in PjBL courses is elective).

An exemplar PjBL course is Introduction to Engineering Design, an elective one-semester, client-based design course for freshman (Saterbak, Volz, & Wettergreen, 2016). After the first week of class, students are placed on design teams to solve an authentic problem proposed by clients from medicine, industry, humanitarian organizations, and other entities at the university. Each four- to six-student team works on a different client-sponsored project. The first half of the semester is devoted to defining the design problem, developing the design context review, establishing design criteria, brainstorming solutions, using an evaluation matrix to select a solution, and then describing the selected solution. In the second half of the semester, students spend time physically prototyping their design solution using the appropriate tools and materials and testing it against their design criteria.

4.4 | Measures

For all attitude measures, participants were instructed to focus their responses on their particular area of interest in STEM to allow for the possibility that students might be more familiar with and/or have different attitudes in their area of interest (e.g., chemistry), compared to other STEM domains (e.g., mechanical engineering, computer Science, and mathematics).

4.4.1 | STEM self-efficacy

Eight items from the Motivated Strategies for Learning Questionnaire (Pintrich & de Groot, 1990) were adapted to assess student STEM self-efficacy. Items were modified to reflect STEM efficacy rather than general course-related efficacy in that the acronym STEM was added before the word "classes" for each item. Participants rated their agreement with statements on a Likert scale from *1 = strongly disagree* and *5 = strongly agree*. See Pintrich and de Groot (1990) for the actual questionnaire. Sample items are "I generally believe I will receive excellent grades in my STEM classes," and "I'm confident I can understand the most complex material presented by my instructors in my STEM courses."

4.4.2 | STEM skills efficacy

The STEM skills efficacy assessment is a 6-item measure developed for this project to assess confidence in executing specific skills trained in the STEM curriculum. Natural science and engineering faculty provided input into the development of the scale to ensure that items reflected skills taught as part of both curricula. Participants rated the extent to which they would be effective at executing STEM-related tasks on a Likert-type scale from 1= *very ineffective* to 5 = *very effective*. Questions are, "Working with and delivering a project/solution to a client," "Designing and building a physical prototype," "Working as a team member," "Preparing and delivering an oral presentation," "Conducting open-ended research," and "Writing and editing a technical document."

4.4.3 | Attainment value

We used a three-item measure adapted from the Academic Self-Description Questionnaire II (ASDQII; Marsh, 1990). Specifically, items were modified to refer to STEM (we provided the definition of STEM in the instructions). Questions are "It is personally important to me to do well in STEM classes," "I consider myself to be a person who does well in STEM disciplines," and "I'm proud of my ability to do well in STEM courses." Participants were instructed to rate their level of agreement on a Likert scale where *1 = strongly disagree* and *5 = strongly agree*.

4.4.4 | Intrinsic value

Intrinsic value was measured by a four-item measure developed based on Eccles and Wigfield (2002) and used in prior research (Rittmayer & Beier, 2008). Items were, "I enjoy my STEM courses more than other courses I have taken," "I derive more satisfaction from STEM courses than any other courses," "I prefer working on homework related to my STEM courses more than any other homework," and "I seem to be always thinking of topics related to STEM, even when I'm not in class or studying." Participants rated their level of agreement on a Likert scale, where *1 = strongly disagree* and *5 = strongly agree*.

4.4.5 | Utility value

Utility value was assessed with a three-item measure developed from Eccles and Wigfield (2002) and used in prior research (Rittmayer & Beier, 2008). Items are "Getting a degree in a STEM discipline will be important for reaching my long-term career goals," "It is important to me to do well in STEM courses, because I want to go to graduate school in STEM after this," and "I need to do well in my STEM courses to be able to pursue my career goals." Participants rated their level of agreement on a Likert scale where *1 = strongly disagree* and *5 = strongly agree*.

4.4.6 | Relative cost

Relative cost was measured with a three-item measure developed from Eccles and Wigfield (2002) and used in prior research (Rittmayer & Beier, 2008). Items are "Pursuing a degree in a STEM discipline requires a fair amount of sacrifice in terms of my social life," "I spend a lot of time studying for my STEM courses while other students I know study relatively little," and "Doing well in my STEM courses requires me to be focused on STEM at the expense of other subjects that might be interesting to me." Participants rated their level of agreement on a Likert scale, where *1 = strongly disagree* and *5 = strongly agree*.

4.4.7 | STEM career aspirations

We used five items from the Scientific Possible Selves questionnaire to assess career aspirations in STEM (Beier, Miller, & Wang, 2012). Participants indicated their level of agreement on a Likert scale from 1 (Strongly disagree) to 5 (Strongly agree). Questions are "I have always hoped to have a STEM job one day," "Having a STEM job one day is very important to me," "I expect to get a degree needed for a job in science," "It is very likely that I will get a job in science in the future," and "I expect to have a strong professional career in science in the future."

5 | RESULTS

Descriptive statistics, inter-correlations, and internal consistency reliability estimates (coefficient α; Cronbach, 1951) for study variables are shown in Table 3. As expected, the subjective task value variables are significantly positively correlated with each other, with the exception of relative cost. Moreover, perceptions of subjective task value are related to self-efficacy such that students who have higher self-efficacy are likely to have higher attainment value and view STEM activities as intrinsically interesting and useful (correlations range from small, $r = .194$, $p < .001$ for intrinsic value and STEM skills efficacy to large $r = .723$, $p < .001$ for STEM self-efficacy and attainment value). With the exception of STEM self-efficacy, perceptions of the relative cost of engaging in STEM activities was significantly negatively related to the other study variables, and the magnitude of these relationships was relatively small (r's ranging from -0.107, $p = .019$ for STEM skills efficacy to -0.350, $p < .001$ for utility value). The self-efficacy and subjective task value variables were all significantly correlated with STEM career aspirations in the expected directions. That is, STEM self-efficacy, STEM skills efficacy, attainment value, intrinsic value, and utility value were all positively correlated with STEM career aspirations (r's were medium to large in magnitude from $r = .258$, $p < .001$ for STEM skills efficacy to $r = .722$, $p < .001$ for utility value). Relative cost was negatively related to STEM career aspirations ($r = -.272$, $p < .001$).

Correlations between self-efficacy, subjective task value, career aspirations, and URM status (yes = 1/no = 0) and gender (women = 2/men = 1) are shown in the bottom two rows of Table 3; these point-biserial correlations show the relationship between dichotomous variables (URM status and gender) and the continuous variables. The negative correlations between attitudes and gender show that women had significantly lower STEM self-efficacy, attainment, intrinsic, and utility value ratings than did men. Women also rated their STEM career aspirations lower than men did, although each of these effects was small in magnitude (e.g., gender and STEM self-efficacy was $r = -.291$, $p < .001$; gender and STEM career aspirations was $r = -0.129$, $p = .004$). URM students were likely to have significantly lower STEM self-efficacy ($r = -0.104$, $p = .021$) and lower attainment value ($r = -0.140$, $p = .002$) than non-URM students, but these effects were small in magnitude. Moreover, there was no significant difference in STEM skills efficacy, utility value, intrinsic value, or relative cost based on URM status. Furthermore, neither gender nor race was significantly related to STEM skills efficacy.

Table 4 shows the means and standard deviations by learning condition (PjBL or not) for all variables and the statistical significance of the comparison by condition. Although PjBL was associated with attitude trends in the right direction, only STEM skills efficacy and utility value (i.e., the extent to which the student believed the course would be important for long-term career goals) were significantly different based on PjBL status ($t[481] = -4.611$, $p < .001$, $d = 0.42$ for STEM skills efficacy and $t[483] = -3.526$, $p < .001$, $d = 0.32$ for utility value). This result provides mixed support for Hypothesis 1, which stated that PjBL learning experiences would result in higher STEM self-efficacy and STEM skills efficacy (H1a) and more positive subjective task value ratings related to STEM (H1b). In support of Hypothesis 2, career aspirations in STEM were significantly higher for students who took at least one PjBL compared to students who did not ($t[487] = -3.025$, $p = .003$, $d = 0.27$).

In terms of selecting a STEM major (Hypothesis 3), of the 492 students included in the sample, few did not declare a STEM major at the end of their fourth semester ($n = 60$). Although there were more students who left the STEM fields in the non-PjBL group (i.e., 35 without a PjBL course

TABLE 3 Means, standard deviations, reliability estimates and intercorrelations among study variables

Variable	*M (SD)*	1.	2.	3.	4.	5.	6.	7.	8.
1. STEM Self-efficacy	3.525(1.003)	(.96)							
2. STEM Skills efficacy	3.932(0.625)	0.309**	(.75)						
3. Attainment value	4.021(0.867)	0.723**	0.273**	(.85)					
4. Intrinsic value	3.605(1.024)	0.528**	0.194**	0.549**	(.90)				
5. Utility value	3.933(0.908)	0.374**	0.209**	0.548**	0.581**	(.74)			
6. Relative cost	2.305(0.897)	−0.037	−0.107*	−0.194**	−0.197**	−0.350**	(.73)		
7. STEM Career aspirations	4.137(0.985)	0.400**	0.258**	0.551**	0.575**	0.722**	−0.272**	(.94)	
8. Gender	NA	−0.291**	−0.076	−0.165**	−0.235**	−0.118**	−0.052	−0.129**	–
9. URM Status	NA	−0.104*	−0.008	−0.140**	−0.066	−0.066	0.072	−0.046	−0.023

Note. STEM = science, technology, engineering, mathematics. Internal consistency reliability estimates (Cronbach's α, 1951) are shown in the diagonal. Attitudes were assessed on a 5-point scale, where 1 = *strongly disagree* and 5 = *strongly agree*. Higher mean values indicate higher levels of the attitude. Gender-coded women = 2 and men = 1; URM status-coded URM = 1 and non-URM = 0. NA = not applicable.

$^{*}p < .05$, $^{**}p < .01$, and $N = 492$.

TABLE 4 Number of subjects (N), Means (M), Standard Deviations (SD), and significance tests with effect sizes by PjBL course status

	No project-based			Project-based						
	N	*M*	*SD*	*N*	*M*	*SD*	*t*	*df*	*p*	*d*
1. STEM Self-efficacy	246	3.467	1.008	244	3.584	0.996	−1.293	488	0.197	0.12
2. STEM Skills efficacy	245	3.805	0.639	238	4.062	0.583	−4.611	481	0.000	0.42
3. Attainment value	245	3.959	0.903	241	4.083	0.864	−1.072	484	0.284	0.10
4. Intrinsic value	243	3.542	1.062	242	3.668	0.982	−1.359	483	0.175	0.12
5. Utility value	245	3.791	0.997	240	4.078	0.782	−3.526	483	0.000	0.32
6. Relative cost	245	2.370	0.926	241	2.238	0.864	1.626	484	0.105	−0.15
7. STEM Career aspirations	246	4.004	1.106	243	4.271	0.825	−3.025	487	0.003	0.27

Note. STEM = science, technology, engineering, and mathematics. Attitudes were assessed on a 5-point scale where *1 = strongly disagree* and *5 = strongly agree*. Higher mean values indicate higher levels of the attitude. Effects sizes (*d*) are standard deviation units.

compared to 25 with at least one PjBL course), this difference was not statistically significant (χ^2 [1, $N = 492$] = 1.90, $p = .168$) providing no support for Hypothesis 3.

We tested Hypothesis 4, which stated that the effect of PjBL on STEM career aspirations would be mediated by STEM self-efficacy and subjective task value, using hierarchical regression and the method described by Baron and Kenny (1986). Conditions for mediation are that (a) the independent variable (PjBL) is related to the outcome variable (career aspirations in STEM), (b) that the independent variable is related to the mediator (subjective task value and self-efficacy), and (c) that the mediator is related to the outcome variable. If the effect of the independent variable on the outcome variable is zero when the mediators are entered into the regression equation, mediation is established. We tested only the variables that met these criteria (i.e., those that demonstrated a significant difference based on PjBL status and showed a significant relationship to STEM career aspirations): Utility value and STEM skills efficacy. Because of the multi-collinearity among study variables (Table 3), we tested these two mediators simultaneously in a hierarchical linear regression to examine their independent effects. The analysis is shown in Table 5.

Model 1 establishes the relationship between the independent variable (PjBL) and outcome variable (career aspirations), $\beta = .136$, $p = .003$), showing that PjBL accounts for a significant 1.8% of variance in career aspirations. The relationship between PjBL and the mediators is established in Model 2 for utility value ($\beta = .158$, $p < .001$) and STEM skills efficacy ($\beta = .206$, $p < .001$). Model 3 establishes full mediation by showing that when utility value and STEM skills are entered into the regression equation, the effect of PjBL on career aspirations is no longer significant. Moreover, there is evidence that both utility value and STEM skills efficacy account for unique variance in career aspirations, 6.6% for STEM skills and 46.5% for utility value, when entered simultaneously into the regression equation (Table 5; $\beta = .113$, $p < .001$ for STEM skills and $\beta = .698$, $p < .001$ for utility value).

To examine Hypothesis 5, we tested whether race or gender moderated the relationship between PjBL and the mediators (self-efficacy and subjective task value variables) and STEM career aspirations with a series of ANOVAs using the general linear model in SPSS. We did not find evidence of significant interactions between PjBL and URM status for any of the self-efficacy or subjective task value variables (p-values ranging from .319 to .789). Similarly, we did not find evidence of significant

TABLE 5 Hierarchical multiple regression analysis testing mediation for self-efficacy and outcome expectations

	Outcome Variables					
	Career Aspirations		Utility Value		STEM Skills	
Predictor	ΔR^2	β	ΔR^2	β	ΔR^2	β
Model 1						
PjBL	.018**	.136**				
Model 2						
PjBL			.025**	.158**	.042**	.206**
Model 3						
STEM Skills efficacy	.066**	.113**				
Utility value	.465**	.698**				
PjBL	.000	-.003				
Total R^2 Model 3	.532					
N	478		484		482	

Note. STEM = science, technology, engineering, and mathematics. PjBL = Project-based learning course. ΔR^2 = change in variance accounted for given the introduction of the predictor variable in the hierarchical regression. Model progression based on Baron and Kenny's (1986) approach for establishing mediation. Model 1 establishes the effect of the quasi-independent variable (PjBL) on the outcome (career aspirations). Model 2 establishes the relationship between the quasi-independent variable (PjBL) and the mediators (utility value and STEM skills efficacy) and Model 3 establishes full mediation by showing that PjBL is no long significant after STEM skills efficacy and utility value are entered into the regression equation.
**$p < .001$

interactions between PjBL and gender for any of the self-efficacy or subjective task value variables (p-values ranging from .124 to .958). We thus found no support for Hypothesis 5; the effect of PjBL on STEM skills efficacy, utility value, and STEM career aspirations was not dependent on student gender or URM status.

6 | DISCUSSION

The current study examined the effect of PjBL on student career aspirations in STEM. The study was framed within expectancy-value theory and SCCT and as such, we examined whether self-efficacy and subjective task value judgments mediated the effect of PjBL on student career aspirations. Results showed that engaging in at least one PjBL course during the first four semesters of college is related to higher levels of career aspirations in STEM disciplines, greater STEM skills efficacy, and higher ratings of the utility of STEM courses. Moreover, we found that these attitudes fully mediated the effect of PjBL on STEM career aspirations as would be posited by expectancy-value theory and SCCT (Eccles & Wigfield, 2002; Lent et al., 1994).

We are not the first researchers to integrate expectancy-value and SCCT models (see Parr & Bonitz, 2015), however, to our knowledge we are the first to show a significant effect of mediation for the social cognitive variables examined here in the context of an intervention. In particular, utility value and STEM skills accounted for over 50% of the variance in career aspirations in STEM. This finding is perhaps not surprising when one considers that the PjBL courses examined here permitted students to practice professional skills central to STEM careers. In essence, authentic experiences with projects affected student perceptions of their own STEM skills and their perceptions of the utility of STEM courses for their future careers, which in turn, strengthened their career aspirations. It is important to note, however, that even though we matched the control group on STEM preparation, it may be that students who enrolled in PjBL courses had fundamentally different career aspirations in STEM than students who did not. The quasi-experimental design of the current study limits our ability to make causal inferences about the effect of PjBL. Nonetheless, our results support the promise of authentic, client-based projects for influencing student efficacy and interest in STEM careers.

The results of this study also echo those of past research relative to personal characteristics (gender and URM status). Specifically, research suggests that URM students and women generally have more negative self-perceptions in STEM (Ceci & Williams, 2011; Ceci, Williams, & Barnett, 2009; Holmes & Hwang, 2016; Robnett, 2013; Zastavker et al., 2006), which is also what we found. That is, STEM perceptions were more consistently negative for women and URM students in the current study. Similar to other researchers (Holmes & Hwang, 2016), we did not find an interaction between PjBL and person characteristics. That is, our findings suggest that PjBL has the potential to positively affect student STEM skills efficacy and perceptions of utility value regardless of race or gender.

One important characteristic of the PjBL courses examined in this study is their authentic nature. Students engaged in solving real-world, client-centered problems within the courses, and these experiences provided them with valuable insight into jobs and job tasks in natural science and engineering fields. In other words, the authentic, client-based projects embedded in the course gave students the opportunity to obtain a realistic job preview (Baur, Buckley, Bagdasavrov, & Dharmasiri, 2014), in ways that instructor-contrived projects could not. These experiences were related to student self-efficacy and perceptions of the utility of STEM courses vis-à-vis a future career. We cannot comment on the extent to which our effects are driven by the authentic nature of the projects because the current study did not specifically compare authentic PjBL with other types of course projects (e.g., closed-ended instructor-developed projects). Future research can tease apart the effect of the authentic nature of client-based projects, versus instructor-developed projects compared to a no project control.

7 | LIMITATIONS

This research has some limitations worth noting. The significant effects of PjBL on STEM skills efficacy, utility value, and career aspirations notwithstanding, we did not find significant effects of PjBL on several of the attitudinal variables examined here (e.g., STEM self-efficacy, attainment value, intrinsic value, and relative cost) or student major choice in STEM after the fourth semester. Although these results were somewhat surprising, they are aligned with studies on active learning approaches and attitudes that have shown mixed results (Atadero et al., 2015; Holmes & Hwang, 2016; Parr & Bonitz, 2015). It may also be that factors other than PjBL – perhaps pre-determined factors – affect these attitudes and major choice. Future research is needed to explore these possibilities. More consistent results supporting the benefits of active learning have been found for cognitive outcomes such as learning and course performance (Freeman et al., 2014).

There are many potential reasons for these null results. It may be, for instance, that PjBL affected those social-cognitive variables that were most related to the course experience (STEM skills efficacy, utility, and career aspirations), and PjBL is simply not linked to students' general perceptions of efficacy, attainment value, or intrinsic value for STEM. Notably, these findings suggest that engaging in PjBL does not affect student perceptions of the relative cost of engaging in STEM courses, even though PjBL courses can be considered challenging to some students given the requirement to work on relatively ambiguous open-ended projects (Thomas, 2000).

Our lack of significant findings might also be a function of the relatively coarse way in which we operationalized participation in PjBL throughout college. We grouped students who had either engaged or not engaged in PjBL (regardless of the number or sequence of PjBL courses taken) across the first four semesters in college without regard to when these courses were taken or how many were taken. This approach permitted a first pass to examine the effectiveness of PjBL, but a more detailed approach would require a larger sample over a longer period of time. Although our findings point to the promise of PjBL for affecting student attitudes and career aspirations, a larger longitudinal study is needed to answer questions about how attitudes develop over the course of a college career. Focus groups conducted with students who participate in and those who do not participate in PjBL and students who declare and do not declare STEM majors would also provide insight into the effectiveness of PjBL courses. As such, more in depth research could identify specific course elements and examine the number and sequencing of PjBL courses that are important for affecting student attitudes.

An additional limitation of the present study is the sample's range restriction. Specifically, this study was conducted at a highly selective private university where students may already have relatively high self-perceptions and intrinsic interest in STEM fields. Indeed, only 60 of the 492 students included in the current study's sample did not intend to major in a STEM discipline at the end of the fourth semester in college and the small number of people switching out of STEM fields likely contributed to the null result for the effect of PjBL on major choice. To provide an idea of the competitiveness of the institution at which this research was conducted, the median ACT score for admitted students in Fall, 2017 was in the 99th percentile (34 of a possible 36). This restriction in talent likely attenuated the results of the current study; that is, we would expect larger effects with a more diverse sample of students.

Along with attenuating the effects found in the current study, range restriction may affect the generalizability of our finding. Although the current study expanded research on PjBL by examining its effects across a breadth of STEM disciplines rather than focusing only on engineering or natural science as other researchers have done (Yadav, Vinh, Shaver, Meckl, & Firebaugh, 2014; Zastavker et al., 2006), the research was conducted at only one university. There may be something unique about the institution where this research was conducted that affected the results; for example, the emphasis on teaching versus research may be different at this institution compared to others. The current study cannot speak to these potential differences, however. Future research should examine these effects with a more diverse sample of students at various institutions.

8 | IMPLICATIONS

The current research highlights the promise of authentic, client-centered PjBL for affecting student career aspirations through perceptions of STEM skills and course utility. Our findings suggest that PjBL approaches have the promise to answer the call to improve STEM curricula in ways that will directly affect the quality of the STEM workforce (NAS, 2010). Furthermore, career aspirations for all students—regardless of race or gender—are likely to be positively affected by PjBL because the experiences provided in PjBL courses increase student self-efficacy for STEM skills and student perceptions of the utility of STEM classes.

It may, however, be challenging to engage STEM instructors in PjBL or other types of active learning given that these approaches tend to require additional resources in terms of instructor time (to engage clients and to ensure the fruition of multiple projects within a semester's timeframe). Indeed, research suggests that faculty perceptions of the amount of work associated with PjBL is a barrier to implementation (Cooper et al., 2015; Helle et al., 2006; Thomas, 2000). For example, for a PjBL course in engineering design project, tools and materials to build prototypes may need to be available.

For a PjBL course that focuses on natural science research projects, access to a wet lab with analytical equipment may be needed. Working with other professional to identify projects and work with teams also requires time and effort.

9 | CONCLUSION

The results of the present study suggest that university investment in active learning activities such as PjBL will pay off by increasing student engagement and career interest in STEM. Although future research is needed to fully explore the effect of PjBL on student retention and career choice, instructors and institutions should explore the feasibility of incorporating these approaches into their STEM curricula. Given the necessity of engaging a diverse and engaged STEM workforce to face the global challenges of today and the future, authentic PjBL provides a promising avenue for the future of STEM education.

ACKNOWLEDGEMENTS

This project was supported in part by a grant from the Howard Hughes Medical Institute to Rice University through the Precollege and Undergraduate Science Education Program. The authors have no conflicts of interest to report.

ORCID

Margaret E. Beier http://orcid.org/0000-0001-5761-5610

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How to cite this article: Beier ME, Kim MH, Saterbak A, Leautaud V, Bishnoi S, Gilberto JM. The effect of authentic project-based learning on attitudes and career aspirations in STEM. *J Res Sci Teach.* 2019;56:3–23. https://doi.org/10.1002/tea.21465