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ARTICLE

The Relationship Between Project-Based Learning and Rigor in STEM-Focused High Schools

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Abstract

Project-based learning (PjBL) is an approach often favored in STEM classrooms, yet some studies have shown that teachers struggle to implement it with academic rigor. This paper explores the relationship between PjBL and rigor in the classrooms of ten STEM-oriented high schools. Utilizing three different data sources reflecting three different perceptions—student surveys, teacher logs, and classroom observations—the study examines the extent to which PjBL and rigor co-occur. Across all three measures, the results show that use of PjBL is associated with higher levels of rigor. However, the study also shows that academic rigor can be present in the absence of PjBL, and that PjBL can be implemented with low levels of rigor. The paper concludes with implications for practice.

Keywords: project-based learning, academic rigor, mixed methods, STEM high schools

Introduction

Policymakers and educators have been concerned for years about ensuring that students leave high school with the skills and knowledge they need to function successfully in a world that is increasingly oriented to and influenced by science and technology (Epstein & Miller, 2011; Peter D. Hart Research Associates/Public Opinion Strategies, 2005). Often termed "21st Century Skills," these skills fall into a set of core areas including mastery of key content areas, the ability to be creative and innovative, the ability to communicate and collaborate effectively, critical thinking and problem-solving, information, media and technology skills, and "soft skills" such as flexibility, initiative, and social/cross-cultural skills (Partnership for 21st Century Learning, 2015). To support the development of these skills, advocates have argued that students need to have the opportunity to engage in integrated and complex learning activities, such as project-based learning, that mirror the type of thinking in which students will be asked to engage outside of school (Asghar, Ellington, Rice, Johnson, & Prime, 2012; Larmer & Mergendoller, 2010). Implicit in the recommendation that schools and teachers implement these strategies is the assumption that they incorporate a level of cognitive challenge or academic rigor that will allow students to build their expertise in 21st century skills. Indeed, proponents of project-based learning often argue that it is an excellent way of merging some of the common buzzwords of high school reform: rigor, relevance, and relationships (Buck Institute of Education, 2015; Harada, Kirio, & Yamamoto, 2008). Yet, some researchers have shown that project-based learning is not always accompanied by academic rigor, conceptualized as students engaging with rich, complex content using higher level thinking and communication (Cook & Weaver, 2015; Han, Yalvac, Capraro, & Capraro, 2015; Lee & Bae, 2008). This paper utilizes data from a larger four-year, National

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Science Foundation-supported study of 10 STEM-focused schools to explore the extent to which academic rigor and project-based learning coexist in these schools. The specific research questions driving this study are:

1. To what extent do students, teachers, and observers report high levels of rigor and high levels of project implementation in STEM-oriented schools?
2. To what extent are high levels of project implementation accompanied by high levels of rigor?

Literature Review

This section of the paper summarizes the literature on project-based learning and academic rigor and considers the extent to which there is overlap between the two concepts conceptually and in the literature.

Project-Based Learning

At their core, project-based learning, problem-based learning, and inquiry-based activities are driven by similar approaches that focus student learning on extended investigations of authentic, complex problems, although each tradition is considered to have some distinctive characteristics (Cook & Weaver, 2015; English & Kitsantas, 2013; Hmelo-Silver, 2004; Savery, 2006). Problem-based learning originated in the medical field and reflects student-centered collaborative learning centered on an ill-structured problem (Goodnough & Cashion, 2006; Savery, 2006; Walker & Leary, 2009). Project-based learning is very similar with its focus on student-centered learning around an authentic problem, but it adds the creation of a product, shared publicly (Buck Institute of Education, n.d.). In addition, project-based learning may be more explicitly guided by the instructor than problem-based learning (Savery, 2006). Inquiry science is a broader umbrella term that focuses on posing and investigating questions, but it may not necessarily be guided by a specific problem or result in the creation of a project (National Research Council, 1996). For clarity, this paper focuses primarily on project-based learning (PjBL), as this is the strategy and approach that the majority of the schools in our study reported using, but we do draw on some of the literature from problem-based learning because of the substantial overlap between the concepts (English & Kitsantas, 2013).

Project-based learning or PjBL has been described as "student-centered instruction that occurs over an extended time period, during which students select, plan, investigate and produce a product, presentation or performance that answers a real-world question or responds to an authentic challenge" (Holm, 2011, p. 1). There are differences in how researchers and educators define the specific characteristics of PjBL; however, in general,

> The design principles of PBS [project-based science] include a context that engages students in extended authentic investigations through a driving question, collaborative work that allows students to communicate their ideas, learning technologies to find and communicate solutions, and the creation of artifacts that demonstrate student understanding and serve as the basis for discussion, feedback, and revision. (Tal, Krajcik, & Blumenfeld, 2006, p. 724)

The Buck Institute of Education, a leading organization in PjBL implementation, agrees with the above definition, including two additional characteristics to make it "gold standard" PjBL: (1) allowing students input and choice within the project; and (2) the opportunity for students to critique and revise their and others' work (Buck Institute of Education, 2015).

PjBL is often implemented in science, technology, engineering, and mathematics (STEM) settings, and the majority of the research concerns PjBL in math, science, or technology-oriented classrooms (i.e., Dochy, Segers, Van de Bossche, & Gijbels, 2003; Finkelstein, Hanson, Huang, Hirschman, & Huang, 2010; Goodnough & Cashion, 2006; Holm, 2011). When PjBL is implemented well, it can result in positive outcomes for students including an improved ability to apply knowledge (Dochy et al., 2003) as well as improved understanding of the content for some topics (Finkelstein et al., 2010).

High quality project-based learning is not necessarily easy to implement in practice, given that teachers need to have a deep understanding of the content being covered and also need to have the skills to make that content understandable to their students (Kanter & Konstantopolous, 2010; Schneider, Krajcik, & Blumenfeld, 2005). In addition, it is a complex approach that can require teachers to revisit their role and become more of a facilitator of learning (Goodnough & Cashion, 2006; Han et al., 2015; Lee & Bae, 2008). As a result, the level and quality of teachers' implementation of PjBL can differ and teachers may face substantial challenges in implementation (Cook & Weaver, 2015; Marx et al., 1994; Schneider et al., 2005; Tamim & Grant, 2013). For example, in their case study of high school STEM teachers' PjBL implementation after a significant professional development experience, Cook and Weaver (2015) reported that implementation of different aspects of PjBL, such as the student choice aspect, varied among the teachers who took the professional development. All of the teachers they examined engaged students in collaborative group work where students created a final product. However, they did note that teachers faced challenges in effectively integrating the course content in a real world context. Another study found that teachers who had participated in a professional development experience on

STEM project-based learning understood the concepts of PjBL but did not necessarily implement them in practice, partly because teachers were not convinced that PjBL would help students do better on the required end-of-year assessments and partly because there was not always sufficient time for preparation (Han et al., 2015). A third study found that teachers have not always received the level of training necessary for effective implementation; as a result they tended to perceive or implement PjBL based on the way they saw it contributing to the learning in their classroom (Tamim & Grant, 2013). Because of the challenges in implementing PjBL well, teachers may resort to doing what advocates call "short duration and intellectually lightweight activities and projects" (Larmer & Mergendoller, 2010, p. 1). Teachers may thus consider themselves as doing project-based learning but not necessarily be meeting its ideal characteristics.

Academic Rigor

Academic rigor is considered an important aspect of a student's educational experience (Boser & Rosenthal, 2012; Mitchell et al., 2005; Wagner, 2008) allowing all students to be challenged in a way that prepares them for college and career (Kay & Houlihan, 2006; National High School Alliance, 2006). Although rigor is not always clearly defined, we believe that it involves engaging students in higher order thinking to learn complex and rich content (Matsumura, Slater, & Crosson, 2008; Mitchell et al., 2005). Rigor also requires students to demonstrate their knowledge through varied communication strategies (Newmann, Lopez, & Bryk, October 1998).

When considering how rigor is implemented in schools, one of the primary foci is course taking, ensuring that students are enrolled in courses that will prepare them for college (Achieve, 2004; ACT Inc., 2007; Burris, Welner, Wiley, & Murphy, 2008). Yet, many researchers and policymakers acknowledge that course selection is only part of the story; that it must be accompanied by rigorous content, instruction, and assessments that are present inside the classroom (Grubb & Oakes, 2007; Matusevich, O'Conner, & Hargett, 2009).

Although, in reality, content, instruction, and assessment are interwoven, they can be considered separately. Rigorous content is generally conceptualized as complex, academically substantive content that addresses the core concepts of the discipline (Matsumura et al., 2008; Matusevich et al., 2009). In their establishment of a rubric to assess the rigor of courses, the North Carolina Department of Public Instruction considered rigorous content thus:

> Advanced, sophisticated curriculum consistently builds upon and extends beyond a standard course of study through universal concepts, complex levels of generalizations and essential questions from multiple perspectives within the topic. Students consistently engage in multiple, complex, thought-provoking and ambiguous texts/materials that challenge their thinking and feelings. (North Carolina Department of Public Instruction, n.d.)

Rigorous content can be presented but not taught in a rigorous way. Rigorous instruction is generally seen as including higher level thinking strategies such as those represented on the higher level by Bloom's Taxonomy and including strategies such as analysis, evaluation, application, and creation (Bloom, 1956; Krathwohl, 2002) as well as problem-solving and reasoning in mathematics (Mitchell et al., 2005; Stein & Lane, 1996). Teachers are often encouraged to ask open-ended questions of their students that probe student's thinking (Matsumura et al., 2008), and students are asked to formulate and test hypotheses (Boston & Wolf, 2006). When rigorous instruction is present, students are also asked to engage in what Newmann and his colleagues (Newmann, Bryk, & Nagaoka, January 2001) call "elaborated communication" or extended explanations, justifications, and demonstration of reasoning (Mitchell et al., 2005). Elaborated communication can be considered an example of rigorous assessment as well.

Rigorous assessments should provide the opportunity for students to demonstrate higher order thinking strategies and be aligned to the content and instructional activities in which the students have engaged. They should also provide the opportunity for students to reflect on and revise their thinking (Boston & Wolf, 2006).

For some researchers, rigor also involves a nature of "authenticity" or work that is related in some way to experiences students will have outside of school, although others might describe that as relevance (Mitchell et al., 2005; Newmann et al., January 2001).

Similar to PjBL, academic rigor in the classroom can be difficult to implement well. Researchers have examined the quality of teacher assignments and student work to develop an understanding of what rigorous instruction looks like in practice and the extent to which it is widely implemented. Newmann and his colleagues collected assignments given by teachers in the Chicago Public Schools in grades 3, 6, and 8. Their results showed that rigorous assignments were not necessarily widespread, particularly at the secondary level and in STEM subjects. For example, less than 10% of the 8th grade math assignments were seen as being moderately or extensively rigorous, although 56% of the 8th grade writing assignments were seen as being at least moderately rigorous (Bryk, Nagaoka, & Newmann, 2000). A study of redesigned high schools found that 40% of teachers in redesigned schools were developing substantially rigorous assignments in English and only 13% in mathematics. In traditional comprehensive high schools, 18% of assignments were substantially rigorous in English and 10% in math (Mitchell et al., 2005). Even when teachers are given curricular materials, they face challenges in asking students questions or to do activities that require higher level thinking and in requiring students to justify their conclusions (Matsumura et al., 2008).

Some of the challenges in implementing rigor might be driven at least partly by concerns among practitioners that many students cannot do rigorous work. Although all students might not be able to complete work at the same level, thus requiring differentiation in instruction (Subban, 2006), researchers have found that students at all levels benefit from cognitively challenging assignments. For example, an extensive study of authentic, intellectual work in Chicago concluded that both lower performing and higher performing students benefited from cognitively challenging work when compared to lower levels of assignments. In the case of mathematics, lower-achieving students benefited more than higher achieving students (Newmann et al., January 2001).

PjBL and Rigor

As described above, previous research suggests that there is significant overlap between the idea of PjBL and academic rigor focused particularly around content and thinking expectations (Cook & Weaver, 2015; Mitchell et al., 2005; Newmann et al., October 1998; Tal et al., 2006). As advocates note, in its ideal incarnation, PjBL teaches the key content and academic standards of a discipline while engaging students in critical thinking, problem-solving, and collaboration (Larmer & Mergendoller, 2010). For example, in their case study of the instructional implementation of PjBL in high school classrooms, Cook and Weaver (2015) articulated that PjBL should incorporate what they called "substance and rigor," which they presented as "PjBL engages students in extended investigations where they can pose questions, gather information, and evaluate their findings as they develop solutions to the problem or driving question" (p. 3). As shown in Figure 1, PjBL can be conceptualized as a specific applied example of rigor. If implemented as intended, PjBL can incorporate the key aspects of academic rigor within the structure of an extended investigation centered on solving a key problem, and, according to some authors, an increased emphasis on student choice.

Despite the substantial overlap, not many studies have explicitly examined the implementation of PjBL and rigor. When studies did consider PjBL implementation and academic rigor simultaneously, the results seemed to indicate that many teachers struggled to implement PjBL with rigor (Cook & Weaver, 2015; Han et al., 2015; Lee & Bae, 2008). For example, one study that examined implementation among seven teachers reported that the degree to which projects "reflected rigor and substantive work was lower. In general there seemed to be a greater emphasis on information seeking and data collection activities than on activities that involved more rigor such as evaluation and interpretation" (Cook & Weaver, 2015, p. 26). In particular, the researchers noted that there were few in-depth discussions about the meaning or quality of evidence. Another study that examined implementation of a STEM-focused PjBL professional development experience found that "the interdisciplinary feature of STEM PjBL caused teachers to focus more on other disciplines without including rigorous mathematics content" (Han et al., 2015, p. 72). On the other hand, a case study of a teacher team in an individual class provided evidence that teachers asked probing questions to encourage students to develop more understanding of the scientific concepts represented in the unit, although the authors seemed to be arguing that this did not allow enough student self-direction to represent true PjBL (Lee & Bae, 2008).

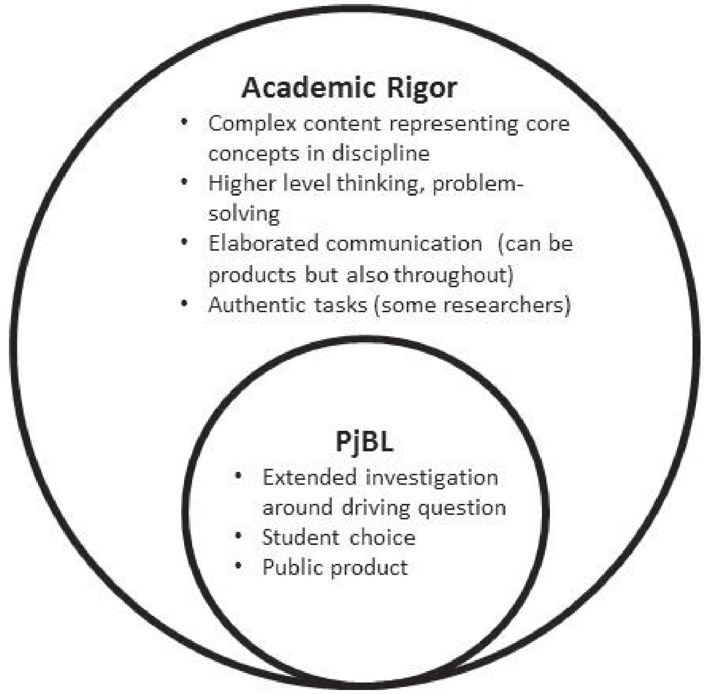

Figure 1. Relationship of PjBL and academic rigor.

This paper is designed to add to the literature base on PjBL and academic rigor by formally and explicitly exploring the relationship between the two in classroom implementation.

Methodology

This paper presents results from a portion of a much larger study whose primary goal was to examine the impact of STEM-focused high schools on student outcomes. This section provides a brief overview of the full study and the intervention being examined and then describes the specific methodology used to look at the questions around PjBL and rigor.

Full Study

Funded by the National Science Foundation, the primary goal of Redesigned High Schools for Transformed STEM Learning was to look at the impact of a multiyear effort to create STEM-focused schools in North Carolina. The study used a quasi-experimental design that matched students attending 10 STEM-focused schools with comparable students in comparable non-STEM high schools. Using administrative data collected from schools by the North Carolina Department of Public Instruction, the study showed that students in STEM schools had higher rates of passing advanced math and science classes than propensity-score matched comparison students, even when models control for race/ethnicity, free or reduced-price lunch status, and middle school academic performance (Glennie, Mason, & Dalton, 2016). The study also examined the impact on student perspectives of the initiative through a survey. Students in STEM schools were more interested in pursuing STEM courses and careers, and they were more likely to indicate their school helped them develop necessary skills and understand the steps needed to pursue college or careers (Glennie, Dalton, & Mason, 2014). Performance-based assessments measuring students' higher-order thinking abilities showed that students did demonstrate proficiency specific to brainstorming, exploration, and research and investigation, but only about half of the students demonstrated other proficiency-based aspects of knowledge (Ernst & Glennie, 2015).

This paper focuses on the association between PjBL and academic rigor in the 10 STEM-focused schools. These schools are described below.

Intervention

The study examined an effort to implement a set of STEM-focused redesigned schools in North Carolina. The schools included in the study fell into three main camps: STEM-focused early college high schools; small STEM-themed high schools; and New Tech High Schools. All three models are inclusive schools, without strict admissions criteria, with small school size (fewer than 400 students) and a focus on innovative instruction.

STEM-focused early college high schools are small schools of choice located on the campuses of community colleges or universities. Targeted at students who are underrepresented in college, early colleges provide students the opportunity to graduate from high school with a high school diploma and up to two years of college credit or an associate degree. The emphasis on STEM gives students clear STEM-oriented pathways that can lead to an associate degree in science or transition them into a STEM-related major at a college or university. Experimental studies of early colleges have found that they increase the number of students who are on-track for college, graduate more students, and enroll more students in postsecondary education (Berger, Turk-Bicakci, Garet, Knudson, & Hoshen, 2014; Berger et al., 2013; Edmunds et al., 2012; Edmunds et al., 2016). Four of the schools in the study are early colleges.

Four of the schools in the study are STEM-themed high schools, small schools of choice that originally spun off from a larger, comprehensive high school or that are housed as an academy within the larger school. These schools are organized around a STEM-oriented theme such as health sciences or engineering and technology. The themes are intended to guide the curricular offerings and the overall feel of the school. For example, health sciences schools may offer less common courses, such as anatomy and physiology, require students to wear scrubs to school, and provide internship opportunities at local hospitals.

These theme-based high schools, as well as the early colleges, are also expected to implement a set of six design principles that represent the characteristics of a high quality high school. Established by North Carolina New Schools, the entity that supported the early colleges and STEM-themed schools, the design principles include: (1) an emphasis on college readiness for everyone, including a default college preparatory curriculum and access to college credit opportunities; (2) a focus on instruction that emphasizes student engagement and encourages students to read, write, think, and talk across all classrooms; (3) the provision of academic and affective supports and the personalization of instruction by staff who know their students well; (4) a professional working environment that fosters collaboration among teachers and promotes ongoing professional learning; (5) leadership that develops a common vision for the school; and (6) the purposeful use of time and structures that support the other design principles (North Carolina New Schools, 2013). Although PjBL is not necessarily an expected instructional strategy for these schools, some schools have chosen the use of projects as a core instructional approach.

The remaining two schools in the study follow the New Tech model. Supported by the New Tech Network, New Tech High Schools implement project-based learning in a technology-oriented environment. According to the Network, "Students collaborate on meaningful projects that require critical thinking, creativity, and communication in order for them to answer challenging questions or solve complex problems" (New Tech Network, n.d.). Technology is another core component of the program. Each school has a one-to-one ratio of students to computers and they use collaborative learning technology and a software management system to support the work. The schools are also expected to have students and teachers jointly take ownership of and responsibility for the learning process. The New Tech model thus has the most explicit focus on the implementation of PjBL of the three different models.

Methodology for Examining PjBL and Academic Rigor

For this specific study, we examined the implementation between PjBL and academic rigor in all ten of the STEM-oriented treatment schools in the larger study. In particular, we sought to understand the extent to which students, teachers, and observers reported high levels of rigor and high levels of project implementation in STEM-oriented schools (Research Question 1). We also wanted to examine the extent to which PjBL and rigor co-occurred in these environments (Research Question 2).

To answer both research questions, we utilized three different data sources that all collected data simultaneously on aspects of PjBL implementation and of academic rigor. Researchers have found that different measures (i.e., observations, surveys, logs) capture different aspects of the instructional environment (Kunter & Baumert, 2006; Mayer, 1999). In this section, each data source and its analysis strategy are described separately.

Students' Perceptions. Students' perceptions of their learning environment have long been considered as valid measures of classroom experience (De Jong & Westerhof, 2001; Doppelt & Schunn, 2008; Dorman, 2001; Fraser & Fisher, 1982; Yazzie-Mintz, 2010) that may be more predictive of student outcomes than teacher perceptions (McCombs, Daniels, & Perry, 2008). For this study, we used the YouthTruth survey, developed by the Center for Effective Philanthropy with the support of the Bill & Melinda Gates Foundation. The full survey includes questions that focus on students' attitudes toward school, their relationships with teachers, the college-oriented activities in the school, supports provided to students, and the extent to which aspects of rigorous or challenging instruction were present in the school. The questions have a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). As part of the development process, the Center for Effective Philanthropy assessed scales for construct validity and reliability and conducts regular factor analyses to ensure that scale questions are reflective of the same underlying constructs (YouthTruth Survey, n.d.). Our team developed a STEM-focused addendum that asked questions about specific STEM-focused activities or instructional strategies. The survey was administered to students in all ten schools in the study. Response rates among treatment schools averaged 83% with a low of 58% and a high of 99% (see Table 1).

For this paper, the questions analyzed focused on academic rigor and involvement in projects. The rigor scale asked students to respond to statements such as "The work that I do for my classes makes me really think" and "Most of my teachers want us to use our thinking skills, not just memorize things" (a full listing of the questions is provided in Appendix A). With our sample, this scale had a reliability (Cronbach's alpha) of .884.

We also used the following two survey questions that were developed for the study to create a composite measure of project-based learning (students had to indicate the frequency of their involvement ranging from "Never" to "Very Frequently"):

- Participated in hands-on group projects that involve building or designing
- Worked with a group to design a solution to a problem

To look at the level of implementation as reported by students, we calculated frequencies for each indicator and for the overall scale scores. We examined the relationships between the level of perceived rigor and the implementation of projects in two ways. First, we conducted correlational analyses between the rigor scale and the PjBL scale. Second, we conducted cross-tabulations between the two sets of scale scores, which had a range of 0 to 5. To minimize the number of cells and make it easier to interpret the results, we recoded the scores into levels of "low" implementation, "medium" implementation, and "high" implementation. A 2 or less scored "low," greater than 2 but less than 4 was considered "medium" implementation, and 4 or higher was considered "high" implementation. Finally, we conducted chi-square analyses (Lewis-Beck, Bryman, & Futing Liao, 2004) to determine whether the values in the different cells were statistically different from each other.

Teacher Logs. Researchers have used web-based logs to collect instructional data from teachers on an ongoing basis as part of long-term studies (Ball, Camburn, Correnti, Phelps, & Wallace, December 1999; Rowan, Camburn, & Correnti, 2004; Rowan, Jacob, & Correnti, 2009). For this study, four teachers in STEM subjects in each of the 10 schools were asked to complete online logs describing their instruction in one of their classes. Teachers received a detailed guide that showed them the process of entering the data into the log. They were asked to enter information about the same class (i.e., first period Algebra I) up to 14 times during a year. By repeatedly collecting the same kinds of information on classes, we could determine the relative importance of lesson attributes and the frequency of strategies that teachers used. The log had questions in four categories: teacher contextual information (the teacher only needed to enter this once); a description of the lesson including purpose, topic, and expectations for the students; the instructional structure of the lesson (materials, student grouping, tasks); and implementation of the lesson (student understanding, engagement, and activities). Teachers were told to provide information only for the lesson taught on the day of the log entry. A total of 32 teachers across the 10 schools completed at least some logs (see Table 1 for the distribution of log entries).

To look at the level of academic rigor as reported by teachers, we used teachers' responses on the emphases of the lessons actually implemented (see Appendix A for sample log). The participants rated the extent to which a lesson incorporated specific characteristics from 1–5, with 1 being "no," 3 being '"somewhat," and 5 being "yes." We combined the teachers' ratings on the importance of each of the following lesson elements to form a scale that reflects different aspects of rigor:

- Embed opportunities for discourse
- Encourage students to generate ideas
- Include challenging concepts
- Make real-world connections
- Allow for revisions
- Focus on "big ideas"

To look at rigorous instruction, we calculated frequencies for the individual indicators making up the rigor scale. To create an overall rigor score, we averaged the individual indicator scores to create a scale value. Because some teachers had many more log entries than other teachers, we averaged all of an individual teacher's log scores for each indicator to create a single mean log score for each teacher relative to rigor.

We then used the following measure of whether students were engaged in PjBL during the lesson: "Working on an investigation, problem, or project over an extended period of time." This was a dichotomous measure for which teachers indicated whether this had happened in their classroom or not.

To examine the relationship between rigor and PjBL in the logs, we classified teachers by low, medium, and high implementation of rigor and PjBL. To classify teachers by implementation of project-related activities in a way that would be more manageable, we grouped the frequency of log records into three categories: "low" was teachers who implemented project-related activities in less than 25% of their lessons; "medium" was implementing project-related activities between 25% and 50%; and "high" was more than 50%. For rigor, a value of 0–2.5 was considered low rigor, between 2.5 and 4 was considered medium, and 4.0 and above was considered high rigor. To examine the extent to which rigor and PjBL co-occur, we conducted cross-tabulations using a similar approach to the YouthTruth survey. Given the relatively small number of logs, we did not conduct chi-square analyses.

Observations. Observations can provide insights into the quality of classroom instruction (Gitomer et al., 2014; Sawada, Piburn, & Judson, 2002). In this study, the observations described the extent to which STEM classrooms in the treatment schools exhibited specific instructional qualities. The study team developed a structured observation protocol, adapted from other protocols including the Local Systemic Change through Teacher Enhancement Classroom Observation Protocol (Horizon Research Inc., 2000), the CLASS protocol (Pianta, Hamre, & Mintz, 2011), and the Reformed Teaching Observation Protocol (Sawada et al., 2002). The protocol collected information about the activities done in the class along a variety of dimensions. Observers could supplement each rating with open-ended write-ups that contained justifications for the ratings.

The study team conducted observations of 39 teachers across the 10 schools (four teachers in each school except for one) using observers who were veteran mathematics and science teachers and professional developers with classroom observation experience. Eight observers conducted the observations, with one observer in each classroom. The study team developed a detailed observation guide for the protocol, and all observers participated in two two-hour trainings on using the protocol and guide.

In this paper, we used the Student Cognitive Engagement in Meaningful Instruction scale (our measures of rigor) and specific questions from the Inquiry Instruction, Project-Based Learning and Problem-Based Instruction, our measure of PjBL (see Appendix A for a copy of the questions used). For each scale, observers were asked whether each specific indicator was present in the classroom. Not all indicators were expected to be present in a classroom at a given time; the indicators served as examples of the kind of instructional practices that would be associated with the concept of rigor. If the indicator was present, observers rated the quality of implementation on a scale of 1 to 4, with 1 being the lowest score and 4 being the highest score; a 0 was noted if the activity was not observed at all.

For the rigor scale, we calculated a mean score by averaging the ratings for each indicator:

- Students experienced high cognitive demand of activities because the teacher did not reduce cognitive demand of activities by providing directive hints, explaining strategies, or providing solutions to problems before students had a chance to explore them, etc.
- Students were asked to explain or justify their thinking.
- Students were given opportunities to summarize, synthesize, and generalize.
- Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.
- Students were asked to apply knowledge to a novel situation.
- Students were asked to compare/contrast different answers, different solutions, or different explanations/interpretations to a problem or phenomena.

The indicators we utilized from the PjBL/Inquiry scale to indicate whether teachers were implementing projects in their classroom were:

- Students had to present or explain results of project.
- Students worked on a project requiring creativity.

Instead of collapsing these two PjBL indicators into a scale, we indicated whether a teacher was noted as doing either one of those activities at all during the class. To assess the level of implementation of rigor and PjBL, we analyzed frequencies for each of the rigor scales and whether teachers implemented any projects. To examine the co-occurrence, we used cross-tabulations to compare the extent to which a teacher did any sort of project with the rigor scale.

To further explore the relationship between rigor and PjBL in these classrooms and to supplement the quantitative data described above, we also summarized the open-ended descriptions of two classrooms: one that implemented a project with high rigor and one that implemented a project with lower rigor.

Using multiple data sources—such as the surveys, logs, and observations—allows us to triangulate our information (Creswell, Plano Clark, Gutmann, & Hanson, 2003) and present a fuller picture of the relationship between rigor and project-based learning. Table 1 presents a summary of the data sources used.

Results

This study examines the co-occurrence of rigor and PjBL in classroom instruction from three different perspectives, that of the student, that of the teacher, and that of the external observer. This section presents the results for each perspective.

Students' Perceptions. As the ultimate beneficiaries of educational activities, students are well suited to present portraits of their own experiences (De Jong & Westerhof, 2001). As described in the methodology section, the project administered a survey to students in STEM-oriented schools. The survey asked students to respond to statements that looked at implementation of activities related to rigor and activities related to STEM-focused PjBL. Table 2 (next page) presents the frequency of the responses with 1 being the lowest rating and 5 being the highest.

As Table 2 shows, most students (over 80%) believed that their school had a relatively high level of rigor (scores of 4 or 5). A slightly smaller percentage (approximately 63%) reported that they did STEM PjBL activities frequently or very frequently. In order to look at the extent to which responses on rigor and PjBL co-occur, we conducted

Table 1. Data source, by school.

School Number	# of Student Surveysa (Response Rate)	# of Teachers/ # of Log Entries	# of Observations (Types of Classes Observed)
1	104 (72%)	4/34	4 (2 Math, 2 Science)
2	203 (83%)	2/18	4 (2 Math, 2 Science)
3	100 (92%)	5/53	4 (1 Math, 2 Science, 1 Engineering)
4	153 (96%)	3/19	4 (2 Math 1 Science, 1 Engineering)
5	313 (99%)	5/51	4 (2 Math, 2 Science)
6	133 (92%)	2/14	4 (2 Math, 1 Science, 1 Technology)
7	108 (64%)	2/7	4 (2 Math, 2 Science)
8	147 (97%)	4/34	3 (2 Math, 1 Science)
9	150 (58%)	2/13	4 (2 Math, 2 Science)
10	164 (85%)	4/55	4 (2 Math, 2 Science)
Total	1575 (83%)	32/298	39 (19 Math, 17 Science, 2 Engineering, 1 Technology)

[a]The number of student surveys reflects the total number of respondents. This differs from the analyzed sample sizes because of missing responses to the questions of interest.

Table 2. Perceptions of rigor and involvement in STEM projects—Student survey.

Rating	Work Hard	Makes Me Think	Use Thinking Skills, Not Memorization	Explain Thinking	Learn a Lot	Correct Mistakes	Academic Rigor Mean—Percentage (Number)	STEM PjBL Activities—Percentage (Number)
Responses	1485	1485	1484	1479	1485	1478	1462	1431
1	2.0% (29)	3.3% (49)	3.2% (47)	1.7% (25)	3.4% (51)	3.1% (46)	1.2% (18)	3.4% (48)
2	2.4% (36)	5.3% (79)	5.2% (77)	3.8% (56)	7.5% (112)	6.8% (100)	2.2% (32)	6.7% (96)
3	5.7% (85)	13.4% (199)	13.3% (198)	9.1% (134)	16.6% (246)	16.6% (246)	12.7% (186)	27.2% (389)
4	27.5% (409)	39.3% (583)	33.8% (501)	35.7% (528)	37.0% (550)	37.9% (560)	40.6% (594)	34.7% (497)
5	59.1% (926)	38.7% (575)	44.5% (661)	49.8% (736)	35.4% (526)	35.6% (526)	43.2% (632)	28.0% (401)

correlation analyses between the rigor and PjBL scales. These correlations were statistically significant but low (Pearson's $r = .226$, $p \leq .001$). We also looked at the relationship descriptively through cross-tabulations of the levels of implementation of rigor and PjBL. As noted above, we recoded the scale scores into levels of "low" implementation, "medium" implementation, and "high" implementation. Table 3 (next page) presents the cross-tabulations.

As the table shows, slightly more than a third of students reported that their school had both high rigor and frequent implementation of projects. Approximately a quarter of respondents indicated that their school had high rigor with moderate frequency of projects, and 16 percent reported that students had medium implementation on both rigor and projects. The chi-square across the cells was statistically significant (95.3, $p \leq .001$).

Although the correlation was relatively low, the cross-tabulations do suggest that when students reported higher implementation of projects they also reported higher perceptions of rigor. For example, 38% of students reported high implementation on both projects and on rigor while less than 10% of students believed that high implementation of projects was not accompanied by high rigor. The converse was not necessarily true, however, because over 30% of respondents saw rigor as high, even when implementation of projects was low or medium. This suggests that projects may have represented rigor in students' minds but that projects did not need to be implemented for students to perceive the presence of rigor. The results do generally indicate that, at least according to students, implementation of projects is usually accompanied by a perception of rigor.

Teacher Perspective. Through online logs, teachers in STEM-oriented schools were asked to document the implementation of a set of lessons over the course of the year (see methodology). On average, teachers reported implementing projects fairly regularly; teachers recorded that their students were "Engaged in problem solving/investigation/experiment" in 42% of their log entries. These reports may not reflect the actual frequency of project implementation because some teachers may have chosen to submit log entries only when they were doing projects, and they may have had different perceptions on what a project was. Nevertheless, this finding does suggest that teachers implemented projects with some regularity. There was a range in teachers' implementation of projects. For example, three teachers reported no projects in any of their log entries and five teachers reported implementing projects in 100% of their log entries.

In general, teachers reported that rigorous instructional activities were a focus of their reported lessons. Table 4 (next page) shows the reported ratings for different indicators of rigorous instruction recorded in the log entries ($N = 298$). It also includes the overall rigor scale, which was calculated as an average of the indicators for each teacher ($N = 33$). As the table shows, teachers were highly likely to report that these specific activities were implemented in their lesson with over 90% of teachers reporting a level 4 or 5.

To examine the relationship between rigor and project implementation, we created a cross-tabulation for rigor and PjBL in Table 5 (next page).

Results show some similar patterns to the student survey. Teachers who reported high implementation of projects also tended to report higher levels of rigor. However, teachers

Table 3. Cross-tabulations for rigor and STEM PjBL—Student survey (*N* = 1430).

			STEM PjBL			Total
			Low	Medium	High	
Academic Rigor	Low	Count	12	13	12	37
		% of total respondents	0.8%	0.9%	0.8%	2.5%
	Medium	Count	53	226	118	397
		% of total respondents	3.7%	15.8%	8.3%	27.8%
	High	Count	79	367	550	996
		% of total respondents	5.5%	25.7%	38.5%	69.7%
	Total	Count	144	606	680	1430
		% of total respondents	10.1%	42.4%	47.6%	100%

Table 4. Frequency of rigorous instructional activities—Teacher logs.

Rating	Opportunities for Discourse	Generate Ideas	Challenging Concepts	Real World Connections	Revisions	Big Ideas	Rigor Scale[a]
1	3.0% (9)	3.0% (9)	2.3% (7)	10.1% (30)	8.1% (24)	2.7% (8)	0
2	3.0% (9)	6.0% (18)	5.0% (15)	11.7% (35)	8.4% (25)	3.7% (11)	3.1% (1)
3	13.8% (41)	15.1% (45)	20.1% (60)	15.1% (45)	20.5% (61)	17.1% (51)	6.3% (2)
4	29.9% (89)	28.2% (84)	31.2% (93)	23.2% (69)	29.2% (87)	35.9% (107)	78.1% (25)
5	50.3% (150)	47.7% (142)	41.3% (123)	39.9% (119)	33.9% (101)	40.3% (120)	12.5% (4)

who reported higher levels of rigor did not necessarily also report higher levels of project implementation. Twenty-five percent of all respondents reported high implementation of projects and high implementation of rigor. Almost as many (19%) reported high implementation of rigor and low implementation of PjBL. This suggests that PjBL is one way that teachers seek to implement rigor in their classrooms but also, not surprisingly, that teachers have other ways in which they might implement rigorous instructional practices.

External observers' perspectives. As shown above, teachers reported relatively high levels of rigor, yet research shows that teachers often overestimate the rigor of their instructional practices (Black & Wiliam, 1998; Bol & Strage, 1996). External observers can provide impartial assessments of classroom activities. As described in the methodology section, the research team observed and rated 39 teachers' classrooms across the 10 schools. These teachers were not always the same ones who completed the logs; however, we are able to look internally within this sample to examine how observers rated the rigor in classrooms relative to the implementation of PjBL. Table 6 (next page) presents the overall ratings; a 0 indicates that the action was not observed during the visit. The scores of 1 through 4 reflect the extent to which that activity was observed during the visit, with 4 being the highest (for purposes of this table, the scale values were rounded).

As the table shows, slightly more than half of the classrooms had students presenting results from a project, and only a third had students working on a project requiring creativity. Across

Table 5. Cross-tabulations for rigor and PjBL—Teacher logs (*N* = 32).

			PjBL			**Total**
			Low	**Medium**	**High**	
Academic Rigor	Low	Count	1	0	0	1
		% of total respondents	3.1%	0.0%	0.0%	3.1%
	Medium	Count	7	2	1	10
		% of total respondents	21.9%	6.3%	3.1%	30.3%
	High	Count	6	7	8	21
		% of total respondents	18.8%	21.9%	25.0%	65.6%
	Total	Count	14	9	9	32
		% of total respondents	43.8%	28.1%	28.1%	100.0%

both measures of project implementation, 46.2 percent of the teachers were doing either of those project-related activities during the observation. Of those that were implementing projects, their ratings were equally distributed between the lower and higher end. Relative to rigor, observers found that the level of rigor ranged substantially. A third of the teachers had low levels of rigor (0 or 1) while approximately half scored in the 2–3 range.

The observation protocol had substantial overlap between the rigor and the PjBL scales so that a high score on the PjBL scale meant that the teacher was implementing PjBL in such a way that they were also likely to receive a high score on the rigor score. As a result, we decided to look at whether a teacher was implementing any type of project at all (regardless of the quality of that project) and the extent to which rigor was also present. We used the same categorizations of low, medium, and high rigor—with low scoring less than 1.5, medium scoring between 1.5 and 3.0, and high scoring 3.0 to 4.0. Table 7 (next page) shows the relationship between project implementation and the rigor rating of that classroom.

The table shows that teachers who were implementing projects scored overall higher on rigor than teachers who were not implementing projects. Only two classes scored high on the rigor scale but did not implement any sort of a project. But the table also shows that three of the classrooms implementing projects scored low (less than 1.5) on the rigor scale. Less than a third of classrooms implementing projects also scored high on the rigor scale.

To further explore what rigor and PjBL look like in action, we include write-ups of two different classrooms: one in which a project was implemented with higher rigor; and one in which a project was implemented with lower rigor.

Implementing a project with high rigor. This Algebra 2 lesson was rated 4 (the highest scale) on both rigor and PjBL and was entirely project-based. Students' assignment was to create a new business in their county. They needed to develop a proposal to the Small Business Administration for a loan and had to meet a set of constraints. They had to produce three different products, one of which was a motorized toy. They were limited to a budget of $500/weekly and 50 hours/week of production time and could only hire five people. Their final presentation needed to include three linear inequalities reflecting the constraints on weekly production costs, time constraints, constraints on employees and a linear equation reflecting the profit on the sale of the products. They also needed to develop a production plan detailing the number of each product to maximize profit and provide an explanation of how the team derived the inequalities or equations. Finally, they needed a marketing brochure or flyer to introduce the business and products. During the class, students were given materials to develop their own mechanized toy, and each group had developed their own solution, including motorized cars, robots, and even a Ferris wheel. In describing the class, the observer wrote:

> Students were at different stages in their development of the mechanized toy, some with designs drawn Online using the 3-D Sketch Up program and some with models of the toy or prototypes. There were students

Table 6. PjBL and rigor ratings—External observations (*N* = 39).

Rating	High Cognitive Demand	Explain or Justify Thinking	Summarize, Synthesize, Generalize	Variety of Means	Apply knowledge	Compare/ Contrast	Rigor Scale	Presenting Results From a Project	Working on a Project Requiring Creativity
0	10.3% (4)	15.4% (6)	23.1% (9)	33.3% (13)	41.0% (16)	35.9% (14)	5.1% (2)	48.7% (19)	66.7% (26)
1	15.4% (6)	15.4% (6)	7.7% (3)	12.8% (5)	10.3% (4)	10.3% (4)	28.2% (11)	5.1% (2)	2.6% (1)
2	28.2% (11)	15.4% (6)	23.1% (9)	15.4% (6)	10.3% (4)	12.8% (5)	20.5% (8)	10.3% (4)	5.1% (2)
3	23.1% (9)	30.8% (12)	28.2% (11)	12.8% (5)	15.4% (6)	23.1% (9)	33.3% (13)	12.8% (5)	10.3% (4)
4	23.1% (9)	23.1% (9)	17.9% (7)	25.6% (10)	23.1% (9)	17.9% (7)	12.8% (5)	23.1% (9)	15.4% (6)

Table 7. Cross-tabulations of implementing a project and Rigor—External observations (*N* = 39).

			No Project	Any Project	Total
Rigor Range	Low	Count	10	3	13
		% of Total	25.6%	7.7%	33.3%
	Medium	Count	6	12	18
		% of Total	15.4%	30.8%	46.2%
	High	Count	2	6	8
		% of Total	5.1%	15.4%	20.5%
Total		Count	18	21	39
		% of Total	46.2%	53.8%	100.0%

in each team working cohesively and concurrently designing their presentation of their three marketable items. Students were also brainstorming solutions to problems they had encountered in developing their 3 items. For example, one team was having a problem with the cardboard being used for their car. It was too flimsy, the wheels not rigid enough to roll. One suggestion was to reinforce the cardboard by making the wheels of two- or three-ply cardboard perhaps by gluing multiple layers. After the first 5 minutes of class, the student teams were working on their own, discussing and asking questions of each other. Rarely did a student ask the teacher a question, instead using the Internet or other resources to answer their own queries. When the teacher was asked a question, the response was usually, "What do you think?" or "Where could you find that?" As I walked around the room from team to team to ascertain what the students were doing, I listened to students as they explained or justified their thinking. The second team was working on a recipe for brownies [as one of their three things to sell]. As I approached, they were discussing their "need to verify" all of their measurements and calculations.

Although one might argue from the description that the content of Algebra II might be suffering at the expense of the project, the observers rated the lesson as a 3 out of 4 on content and wrote that "The teacher discussed the relationships among systems of linear equations, Cramer's Rule and linear programming. The teacher connected the new mathematics information on linear programming to the previous lessons on solving linear equations, linear inequalities and systems of equations."

Implementing a project with low rigor. This earth and environmental science class was implementing a project with a rigor scale score of 1.5. When observed, the class was in the process of finishing films that they were making on natural disasters (earthquakes, hurricanes, tornados, Tsunamis, volcanic eruptions, etc.). Students had been divided into groups and assigned a disaster type that they were supposed to research and then film a public service announcement relative to the disaster. Students used technology for research, writing scripts, filming, and editing. The students were working toward a final product, which was to be a presentation, using the film, made to a panel of community and university experts.

During the majority of the class time, the observer noted that there was no emphasis by the teacher on the content being covered. Instead the teacher gave directions, assisted students with problems that were almost exclusively related to the technology they were using, and reprimanded students. The last 15 minutes of the class were spent reviewing for a test; the teacher had a large blow-up beach ball, which she would toss to a student for an answer after she asked a question. The observer noted that the questions were on the knowledge level. If a student didn't know the answer, the teacher threw the ball to another student with no discussion of the incorrect response the first student had made. When the correct answer was given, she asked another question without clarifying or amplifying on the responses. According to the observer, there were no connections among topics made, and there was no opportunity for questions. The observer summarized the time spent in the classroom as follows:

> This project has the potential to be a meaningful summary (application) of a study of natural disasters. In actuality, the [student] engagement and meaningfulness wasn't apparent. In any given group of 3 or 4, at least two were not on task most of the time. A couple of students were working independently, and they appeared to be more focused in what they were doing. Some students were waiting for the opportunity to leave the room to do additional filming; the teacher suggested they work on their scripts while waiting, but this did not happen. I saw evidence of some narrative being typed on the computer (presumably for the scripts), but, for the most part, the [home page] was on the screens.

This particular classroom shows evidence of a project that had the potential to be a rigorous activity but where the project was being implemented in a less than rigorous manner. It is also possible that the project in this class had been extended over too long a period of time—the teacher indicated that they had been working on this topic all year—leading to lower student engagement.

Discussion

This paper examined the extent to which students, teachers, and observers report high levels of rigor and high levels of project implementation in STEM-oriented schools and the extent to which high levels of project implementation are accompanied by high levels of rigor. The multiple sources of data in this project converge to create a more complete picture of the relationship between projects and rigor, particularly in STEM-oriented schools. Across all three sources, we find many instances of reported high levels of rigor and high levels of project implementation. The findings provide evidence for our conceptual model of PjBL as a specific, applied example of rigorous instruction in the classroom. Across all of the three data sources, reports of higher implementation of PjBL were associated with higher perceptions of rigor. When implemented well, PjBL can provide a structure that can assist teachers in embedding rigor into their instruction. For example, an investigation can be a vehicle for students to engage with complex content over an extended period of time and can provide numerous opportunities for students to engage in higher level thinking. Project presentations can provide students opportunities to explain and justify their thinking.

In some cases, rigor was present in the absence of PjBL. Thus, PjBL appears to provide a strong approach to implementing rigor in the classroom but is not necessary for a rigorous classroom. Teachers can certainly engage students in higher level thinking, problem-solving, and elaborated communication about complex content in the absence of the driving question, extended investigation, and creation of a product that are hallmarks of PjBL.

When implemented to the "gold standard," PjBL should have high levels of rigor. We can consider the observation descriptions in light of advocates' expectations for high quality PjBL. Implemented well, PjBL should include extended authentic investigations through a driving question, collaborative work, use of technology, the creation of artifacts that demonstrate student understanding, allowance for student input and choice, and the opportunity to critique and revise others' work (Buck Institute of Education, 2015; Tal et al., 2006). When we consider the two classrooms described above, we see that both classrooms had extended investigations (creating a business in one, creating a film about natural disasters in the other) although the investigation of the Algebra II class appeared to be more connected to a set of authentic problems that engaged the course content (how to maximize profits given a specific set of constraints). In the environmental class, the investigation was more centered around the creation of a specific project demonstrating knowledge of the content (a public service announcement) but not necessarily solving a specific problem. Both classes incorporated the use of technology, collaborative group work, and the creation of artifacts representing their knowledge. Both classrooms also appeared to be allowing some student choice in terms of the business products they were creating (the Algebra II class) and the content and structure of the film (the environmental class). Opportunity to critique and revise the work could be seen as being embedded in the collaborative group work, although the observers did not record any formal examples of this.

This summary of the two classrooms indicates that, overall, both classrooms could be seen as incorporating almost all of the characteristics of high quality PjBL. What then distinguished the more rigorous and the less rigorous classroom? In the more rigorous classroom, the students were actively engaged in utilizing their content knowledge to answer the driving questions and create their projects. The teacher was also actively engaged in pushing their thinking around these topics. In the less rigorous classroom, the students were not engaged in rich discussion with each other around the content and were not making substantial progress toward their ultimate products; the contributions of the teacher were focused much more on the process and much less on the content or the level of thinking. This is similar to what Han and colleagues (2015) found as they observed some teachers who believed that PjBL meant that they sat to the side and were not involved in supporting student learning. These types of differences were also found in Cook and Weaver's study (2015), where they noted that lower rigor projects emphasized data collection over evaluation and interpretation. Cook and Weaver (2015) also noted that, as we saw in our environmental class, the collaborative group work they observed did not always support rigorous discussion between students

> . . . it ranged from cases where the majority of audible discourse was lacking in substance because it was largely off task or focused on task completion with a heavy emphasis on following procedures or a blend of procedural task without some more substantive evidence focused discussion to a case where the rigor and substance of discourse increased over time as the unit progressed. (p. 26)

Therefore, although PjBL and rigor can reinforce each other, the observational data show that implementation of projects does not guarantee rigor. Observers rated less than one-third of the projects as being implemented with high levels of rigor, a finding echoed elsewhere in the literature (Cook & Weaver, 2015; Han et al., 2015). PjBL advocates agree that too many teachers implement lower-level, "intellectually lightweight" projects (Larmer & Mergendoller, 2010, p. 1) and consider themselves to be doing PjBL. Lower levels of rigor may be present when the project does not engage students in the core content of the discipline or when teachers do not ask students questions that probe their thinking. The observations also show, however, that teachers can implement most of the characteristics of PjBL but not necessarily at a level that is supporting rigor.

A relatively low association between rigor and PjBL may result when teachers implement projects that do not necessarily incorporate all of the characteristics of PjBL. A study specifically designed to examine the relationships between rigor and PjBL could investigate this concept in more depth.

In this study, PjBL and rigor occurred within the context of STEM-oriented schools that did differ in their approaches and had different emphases on PjBL. Although different models had different emphases on PjBL, the quality of PjBL implementation varied more by the individual school than by the model. For example, New Tech is a model in which most PjBL is intended to be the primary mode of instruction (Mosier, Bradley-Levine, & Perkins, 2016). In one New Tech School all of the teachers observed received the highest rating on the PjBL scale. However, the other New Tech School had a range of implementation with one teacher being rated as 3, one as 2, one as a 1, and one not implementing projects at all. Teachers in the other model schools had a variety of ratings, with some doing projects well and others not doing them at all. This suggests that PjBL implementation in some schools may have been more a reflection of the interest/desire of the teacher than a core component of the schools' STEM visions.

This study does include some key limitations that might affect the generalizability of its conclusions. First, the study was not explicitly designed to look at the relationship between PjBL and rigor. As such, the questions and definitions relative to these topics varied somewhat depending on the type of data collected. We might have framed the data collection activities differently if this had been the explicit focus of the study. Nevertheless, the similarity of the general findings indicates that our conclusions are robust enough to withstand slightly different conceptualizations of both PjBL and rigor.

The observations suffer from limitations as well. The protocol was newly developed and its reliability and validity are still being established. Resources allowed for only one observer per classroom. Although the observers received training to align their ratings on the observation scales, different participants might have rated the same event differently. A third limitation is that there was only one observation per classroom; this means that these should be considered as snapshots of instruction and not necessarily as representative of the teachers' entire instructional practice.

The surveys also suffer from limitations. Students were asked about their overall high school experiences, not a specific classroom. Thus, they might have been thinking about different classrooms relative to rigor and to PjBL. This is in contrast to the observations and logs where the data relative to rigor and projects were clearly coming from the same classrooms.

A final limitation is that the self-report data, such as the logs, might suffer from differing understandings of projects and project-based learning. Researchers have shown that teachers have different levels of understanding of project-based learning (Tamim & Grant, 2013); as a result, when teachers report implementation of projects, they may be coming from varying perspectives. An additional focus of inquiry may be to examine the data to understand teachers' different interpretations of projects and PjBL.

Conclusion

This paper adds to the research concerning effective implementation of PjBL by exploring the relationship between PjBL and rigor. While some researchers have explored the concept of rigor as part of a broader exploration of PjBL (Cook & Weaver, 2015; Han et al., 2015), we know of no other articles that have focused specifically on the relationship between the two constructs. In this study, we were able to capitalize on different sources of data including student self-report data, teacher self-report data, and external observations to reach our conclusions. These different sources of data led us to similar conclusions, which strengthen the validity of the findings.

The study shows that PjBL can be a strong approach to use as teachers seek to implement rigor in their classrooms. The study also shows, however, that implementation of projects is not necessarily a guarantee of rigor. This finding has several implications for schools seeking to implement PjBL effectively.

The primary implication is that schools should recognize that high quality PjBL implementation requires that it be implemented with rigor (Buck Institute of Education, 2015). To do this, the content of the projects would need to be complex and reflect core concepts of the discipline (Matsumura, Garnier, Pascal, & Valdes, 2002; Newmann et al., October 1998). Teachers should examine the questioning, problem-solving activities, and tasks in the projects to ensure that they require students to engage in higher level thinking such as analyzing, synthesizing, evaluating, or creating (Krathwohl, 2002). There should also be opportunities embedded throughout the project and during the presentation time to get students to explain and justify their thinking in depth.

Ensuring that rigor is present within PjBL implementation will likely involve engaging teachers in collaborative review of their projects using the lens of rigorous instruction. This type of review of practice has been shown to be one of the most effective strategies to support changes in instructional practice (Huffman, Thomas, & Lawrenz, 2003). Collaborative examination of projects will also allow staff in a school to gain a common understanding of rigorous implementation of PjBL and will help build a collection of high quality PjBL activities upon which teachers can draw. It may also help ensure that more teachers in the school implement projects.

Overall, the data from this study confirm that PjBL can be an effective vehicle for implementing rigor in schools. They also suggest that more work needs to be done in ensuring that PjBL is implemented with the rigor of which it is capable.

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Appendix A: Measures

YouthTruth Survey Questions: Academic Rigor.

	Strongly Disagree		Neither Agree or Disagree		Strongly Agree
In order to receive a good grade, I have to work hard in my classes.	1	2	3	4	5
The work that I do for my classes makes me really think.	1	2	3	4	5
Most of my teachers want us to use our thinking skills, not just memorize things.	1	2	3	4	5
Most of my teachers want me to explain my answers—why I think what I think.	1	2	3	4	5
In most of my classes, we learn a lot almost every day.	1	2	3	4	5
In most of my classes, we learn to correct our mistakes.	1	2	3	4	5

Project-Based Learning Questions.

	Never	Rarely	Sometimes	Frequently	Very Frequently
Participated in hands-on group projects that involve building or designing	1	2	3	4	5
Worked with a group to design a solution to a problem	1	2	3	4	5

Teacher Log Entry

Note: Bold questions are those selected for inclusion in the rigor scale.

This particular lesson	1 no	2	3 somewhat	4	5 yes
resulted in active participation by all					
contained embedded opportunities for discourse					
encouraged students to generate ideas					
included challenging concepts					
encouraged collaboration					
made real-world connections					
included scaffolded questions/prompts					
allowed for revisions					
focused on “big” ideas					
increased students’ confidence					
excited my students					

Observation Rigor Scale: Student Cognitive Engagement in Meaningful Instruction

Select one from scale: 0 = not observed to 4 = very descriptive of the observation.

Students experienced high cognitive demand in activities because teacher did not reduce cognitive demand of activities by providing directive hints, explaining strategies, or providing solutions to problems before students had a chance to explore them, etc.	(0) ☐	(1) ☐	(2) ☐	(3) ☐	(4) ☐
Students were asked to explain or justify their thinking.	(0) ☐	(1) ☐	(2) ☐	(3) ☐	(4) ☐
Students were given opportunities to summarize, synthesize, and generalize.	(0) ☐	(1) ☐	(2) ☐	(3) ☐	(4) ☐
Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.	(0) ☐	(1) ☐	(2) ☐	(3) ☐	(4) ☐
Students were asked to apply knowledge to a novel situation.	(0) ☐	(1) ☐	(2) ☐	(3) ☐	(4) ☐
Students were asked to compare/contrast different answers, different solutions, or different explanations/interpretations to a problem or phenomena.	(0) ☐	(1) ☐	(2) ☐	(3) ☐	(4) ☐
Summary: Quality of student cognitive engagement in meaningful instruction.					

Record specific examples below.

Observations: Project-Based Learning Indicators

Select one from scale: 0 = not observed to 4 = very descriptive of the observation. NA = not applicable to activity being observed (since projects may not occur in every lesson).

Students worked on a project requiring creativity.	(0) ☐	(1) ☐	(2) ☐	(3) ☐	(4) ☐	NA ☐
Students had to present or explain results of project.	(0) ☐	(1) ☐	(2) ☐	(3) ☐	(4) ☐	NA ☐

Record specific examples below.