

REL Pacific Ask A REL Response

Curriculum and Instruction, Math
November 2021

Question:

What does research say about how project-based learning is related to student learning in math?

Response:

Following an established REL Pacific search protocol, we conducted a web-based search for resources related to project-based learning in math (see Methods section for search terms and resource selection criteria). We first prioritized studies in the Pacific and other Indigenous contexts for greater relevancy to our partners in the Pacific region; however, we included studies with more generalizable findings due to the limited amount of research available in these contexts.

References are listed in alphabetical order, not necessarily in order of relevance. Descriptions of the resources are quoted directly from the publication abstracts. We have not evaluated the quality of references and the resources provided in this response. We offer them only for your reference. Also, our search included the most commonly used research resources, but they are not comprehensive and other relevant references and resources may exist.

Research References

Boaler, J. (1998). Open and closed mathematics: Student experiences and understandings. *Journal for Research in Mathematics Education*, 29(1), 41–62. <https://eric.ed.gov/?id=EJ558834>; full text available at <https://www.semanticscholar.org/paper/8032a8dc58e2f878bc8f3fb12812075c2d66471a>

From the abstract: “Reports on three-year case studies of two schools using alternative mathematical teaching approaches. One used the traditional textbook approach and the other used open-ended activities at all times. Concludes that students who followed a traditional approach developed a procedural knowledge, while students who learned mathematics in an open project-based environment developed a conceptual understanding.”

Cervantes, B., Hemmer, L., & Kouzekanani, K. (2015). The impact of project-based learning on minority student achievement: Implications for school redesign. *Education Leadership Review of Doctoral Research*, 2(2), 50–66. <https://eric.ed.gov/?id=EJ1105713>

From the abstract: “Project-Based Learning (PBL) serves as an instructional approach to classroom teaching and learning that is designed to engage students in the investigation of real-world problems to create meaningful and relevant educational experiences. The causal-comparative study compared 7th and 8th students who had utilized the PBL with a comparison group in which PBL was nonexistent. Using outcome measures of academic achievement in mathematics and reading, multivariate and univariate analyses of the data showed that the PBL groups performed at a higher achievement level than did the non-PBL students. Theoretical and practical implications are discussed.”

Craig, T. T., & Marshall, J. (2019). Effect of project-based learning on high school students' state-mandated, standardized math and science exam performance. *Journal of Research in Science Teaching*, 56(10), 1461–1488. <https://eric.ed.gov/?id=EJ1233981>

From the abstract: "In a technologically driven society, math and science students in the United States are falling further and further behind their international counterparts, resulting in an influx of STEM focused, reformed K–12 schools, including schools focused on project-based learning (PBL). This article reports a study of the effectiveness of PBL on high school students' performance on state mandated standardized mathematics and science achievement measures. Manor New Tech High School is a nationally recognized model STEM school, with a diverse student population, where all instruction is delivered through PBL. Although there is ample research suggesting that PBL is advantageous for increasing STEM learning compared to conventional teaching approaches, there is a lack of studies randomly assigning students to receive PBL. Further, some of the effects observed for students attending project-based schools could be due to a self-selection bias for students or parents that choose such an alternative learning environment. This study addresses both of these concerns and found that students taught through PBL, as a group, matched performance of conventionally taught students on all science 11th grade and mathematics 9th, 10th, and 11th grade TAKS achievement measures and exceeded performance by a scale score increase of 133 for the 10th grade science TAKS measure by ($B = 133.082$, $t = 3.102$, $p < 0.05$). One possible explanation of the differences observed in this study could be the TAKS instrument used to capture student math and science achievement that interprets 'real-life applications' of content differently between math and science questions. These results align with literature on the effects of PBL and deepen our understanding of these effects by providing a controlled study with random assignments to the PBL experience. Future research looking at the effect of PBL on achievement on the PISA could be beneficial in identifying benefits of PBL implementation in schools."

Han, S., Capraro, R., & Capraro, M. M. (2015). How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: The impact of student factors on achievement. *International Journal of Science and Mathematics Education*, 13(5), 1089–1113. <https://eric.ed.gov/?id=EJ1074282>; full text available at <https://www.researchgate.net/publication/271658486>

From the abstract: "The purpose of this study was to investigate whether participating in science, technology, engineering, and mathematics (STEM) project-based learning (PBL) activities effected students who had varied performance levels and to what extent students' individual factors influenced their mathematics achievement. STEM PBL has been a critical challenge to be embedded in schools, thus the effect of STEM PBL should...be examined. Teachers in 3 high schools attended sustained professional developments provided by 1 STEM center based in a Southwestern university and were required to implement STEM PBLs once in every 6 weeks for 3 years (2008 through 2010). The participants were 836 high school students in these 3 schools who took the Texas Assessment of Knowledge and Skills (TAKS) test and had scores at least in the initial year. Hierarchical linear modeling was used to analyze the data using student's mathematics TAKS scores and demographic information for the longitudinal study. STEM PBL instruction influenced student achievement in mathematics by both student demographic backgrounds and performance levels. Low performing students showed statistically significantly higher growth rates on mathematics scores than high and middle performing students over the 3 years. In addition, students' ethnicity and economic status were good predictors of academic achievement. Results of the present study implied that STEM PBLs in schools benefitted low performing students to a greater extent and decreased the achievement gap."

Han, S., Capraro, R. M., & Capraro, M. M. (2016). How science, technology, engineering, and mathematics project based learning affects high-need students in the U.S. *Learning and Individual Differences, 51*, 157–166. <https://www.sciencedirect.com/science/article/abs/pii/S1041608016301960>

From the abstract: “The purpose of this study was to investigate how science, technology, engineering, and mathematics (STEM) project based learning (PBL) affected high-need students in the United States (U.S.) in terms of their academic achievement. Among high-need students in the U.S., we focused on two student groups: Hispanic and at-risk students. The participants included 528 students in the three STEM PBL high schools and 2688 students in non-STEM PBL schools in the same region. Approximately 71% of the participants were Hispanic, at-risk, or Hispanic and at-risk. Latent growth modeling with repeated measures was used to analyze the data. The data were mathematics tests from 2008 to 2010 of the Texas Assessment of Knowledge and Skills. STEM PBL instruction positively influenced Hispanic students’ achievement in mathematics, but not at-risk students. The findings of this study imply that curriculum integrating STEM PBL may help Hispanic students having language and cultural differences improve communication and collaboration skills in classrooms.”

Note: REL Pacific was unable to locate a free link to the full-text version of this resource. Although REL Pacific tries to provide publicly available resources whenever possible, this resource may be of sufficient interest to the reader to warrant finding it through university or public library systems.

Holmes, V. L., & Hwang, Y. (2016). Exploring the effects of project-based learning in secondary mathematics education. *The Journal of Educational Research, 109*(5), 449–463. <https://eric.ed.gov/?id=EJ1105442>

From the abstract: “This mixed-method, longitudinal study investigated the benefits of project-based learning (PBL) on secondary-mathematics students’ academic skill development and motivated strategies for learning (i.e., cognitive, social, and motivational). The focus of this study was academic skill development (algebra- and geometry-assessment scores) and other factors related to secondary mathematics learning, with comparable traditional high schoolers serving as the control group. In addition, the relationship between PBL and racially/ethnically and economically diverse secondary students was investigated. Results showed that at-risk and minority students benefited greatly from PBL in learning mathematics. The academic performance gap was present, but its width diminished significantly. Compared to their public school counterparts, PBL students were more intrinsically motivated, showed significantly higher critical thinking skills, and appreciated peer learning. Impact of socioeconomic status on the PBL approach needs further investigation.”

Jenkins, J. (2016). *The effectiveness of project-based learning on mathematics proficiency with African American students*. (Publication No. 10601874) [Doctoral dissertation, Mercer University]. ProQuest Dissertations & Theses Global. <https://eric.ed.gov/?id=ED578461>

From the abstract: “This sequential exploratory mixed methods study addressed the problem of low academic achievement in mathematics, specifically for African American middle school students who historically score below proficient levels on standardized mathematics assessments. The purpose was to investigate the effectiveness of the Project-Based Learning (PBL) approach on African American students’ academic achievement, and to determine what factors, if any, impact African American students’ motivation during PBL mathematics. Eight sixth-grade students from a private school in the southeastern United States, identified as performing below proficient level in mathematics, participated in this study. Data collection included two focus group interviews, a six-

week PBL mathematics unit, classroom observations, and a pre-and post-benchmark assessment. The quantitative results indicated that on average, the students performing below proficient level significantly improved their performance from the pre-test to the posttest. However, their scores were significantly lower than the students who historically performed at math proficient levels, and the PBL unit did little to close the achievement gap. The qualitative data suggest three factors, student perceived level of rigor of the mathematics assignments, the nature of the peer-to-peer interactions, and the presence of classroom-based student activities that the students perceived to be fun and valuable, impact the students' motivation in PBL. Recommendations for future research include studies of long term impacts on mathematics academic achievement and motivation when students are immersed in PBL over longer periods of time and studies comparing students' mathematics scores on the SAT or ACT that completed PBL instruction opposed to more traditional methods."

Viro, E., & Joutsenlahti, J. (2020). Learning mathematics by project work in secondary school. *LUMAT: International Journal on Math, Science and Technology Education*, 8(1), 107–132. <https://eric.ed.gov/?id=EJ1272252>

From the abstract: "In project-based learning, pupils have two central learning objectives: to understand the content of the subject and to develop their twenty-first-century skills. This article concerns the use of project work in mathematics learning, considered here in the context of the Finnish national core curriculum, mathematical proficiency, and pupils' previous level of attainment. The research consisted of two case studies in which a coordinate system project and a statistics project were tested with secondary school pupils (N=59+58). The main findings show it is possible to study the mathematics of the curriculum and to develop all types of mathematical proficiency using project work. Additionally, the pupils' grades on the project work correlate positively with their overall grades in mathematics."

Yancy, Y. G. (2012). *The effects of project-based learning activities on intrinsic motivation and skill acquisition of rural middle school math students*. [Doctoral dissertation, Union University]. ProQuest Dissertations & Theses Global. <https://eric.ed.gov/?id=ED548160>

From the abstract: "This study was conducted in a middle school math class and investigated the effects of project-based activities on the middle school math students' skill acquisition and intrinsic motivation. After math-related project activities were implemented and completed, an analysis of how the students were affected in the areas of math skills and motivation was conducted. The study involved a rural school district in South Mississippi. The participants were asked to complete a pretest and posttest using The Motivated Strategies for Learning Questionnaire (MSLQ) and a math test that focused on objectives for that academic period. These data were collected by the cooperating teacher after a 12-week treatment period. A one-way Analysis of Variance (ANOVA) was used to analyze the scores from the math pretest and posttest. The paired-sample t-test and the independent sample t-test were used to evaluate the MSLQ results and to identify if significant changes in the participants' motivation and skill acquisition existed. The control and experimental groups were randomly selected by the cooperating teacher. In analyzing the experimental group's results from the MSLQ questionnaire, the research showed no significant change in the intrinsic motivation of the participants. In contrast, when gender results of the experimental group were analyzed, the female participants' scores increased slightly on two of the sections of the MSLQ, while the scores of the males stayed about the same on two of the sections. On the intrinsic goal orientation and self-efficacy for learning sections of the MSLQ, the pretest and posttest scores of the male participants remained the same, while their scores on the task value pretest decreased slightly

on the posttest. For the female students, the pretest scores increased on both the intrinsic goal and the task value section. On the self-efficacy for learning and performance section the scores for the females decreased slightly on the posttest. When the score from the math test created by the researcher and cooperating teacher was analyzed, the alternative hypotheses were accepted, that participating in the math-project activities did slightly improve both male and female students' scores."

Additional Resources to Consult

Ask A REL Mid-Atlantic at Mathematica. (2019). *How is project-based learning used in a range of subject-matter classrooms (English, social studies, STEM, etc.)?*

https://ies.ed.gov/ncee/edlabs/regions/midatlantic/askarel_80.asp

Ask A REL Mid-Atlantic at Mathematica. (2018). *What does the research say about project-based learning (PBL) for improving and assessing student learning in elementary school?*

https://ies.ed.gov/ncee/edlabs/regions/midatlantic/askarel_78.asp

Condliffe, B. (2017). *Project-based learning: A literature review. Working paper.* MDRC.

<https://eric.ed.gov/?id=ED578933>

Additional Organizations to Consult

Buck Institute for Education's PBLWorks: <http://www.bie.org/>

From the website: "At PBLWorks, we build the capacity of teachers to design and facilitate quality Project Based Learning and the capacity of school and system leaders to set the conditions for teachers to implement great projects with all students. ... At the Buck Institute for Education (BIE), our highest priority is to help teachers prepare students for successful lives. We do this by showing teachers how to use Project Based Learning in all grade levels and subject areas. As a mission-driven nonprofit organization, BIE creates, gathers, and shares high-quality PBL instructional practices and products and provides highly effective services to teachers, schools, and districts."

George Lucas Educational Foundation's Edutopia – Project-based Learning Page:

<https://www.edutopia.org/project-based-learning>

From the website: "The George Lucas Educational Foundation is a nonprofit, nonpartisan, private foundation that is operated for educational purposes, and, as such, we do not take positions on any legislation or ballot measures, nor do we endorse or oppose any candidates in elections to public office. We welcome all who are devoted to improving education. ... Edutopia is a trusted source shining a spotlight on what works in education. We show people how they can adopt or adapt best practices, and we tell stories of innovation and continuous learning in the real world."

Methods

Keywords and Search Strings

The following keywords and search strings were used to search the reference databases and other sources:

- “Project-based learning” AND math
- "Project-based learning" AND mathematics
- "Project-based learning" AND math -science
- Project-based math
- Project-based mathematics

Databases and Resources

We searched ERIC, a free online library of more than 1.6 million citations of education research sponsored by the Institute of Education Sciences, for relevant resources. Additionally, we searched the following academic databases: JSTOR, Google Scholar, the commercial search engine Google, and the Institute of Education Sciences website.

Reference Search and Selection Criteria

REL Pacific searched ERIC and other academic journal databases for studies that were published in English-language, peer-reviewed research journals within the last 10 years. We made one exception for Boaler (1998), as it is a seminal study highly cited (Google scholar citation count as of 10/18/21: 1109) in research examining project-based learning in math. Sources included in this document were last accessed in September 2021.

REL Pacific prioritized documents that are accessible online and publicly available, and prioritized references that provide practical information based on peer-reviewed research for the educators and education system leaders who requested this Ask A REL.¹ For questions with small or nonexistent research bases, we may rely on, for example, white papers, guides, reviews in non-peer-reviewed journals, interviews with content specialists, and organization websites. For example, given the dearth of research on project-based learning in math, we included relevant non-peer-reviewed dissertations. Additional methodological priorities/considerations given in the review and selection of the references were:

- Study types—randomized control trials, quasi experiments, surveys, descriptive data analyses, literature reviews, etc.
- Target population, sample size, study duration, etc.
- Limitations, generalizability of the findings and conclusions, etc.

¹ This memorandum is one in a series of quick-turnaround responses to specific questions posed by education stakeholders in the Pacific Region (American Samoa, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia, Guam, Hawai'i, the Republic of the Marshall Islands, and the Republic of Palau), which is served by the Regional Educational Laboratory (REL Pacific) at McREL International. This memorandum was prepared by REL Pacific under a contract with the U.S. Department of Education's Institute of Education Sciences (IES), Contract ED-IES-17-C-0010, administered by McREL International. Its content does not necessarily reflect the views or policies of IES or the U.S. Department of Education, nor does mention of trade names, commercial products, or organizations imply endorsement by the U.S. Government.