PBL BRIEF #1

WPI

Project-Based Learning in Minority-Serving Institutions

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Briefer Brief

- Project-based learning (PBL) has been demonstrated to be equally effective (Laursen et al., 2011; Corkin, Horn, & Pattison, 2017) and, in some studies, more effective (Han, Capraro, & Capraro, 2015; Mehalik, Doppelt, & Schuun, 2008) at increasing student learning with underrepresented minority students as it is with White and Asian students.
- PBL has been found to be more appealing to underrepresented minority students than traditional lecture-based courses (Dierker et al., 2015), which can increase student engagement.
- For minority-serving institutions with open admissions policies, PBL has been demonstrated to improve students' motivation to succeed and boost students' self-efficacy (Corkin, Horn, & Pattison, 2017; Schaffer, Chen, Zhu, & Oakes, 2012), which translates into learning gains.
- In team-based PBL, low achievers can benefit from working with high achievers, as low achievers access the knowledge of high achievers, gain encouragement and efficacy to meet learning objectives (Slavin, 1991, 1995; Laursen et al., 2011; Donovan, Connell, & Grunspan, 2018).
- PBL requires students to engage in self-regulated learning, which can be a challenge for low achievers and may hinder their ability to effectively collaborate during planning and execution of collaborative projects (English & Kintsantas, 2013).
- The quality of interactions among group members during projects has a greater impact on learning than arranging groups according to students' prior achievement (Cheg, Lam, & Chan, 2008).

Introduction

Experiential, inquiry-based pedagogies[1], including project-based learning (PBL), have gained traction in higher education in the United States. Yet underrepresented minority students[2] are less likely to experience PBL through learning opportunities such as undergraduate research experiences, internships, and field experiences than their White peers.[3] Proposing PBL as a means of leveling the playing field can raise questions about how best to serve academically vulnerable student populations. For Minority-Serving Institutions, the mission and student populations served deserve thoughtful attention when choosing pedagogical and curricular approaches. More than half of all Minority-Serving Institutions have open-access policies in which college applicants are not denied admission based on prior academic achievement; this results in a disproportionate need for providing developmental education.[4] In contrast, many of the most highly visible proponents of PBL are selective institutions primarily serving disproportionately advantaged student populations.[5] Given these contrasting contexts between those arguing for greater PBL in higher education and the objectives of Minority-Serving Institutions, questions about the transferability of PBL and its positive outcomes for students may arise.

Although proponents of PBL are often situated within relatively privileged institutions, there is evidence that the pedagogies and curricula of PBL benefit the students who enroll in Minority-Serving Institutions. At its best, PBL involves authentic opportunities to engage in real-world problem-solving, often with and for stakeholders with real consequences.[6] Underrepresented minority students often find the community-facing aspect of PBL appealing.[7] In this brief, the research regarding the effectiveness of PBL for Minority-Serving Institution contexts is reviewed.[8,9] The research brief begins with literature on the effectiveness of PBL with underrepresented minority students. With the increased need for developmental education at Minority-Serving Institutions, the brief also describes the

effectiveness of PBL with low academic performers. Finally, we summarize trends from case studies on the use of PBL in Minority-Serving Institutions as a guide to further reading.

Effectiveness of PBL with Underrepresented Minority Students

The evidence regarding the effectiveness of PBL with underrepresented minority students is mixed. In many studies, PBL has been found to be equally effective at increasing student learning with underrepresented minority students as it is with White and Asian students. For example, learning gains associated with an inquiry-based mathematics course did not vary by race/ethnicity in the four universities evaluated by Laursen and colleagues (2011). There were no effects of race/ethnicity in Corkin, Horn, and Pattison's (2017) models of the significant effects of active learning on introductory biology students' motivation, interest, and perceptions of classroom climate. Such studies conclude that students of all racial/ethnic backgrounds experience similar learning gains during educational experiences that use PBL. While underrepresented minority students in these studies benefited from PBL, there was no additional benefit above and beyond that experienced by their White and Asian peers.

While many studies in higher education are conducted within single institutions, studies of secondary students offer additional evidence across institutions, some with longitudinal designs.[10] Such studies often find that while PBL might not eradicate equity gaps, it can diminish the differences in learning gains across underrepresented minority students and their White and Asian peers. Han, Capraro, and Capraro (2015) conducted a study of 836 students in three Texas high schools with regular PBL in mathematics and science classes and 1,054 students matched from non-PBL schools. In this longitudinal study, they found that Hispanic students who regularly experienced PBL in mathematics and science classes experienced greater growth in mathematics performance than students of other races/ethnicities. In schools not using PBL, there were no differences across Hispanic and non-Hispanic students. Because the researchers used propensity matching techniques and hierarchical linear modeling, these comparisons control for several possible confounding factors, including performance level and socioeconomic status.

In another study, Mehalik, Doppelt, and Schuun (2008) found that project-based learning pedagogies that allow students to design and test new knowledge as they solve problems does a better job of closing equity gaps than scripted inquiry similar to that used in traditional science labs. The researchers compared student learning gains in 26 science classes using PBL with 587 middle school students taught by 10 teachers with learning gains in 20 science classes with 466 middle school students taught by 5 teachers in the same urban public school district. African American students who participated in PBL science lessons experienced eight times more learning than those whose science lessons used a scripted inquiry approach. African American students in the PBL group demonstrated significantly greater gains on pre-/post-lesson science tests of the concepts taught, as compared to non-African American students in the scripted inquiry group. However, the equity gap remained, with non-African American students in the PBL group demonstrating greater learning gains than African American students.

The effectiveness of PBL with underrepresented minority students compared to their White and Asian peers is mixed across studies. However, the preponderance of evidence suggests that PBL is at least as effective for underrepresented minority students and may, in fact, be a better pedagogical approach than traditional lecture and other teacher-centered approaches. Given the value of PBL, it is interesting to note that PBL is more appealing to underrepresented minority students than traditional lecture-based courses. Dierker and colleagues (2015) examined enrollment patterns for a multidisciplinary, project-based introductory statistics course designed with the explicit goal of increasing access for students underrepresented in STEM, as compared with a traditional lecture-based course. Offered between 2009 and 2014 at a selective liberal arts college, their analysis of 450 students self-selecting into the PBL course and 344 students self-selecting into the traditional course suggests that PBL can open access to underrepresented minority students. Freshman and sophomore Black students were more likely to enroll in the PBL version of the course than into a traditional statistics course, even after controlling for several other factors. Additionally, the PBL course attracted undergraduate minority students with significantly lower math SAT scores than the traditional statistics course; among White and Asian students, there were no differences in math SAT scores across PBL and traditional versions of the course.

Effectiveness of PBL with Low Academic Performers

With missions of serving students historically undereducated by the schooling systems of the U.S., Minority-Serving Institutions disproportionately educate students in need of developmental education. The research on whether and how PBL impacts student learning among low academic performers is therefore relevant for understanding its promise for Minority-Serving Institutions. Research in this area demonstrates that PBL provides great value to low academic performers. There is growing confidence among educational researchers that PBL improves motivation to succeed and boosts student self-efficacy,[11] which translate into learning gains.

Historically, educational researchers have debated how best to structure groups during cooperative learning[12] —a common arrangement during PBL—to best influence motivation and self-efficacy for all group members. On one side, educators have argued that low achievers benefit from working with high achievers, as low achievers can access the knowledge of high achievers, gain encouragement and efficacy to meet learning objectives.[13] For example, Laursen and colleagues (2011) evaluated the impact of inquiry-based learning in mathematics courses for students at four universities (three public and one private) hosting IBL Mathematics Centers supported by the Educational Advancement Foundation. On average, students in inquiry-based learning classes spent more than 60% of class time on student-centered activities that were problem-based, collaborative, and applied to real-life applications; those in non-inquiry-based classes spent 87% of their time listening to instructors talk. Undergraduate students with the lowest scores on a pre-test of math skills benefited the most from inquiry-based learning. Students with a low GPA (2.5 or below) who took an inquiry-based math class saw greater gains in grades for subsequent required courses than those who took math classes with traditional instruction. Students with fewer college math courses experienced greater gains in learning than those with more experience in college math going into inquiry-based math classes.

On the other side of the group composition debate, some researchers have questioned whether group work benefits high achievers. Researchers have pointed out that PBL requires students to engage in self-regulated learning, which can be a challenge for some students[14] and can influence how well they engage others while planning and executing projects. Some studies have found that assigning students to heterogeneous groups with both low achievers and high achievers actually hinders the progress of high achievers.[15] A meta-analysis by Lou and colleagues (1996) assessed 20 findings from 12 studies and found that low achievers performed better in heterogeneous groups, whereas high achievers performed equally well in either homogeneous or heterogeneous groups.

Using multilevel modeling, Donovan, Connell, and Grunspan (2018) found that low achievers had higher learning outcomes when working in groups with both low achievers and high achievers in a large-enrollment, student-centered biology class for nonmajors than high achievers; high achievers performed equally well in heterogeneous and homogenous groups. However, they also tested the effect of three methods of group formation with nonmajors in a large-enrollment, student-centered biology class for nonmajors. In this study, 302 students in two class sections were sorted into a set of groups maximizing heterogeneity and another set of groups maximizing homogeneity based on mastery of key concepts. In a third and fourth section, 356 students were assigned to groups maximizing heterogeneity based on GPA and a set of self-reported demographics. In a fifth section, 170 students were allowed to self-select into groups. Students in groups assigned to maximize heterogeneity—by both sets of metrics—had the highest achievement in the course. Both low achievers and high achievers reported more positive attitudes toward group work when they had heterogeneous groups regardless of how their groups were formed.

One way of re-interpreting the issue of group composition is to ask whether some other aspect of students' learning context better explain why high achievers sometimes report lower quality experiences than their low-achiever teammates. Cheng, Lam, and Chan (2008) examined group processes, self-efficacy, college efficacy, and student achievement of 1,921 Hong Kong secondary students working in 367 PBL teams to determine the role of group work processes in mediating the contribution of group composition to student learning. Using hierarchical linear modeling to analyze students within their teams, the researchers found that the quality of group processes was the most salient factor in determining students' learning efficacy for both low achievers and high achievers—not group composition.

Furthermore, when faced with low-quality group processes, Cheng and colleagues found that high achievers reported lower collective efficacy than low achievers. High achievers recognized and reported lower confidence in the group when there were poor quality processes than did their low achiever teammates. Together, these findings suggest that attending to the quality of interactions among group members during projects has a greater impact on learning than investing time in arranging groups according to students' prior achievement. Doing so might also mitigate previously found negative consequences of the group work frequently used in PBL for high achievers placed on teams with low achievers.

Case Studies of Project-Based Learning at Minority-Serving Institutions

There are several case studies of PBL curricula and pedagogy describing implementation and associated outcomes at individual institutions (see Table 1). Many Minority-Serving Institutions reporting on their experiences situate their decision to use PBL explicitly within their missions to provide opportunities for their students to succeed. PBL is also frequently situated within and alongside multiple student-centered learning strategies, such as electronic portfolios and simulation. We suggest these case studies as further reading. The details these articles provide on their own institutional contexts, the PBL strategies implemented, and their corresponding outcomes may provide additional inspiration and practical knowledge.

Table 1. Case Studies of Project-Based Learning in Minority-Serving Institutions

Citation	Institutional Context	PBL Practices Studied
Bosman, L. B., Chelberg, K. L., & Fernhaber, S. A. (2017). Introduction to engineering: A constructivist-based approach to encourage engagement and promote accessibility. *Global Journal of Engineering Education, 19*(3), 237-242.	A baccalaureate Minority-Serving Institution in the Midwest	An assignment in an Introduction to Engineering course that has students create a fictional book series that introduces young readers to engineering fields
Bray, N. J., Johnson, S., Katsinas, S. G., & Shadduck, P. (2019). Course revision in introductory STEM courses: An exploratory study at an HBCU community college. *Community College Journal of Research and Practice, 43*(7), 481-493.	A community college Historically Black College & University	Professional development of faculty in the natural sciences to expand their strategies related to WestEd's Reading Apprenticeship program
Chen, P., Hernandez, A., & Dong, J. (2015). Impact of collaborative project-based learning on self-efficacy of urban minority students in engineering. *Journal of Urban Learning Teaching and Research, 11,* 26-39.	California State University, Los Angeles, a public Hispanic-Serving Institution	An undergraduate senior-level computer networking class using collaborative project-based learning to increase students' self-efficacy
Ellins, K. K., & Olson, H. C. (2012). Enhancing geoscience education within a minority-serving preservice teacher population. *Journal of Geoscience Education, 60,* 34-44.	The University of Texas at Austin & the Huston-Tillotson University, an Historically Black College & University	Redesign of a special topics course in geosciences for preservice middle and high school science teachers and STEM majors with an emphasis on guided-inquiry and project-based learning
Jackson, K. M., & Winfield, L. L. (2014). Realigning the crooked room: Spelman claims a space for African American women in *STEM. Peer Review, 16*(2), 9-12.	Spelman College, a highly selective private liberal arts Historically Black College & University	The Spelman MILE for STEM undergraduates, which combines liberal arts curriculum with active learning high-impact practices
Jung, H. B., Zamora, F., & Duzgoren-Aydin, N. S. (2017). Water quality monitoring of an urban estuary and a coastal aquifer using field kits and meters: A community-based environmental research project. *Journal of Chemical Education, 94,* 1512-1516.	New Jersey City University, a public baccalaureate Hispanic-Serving Institution	Summer research in water resources for URM students in an NSF-funded LSAMP program
Sieg, R. D., Beverly, N., Narayanan, M., Surendran, G., Sabatini, J., & Smyth, D. S. (2019). Incubating the SENCER ideals with project-based learning and undergraduate research: Perspectives from two liberal arts institutions. *Science Education & Civic Engagement, 11*(1), 50-63.	Mercy College, a private Hispanic-Serving Institution, & Young Harris College	College- and department-wide curricular and pedagogical efforts to support student success and retention in STEM majors using high-impact practices and project-based learning
Urizar, G. G., Henriques, L., Chun, C.-A., Buonora, P., Vu, K.-P. L., Galvez, G., & Kingsford, L. (2017). Advancing research opportunities and promoting pathways in graduate education: A systemic approach to BUILD training at California State University, Long Beach (CSULB). *BMC Proceedings, 11*(Suppl 12), 26-40.	California State University, Long Beach, a public baccalaureate Hispanic-Serving Institution	A large-scale, multidisciplinary research infrastructure for underrepresented groups of graduate students funded by the National Institutes of Health Building Infrastructure Leading to Diversity (BUILD) Initiative
Yilmaz, M., Ozcelik, S., Yilmazer, N., & Nekovei, R. (2012). A two-semester project-based robotics curriculum. In *American Society for Engineering Education.* American Society for Engineering Education; Yilmaz, M., Ozcelik, S., Yilmazer, N., & Nekovei, R. (2013). Design-oriented enhanced robotics curriculum. IEEE Transactions on Education, 56(1), 137-144; Yilmaz, M. (2016). A computer design and assembly active learning project. In *International Conference Frontiers in Education: Computer Science and Computer Engineering,* 129-135.	The Frank H. Dotterweich College of Engineering at Texas A&M University-Kingsville, a public Hispanic-Serving Institution	Transformation of a traditional lecture format 2-course robotics curriculum into hands-on design experiences, with a national design competition & mentoring components

Notes

[1] Hart Research Associates. (2016). *Recent trends in general education design, learning outcomes, and teaching approaches.* Washington, DC: Association of American Colleges and Universities; Wurdinger, S., & Allison, P. (2017). Faculty perceptions and use of experiential learning in higher education. *Journal of e-Learning and Knowledge Society, 13*(1).

[2] We use the National Research Foundation's term "underrepresented minority student" to reference Black, Latinx, and Indigenous students.

[3] National Survey of Student Engagement. (2018). *Engagement insights: Survey findings on the quality of undergraduate education – annual results 2018.* Bloomington, IN: Indiana University Center for Postsecondary Research.

[4] Bustillos, L. T. (2012). *Rethinking remedial education: The role of MSIs in serving under-prepared students in the 21st century.* Washington, DC: Institute for Higher Education Policy.

[5] Olin College of Engineering, which also uses a project-based learning curriculum, is highly selective, with the middle 50% of its class entering in Fall 2017 scoring between 1470 and 1560 on combined SAT (97th to 100th percentile, nationally). Worcester Polytechnic Institute, which requires several project-based learning experiences for all students and provides an annual Institute of Project-Based Learning in collaboration with the Association of American Colleges and Universities, is ranked "more selective." The middle 50% of the class entering in Fall 2019 had a combined SAT score ranging from 1310 to 1480 (81st to 99th percentile, nationally). Aalborg University in Denmark is an internationally-recognized proponent of its PBL model which, while focused on problem-based learning instead of project-based learning, has become well-known in higher education. The university was ranked #4 in the world within the field of Engineering in 2018 according to US News World Ranking. A certificate program in project-based learning are offered at the University of Pennsylvania's School of Education, which is consistently ranked one of the top graduate schools of education in the country.

[6] Thomas, J. W. (2000). *A review of research on project-based learning.* San Rafael, CA: The Autodesk Foundation.

[7] Mallinson, C. (2018). Technology-enhanced project-based learning: A platform for graduate student research and outreach on campus and in the community. *Journal of English Linguistics, 46*(3), 229-245.

[8] For information on the methods of the literature review for this brief, please contact Dr. Kimberly LeChasseur at the Center for Project-Based Learning, Worcester Polytechnic Institute at kalechasseur@wpi.edu.

[9] Because the definitions of institution types varies widely across time and studies, we use the broad focus on Minority-Serving Institutions to include Historically Black Colleges and Universities, Hispanic-Serving Institutions, Tribal Colleges and Universities, and other institutions with explicit missions, policies, and practices focused on educating Black, Latinx, Indigenous, and other non-White students. See Cunningham, A., Park, E., & Engle, J. (2014). *Minority-serving institutions: Doing more with less.* Lumina Foundation.

[10] Chen and Yang's (2019) meta-analysis of PBL effects found that students' education level is not a significant moderator, suggesting that the effects found with secondary students are also likely to be recreated with tertiary students. See Chen, C.-H., & Yang, Y.-C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educational Research Review, 26*, 71-81.

[11] Corkin, D. M., Horn, C., & Pattison, D. (2017). The effects of an active learning intervention in biology on college students' classroom motivational climate perceptions, motivation, and achievement. *Educational Psychology, 37*(9), 1106-1124; Schaffer, S. P., Chen, X., Zhu, X., & Oakes, W. C. (2012). Self-efficacy for cross-disciplinary learning in project-based teams. *Journal of Engineering Education, 101*, 82-94.

[12] See Lou, Y., Abrami, P. C., Spence, J. C., Poulsen, C., Chambers, B., & d'Apolonia, S. (1996). Within-class grouping: A meta-analysis. *Review of Educational Research, 66,* 423-458; Lou, Y., Abrami, P. C., & Spence, J. C. (2000) Effects of within-class grouping on student achievement: An exploratory model. *Journal of Educational Research, 94,* 101-112; Cheng, R. W-y., Lam, S.-f. L., & Chan, J. C.-y. (2008). When high achievers and low achievers work in the same group: The roles of group heterogeneity and processes in project-based learning. *British Journal of Educational Psychology, 78,* 205-221.

[13] Slavin, R. E. (1991); Are cooperative learning and untracking harmful to the gifted? *Educational Leadership, 48,* 68-71; Slavin, R. E. (1995). *Cooperative learning: Theory, research, and practice* (2nd ed.). Boston: Allyn & Bacon.

[14] English, M. C., & Kintsantas, A. (2013). Supporting student self-regulated learning in problem- and project-based learning. *Interdisciplinary Journal of Problem-Based Learning, 7(2),* 6.

[15] See Robinson, A. (1990). Cooperation and exploitation? The argument against cooperative learning for talented students. *Journal for the Education of the Gifted, 14,* 9-27; Fuchs, L. S., Fuchs, D., Hamlett, C. L., & Karns, K. (1998). High-achieving students' interactions and performance on complex mathematical tasks as a function of homogeneous and heterogeneous pairings. *American Educational Research Journal, 35,* 227-267; Hooper, S., & Hannafin, M. J. (1991). The effects of group composition on achievement, interaction, and learning efficiency during computer-based cooperative instruction. Educational Technology, *Research and Development, 39,* 27-40.

Works Cited

Bosman, L. B., Chelberg, K. L., & Fernhaber, S. A. (2017). Introduction to engineering: A constructivist-based approach to encourage engagement and promote accessibility. *Global Journal of Engineering Education, 19*(3), 237-242.

Bray, N. J., Johnson, S., Katsinas, S. G., & Shadduck, P. (2019). Course revision in introductory STEM courses: An exploratory study at an HBCU community college. *Community College Journal of Research and Practice, 43*(7), 481-493.

Chen, P., Hernandez, A., & Dong, J. (2015). Impact of collaborative project-based learning on self-efficacy of urban minority students in engineering. *Journal of Urban Learning Teaching and Research, 11,* 26-39.

Cheng, R. W.-y., Lam, S.-f., & Chan, J. C.-y. (2008). When high achievers and low achievers work in the same group: The roles of group heterogeneity and processes in project-based learning. *British Journal of Educational Psychology, 78,* 205-221.

Corkin, D. M., Horn, C., & Pattison, D. (2017). The effects of an active learning intervention in biology on college students' classroom motivational climate perceptions, motivation, and achievement. *Educational Psychology, 37*(9), 1106-1124.

Dierker, L., Cooper, J., Selya, A., Alexander, J., & Rose, J. (2015). Evaluating access: Comparing enrollment patterns in traditi onal versus multidisciplinary, project-based introductory statistics courses. *Journal of Interdisciplinary Studies in Education, 4*(1), 22-37.

Donovan, D. A., Connell, G. L., & Grunspan, D. Z. (2018). Student Learning Outcomes and Attitudes Using Three Methods of Group Formation in a Nonmajors Biology Class. *CBE—Life Sciences Education, 17*(4), ar60.

D'Souza, M. J., Kroen, W. K., Stephens, C. B., & Kashmar, R. J. (2015). Strategies and initiatives that revitalize Wesley College STEM programs. *Journal of College Teaching and Learning, 12*(3), 195-208.

Ellins, K. K., & Olson, H. C. (2012). Enhancing geoscience education within a minority-serving preservice teacher population. *Journal of Geoscience Education, 60,* 34-44.

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,* 1089-113.

Jackson, K. M., & Winfield, L. L. (2014). Realigning the crooked room: Spelman claims a space for African American women in STEM. *Peer Review, 16*(2), 9-12.

Jung, H. B., Zamora, F., & Duzgoren-Aydin, N. S. (2017). Water quality monitoring of an urban estuary and a coastal aquifer using field kits and meters: A community-based environmental research project. *Journal of Chemical Education, 94,* 1512-1516.

Laursen, S., Hassi, M. L., Kogan, M., Hunter, A. B., & Weston, T. (2011). *Evaluation of the IBL mathematics project: Student and instructor outcomes of inquiry-based learning in college mathematics.* Boulder, CO: University of Colorado Boulder.

Lou, Y., Abrami, P. C., Spence, J. C., Poulsen, C., Chambers, B., & d'Apollnia, S. (1996). Within-class grouping: A meta-analysis. *Review of Educational Research, 66,* 423-458.

Mehalik, M. M., Doppelt, Y., & Schuun, C. D. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education, 97*(1), 71-85.

Sieg, R. D., Beverly, N., Narayanan, M., Surendran, G., Sabatini, J., & Smyth, D. S. (2019). Incubating the SENCER ideals with project-based learning and undergraduate research: Perspectives from two liberal arts institutions. *Science Education & Civic Engagement, 11*(1), 50-63.

Urizar, G. G., Henriques, L., Chun, C.-A., Buonora, P., Vu, K.-P. L., Galvez, G., & Kingsford, L. (2017). Advancing research opportunities and promoting pathways in graduate education: A systemic approach to BUILD training at California State University, Long Beach (CSULB). *BMC Proceedings, 11*(Suppl 12), 26-40.

Yilmaz, M., Ozcelik, S., Yilmazer, N., & Nekovei, R. (2012). A two-semester project-based robotics curriculum. In *American Society for Engineering Education.* American Society for Engineering Education.

Yilmaz, M., Ozcelik, S., Yilmazer, N., & Nekovei, R. (2013). Design-oriented enhanced robotics curriculum. IEEE Transactions on Education, 56(1), 137-144.

Yilmaz, M. (2016). A computer design and assembly active learning project. In *International Conference Frontiers in Education: Computer Science and Computer Engineering,* 129-135.

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