PBL BRIEF #9.0 SERIES
WPI ALUMNI SURVEY FINDINGS

9.5 Building Students Self-Efficacy Through Project-Based Learning

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Briefer Brief

- Among undergraduate students, self-efficacy has been determined to be a powerful driver of several outcomes, such as academic achievement (Yusuf, 2011; Schneider & Preckel, 2017), persistence to degree (Larson, et al., 2015), and preparation for graduate school (Cardona, 2013; Tate, et al., 2015) and careers (Wright, Jenkins-Guarnieri, & Murdock, 2013; Stajkovic & Luthans, 1998).
- The majority of alumni in a recent study at Worcester Polytechnic Institute (WPI) indicated that their project experiences increased their self-efficacy.
- Self-efficacy played a major role in increasing all learning outcomes examined, including both the development of technical knowledge and professional skills, such as teamwork and communications skills.
- Alumni indicated their project experiences afforded them self-efficacy appraisals along each of Bandura's four types (i.e., performance accomplishment, vicarious experiences, verbal persuasion, and physiological cues), though performance accomplishment was most frequently discussed.

Introduction

One of the ways project-based learning is particularly powerful is through its ability to improve students' self-efficacy.[1] Similar to self-confidence, self-efficacy is the extent to which we believe we can do something.[2] Self-efficacy plays an important role in how well we learn: those who already believe they are good at learning or at a particular topic being studied are able to learn more efficiently and more effectively. Among undergraduate students, self-efficacy has been determined to be an indirect driver of several outcomes, such as academic achievement[3], persistence to degree[4], and preparation to succeed in graduate school[5] and careers.[6]

Much has been studied about the role of self-efficacy in learning[7] and there is a wealth of evidence that project-based learning (PBL) can boost self-efficacy.[8] The research in this brief describes findings of an alumni study of Worcester Polytechnic Institute's multi-project graduation requirements. The first section describes evidence that PBL can be particularly supportive of developing self-efficacy. The brief then summarizes how self-efficacy can be boosted through PBL. The final section describes how the study was conducted.

The Role of Self-Efficacy in Learning Outcomes

Self-efficacy is influential in learning because of its role in motivation, which in turn influences student behaviors.[9] For undergraduate students, regulating motivation becomes particularly meaningful as students make the transition from a more prescriptive learning environment in secondary schooling to a highly ambiguous and student-driven learning environment in college. Those who translate failure into personal deficiencies are more likely to become immobilized with stress and to choose not to tackle difficult unknown paths.[10] In other words, sense of self-efficacy can act as a self-reifying loop that either strengthens undergraduate students' successes over time or leads them into downward spirals.

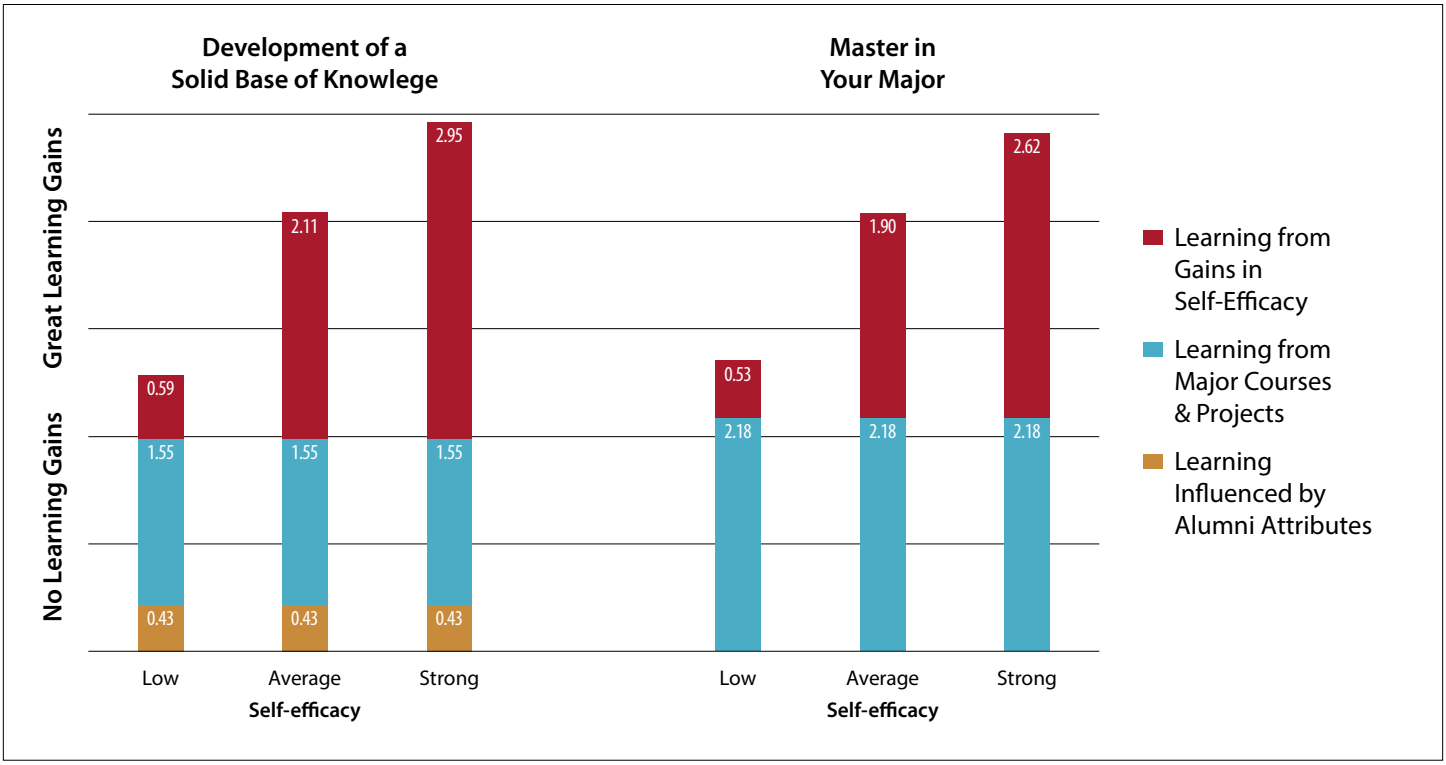
At WPI, analyses in an alumni survey indicate that the extent to which students have developed self-efficacy plays a large role in their growth across learning outcomes. Technical knowledge, which was captured in the survey through two items, approximately doubles when students gain a strong sense of self-efficacy compared to those who report little

to no gains in self-efficacy (see Figure 1). This was assessed using multiple hierarchical regression modeling to isolate the relative influence of self-efficacy compared to course experiences after controlling for student demographics and response bias.

When we compare the average experiences reported by alumni, the learning that is attributable to course experiences in the major, the proportion of courses using projects, and the learning gained from major projects required for graduation taken together is approximately the same or even slightly less than the learning attributable to gains students experience in their self-efficacy.

This holds for both technical knowledge (see Figure 1) and professional skills, like identifying problems and synthesizing information from multiple sources (see Figure 2), as well as teamwork and communication skills (see Figures 2 & 3). The role of self-efficacy is even larger for developing cross-cultural skills, mattering far more than classroom and project-based experiences alone (see Figure 3). Self-efficacy can therefore be thought of as an amplifier of learning activities that faculty design to support learning of this knowledge and these skills.

Figure 1. Impact of Various Levels of Self-Efficacy on Learning Technical Knowledge



Boosting Self-Efficacy through PBL

PBL is often touted as a way to develop students' professional skills while teaching content.[11] One of the ways it does this is through giving students ownership over their own learning.[12] This, in turn, allows students to determine that they are capable of doing difficult work to develop new knowledge and skills. A study of alumni from Worcester Polytechnic Institute in 2021 found that 94% of respondents indicated that their project experiences moderately to very much increased their ability to take responsibility for their own learning; between 77% and 88% of alumni also indicated that projects increased other aspects of their self-efficacy (see Figure 4).

Figure 2. Impact of Various Levels of Self-Efficacy on Learning Professional Skills

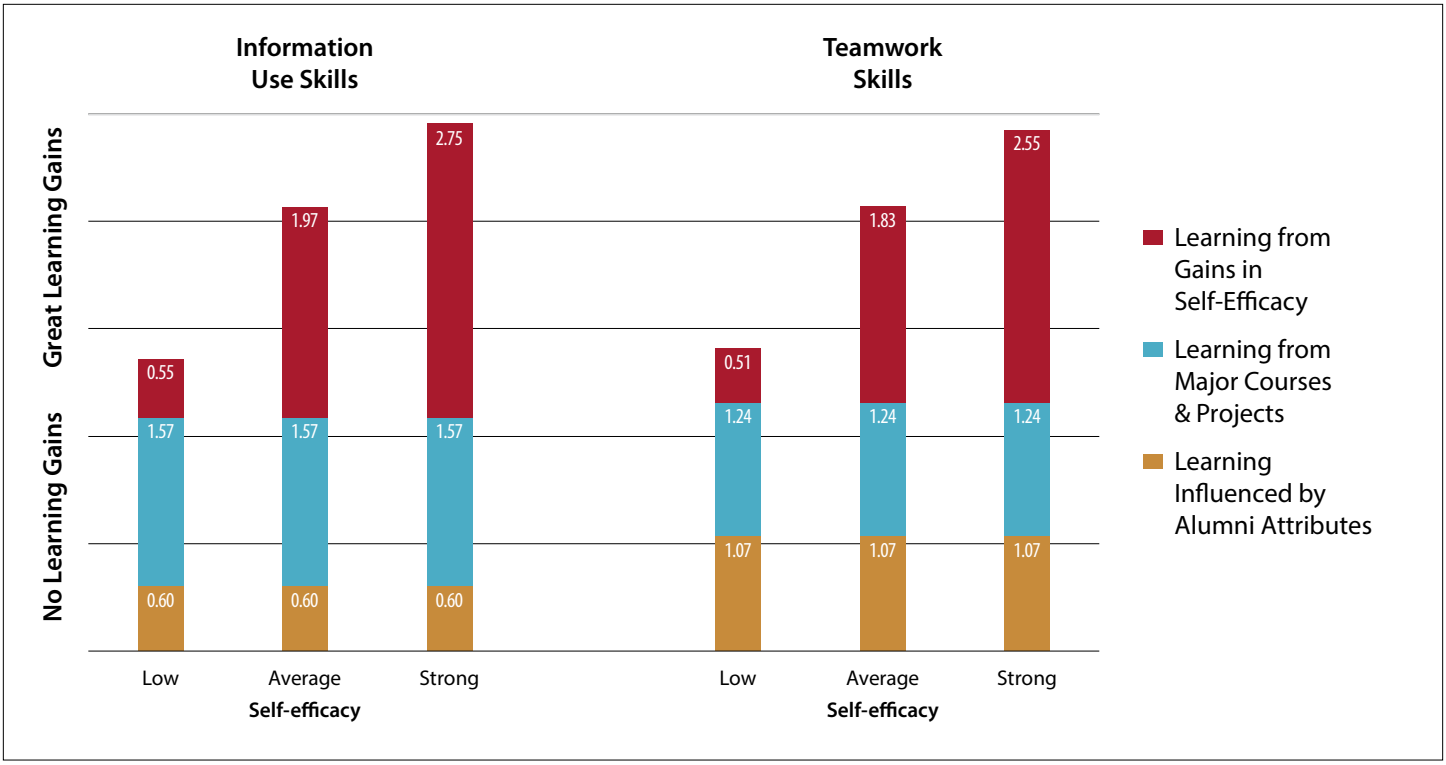


Figure 3. Impact of Various Levels of Self-Efficacy on Learning Professional Skills

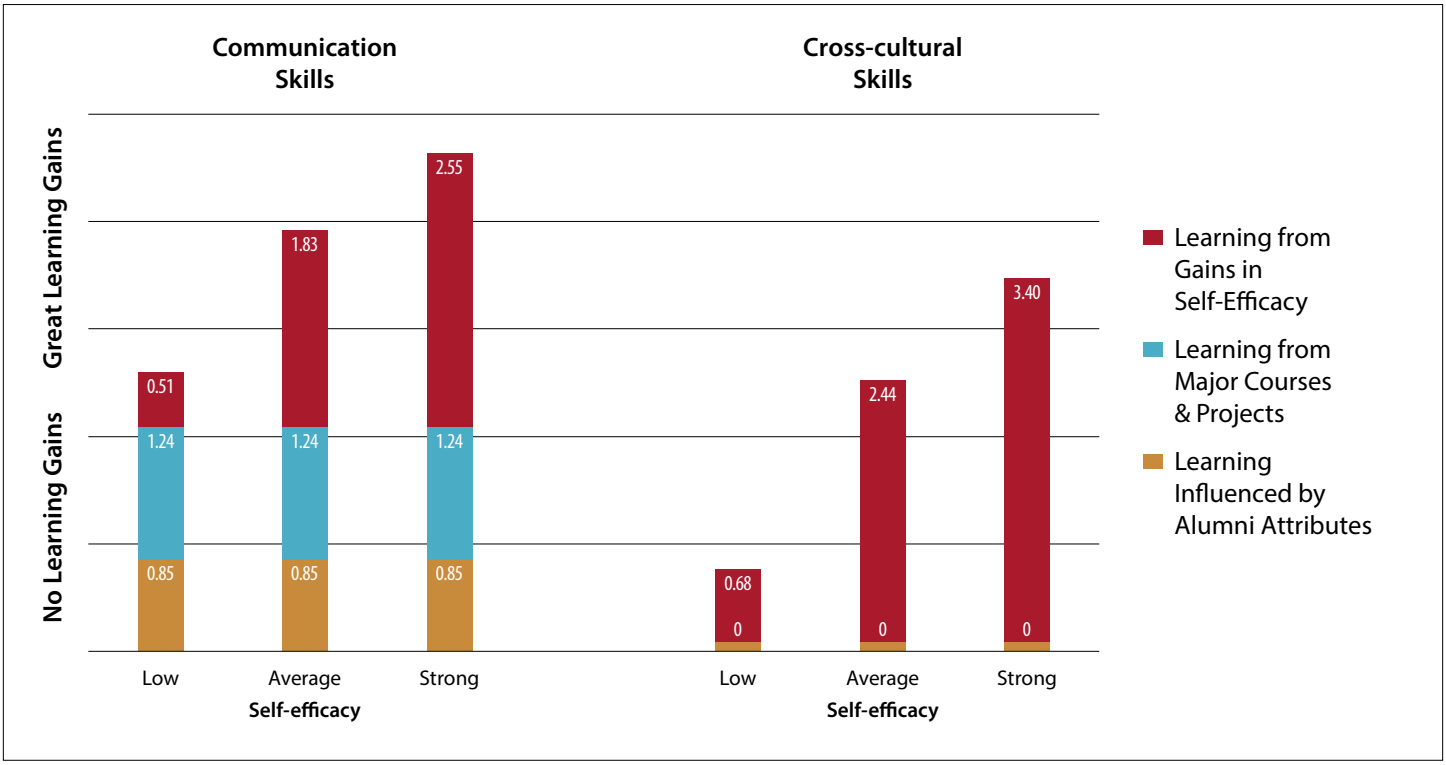
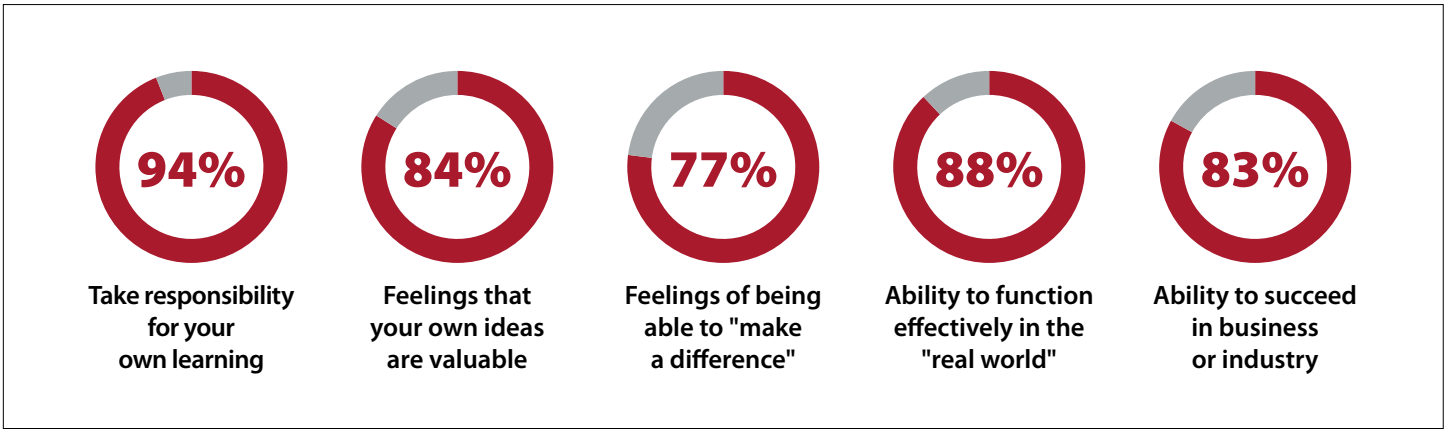


Figure 4. Percentage of Alumni Indicating Aspects of Self-efficacy Increased with Project Work



Projects can build self-efficacy through each of the major mechanisms that influence it. According to Bandura (1977) and robust research using his self-efficacy theory[13], there are four ways that people receive information that impacts their sense of self-efficacy, called self-efficacy appraisals. The first perhaps is the most familiar and the easiest to see at work during projects: performance accomplishment. When people have a track record of having accomplished something in the past, they know that it is possible or even likely that they will succeed with similar tasks again before they even begin. Many alumni in the study recounted how their accomplishments during their projects at WPI developed their belief in their own skills, such as one Applied Mathematics major from the Class of 1996, who stated,

> Working hard during my [capstone project] and delivering published documentation of the results really improved my self confidence that I could deliver results and have impact in a real-world environment. (white man)

And an Electrical Engineering major from the Class of 1988, who shared,

> Both my [projects] involved a lot of work and presented challenges. Overcoming those challenges provided me with confidence and a work ethic I have carried with me through my career. (BIPOC man)

A second type of self-efficacy appraisal comes through vicarious experiences. This was the mechanism noted least often by our alumni in this study, though some still did note how important it could be to see others like themselves succeed. When discussing their humanities and arts project, an alumnus shared, "I gained a lot of self-confidence through theater [projects]. I met people like me who enjoyed the same things I did." *(Class of 2006, Chemistry and Biochemistry Major, white woman)* Another woman who graduated earlier in WPI's PBL history described how much being surrounded by other women mattered to her self-efficacy and learning:

> The WPI experience was the beginning of being a woman in a man's work world. Ironically my IQP was with female students, a female professor, and a female teacher. My MQP was also with women students but a male professor. He was great. To have those projects as all male would not have helped me grow. *(Class of 1989, Civil Engineering major, white woman)*

While this kind of vicarious experience might also be available in more teacher-driven, lecture-based learning experiences, projects can be used to emphasize the contributions of team members to reach goals. Making those who are least visible more accessible to others like them can diversify which types of experiences are more readily available to influence students' beliefs that people like them can succeed.

Third, verbal persuasion can be an important self-efficacy appraisal. Projects that are guided by faculty as coaches and advisors rather than experts allow students whose self-efficacy needs to be developed to get regular encouragement. Alumni often pointed to this role of faculty advisors in their recollection of what stood out the most for them during their projects at WPI. One alumnus shared, "Our team's relationship with our advisor was such a great experience that it has informed the way I work with

junior employees, promote their work, and encourage the expansion of their careers." *(Class of 1994, Electrical Engineering major, BIPOC man)* Although the alumnus does not describe the verbal persuasion in detail, it is clearly referenced as being empowering of this individual.

Another alumnus offered a similar experience:

> Our advisor … pushed us to be great—technically, writing, the local impact—to each other, with other professors, and with staff and administration. He encouraged our novel idea, and that has stayed with me to continue to push forward on new ideas even if tradition has been in another direction. *(Class of 2008, Civil Engineering major, white woman)*

The final type of self-efficacy appraisal takes place as people check in with their physical sensations of stress and readiness. Although not often referenced directly in the alumni survey, this mechanism appears to be provided through the intense presentation demands on students. High-quality PBL involves public products and, at WPI, these often take the form of presentations to project sponsors. As one representative alumni shared,

> My IQP included an intense presentation component. We had government officials up and down the ranks attend our final presentation. It was known that we were influencing decision makers. The level of scrutiny to every word written, how it was spoken, and the subtleties of the story being told was extremely high. Pushing through the countless revisions and rehearsals made me a much better writer, presenter, and ultimately adopted the same high bar or excellence in my future work. It is what I now promote and pass down to those I work with to raise their level of performance. *(Class of 2005, Electrical & Computer Engineering major, white man)*

Projects that leverage real-world problems and engage students in highly authentic work can offer opportunities to practice the kinds of high-stakes work that might feel intensely uncomfortable at first, becoming less so over time.

Discussion and Future Research

Our analyses suggest one lever for increasing student learning that is particularly effective is to help them improve their self-efficacy. This can be done through PBL by offering students opportunities to tackle difficult, ambiguous tasks and building a series of accomplishments that demonstrate they are capable of future success. One area for future work is to better understand how to disrupt the negative loop when students who begin a project with low self-efficacy experience failure.[14] How do we better support students in that moment to keep them from turning this into further evidence of their lack of ability?

This need to break through the reinforcing loops of students' self-efficacy points to the potential promise of multiple projects. PBL affords opportunities for students to increase their self-efficacy, as demonstrated here. Undergraduate students who have their autonomy supported, as happens in high-quality PBL, demonstrate greater academic success; however, this relationship is mediated by their sense of self-efficacy.[15] This suggests that PBL can be part of a reinforcing loop that increases self-efficacy, which in turn further amplifies its impact on students in the future.

At WPI, all students are required to complete multiple projects, with stronger doses of PBL contributing to stronger outcomes (see Research Brief 9.3 PBL at Scale: Developing Skills and Knowledge Through Multiple Projects and Research Brief 9.4 PBL at Scale: The Long-term Impact of Multiple Projects on Careers). Students who experience setbacks might benefit greatly from quickly moving into another opportunity to succeed. Social learning theory suggests that students with low self-efficacy might not make this choice on their own. Programs and institutions of higher education can provide the structures to make this happen even when students are unable or unwilling to choose it for themselves. Additional research into how multiple project experiences benefit students might explore this further.

The WPI Alumni Study

WPI conducted an alumni survey of its signature PBL offerings in 2021. A survey with closed- and open-response items was emailed to 15,528 alumni who graduated from WPI between 1980 and 2019. Data were collected through Qualtrics. One reminder was sent one week after the original invitation to participate to alumni who had not yet submitted a response.

Of those invited, 2,236 alumni responded, yielding a low—but typical—response rate of 14%. The sample included in the analyses presented here includes 61% men, 39% women, and less than one percent non-binary or gender-fluid alumni. The majority of respondents were white (89%), 6% identified as Asian, 4% identified as Hispanic/Latino (any race), 1% identified as Black/African American

or African, and 1% identified as Middle Eastern or North African. Within the sample, 62% were engineering majors, 35% were science majors, and 3% majored in other subjects, such as business or social sciences, without also earning a science or engineering degree. These characteristics reveal a sample that is largely representative of alumni demographics within these years. (Women students are slightly overrepresented and non-binary and gender-fluid students are underrepresented).

Notes

[1] Shin, M. H. (2018). Effects of Project-Based Learning on Students' Motivation and Self-Efficacy. English teaching, 73(1), 95-114; Bilgin, I., Karakuyu, Y., & Ay, Y. (2015). The effects of project based learning on undergraduate students' achievement and self-efficacy beliefs towards science teaching. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(3), 469-477; 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.

[2] Schunk, D. H., & DiBenedetto, M. K. (2016). Self-efficacy theory in education. In *Handbook of motivation at school* (pp. 34-54). Routledge.

[3] Yusuf, M. (2011). The impact of self-efficacy, achievement motivation, and self-regulated learning strategies on students' academic achievement. *Procedia-Social and Behavioral Sciences, 15*, 2623-2626; Schneider, M., & Preckel, F. (2017). Variables associated with achievement in higher education: A systematic review of meta-analyses. *Psychological bulletin, 143*(6), 565.

[4] Larson, L. M., Pesch, K. M., Surapaneni, S., Bonitz, V. S., Wu, T. F., & Werbel, J. D. (2015). Predicting graduation: The role of mathematics/science self-efficacy. *Journal of Career Assessment, 23*(3), 399-409.

[5] Cardona, J. J. (2013). *Determined to Succeed: Motivation Towards Doctoral Degree Completion* (Doctoral dissertation); Tate, K. A., Fouad, N. A., Marks, L. R., Young, G., Guzman, E., & Williams, E. G. (2015). Underrepresented first-generation, low-income college students' pursuit of a graduate education: Investigating the influence of self-efficacy, coping efficacy, and family influence. *Journal of Career Assessment, 23*(3), 427-441.

[6] Wright, S. L., Jenkins-Guarnieri, M. A., & Murdock, J. L. (2013). Career development among first-year college students: College self-efficacy, student persistence, and academic success. *Journal of Career Development, 40*(4), 292-310; Stajkovic, A. D., & Luthans, F. (1998). Self-efficacy and work-related performance: A meta-analysis. *Psychological bulletin, 124*(2), 240.

[7] Huang, C. (2013). Gender differences in academic self-efficacy: A meta-analysis. *European journal of psychology of education, 28*, 1-35; Panadero, E., Jonsson, A., & Botella, J. (2017). Effects of self-assessment on self-regulated learning and self-efficacy: Four meta-analyses. *Educational research review, 22*, 74-98.

[8] Shin, M. H. (2018). Effects of Project-Based Learning on Students' Motivation and Self-Efficacy. *English teaching, 73*(1), 95-114; Bilgin, I., Karakuyu, Y., & Ay, Y. (2015). The effects of project based learning on undergraduate students' achievement and self-efficacy beliefs towards science teaching. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(3), 469-477; 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.

[9] Bandura, A. (1982). Self-efficacy mechanism in human agency. *American psychologist, 37*(2), 122-147.

[10] Komarraju, M., & Nadler, D. (2013). Self-efficacy and academic achievement: Why do implicit beliefs, goals, and effort regulation matter?. *Learning and individual differences, 25*, 67-72; Honicke, T., & Broadbent, J. (2016). The influence of academic self-efficacy on academic performance: A systematic review. *Educational research review, 17*, 63-84.

[11] De los Ríos-Carmenado, I. G. N. A. C. I. O., Lopez, F. R., & Garcia, C. P. (2015). Promoting professional project management skills in engineering higher education: Project-based learning (PBL) strategy. *International journal of engineering education, 31*(1), 184-198; Fernandes, S. R. G. (2014). Preparing graduates for professional practice: findings from a case study of Project-based Learning (PBL). *Procedia-Social and Behavioral Sciences, 139*, 219-226; Muliyati, D., Bakri, F., Siswoyo, S., Ambarwulan, D., Septyaningrum, L. D., Budi, A. S., & Fitriani, W. (2020, April). The implementation of project-based learning to enhance the technological-content-knowledge for pre-service physics teacher in ICT courses. In *Journal of Physics: Conference Series* (Vol. 1521, No. 2, p. 022023). IOP Publishing; Spires, H. A., Himes, M. P., & Krupa, E. (2022). Supporting students' science content knowledge and motivation through Project-Based Inquiry (PBI) Global in a cross-school collaboration. *Education Sciences, 12*(6), 412.

[12] English, M. C., & Kitsantas, A. (2013). Supporting student self-regulated learning in problem-and project-based learning. *Interdisciplinary journal of problem-based learning, 7*(2), 6.

[13] Sheu, H. B., Lent, R. W., Miller, M. J., Penn, L. T., Cusick, M. E., & Truong, N. N. (2018). Sources of self-efficacy and outcome expectations in science, technology, engineering, and mathematics domains: A meta-analysis. *Journal of Vocational Behavior, 109*, 118-136.

[14] Chan, E., & Yang, N. (2018). Failing to Learn: Practical techniques for using failure as an active learning trigger for science and engineering education (IRSPBL 2018). In *7 th International Research Symposium on PBL* (p. 237).

[15] Gutiérrez, M., & Tomás, J. M. (2019). The role of perceived autonomy support in predicting university students' academic success mediated by academic self-efficacy and school engagement. *Educational Psychology, 39*(6), 729-748.

Works Cited

Cardona, J. J. (2013). *Determined to Succeed: Motivation Towards Doctoral Degree Completion* (Doctoral dissertation).

Larson, L. M., Pesch, K. M., Surapaneni, S., Bonitz, V. S., Wu, T. F., & Werbel, J. D. (2015). Predicting graduation: The role of mathematics/science self-efficacy. *Journal of Career Assessment, 23*(3), 399-409.

Schneider, M., & Preckel, F. (2017). Variables associated with achievement in higher education: A systematic review of meta-analyses. *Psychological bulletin, 143*(6), 565.

Tate, K. A., Fouad, N. A., Marks, L. R., Young, G., Guzman, E., & Williams, E. G. (2015). Underrepresented first-generation, low-income college students' pursuit of a graduate education: Investigating the influence of self-efficacy, coping efficacy, and family influence. *Journal of Career Assessment, 23*(3), 427-441.

Wright, S. L., Jenkins-Guarnieri, M. A., & Murdock, J. L. (2013). Career development among first-year college students: College self-efficacy, student persistence, and academic success. *Journal of Career Development, 40*(4), 292-310.

Yusuf, M. (2011). The impact of self-efficacy, achievement motivation, and self-regulated learning strategies on students' academic achievement. *Procedia-Social and Behavioral Sciences, 15*, 2623-2626.

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