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META-ANALYSIS OF THE EFFECTIVENESS OF PROJECT-BASED LEARNING APPROACH ON ACADEMIC ACHIEVEMENT IN HIGHER EDUCATION WORLDWIDE

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META-ANALYSIS OF THE EFFECTIVENESS OF PROJECT-BASED LEARNING APPROACH ON ACADEMIC ACHIEVEMENT IN HIGHER EDUCATION WORLDWIDE

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Abstract

This research study conducted a meta-analysis to integrate the studies that investigated the effectiveness of project-based learning on academic achievement based on a worldwide higher-education population. The researcher explored the variables that previous meta-analysis studies used to evaluate academic achievements, such as student grade point average (GPA), course grades, and test scores, to explore the use of these variables in project-based learning. There were 17 studies in total included in the meta-analysis evaluating the effect size of academic achievement, which was influenced in moderator variable by subject-matter areas, school location, hours of instruction, technology support, and group size.

The researcher calculated Cohen's *d* to measure the effect sizes to investigate the standardized mean difference between the means of two groups and converted it to Hedges's *g* for an unbiased effect size estimate. The average effect size of 17 articles is 1.64, with a standard error of 0.42. The 95% confidence interval (CI) is (1.56, 1.72). Hence zero is not in the CI, indicating that the average effect size is statistically significant at the .05 level. The research result concluded that project-based learning had a very large effect size on improving student academic achievement in higher education worldwide. Moderator analyses were conducted for Study Design, Conditions, and Institution Type. These analyses were different with statistically significant at .05 level, contributing to the heterogeneity of effect sizes. As the five moderator variables, technology support had a positive effect on improving student academic achievement. There was a difference between an individual or 2-5 students group size and STEM or non-STEM subject-matter areas, effecting project-based learning. Studies from the Southeastern countries had the most effective results of using project-based learning in higher education. To

analyze the effect of the instructional hours of project-based learning per week, the dissertation researcher needed more data. Two or fewer instructional hours, however, were more effective than the other groups.

In addition to the moderator analyses, additional analyses were performed, investigating the year of publication, study limitations, and sample sizes. All three of these variables contributed to the heterogeneity of the effect sizes as they were statistically significant. Two groupings of the year of publication were assessed for differences using the analysis of variance assuming a fixed effects model. The two groupings of the year of publication, 2011 to 2017 and 2018 to 2020, yielded statistically significant differences. 2011 to 2017 had fewer studies and a very large average effect size. Study limitations were coded as one, two, three, four, or more. Three and four were combined, as there was only one study with four or more limitations. The largest average effect size was for those studies with two limitations, followed by the one-limitation and the two-limitations category. The largest average effect size was for the largest sample-size grouping and that grouping's confidence interval did not overlap with the two smaller sample-size groupings.

This dissertation, written under the direction of the candidate's dissertation committee and approved by the members of the committee, has been presented to and accepted by the Faculty of the School of Education in partial fulfillment of the requirements for the degree of Doctor of Education. The content and research methodologies presented in this work represent the work of the candidate alone.

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CHAPTER I

INTRODUCTION OF PROBLEM

Project-based learning is a widely used instructional strategy in higher education (Chen et al, 2019). During the study, the researcher noted the implementation of project-based learning across various classrooms, including courses on business, education, and technology education. Given the extent of usage of project-based learning, it is vital to further review its benefits within higher education. To what extent is project-based learning helpful with students in colleges? Is it helpful with improving students' achievements compared with traditional lecture learning? The purpose of this study is to understand project-based learning and try to evaluate its effectiveness on student academic achievement. This study also investigated other influencing variables that effected project-based learning across prior experiments.

As a curriculum and as an instruction approach, project-based learning has been used since the 1980s. Prior research across disciplines indicates that project-based learning effective in raising the quality of instruction, and enables students to use the knowledge and skills they learned to solve real-world problems (Condliffe et al., 2017; Guo et al., 2020; Iryna et al., 2017; Krajcik & Shin, 2014; Kokotsaki et al., 2016; Thomas, 2000). Project-based learning is also effective in the ways that it allows instructors to respond to student needs and provides opportunities for students to apply for their knowledge and skills (Parker et al., 2013).

As a learning and teaching approach, project-based learning is student-centered, requiring students to engage in real-world tasks and develop a project to report to an audience (Thomas, 2000). As a learning approach, project-based learning is aligned with constructivism, as students create new knowledge based on their experiences (Arik & Yilmaz, 2020). In project-based learning, the learning process involves students saying, “I need to know” rather than teachers saying, “you should know” (Chen & Yang, 2019). Instead of traditional homework, students learn the class materials and apply their knowledge from textbooks through the completion of a project (Larmer & Mergendoller, 2011). The project is the main academic achievement that instructors use to evaluate student learning outcomes.

Through the use of project-based instruction, education has evolved from teacher-centered to student-centered in both kindergarten(K)-12th grade and higher education (Condliffe et al., 2017; Guo et al., 2020; Iryna et al., 2017; Krajcik & Shin, 2014; Kokotsaki et al., 2016; Thomas, 2000). Partnership for 21st-Century Skills have identified critical skills necessary for students’ college and career success and include critical thinking, problem solving, collaboration, communication, creativity, and motivation (Pellegrino et al., 2012). Project-based learning encompasses the desired knowledge sets, skills, and outcomes articulated by partnership for 21st-century skills and prepares students with lifelong learning skills such as self-regulation, inquiry, and metacognition (Jensen, 2015).

As an essential quantitative research method, meta-analysis has been used by a large number of researchers to investigate the effectiveness of project-based learning. Through the aggregation and reporting of findings from individual research studies, meta-analysis has the advantage of deeply examining different aspects of project-based learning. Meta-analysis is a statistical method that analyzes multiple research studies to obtain a combined result, determining the average effect size. In a more focused approach on research that addresses the effectiveness of project-based learning for academic achievement, the meta-analyst codes for the moderator variables explain differences in effect sizes. There are four meta-analysis research studies that investigate the effectiveness of project-based learning on student achievement in the 2010s and unanimously found positive average effect sizes, ranging from medium and large (Ayaz & Soylemez, 2015; Baleman & Keskin, 2018; Chen & Yang, 2019; Jensen, 2015). The main findings from each meta-analysis research study are summarized in Table 1.

Table 1

Summary of Recent Meta-Analysis for Project-Based Learning

Author	Location and Levels	Focus	*N* of Studies	Average Effect Size	Homogeneity Test	Moderator Variables
Ayaz & Soylemez (2015)	Turkey Primary to University	Student academic achievement in science education in Turkey	41	1.00	271.8	Fields of science, education levels, sample size, practicing time, methods used, and publication type
Balemen & Keskin (2018)	Worldwide Primary to University	Academic performance in physics, chemistry, biology, and science	48	1.06	Not specified	Publication type and status, subject area, education level, sample size, and techniques used
Chen & Yang (2019)	Worldwide Primary to University	Student academic achievement	30	0.71	184.58	Subject area*, school location*, hours of instruction*, group size, and technology support*
Jensen (2015)	Worldwide Grades 6-12	Academic achievement	36	0.50	368.03	Grade level*, Subject area*, Location*, and ability level

*Statistically significant moderator variables

The majority of research studies were primary to 12th grade. There were three meta-analyses investigating the effectiveness of project-based learning on academic achievement that included colleges and universities. Each of the four studies investigated moderator variables, however, only three of those studies investigations were supported by statistically significant homogeneity tests. Baleman and Keskin (2018) might have conducted a homogeneity test, but they did not report the results of one in their article. Jensen (2015) did not focus on higher education, but the research result supported there was a difference between the effectiveness of project-based learning in middle school and high school. It also supported the necessity of investigating the effectiveness of project-based learning in higher education. Of those studies including colleges and universities and conducting moderator analyses, only Chen and Yang (2019) reported statistically significant differences in subject area, school location, and technology support. There are possible reasons for the nonsignificant moderator results, including thatall of the coded levels of the moderator variables were equally effective or that there were small numbers of studies in theof levels of themoderator variables. For the Ayaz and Soylemez (2015) moderator analyses, one of the categories was based on only one effect size for the fields of science, three study effect sizes for education level, and three for publication type. Those categories would best be omitted from the moderator analysis. Given the heterogeneity of effect sizes in the meta-analyses, there must be moderator variables that could be the source of the homogeneity as Chen and Yang (2019) found in their meta-analysis. Therefore, there was a need to investigate differences within the educational levels, particularly higher education.

For the three meta-analyses that included colleges and universities, the average effect sizes are summarized in Table 2. The average effect sizes for colleges and universities ranged from medium to large and were compared with the average effect size reported in Table 1. The 95% confidence interval for the three studies with colleges and universities covers the average effect size for each meta-analysis reported in Table 1. In comparing the number of studies for colleges and universities, the researcher concluded that the majority of the research studies for the meta-analyses are based on K-12 data. The imbalance in number of studies conducted at the college and university level suggested that there is a need for investigating that educational level separately.

Table 2

Average Effect Sizes for College and University Information from the Meta-Analyses Reported in Table 1

Author	N of Studies	Average Effect Size	95% CI of the average effect size
Ayaz & Soylemez (2015)	9	0.68	0.23-1.14
Balemen & Keskin (2018)	10	0.91	0.48-1.34
Chen & Yang (2019)	6	0.57	0.36-0.77

Until 2021, researchers used meta-analysis as a powerful method to explain the effectiveness of project-based learning for students in all educational levels. there are currently no studies, however, investigating the effectiveness of project-based learning on academic achievement within higher education with a global perspective. As educational research has proven that traditional direct instruction is limited in teaching the skills of exploring, creating, and constructing solutions, project-based learning has filled this void (Chen & Yang, 2019). A project-based learning approach successfully changes instruction from teacher-centered to student-centered learning to involve students in the learning process. The three meta-analysis research studies within higher education were conducted in individual countries, individual subjects, or focused generally on the effectiveness of project-based learning within all educational levels.

Project-based learning increases student motivation by ------expanding metacognitive skill, self-regulation skill, and self-assessment or self-evaluation (Chen & Yang, 2019; Jensen, 2015; Thomas 2000), which, in turn, increases academic achievement. The research results from the 2010s indicate that project-based learning had positive effects on student achievement. Therefore, there remains a need to examine different elements of project-based learning to better understand its effectiveness, including technology support, group size, subject area, hours of instruction, and university location. These aspects were considered as moderator variables in meta-analysis within this study.

Purpose

This study was a meta-analysis of the effectiveness of project-based learning on academic achievement and the moderator variables, or elements that might effect academic achievement, in higher education worldwide. Project-based learning is a student-centered approach that requires students to engage in real-world tasks, enabling students to learn knowledge and enhance skills (Thomas, 2000). Researchers discovered the advantages of project-based learning for improving academic achievement in specific courses.

Meta-analysis is a powerful method to evaluate the effectiveness of project-based learning approach across a body of research studies. Historically it has been utilized by different researchers many times to study various populations. Thus, this research study conducted a meta-analysis to integrate the studies that investigated the effectiveness of project-based learning on academic achievement in higher education worldwide.

To investigate the effect of moderator variables in the meta-analysis, the following five moderator variables were considered, including technology support, group size, subject area, hours of instruction, and university location.

Background and Need

A project-based learning approach has been applied by researchers and instructors for students in different age levels since the 1980s. Erogan et al. (2016) described the consistency of using project-based learning in university-level classes. This research further supports the positive effect of STEM project-based learning on student achievement. Hasni et al.'s (2016) review of scientific publications that describe project-based learning teaching and learning in grades K-12 concluded five features of this instructional modality, including

1. engaging students in investigating a real-life question or problem that drives activities and organizes concepts and principles;
2. resulting in students developing a series of artefacts, or products, that address the question or problem;
3. enabling students to engage in investigations;
4. involving students, teachers, and members of society in a community of inquiry as they collaborate about the problem; and
5. promoting students' use of cognitive tools. (Hasni et al., 2016, p.204)

These five features mirror the findings of Thomas' (2000) meta-analysis. Hasni et al. (2016) found that in order for project-based learning to be effective, students must start with a scientific question and end with a final product, engaging in design activities. In middle school (grades 6-8), Knezek and Christensen (2019) found that students participating in energy-monitoring, project-based learning classes have positive dispositions toward STEM. The literature provides support for the effectiveness of a project-based learning approach in different levels of education.

In the development of project-based learning theory, Darling-Hammond et al. (2008) first reviewed literature about inquiry approaches that included project-based, problem-based, and design-based learning methods. By articulating the design principles of inquiry-based approaches, Darling-Hammond et al. (2008) identified the principles of problem design, includingcycles of work with ongoing assessment and feedback, authentic audiences and deadlines, scaffolds and resources for learners, productive classroom norms and activity structures, new roles for teachers and students, and opportunities for learning reflection.

Project-based learning has several fundamental features(Krajcik & Czerniak, 2014; Larmer & Mergendoller, 2020):

- Motivate students through an "entry event."
- Use of a driving question in which students are interested. This question is robust enough to allow for investigation and exploration.
- Encouragement of studentvoice and choice. Studentss make the decisions to construct the final product.
- Focus on the application of 21st-century skills such as collaboration and problem-solving.
- Allow time for revision and reflection to give students the opportunity to make the product better and develop metacognition.
- Present the final project to an audience.

According to Chen & Yang, 2019), project-based learning has two essential components, a question and a product. The question organizes and drives learning activities. The product represents the solution, which results from the activities used to address the driving question (Chen & Yang, 2019). Project based learning is not the use of a project at the conclusion of learning, rather, it is an extended inquiry process, given to students at the beginning of a unit and launched as an entry event(Lee, 2018). To design a project-based learning unit a teacher should consider 21st-century skills as they develop an entry event driving question, need-to-knows (NTKs), the project planning form, the project calendar, scaffolding instruction, and a project rubric (Lee, 2018, p. 3).

Given that complexities of project-based learning (Thomas, 2000), additional variables outside of the teaching strategy may have an effect on the measurement of academic achievement and learning outcomes. This dissertation investigated these variables, which were called moderator variables. Based on prior literature, five moderator variables were idenfied asncluding technology support, group size, subject matter area, hours of instruction, and university location. the effect sizes for the five moderator variables based on four meta-analyses are presented in Table 3.

Table 3

Average Effect Sizes for the Four Moderator Variables from the Meta-Analyses Reported in Table 1

Author	Moderator Variables	*N* of Studies	Average Effect Size	95% CI of the average effect size
Ayaz & Soylemez (2015)	*Subject Matter Areas*			
	Physics	20	1.05	0.72-1.38
	Chemistry	5	0.87	0.21-1.53
	Biology	16	0.95	0.59-1.32
	General	1	1.44	-0.10-2.99
Balemen & Keskin (2018)	*Subject Matter Areas*			
	Science	35	0.97	0.73-1.22
	Chemistry	2	1.01	-0.00-2.02
	Physics	6	1.15	0.56-1.74
	Biology	5	1.36	0.71-2.02
Chen & Yang (2019)	*Group Size*			
	2-4	11	0.82	0.69-0.95
	5 and above	8	0.70	0.52-0.88
	one person	2	0.53	-1.01-2.07
	Not specified	9	0.70	0.65-0.75
	Hours of Instruction			
	Less or equal than 2 hours	6	0.35	0.07-0.63
	Above 2 hours	12	0.76	0.64-0.89
	Not specified	12	0.72	0.67-0.76
	School Location			
	Europe and North America	10	0.71	0.66-0.76
	Western Asia	10	0.93	0.77-1.09
	East Asia	9	0.42	0.23-0.60
	Subject Matter Areas			
	Social sciences	6	1.05	0.79-1.30
	Science and mathematics	11	0.64	0.54-1.74
	Technology and engineering	9	0.81	0.61-1.01

Table Continues

	Others	4	0.70	0.63-0.78
	Technology Support			
	Without support	13	0.61	0.49-0.73
	With support	16	0.74	0.69-0.79
Jensen (2015)	*School Location*			
	Turkey	8	1.11	0.65-1.57
	United States	18	0.37	0.20-0.54
	Subject Matter Areas			
	Science	16	0.83	0.53-1.14
	Math	7	0.50	0.15-0.63
	Social studies	10	0.39	

The dissertation focused on students in higher education. The project-based learning approach was the only approach that was treated in the meta-analysis. Articles that qualified for the meta-analysis included published and unpublished studies from educational and psychological databases, dissertations, and conferences from 2010 to 2020. Thus, the research studies for meta-analysis included journal articles, dissertations, and conference papers.

As teachers use technological support in class, such as Internet-capable devices, computer-based stimulations, visualization tools, and interactive multimedia, the technology has the potential to motivate students and help them investigate, communicate, and collaborate with other students or industry peers, creating the product that truly represents their understanding (Chen & Yang, 2019; Hung et al., 2012). Technology is useful but is not a must-have requirement in project-based learning. Thus, technology support was identified within the study as a moderator variable for investigation.

Group work improves motivation and makes it easy to obtain feedback from peers (Uziak, 2016). Working in teams to come up with a project together is a critical factor in project-based learning. Students collaboratively develop an action plan, individually collect and analyze data, and present their work to the class together (Johnson et al., 2013). Chen & Yang (2019) identified that students in a large group (more than five students) have more interpersonal interactions with group members than students who worked individually or in a small group, but they also spend more time on communication and coordination (Chen & Yang, 2019). Project-based learning is applicable to individual, small-group (two to four students), and big-group (more than five students) projects for investigating effectiveness. Thus, group size was identified as a moderator variable for this study.

Project-based learning has been deployed across many disciplines in the last decade, but there is very little literature around the effectiveness of project-based learning across different subject areas. Research studies provide evidence from different subjects in K-12, STEM, and non-STEM subjects to support the positive effect of project-based learning on academic achievement across different subject areas. Thus, the researcher investigated the effectiveness of different subject areas as a moderator variable.

Chen and Yang (2019) investigated the effect of hours of instruction by dividing studies of teacher instruction into two categories, more than or less than two hours of instruction per week. The authors recommend the use of project-based instruction as a teaching modality throughout the day rather than separate instructional time. Project-based learning is a complete curriculum and will be further detailed in chapter II. The dissertation considered instructional time as a moderator variable to further understand the effect of time spent using project-based learning. . Chen and Yang (2019) divided studies into three geographical groups: Europe and North America, Western Asia, and East Asia. Jensen (2015) also divided studies between those in the United States and those in Turkey. Neither Ayaz and Soylemez (2015) nor Balemen and

Keskin (2018) investigated school location as a moderator variable. This dissertation identified the categories of university location as a final moderator variable.

Theoretical Framework

Constructivism is the theoretical framework for project-based learning (Ayaz & Soylemez, 2015; Chen & Yang, 2019, Jensen, 2015). The central activity of project-based learning is the transformation and construction of new knowledge (Thomas, 2000). To understand the ways in which constructivism structures project-based learning, we must first consider the essential criteria of this modality of instruction and compare it to constructivist theory.

There are five criteria that a project must have in order to be considered project-based learning (Thomas, 2000). Project, which is the core of project-based learning, can be understood as an act of creation over time (Chen & Yang, 2019) and it involves students in a constructive investigation (Thomas, 2000). Researchers after Thomas (2000) further developed the criteria:

1. Centrality. Project-based learning is essential to the curriculum.
2. Driving question. Project-based learning is focused on questions or problems that drive students to struggle with the central concepts and principles of a subject.
3. Constructive investigations. The projects involve students inan investigation that directs students to inquire, build knowledge, and find a resolution.
4. Autonomy. Students drive the projects.
5. Realism. Projects are applicable to the real world , not just school..

Project-based learning is structured based on the constructivist theory that students created their deep understanding of learning materials by working with useful ideas within the real-world contexts. According to Krajcik and Shin (2014, pp. 277-278), project-based learning was developed with learning theories from four major ideas in mind, including active construction, situated learning, social interactions, and cognitive tools.

Active construction means that learners construct knowledge based on the experience and interaction in the real-world to acquire a deep understanding. Learning happens when students process a meaningful task, focus on ideas in depth, and learn the connections between key ideas to form an integrated understanding (Fortus & Krajcik, 2012, p. 795).

Situated learning refers to students experiencing phenomena such as taking part in different science practices and understanding the value and meaning of tasks. Students accept information that they learn within meaningful context and connect that information with prior knowledge and experience. Through this process, they develop conceptual understanding in situated learning.

Social interaction is important in the construction of shared knowledge. Students, teachers, and community members develop knowledge by sharing and using information, and debating with each other.

Learning technologies are applied within project-based learning to develop cognitive tools, such as graphic, visual maps, and computer software, so students have sufficient resources, allows them to interact with the material in multiple ways and to connect new information with their prior knowledge and experience (Krajcik & Shin, 2014, pp. 277-278).

There are seven core principles of constructivist theory that are evident within project-based learning:

1. Knowledge is actively constructed by the learner, not passively received from the outside. Learning is something done by the learner, not something that is imposed on him.
2. Learners come to the learning situation with existing ideas about many phenomena. Some of these ideas are ad hoc and unstable; others are more deeply rooted and well developed.
3. Learners have their own individual ideas about the world, but there are also many similarities and common patterns in their ideas. Some of these ideas are socially and

culturally accepted and shared and are often part of the language, supported by metaphors. They also often function well as tools to understand many phenomena.
4. These ideas are often at odds with accepted scientific ideas and some of them may be persistent and hard to change.
5. Knowledge is represented in the brain as conceptual structures and it is possible to model and describe these in some detail.
6. Teachers have to take the learner's existing ideas seriously if they want to change or challenge these.
7. Although knowledge in one sense is personal and individual, the learners construct their knowledge through their interaction with the physical world, collaboratively in social settings and in a cultural and linguistic environment. (Sjoberg, 2010, p. 486)

Thus, both the criteria of project-based learning and the principles of constructivism require students to be at the center of learning as they build upon their prior knowledge through interaction with the outside environment Therefore, educational constructivism provides a theoretical framework for this study.

Educational constructivism

As educational constructivism identifies learning as individuals constructing knowledge and negotiating with social contexts, constructivism is not considered as a single theory but several "sects" that have implications on education (Jensen, 2015), including psychological, social, and radical constructivism. These different theories also affect instructional practices, teaching methods, and the potential achievement.

Constructivism and Vygotsky's Thought and Language

Piaget (1977) first developed the concept of constructivism as the development of knowledge through the assimilation of new concepts within existing schema. Piaget focused on the general aspects of the development of knowledge. He did not focus on education, let alone quality of teaching or conditions for learning. Constructivism has evolved from a Piagetian perspective and has drawn on other theorists who put more stress on social and cultural conditions for learning, which may explain why there are so many varieties of constructivism.

A main contributor to this development has been from a contemporary of Jean Piaget, Lev Vygotsky. His work remained virtually unknown in the West until its rediscovery in the 1960s, when *Thought and Language* from 1934 was translated from its original Russian into English in 1962. It was not until the end of the 1970s that his works started to get attention, and his collected works were available in English in the late 1990s.

Both Piaget and Vygotsky are idenfitied as constructivists. Some of the differences between the two were explained by the fact that they had rather different research agendas. Although Piaget was interested in epistemology and knowledge, Vygotsky was more interested in understanding the social and cultural conditions for human learning. Hence, Vygotsky's writings were closer to the concerns of educators. With his stress on the social and collaborative nature of learning, Vygotsky was often considered to be the father of social constructivism, whereas Piaget was often classified as a father of personal (or cognitive) constructivism. Piaget and Vygotsky corresponded and that Piaget acknowledged to be inspired by Vygotsky's ideas. Within this study, Piaget's psychological constructivism forms the theoretical framework for individual student knowledge construction, and Vygotsky's social constructivism provides the theoretical framework for group collaboration in project-based learning.

Psychological constructivism

Psychological constructivism defines that learners construct knowledge internally by accommodating new experience to existing schemas of knowledge that enables them to solve problems and be curious (Jensen, 2015). When students have a problem to solve in project-based learning, they are confronted with new information and add the information into their existing schema (O'Donnell & Hmelo-Silver, 2013).

Piagetian constructivism

The psychologist and epistemologist Jean Piaget first developed many of the core ideas of constructivism. Piaget described that knowledge should be studied empirically where it was constructed and developed. Within the hard sciences, such as physics and mathematics, Piaget identified that learning often occurs in isolation rather than through social interaction, which was also applied to children's development with regard to the development of logical thinking and knowledge growth (Sjoberg, 2010, p. 487).

Driver and Easley (1978) were influenced by Paigetan theory in their review of research on children's ideas and perceptions regarding natural phenomena This research triggered a new interest in children's concrete thoughts and understanding. Piagetian theory has since been applied to K-12 and undergraduate students learning how children grow knowledge and logical thinking skills (Sjoberg, 2010, p. 487).

Social constructivism

Social constructivism addresses that learning is more productive when students work together rather than individually. Social constructivism identifies that language is an instrument through which socially-developed knowledge, norms, beliefs, and rules are transmitted (Jensen, 2015). Thus, learning happens through social interaction with people. As Vygotsky (1962) noted, when a learner completes a task with scaffolded help by a teacher, the individual was working within the zone of proximal development or the space just beyond their current understanding Social constructivism of learning is a collaboration of everyone in the classroom, including the teacher as facilitator and guide and the students as co-contributors, inquirers, problem-solvers, and problem-posers (Jensen, 2015). This theory is consistent with the project-based learning criteria that students learn through real-world problems and develop solutions as learning outcomes. Even through project-based learning does not require group work, team collaboration is a commonly used structure by classroom teachers (Chen &Yang, 2019).

Radical constructivism

According to Von Glasersfeld (1989, p. 134), no instructor should assume that all learners have the same understanding or that their instruction produces the same mental models for all students. Glasersfeld (1989) emphasizes reflective practices in the classroom coupled with opportunities for students to discuss their views of and tentative approaches to solving aproblem (Jensen, 2015). Thus, students could think about and discuss their learning to achieve deeper, more informed, and more accurate understandings (Jensen, 2015). Therefore, the next step is to measure the extent to which project-based learning helps students achieve deeper, more informed, and more accurate understandings, which could be identified as academic achievement.

Essential features of project-based learning and educational constructivism

Project-based learning and constructivism both include encouraging cooperation and collaboration, problem-solving, problem-posing, and investigating. The project-based learning approach encourages students to communicate their thoughts with others and participate in the learning experience to achieve knowledge construction (Jensen, 2015). Teachers, active facilitators of the learning process, ask probing questions, provide feedback, and encourage students to dig deeper or utilize each other and outside sources as resources in project-based learning (Jensen, 2015).

Research Questions

To better understand the value of problem-based learning, its components, potential variables, and the effect of problem-based learning on academic achievement, this study employed six research questions.

1. What is the average effect size of using project-based learning on academic achievement in higher education?
2. To what extent does technology support influence the effectiveness of project-based learning on academic achievement as a moderator variable?
3. To what extent does individual, small-group, or large-group influence the effectiveness of project-based learning on academic achievement as a moderator variable?
4. To what extent does discipline or subject matter area influence the effectiveness of project-based learning on academic achievement as a moderator variable?
5. To what extent does hours of instruction influence the effectiveness of project-based learning on academic achievement as a moderator variable?
6. To what extent does university location influence the effectiveness of project-based learning on academic achievement as a moderator variable?

Definition of Terms

Academic achievement, or academic performance, refers to the extent to which students attain their learning goals. Learning goals are assessed at the conclusion of instruction through teacher-developed, researcher-developed, standardized post-, or retention tests (Chen & Yang, 2019, p.74; Jensen, 2015, p.15).

Cognitive domain are competencies that are related to thinking skills, such as reasoning, problem-solving, and memory, including content knowledge and creativity (Condliffe et al., 2017, p. 35).

Cognitive tools, including visual aids, graphic organizers, computer software, and manipulatives, can amplify and build on what students learn to help them understand a conceptual idea, explain the range of questions that students can investigate, and offer learning experiences that might not otherwise be possible (Lee, 2018, p. 9).

Conceptual understanding refers to an understanding of a concept that is applicable outside of the singular learning experience. It requires giving students sufficient time to engage in inquiry, rather than requesting students to memorize. Teachers access the progress of students in order to adjust instruction and student work (Condliffe et al., 2017, p. 62).

Deeper learning is the process through which students develop 21st-century competencies, through the process of truly understanding a concept. Deep learning occurs when students use cognitive, intrapersonal, and interpersonal skills (Condliffe et al., 2017, p. 34).

Discipline or subject matter area is specific content that is taught within the course, including mathematics, reading, and so on. For this study, two subject areas will be considered: STEM and non-STEM (Chen & Yang, 2019, p. 72).

Driving question refers to the question or problem that project-based learning is focused on and has students encounter and struggle with the central concepts and principles of a discipline (Condliffe et al., 2017, p. 60).

Formative assessment is the assessment in the classroom that takes place in the course of ongoing, daily lives of teachers and students and can be used directly to improve learning (Cox-Peterson & Olsen, 2002, p. 99).

Group size is the number of students in the treatment group in the experiment, including one person, two to five people, and more than five people (Chen & Yang, 2019, p. 76).

Hours of instruction refers to the hours per week that instructors teach students by project-based learning, including 2 hours or below and above 2 hours per week (Chen & Yang, 2019, p. 74).

Integrated understanding refers to ideas that are connected to each other to allow learners to be aware of and be able to use relationships between various ideas to solve problems and understand the world they live in (Fortus & Krajcik, 2012, p. 783).

Need-to-knows (NTKs) is something that students have to understand in order to answer the driving question and complete the project successfully (Lee, 2018, p. 5).

Project-based learning is student-centered, requiring students to engage in real-world tasks and develop a project to report to an audience, enabling the students to acquire knowledge and enhance skills (Thomas, 2000, pp. 3-4).

Scaffolding instruction refers to the teacher support and the activities that support the problem-solving process (Lee, 2018, p. 7).

Situated learning involves students in experiencing phenomena as they take part in various scientific practices such as designing investigations, making explanations, constructing, modeling, and presenting their ideas to others (Krajcik & Shin, 2014, p. 277).

Summative assessment is the assessment that is administered following a unit of instruction to provide evidence about student understanding (Cox-Peterson & Olsen, 2002, p. 106).

Tangible product refers to the shared artifacts or publicly accessible external representations of the class learning that address the driving question to accomplish at the end of project-based learning process (Krajcik & Shin, 2014, p. 277).

Technology support is the technological assistance that teachers provide in classroom, such as Internet-capable devices, computer-based simulations, visualization tools, or interactive multimedia (Chen & Yang, 2019, p. 72).

21st-century skills are skills that employers seek from new graduates, including problem solving, critical thinking, creative exercise, and teamwork skills (Lee, 2018, p. 3).

University location is the continent where the university population is located, including Europe and North America, Western Asia, and East Asia. (Chen & Yang, 2019, p. 74).

Summary

This study investigated the effectiveness of project-based learning on academic achievement in higher education by using a meta-analysis. Theories of constructivism provided support for the rationale. The elements of project-based learning, as defined by prior research, were used to construct the framework for selecting studies that used a project-based learning method. The next chapter will review the literature that is related to project-based learning since 2010, which reflects the most recent research outcomes of project-based learning and the five moderator variables, including technology support, group size, subject matter area, hours of instruction, and university location.

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this dissertation was to investigate the effectiveness of project-based learning on academic achievement in higher education worldwide. Researchers have applied project-based learning methods in diverse learning environments to investigate the effectiveness of technology support, group size, hours of instruction, subject matter areas, and school locations. Most of the studies were based on students in kindergarten (K) to 12^{th} grade. This chapter contains a review of the literature about project-based learning approach with the variables above.

Technology Support

As project-based learning is a learner-centered approach that relies on formative assessment with ongoing feedback, it must involve the process of conversation and discussion. Technology support is necessary to have conversation and discussion available for onsite, hybrid, and online classes. Chanpet et al. (2020) investigated the role that technology played in addressing the limitation using online project-based learning and formative assessment to evaluate the achievement in a media-creation course at a Thai university. There were 30 learners assigned to the online section and 30 to a face-to-face section. All participants were in a program for Bachelor of Education specializing in English as a foreign language and enrolled in the media-creation course. The course normally was taught onsite but was designed online with formative assessment in the study. Researchers designed the experiment as a posttest only research by evaluating the learners' online postimplementation project-based learning knowledge and skills compared with a face-to-face group learning. The study assessed the learners' perceptions of the convenience, benefits, and barriers of the technology and assessed the learners' perceptions of their project-based learning skills and knowledge after using the technology. The research result showed that technology provided a scaffold to support the activities and interactions for both students and teachers. According to the results of postimplementation measurement, learning management system with communication and file-sharing functions supported not only achievement but also the learning process by improving learners' perceptions, knowledge, and skills. For constructivist project-based learning, it is essential to have technological communication tools to support conversation, interaction, collaboration, sharing, construction, and creation between the teacher and between learners for purposes of ongoing achievement formative assessment and feedback. The communication tools also had transcripts for self-monitoring, reflection, and evidence in the e-portfolios and transcripts for feedback from the instructor (Chanpet et al., 2020). Thus, a learning management system is a useful tool in enhancing the achievement project-based learning classes.

Project-based learning is characterized by applying knowledge, management of resources, and self-directed learning. In order to accomplish these characteristics, technological design must be used to facilitate communication, classroom interaction, and active learning. The technological designs, however, are costly. Eickholt et al. (2019) presented two economical options, Practical Active Learning Stations (PALS) and Hardware-based system (HBS), for flexible learning spaces that supported project-based learning and with the cost much less than typical technological classrooms. The two options were paired with a traditional classroom and a prototypical active learning classroom for a computer science course that employed a group-based active learning pedagogy for onsite projects. Researchers of the study conducted their experiments in Fall 2018 and Spring 2019 semesters. There were 42 participants in the prototypical Active Learning Classroom (ALC) and 23 participants in the PALS in Fall 2018. In Spring 2019, there were 22 participants in the PALS and 22 participants in the traditional classroom. All participants were undergraduate students.

According to the results of the quasi-experimental research, the low-cost and technological learning environments was conductive to student learning by supporting project-based learning and reducing the cost; thus, it was feasible to develop the PALS and HBS. The technology support enhanced student learning experience and improved their academic achievement compared with the results of control group. Even though project-based learning does not require an active learning environment or any specific technology, its pedagogy relied on student collaboration that should take place in a learning environment that supported collaboration and focused the students on the peers. The research results also revealed that engineering subject-matter areas are more applicable for the deployment of economical and flexile learning environments to improve student achievement. It was because many of the labs or classrooms used in engineering departments were more open, offered more storage, and did not have fixed tables or stadium style seating. As the research results provided additional support for the use of economical and flexible learning spaces, Eickholt et al. (2019) concluded that the low-cost but active learning environments tailored to support peer collaboration and academic achievement within the reach of more institutions.

Engineering education is always a popular field for researchers to investigate project-based learning with the feasibility of attaining cognitive objectives and involving students' critical thinking. Gil (2017) conducted a posttest only experiment to explore the development, implementation, and assessment of project-based engineering course with MATLAB applications for a college-level Multimedia and Engineering course. Gil analyzed the efficacy of short projects as a learning tool when compared with long projects. Participants were 79 undergraduate students from a Multimedia and Engineering course during their senior years of their Bachelor's degree. The instructional goal was "for the students to not only acquire image-specific technical skills but also a general knowledge of data analysis to locate phenomena in pixel regions of images and video frames" (p. 508). The learning accomplishments included "knowledge assimilation, student motivation, and skill development using a continuous evaluation strategy to solve practical and real problems by means of short projects designed with MATLAB application" (p. 508). The research results showed that students who took part in short projects made a statistically significant improvement in academic achievement when compared with students who participated in long projects. Also, the assessment that the teacher used and the type of questions selected in examinations affected the students' final assessment results (Gil, 2017). The study provided good evidence of using technology support in project-based learning and to what extent students' achievements are affected by different technological-based methods.

Project-based learning has been designed to engage students in solving real-world problems. Blumenfeld et al. (1991) studied that ways that projects help people learn and what project design factors motivate students. By investigating the difficulties that students and teachers face in project-based learning, technology supported them in many ways to improve the learning outcomes. As technology developed, students had technological support during the different phrases in project-based learning. Technology also supplied teachers' instructional and managerial roles, relieving some complexities of implementing projects by enhancing the knowledge and professional competence of the instructors (Blumenfeld et al., 1991). The same theory has been used in many research studies. For example, Eskrootchi and Oskrochi (2010) suggested that students learn best by constructing knowledge from a combination of experience, interpretation, and structured interactions with peers and teachers by using technology. By investigating the effectiveness of project-based learning in a technology-rich environment, Eskrootchi and Oskrochi (2010) developed a science project that was integrated with a simulation software package, Structural Thinking and Experiential Learning Laboratory with Animation (STELLA), to help students promote deep understanding of land use. The research was quasi-experimental with 72 students between sixth and eighth grade.

> Three separate multi-age classrooms were included in the study. The multi-age classrooms were randomly allocated to one of the three treatment groups. Students from all groups read the project materials on-line through KanCRN and benefited from on-line learning features such as collaboration with peers, finding definitions of related terminologies and using hyperlinks to additional information. (Eskrootchi & Oskrochi, 2010, p. 238)

In the experiment, the pretest included the understanding of the watershed concept and content knowledge with three different treatment groups of traditional lectures, Project-Based Experimental Simulation group (PBES), and Project-Based Simulation group (PBS). Students were pretested about their understanding of the watershed concept and content knowledge. The first treatment group, which included 19 students, were the traditional lectured group (TL), taught the subject with traditional lectures. The second treatment group, PBES, included 33 students who were taught the subject with an experimental model and a simulation model. The third group, PBS, included 20 students who were taught with a simulation model but not an experimental model. To improve their achievements, students also were divided into subgroups within each classroom based on their pretest scores. Based on the research results of the three dependent variables of content knowledge, comprehension of the project, and students' attitudes toward the project, the researchers concluded that features of project-based learning should be implemented to improve student achievement. Incorporating computer-simulation modeling into project-based learning required careful planning and implementation. Although the PBES had higher achievement scores than the PB class, the PBS group, which used computer-based simulation but did not perform the experimental part of the project and consequently could not benefit from the project to its full potential, did not have higher achievement scores than the PB class (Eskrootchi & Oskrochi, 2010). Thus, educators must be careful when using technology in project-based learning.

With the purpose of improving achievement, motivation, and problem-solving skills, Hwang et al. (2014) investigated the effectiveness of a peer-assessment-based game-development approach in an elementary-level (K-5) science course. Peer-assessment is a learning strategy that helps students make reflections and experience in-depth learning in game-development approach. The quasi-experimental research study with 167 students with an average age of 2-year-old placed 82 students in the experimental condition and placed 85 students in the comparison group. The researchers administered a pretest to measure students' learning motivation and problem-solving. A posttest was conducted using the learning motivation scale, problem-solving skill scale, and technology acceptance questionnaire. The researchers found that students in the experimental condition had higher achievement, learner motivation, and problem-solving-skill scores than those in the comparison group. Therefore, using peer-assessment was found to be a successful method for supporting student learning.

Moreover, the peer-assessment-based game-development approach also improved students' deep learning status such as in-depth thinking, creativity, and motivation (Hwang et al., 2014). The use of peer-assessment and hands-on game-development successfully supporting student learning serves as a positive example of using project-based learning with technology support.

Collaborate project-based learning also is helpful in developing the skills of searching, analyzing, communicating, and managing time. Paschalis (2017) developed a learning management system (LMS) -based collaboration script and a group investigation method to support tutors and 20 college students in a database course. The experimental results indicated that students who used the LMS-based collaboration script and group investigation method had better levels of collaboration and achievement than students who did not. Also, the online learning environment provided the tutors with an efficient way to guide students in collaborate project-based learning.

Hallermann et al. (2011, p. 28) mentions that although project-based learning could take advantage of a technology-based classroom, teachers are still able to implement project-based learning effectively without any technology support. Meanwhile, Chen and Yang (2019) concluded that project-based learning was more effective with technology support, which is consistent with Eskroochi and Oskrochi's (2010) research results. Technology provides students various ways to acquire information or integrate ideas (Chen & Yang, 2019). Members in a project-based learning group can contribute knowledge through a shareable platform to learn and collaborate as they problem-solve (Rick et al., 2009; Rogers & Lindley, 2004). From the instructor's perspective, technology support offers the opportunity to conduct meaningful learning activities in technology-enhanced classrooms (Hwang et al., 2014). Blumenfeld et al. (1991) suggested that project-based learning makes use of technology because it can help students work on their projects and make information more accessible. It is necessary for teachers to enhance their technological knowledge to be able to assist students in using technological support tools (Eskroochi & Oskrochi (2010). Thus, this dissertation considered technology support in project-based learning as one moderator variable in the meta-analysis.

Group Size

Group size is an important part of a project-based learning approach. Bertucci et al. (2010) investigated the effect of cooperative-learning group size (small, medium, and individual) on achievement, social support, and self-esteem. Sixty-two seventh-grade Italian students were assigned randomly into comparison and treatment groups. Cooperative learning in small (two students) and medium groups (four students) promoted better achievement and academic support than individual learning. Additionally, learning in small groups developed a higher level of social self-esteem than medium groups and individual learning (Bertucci et al., 2010).

When approaching project-based learning, some researchers aim at the difference between small and large groups. Mulhim and Eldokhny (2020) conducted experimental research to compare group sizes of students developing webpages in a project-based learning environment. Their focus was investigating the effectiveness of group size on academic achievement and the quality of the final project. Seventy-two undergraduates in a teacher program in Saudi Arabia were divided randomly into different sized groups. The small groups included 3 to 4 students and large groups included 7 to 8 students. There were statistically significant differences between the small and large group sizes on the posttest of student academic achievement and project quality. There was a stronger effect on outcome scores in the large group size, which differs from the results of prior research studies (Bertucci et al., 2010; Hallermann et al., 2011; Larmer & MerMergendoller, 2010). Mulhim and Eldokhny indicated that the research result was consistent with the social independence theory and that the goal of each group member was achievable when other members accomplished their goals. The more students in a group, the more learners collaborated, engaged, interacted, and put forth efforts to achieve the project goal and create outstanding academic achievements (Mulhim & Eldokhny, 2020).

The definition of small and large groups used by Mulhim and Eldokhny (2020) is consistent with Chen and Yang's (2019) definition of the group size as a moderator variable, which supports the concept definition of group size used for this dissertation. Chen and Yang conducted moderator analysis on group size with the following groups: small (two to four participants), large (five and more participants), one-person group, and not specified in the research article. Their findings were based on 11 studies of small groups, eight studies of large groups, two studies of individuals, and nine studies of not specified groups. The average effect sizes were 0.82 for small group, 0.70 for large group, 0.53 for the one-person group, and 0.70 for the not specified group. The largest effect size was for the small group and the smallest effect size was for the one-person group. These results could possibly be affected by the use of technology, which could foster communication and sharing and whole-class presentation (Chen & Yang, 2019).

For collaborative learning, Bertucci et al. (2010) suggested grouping students who have no prior experience into small groups. Larmer and Mergendoller (2010) claimed that students should form teams with three or four people in project-based learning. Given the lack of consistency in project-based learning group sizes, additional research should be conducted to investigate the effect of group size on student outcomes. Therefore, this dissertation considered group size as a moderator variable.

Subject-Matter Areas

Project-based learning has been used in many content areas, most frequently in Science, Technology, Engineering, and Mathematics (STEM) education. Meta-analyses reported on in chapter I investigated variation in subject- matter areas within project-based learning. All four of the moderator analyses investigated individual subject-matter areas rather than categorizing them as STEM or non-STEM. Both Chen and Yang's (2019) and Jensen's (2015) meta-analyses included the non-STEM subject area social sciences or -/social studies. Ayaz and Soylemez (2015) and Balemen and Keskin (2018), however, studied only STEM subject areas. Results of the four investigations are reported in Table 3 found in chapter I.

Ayaz and Soylemez (2015) investigated the subject-matter areas of physics, chemistry, biology, and general (sciences) within 20, 5, 6, and one studies, respectively. The average effect sizes were 1.05, 0.87, 0.95, and 1.44, respectively. All of the average effect sizes were large with two average effect sizes over one standard deviation. The number of studies for general (sciences) wass only one and cannot be considered with the other studies with much larger numbers.

The subject-matter areas for Baleman and Keskin (2018) include science, chemistry, physics, and biology. Three of the subject-matter areas were the same as for Ayaz and Soylemez (2015). Baleman and Keskin included 35 studies of science, 2 of chemistry, 6 of physics, and 5 of biology. The average effect sizes were all large. Three of the average effect sizes were greater than one standard deviation. They were 0.97, 1.01, 1.15, and 1.36, respectively. The subject-matter area of chemistry is based on only two studies, which varies greatly from the number of studies included in other subject areas, making comparison difficult.

Chen and Yang's (2019) subject-areas include the non-STEM subject social sciences (n = 6) and STEM subject-matter areas of science and mathematics (n = 11), technology and engineering (n=9), and others (n=4). The values for the average effect size were, in respective order, 1.05, 0.64, 0.81, and 0.70. Only one average effect size was greater than one standard deviation and that is for social sciences. All of the hard sciences had either medium or large average effect sizes. Chen and Yang conducted post-hoc comparisons that indicated that project-based learning had a statistically significantly greater effect than traditional teaching methodologies in the social sciences, combined technology and engineering, and science and mathematics. The average effect sizes for social sciences were highest for English, French, history, and geography, in descending order. Within technology and engineering the highest average effect sizes were found in computer science, web design, digital logic, machine control, and mechatronics, in descending order. In science and mathematics, the effect sizes were greatest in basic science, physics, chemistry, life science, earth science, agricultural science, and mathematics, in descending order. In addition, the effect of using project-based learning in the social sciences was statistically significantly better than that in science and mathematics.

The last meta-analysis was conducted by Jensen (2015). Jensen included the subject-matter areas of science, mathematics, and social studies. This was the only meta-analysis of the four that included non-STEM subject-matter areas and the only one among students in grades 6 to 12. Included within the meta-analysis were 16 studies of science, 7 studies of mathematics, and 10 studies of social studies. The average effect sizes are smaller than the previous meta-analyses. Science had an effect size of 0.83, 0.50 for mathematics, and 0.39 for social studies.

The following two subsections provide information regarding subject-matter areas based on the use of project-based learning in STEM and non-STEM coursework.

In STEM Higher Education

Project-based learning methods have been used in STEM programs since the 1980s. It is essential that new graduates have more than industry knowledge and skills to be successful in competitive workforce markets. For this reason, Fain et al. (2016) investigated the perceptions of marketing and engineering students who took project-based learning. The study selected marketing and engineering education for specific reasons. Marketing is based heavily on integrating theory and practice that project-based learning has included in the curriculum from early stages of marketing instruction. Engineering provides students discipline-based skills from the beginning to enable translation of knowledge to practice. Fain et al. (2016)'s study had marketing students participate in solving an industrial marketing problem, whereas engineering students worked on developing a new product for an industrial partner. After completing the project, 40 marketing and 32 engineering students participated in a 49-item survey to provide perceptions of the class. The questionnaire covered many aspects of project-based learning including discipline-based questions, general skills, teamwork, project-relevant skills, communication-related skills, interpersonal skills, and project outcomes. According to the research results, students were satisfied with the project-based learning approach, noting improvement in their project management and teamwork skills. The Cronbach coefficient alpha of all marketing and engineering content-specific items were above .70, indicating a sufficient reliability for the study. Therefore, a project-based learning approach provides support for students' building of content-knowledge as well as improving project management and teamwork skills

For evaluating the effectiveness of interdisciplinary project-based learning in science programs that develop discipline achievement and employability skills in Australia, Hart (2019) reviewed literature on interdisciplinary studies offered in science and science-based degrees. Hart analyzed six areas, including discipline knowledge, communication, teamwork, interdisciplinary effectiveness, critical thinking, problem solving, and self-management. Hart (2019) assigned the projects to different categories based on the interdisciplinary breadth and depth. Interdisciplinary breadth was determined by the mix of disciplines in the project, and interdisciplinary depth was determined by the project task. Hart (2019) analyzed the data by cross-tabulation and Fisher's two-tailed exact test to compare the project categories with each skill development item and used odds ratio to calculate the effect size. The study found a large gap between skill gains that were self-reported and those that were measured by another means. Another finding from the study was a reduction in the reporting of single discipline achievement as the interdisciplinarity of the project increased. The last finding was that perceived discipline achievement gains were not different regardless of the project interdisciplinary breadth or depth. The findings indicate that instructors should embrace curriculum mapping and the embedding of employability skills throughout the degree program. A project-based learning approach was predictable with improving achievement, developing multiple employability skills by using paramount constructive alignment, accurate learning objectives, and explicit teaching and assessment. Thus, interdisciplinary project-based learning units were effective in improving academic achievements and developing employability skills (Hart, 2019).

Mohammad (2017) measured the effectiveness of mixed teaching modalities in a microprocessor course through the combination of a spiral and project-based learning approach. As the project-based learning approach was student-centered, a spiral teaching method had students learn the basic without details at the beginning and learn the details as they progressed. By proposing a hybrid spiral project-based learning methodology, the study used the spiral method to construct the boundaries of instruction and used project-based learning to instruct each step of course, with an online survey and test to determine the research results. According to the survey results and test data, students improved their knowledge and skill-level achievement after taking the microprocessor course. The research provides a vivid example of using project-based learning alongside other teaching modalities to improve student practical knowledge for career development (Mohammad, 2017).

Project-based learning, as an approach to providing practical experience in learning, has been effective in many research studies in the 2010s. According to Robinson's (2016) statement, chemistry students must perform analyses with high level of accuracy and precision, interpret data, and communicate scientific results, but they lacked motivation of engagement sometimes if not knowing the importance of their coursework. Project-based learning laboratories were a potential solution of having students independently work on the steps above and answer real-world questions (Larmer & Mergendoller, 2015). By describing two project-based learning cases that were reliable in most instrumental analysis course, Robinson (2016) concluded the key features in developing a project-based learning environment and the strategies for implementing projects with large numbers of students. The study processed project-based learning pedagogy with 60 sophomore and senior students in a U.S. university and allowed the students to participate in the entire analytical process by troubleshooting or repeating the procedures, including accuracy and precision, Baxter Biopharma Solutions Project, traditional experiments, and Brewery Project (Robinson, 2016). The two projects mentioned above were specific practical projects in chemistry education. Following the six project-based learning features (Lee, 2018), the study conducted the project and collected research results by assessing the project assignment and administering a survey. The final essay score did not match the strict quality assurance measurement, but students successfully answered the driving question and agreed with the project-based learning style in a laboratory. The study resulted in high achievement and motivation scores (Robinson, 2016).

Students in STEM majors, such as mechanical engineering and technology, easily face the difficulties of connecting lecture material to real-life experience and improving their achievement, which creates the necessity of using a project-based learning approach in instruction. Sharma (2011) organized a project-based learning laboratory to provide semester-long industrial processes of design, development, testing, and optimization for sophomore mechanical engineering students. The 15-week lab schedule had five sessions including introduction, design, construction, test and modify, and presentation report. Students in each group of projects had to assess the other students' efforts. The research calculated the final project grade with 40% of the individual lab grade, 20% of the presentation score, 20% of the progress report, and 20% based on the filing scaled distance and repeatability. The two fluid mechanics laboratory projects, pipe friction and water distribution, allowed students to experience both theory and the process of engineering with real-world goals and criteria (Sharma, 2011).

Panwar et al. (2020) conducted an online robotic competition, known as e-Yantra Robotics Competition, at a technological institution in India. Students received hands-on practice in project-based learning., Data collection occurred across various editions of the competition between 2016 and 2018. The research successfully provided a large sample size out of the classroom environment and facilitated collaborative learning at the same time. Results of the study indicate that project-based learning supported the development of students' intrapersonal and interpersonal skills. The researchers recommended that instructors apply a project-based learning approach to online college curricula, such as the use of e-Yantra, for extra credits or program certifications (Panwar et al., 2020).

Project-based learning always starts from a driving question (Krajcik & Shin, 2014, p. 276; Larmer & Mergendoller, 2015; Thomas, 2000), which differs from a traditional case study approach. Tatachar and Kominski (2017) compared the effect of a traditional case-based exercise with a student-question-creation exercise, which mirrors project-based learning practices.. 84 second-year pharmacy students in a pharmacotherapy course completed a pretest-posttest exam to assess achievement and an online survey to assess perceptions. After the pretest, students were assigned randomly to 12 groups of six to seven students and were asked to complete either a case-based exercise or a student-question-creation exercise. Following the exercise, participants completed a posttest exam. Students' perceptions were evaluated with an online survey at the completion of both exercises. There were statistically significant difference between the groups. The student-question-creation group reported higher levels of enjoyment and interest in the subject matter than the case-based group. With regard to academic achievement, there was no statistically significant difference between the test results of two groups. It is possible that there were extraneous influences regarding the effectiveness of the student-centered learning approach. The research studies above support the claim that project-based learning is effective in developing students' knowledge and skills, applicable to their lives and work after graduation (Tatachar & Kominski, 2017).

In K-12 education, stakeholders provide professional development programs to high-school science and mathematics teachers to ensure that innovative instructional practices are sustainable in class. Erdogan et al. (2020) explored the effectiveness of consistently using STEM project-based learning on student achievement over the course of 4 years by collecting data from 565 students in three urban high schools in the Southwest United States. The first school had a high level of STEM project-based learning implementation, the second school had an average level of STEM project-based learning implementation, and school three had no STEM project-based learning implementation. Longitudinal analysis was conducted using a latent growth modeling and indicate that students in school one acquired higher achievement than students in schools two and. The study results imply that the influence of teaching practices to students' long-term success is based the value of consistently using innovative instructional practices in education (Erdogan et al., 2016).

To explore the effects of project-based learning on academic achievement, Hung et al. (2012) proposed a project-based learning digital storytelling approach to a science course in an elementary school in Taiwan, China. Researchers assigned 117 students in fifth grade to the experimental and control groups and measured achievement via a science learning motivation scale, a problem-solving competence scale, and a science achievement test. Hung et al. (2012) concluded that the project-based learning approach enhanced students' achievements on all three measures (Hung et al., 2012).

Cervantes et al. (2015) compared the project-based achievements in STEM and non-STEM education through mathematics and reading achievement test scores on the State of Texas Assessments of Academic Readiness (STAAR). A project-based learning group was compared with a traditional lecture learning group among students in seventh and eighth grades in an urban school district in South Texas. Cervantes et al. conducted a multivariate analysis of variance (MANOVA) to investigate the achievement test scores differences and computed mean difference effect size by Cohen's *d* to evaluate the practical significance. Students were compared within the same grade for both reading and mathematics. The analysis results showed that students in the project-based learning group achieved higher proportion of correct answers than students in the non-project-based learning group across grade levels and subject areas. For the practical significance result, most learning categories had medium effect sizes. One category of mathematics achievement in seventh grade had a large effect size and five mathematics achievement learning categories in eighth grade had small effect sizes. Cervantes et al. suggested a shift toward project-based learning in K-12 schools and improvement of professional development for teachers and administrators in both mathematics and reading courses.

In non-STEM Higher Education

Project-based learning has been applied in subjects other than STEM since 2016. Ampera and Baharuddin (2020) developed a project-based learning media within an Indonesian clothing design program. The project contents required four steps from students, including explaining how to draw body proportions, drawing body proportions, explaining how to make sketches of clothing, and making sketches of clothing. To test the validity of the program, Ampera and Baharuddin conducted six steps of validation. First subject-matter experts were consulted, including material experts, learning design experts, and instructional media experts. Next trials of the program were conducted, including individual trials, small trials, and limited field trials. Data collection included a questionnaire, an interview, an expert test sheet, and a test. Each measure was analyzed using both qualitative and quantitative methods. The research results indicated that the project-based learning media was effective for both class learning and interactive independent learning by improving final test scores. They concluded a “very eligible” validity test result. The researchers computed a one-sample *t* test and calculated the effectiveness of the developed project-based learning media as d=0.76, which is close to a large effect size (Ampera & Baharuddin, 2020). Results of this study support the effectiveness of project-based learning as a method of improving achievement, as was measured in this dissertation.

With the purpose of changing methodological paradigm from traditional class to student-centered education, many researchers in the 2000s investigated project-based learning for improving students’ achievement level to increase student employability after graduation. Parrado-Martinez and Sanchez-Andujar (2020) conducted empirical research of using project-based learning in finance postgraduate studies at a university in Spain. The researchers investigated students’ academic achievement level, to what extent project-based learning changed the competence of employability, and explored students’ attitude about the usefulness, advantages, and disadvantages of project-based learning. The independent variable was a project-based learning approach. The dependent variables were competences of planning and organizing, teamwork and cooperation, information management ability, oral communicative competence, and creativity and innovation, by investigating the test scores. After explaining the project-based learning methodology to the participants, participants were placed into six groups of four to five students. Each group collected information about a financial source directly from the financial entities, public organizations, and private firms. The information that they acquired included loans, leasing, renting, crowdfunding, subsides, and venture capital firms. Results of participant test scores support the argument that project-based learning improves the competences of teamwork, communication, creativity, and organization and information management. Participants perceived learning about financial sources and contacting the real businesses as being the most beneficial for their learning process (Parrado-Martinez & Sanchez-Andujar, 2020). These findings support the argument that project-based learning improves competence at workplace.

Project-based learning is utilized in business programs in higher education, which specifically focuses on improving academic achievement and making students competitive in the labor market. Chemborisova et al. (2019) highlight the basic entrepreneurial knowledge of students and its development through use of a project-based learning. In their study, a business consultant game was used as a project-based learning activity. They evaluated the game’s effectiveness using a questionnaire. The participants were 140 economics-major first-year postgraduate students between the ages of 21 and 23 in Moscow, Russia. As a quasi-experimental research with posttest only, the research randomly assigned students to two groups. The test group completed the project and answered the questionnaire afterwards. The control group did not have a project to complete but answered the questionnaire. Chemborisova et al.

(2019) used a Likert scale from 0 to 3 to investigate the students' entrepreneurial knowledge level including technical, managerial, entrepreneurial, and personal relevant knowledge. Participants improved on 13 of the16 assessed entrepreneurial knowledge sections in the project-based learning approach condition, which indicated that the entrepreneurial knowledge level of students in the project-based learning group was 12% higher than the knowledge level of students in the control group. Therefore, project-based learning was able to help students learn to evaluate project risks and make decisions. The study provides a good example of having educators use project-based learning to support real-world needs of their students and develop their skills that will be necessary past graduation. As project-based learning uses real-world problems (Condliffe et al., 2017; Parker et al., 2013; Thomas, 2000; Larmer & Mergendoller, 2015), it requires the instructors to have real-world experience to support students' in developing entrepreneurial knowledge.

Project-based learning also has been utilized in business general education. Kleczek et al. (2020) used the project-based learning method to solve "wicked" problems in a collaborative education-enterprise learning environment. A wicked problem is a complex problem, usually involving a social or political issue, that is too convoluted to solve by rational systematic processes (Rittel & Webber, 1972). Wicked problems do not have one confirmed solution and trying to solve them may cause other problems (Harris et al., 2017). Kleczek et al. identified elements of project-based learning, including activities, interactions, and networks and the positive or negative learning outcomes from these elements. Thirty students, 12 faculty members, and business owners and managers from four high tech partners collaborated and participated in the study. The research results indicate that the more the teaching process was focused on solving the problem, the greater the learning effects were (Kleczek et al., 2020). The learning outcomes that Kleczek et al. investigated served as a model for this dissertation within the concept of academic achievement. Both the positive and negative learning outcomes that Kleczek et al. discussed in the journal article are provided in Table 4.

Kleczek et al. (2020) also suggested three methods to improve the effectiveness of project-based learning method for future studies, including using smaller project size, scaffolding the management of information, and involving students in groupings. The researchers suggested including the introduction of various small projects rather than challenging students with big projects. They also suggested instructors teach students how to manage complex information and dynamic project requirements. Finally they suggested that students should participate in selecting and organizing student teams. By focusing on the students' perspective and on the development of problems in design thinking, the study demonstrates a thoughtfully developed project-based learning approach (Kleczek et al., 2020). The study addresses using project-based learning in one specific subject but does not provide data to help with quantitative research such as meta-analysis for future studies. Kleczek et al.'s report of advantages and disadvantages will be further detailed in the discussion of this dissertation.

Project-based learning has been used worldwide to provide students with the knowledge and real-world skills to enter the workplace. For example, Kenya faced forest-relevant challenges for many years and needed to improve forestry and nature-based education as well as train expertise in higher education, so Munezero and Bekuta (2016) investigated a project-based approach to improve the achievement of extracurricular activities for undergraduates at a university in Kenya. By introducing the project-based learning activity to students who

Table 4

Replicable Elements of the Learning Process and Outcomes from the Student View

Elements	Learning outcomes
Processes with positive outcomes	
● Collecting the real business data that students did not know the process	Better understanding of the other stakeholder's problem
● Working on solutions of real business problems in a business partner workplace	Student enthusiasm
● Using the method taught in class in the context of real business partner's problems and information	Increased understanding of real business mechanisms behind a specific problem
● Vivid problem definitions with exercises	Easily re-defining of the project problems within a real business environment
● Trend analysis	Successful preparation of project challenge forecast
● Trend-watching	Relevant skills for future work
Processes with negative outcomes	
● Designated team-based tests	Not enough time for team integration Communication problems among team members Unequal workload and contribution to the project
● All teams working on the same project	Teams doing together since there were not sufficient business partner managers to arrange the three separate interviews for different groups Limit project-relevant information gathered
● Too much time on theories and tasks that were not relevant with the project challenge	Using extra time to finish particular tasks Project delay Poor results for the project challenge

Source: Kleczek et al. (2020)

followed a traditional teaching paradigm via multiple case studies, the research explored the project's implementation and student experience to identify the benefits and challenges. The goal of the project was to equip students with technical, interdisciplinary, and interpersonal skills that were important for the workplace. The research results indicated a positive ffect of project-based learning on student achievement within extracurricular activities in Kenya (Munezero & Bekuta, 2016).

For producing interactive journalistic products and creating essential achievements in journalism education, Siitonen et al. (2019) investigated two pilot courses of project-based learning in Finlandl Achievement was analyzedusing news games, materials that students produced in the games, student feedback, and observations from teachers during the project. Students received feedback from media companies and built their expertise of journalism through the project-based learning process (Siitonen et al., 2019).

Assessments of the Achievement in Different Subject-Matter Areas

To explore the effectiveness of project-based learning, it is inevitable to identify and utilize diverse assessments in education. In STEM education, Carparo and Corlu (2013) identified the shift within project-based learning from summative to formative assessments, with a preference of interpersonal domain authentic assessment. Within both formative and summative assessments, students transition from authorized-imposed regulation to self-regulation in learning. The researchers discovered that formative assessment emphasizes the connection between grades and the evaluation of products and feedback of learning. Alternatively, they identified that summative assessment concentrate on evaluating the completed achievement that followed a predetermined instructional period. STEM project-based learning assessment was applicable for both individual and group performance, so it was essential to match the formative assessment with the learning activity and settings to make sure every student contributed to a project. Authentic assessment focused on knowledge products, using real-world application to connect with learners and matching the learning content with knowledge product; for instance, students listed what they learned or filed reports about the process (Capraro & Corlu, 2013). The study listed the assessments under STEM project-based learning, traditional instruction, and both.

Capraro and Corlu (2013) compare project-based learning to learning to ride a bicycle.; Project-based learning is not one task but the interaction of several small tasks. They found that project-based assessment included choosing achievement, planning content, determining a scenario, writing the scenario, developing formative assessments, creating rubrics, and designing summative assessments (Capraro & Corlu, 2013). The research provides directions for teachers to enhance the instructions in class (Capraro & Corlu, 2013). The distinction of assessments in project-based learning and traditional instructions provides the direction of identifying academic achievement in the meta-analysis of this dissertation, which includes grade point average (GPA), grades, and test scores. Capraro and Corlu (2013) emphasized using formative assessment, withmaking connections between grading and evaluating knowledge products, which, they described, is a necessity in the current age of accountability.

Using formative assessment, Cifrian et al. (2020) applied and developed self- and peer-evaluation strategies among 75 undergraduate students in a project-based chemical engineering course for 2 academic years in Spain. The rubric of formative assessment was used during the continuous learning process in which students participated actively using the criteria to create high-quality content and produce oral presentation (Cifrian et al., 2020). In measuring student perception, the researchers created an anonymous and voluntary survey instrument. Cifrian et al. (2020) believed that the assessment, the learning methodology, and the experience gained with the survey result contributed to student learning outcomes. The formative assessment rubrics enabled regular, timely, detailed, and constructive feedback of the teamwork activities for both students and teachers (Cifrian et al., 2020). Rubrics were essential for learning activities that had high qualitative contents and were susceptible to student subjectivity. Furthermore, students participated in the design and application of the rubric (Cifrian et al., 2020). Assessments must match the learning objectives and accurately measure qualitative learning activities. The identification of formative and summative assessments provided the theoretical background that this dissertation used to determine types of assessments of academic achievement for the meta-analysis.

Chen and Yang (2019) found that project-based better supports student learning than traditional teaching methodologies, especially in social science. Rsearchers concluded that project-based learning could be effective in multiple non-STEM subject matter areas such as language learning, history, and geography. In all subjects, project-based learning can be implemented using authentic projects and assessments. Larmer (2015) explained that project-based learning was effective for language learners because reading and writing were purposeful and connected to students' personal meaningful experiences. This study found that project-based learning was practiced sufficiently across both STEM and non-STEM subject matter areas. Thereforethis dissertation considered subject matter areas with the subgroups STEM and non-STEM as one moderator variable in the meta-analysis.

Hours of Instruction

For discovering preservice technology, teachers' cognitive structure, and the infusion of the engineering design process into STEM project-based learning, Lin et al. (2021) conducted a quasi-experimental design with 28 preservice technology teachers. Participants created flow maps of engineering class designs and evaluated their learning outcomes. A chi-square test was conducted and demonstrates that

> first, applying the engineering design process to STEM project-based learning was beneficial for developing preservice technology teachers' schema of design thinking, especially with respect to clarifying the problem, generating ideas, modeling, and feasibility analysis; second, it was important to encourage teachers to further explore the systematic concepts of engineering design thinking and expand their abilities by merging the engineering design process into STEM project-based learning. (Lin et al., 2021, p. 4)

The research results suggest that teachers invested in sufficient hours of instruction in the project-based learning process. One of the research limitations was that the flow map method used in the experiment was time consuming and made it difficult to increase the number of research subjects. Thus, the researchers concluded that the preservice teachers spent too much time on problem definition and were slow to transition to developing alternative solutions and project implementation (Lin et al., 2021). As freshmen and seniors may spend different amounts of time in the problem-solving stage, such as reading and describing problems, different studies indicate different numbers of hours of instruction even though all being college-level project-based learning experiments. Given this fluctuation, this dissertation considered the hours of instruction in the moderator analysis.

Chen and Yang (2019) found that the effect of implementing project-based learning for more than 2 hours per week compared with traditional instruction was better than that seen with less than two hours per week compared with traditional instruction. Thus, Chen and Yang (2019) did-o not suggest a one-shot intervention that lasts only one lecture of 50 minutes or less. Given the shift from traditional instruction, open-ended project-based learning could be difficult to adjust to at the beginning, but becomes easier with more experience (Barron & Darling-

Hammond, 2008; Hallermann et al., 2011, p.12; Larmer, 2015). Larmer & Mergendoller (2011) also suggested to develop project-based learning as the main course, adjusting daily or weekly schedules to provide longer and more flexible blocks of class time. Thus, this dissertation considered hours of instruction as a moderator variable in the meta-analysis.

University Location

Only two of the four meta-analyses reported in chapter I investigated university location as a moderator variable. Chen and Yang (2018) assessed average-effect-size differences for schools located in Europe and North America (n = 10), Western Asia (n = 10), and East Asia (n = 9). The average effect sizes were 0.71, 0.93, and 0.42, respectively. Western Asia had the highest average effect size, which is alarge effect size. Europe and North America were in the upper range of medium for the average effect size and East Asia had the smallest of the average effect sizes. Jensen (2015) had only two locations: Turkey (n = 8) and the United States (n = 18). The average effect sizes are very different with 1.11 (very large) and 0.37 (small).

Linnes (2020) studied e-collaboration successes, challenges, perceptions, and tools among students in a graduate-student online course. The survey included a question aboutuniversity locations. The survey results listed the participants' location of origin, consisting of the United States (48.8%), Middle East (19.8%), Asia (16.3%), Europe (10.5%), and South America (4.7%). Linnes (2020) did not analyze the location data because of the study's small sample size. For this dissertation, the researcher collected data from multiple studies to analyze the university location as a moderator variable.

The research results of Chen and Yang (2019) showed that the effects of project-based learning compared with traditional instruction in Europe and North America and Western Asia were significantly greater than the effect in East Asia. Although Hallermann et al. (2011, p. 10) notes that every school had a place for project-based learning, the effectiveness on academic achievement might be different based on the school location. The reason could be that compared with students in East Asia, students under Western contexts might be subject to less intense competition at school. Also, teachers may not have to cover all textbook content in class in Western contexts, so students and teachers could pay more attention to project-based learning approach (Chen & Yang, 2019). Researchers also explained that schools in Europe, North America, and West Asia might have more practical experiences of project-based learning and access to the supporting resources (Chen & Yang, 2019). These differences in access to resources might be related to culture and resource differences among countries. It was deemed possible that students found it difficult to control their time and obtain information, so they faced problems working to complete their projects (Barron & Darling-Hammond, 2008; Hallermann et al., 2011, p. 114). This dissertation further investigated university location as a moderator variable in the meta-analysis.

Summary

Researchers in the 2010s have examined technology support, group size, and subject-matter areas and their various effects on project-based learning. All of the five variables were considered as moderator variables in this dissertation. The following chapter contains the research methodology and coding sheet of the meta-analysis.

CHAPTER III

METHODOLOGY

The purpose of the meta-analysis was to assess the average effect size for the effectiveness of project-based learning on academic achievement in higher education worldwide. Academic achievement refers to the extent to which students attain their learning goals, as assessed by teacher-developed, researcher-developed, standardized posttest, or retention tests (Chen & Yang, 2019, p.74; Jensen, 2015, p.15). Achievement is assessed under both traditional and project-based learning conditions, and was used to obtain the effect sizes for individual studies in this meta-analysis. To evaluate academic achievement in project-based learning, the researcher evaluated variables in prior meta-analyses, including student grade point average (GPA), course grades, and test scores. The five moderator variables that were used in this dissertation include technology support, group size, discipline or subject-matter area (Statistics, Technology, Engineering, and Mathematics (STEM) and non-STEM groups), hours of instruction, and university location. Experimental, quasi-experimental, pre- and posttest comparison, and posttest only research investigating the relationship between project-based learning and college academic achievement in STEM and non-STEM courses were included. This chapter contains details of the search path of studies for the meta-analysis, the research coding process, and the calculation of effect-size. Inclusion and exclusion criteria, reliability and validity of the studies, and characteristics of the studies are provided.

Research Design

The researcher deployed a meta-analysis design to compare and integrate the results from experimental pretest posttest, experimental posttest only, quasi-experimental pretest posttest, quasi-experimental posttest only, pre- and posttest comparison, and posttest only research that investigated the effectiveness of project-based learning on academic achievement among college students. The meta-analysis included published and unpublished research that were conducted as early as 2010 in Western Asia, Eastern Asia, Southeast Asia, Europe and North America, and other areas in the world. The independent variable was teaching methodology, either project-based or traditional learning conditions. The dependent variable was the instruments that researchers used to measure the academic achievement, including GPA, grades, and test scores. Meta-analysis is a quantitative research synthesis that summarizes and compares results from empirical literature, which involves the research results of more than one study by collecting effect sizes of individual studies and conducting statistical analyses (Card, 2012, pp. 3-6).

There were 17 studies included in this meta-analysis. It is necessary to compare all of the effect sizes from the eligible studies for the meta-analysis to integrate all research results. The combined effect size of academic achievement was influenced by subject matter areas, school location, hours of instruction, technology support, and group size. This meta-analysis provided quantitative data to support the qualitative literature reviews of the project-based learning method and summarized quantitative results from all 17 research studies, indicating that using project-based learning was effective in increasing student academic achievement.

Data Sources and Search Strategies

For searching and selecting articles, this study followed the steps shown in Figure 1, including initial search and screening, application of internal and external criteria, final selection, and data extraction. The researcher completed an initial search to screen studies for the meta-analysis based on the following criteria:

1. Studies published between 2010 and 2021.
2. Studies that assessed the effect of project-based learning on academic achievement, as measured by student GPA, course grades, and test scores.
3. Studies that were contained in the research result by implementing the following conditions:
    1. Search for the keywords within the educational and psychological data resources including American Society for Engineering Education (ASEE), Elton B. Stephens Company Information Services (EBSCO), Educational Resource Information Center (ERIC), American Psychological Association (APA) Psyclnfo, Semantic Scholar, ProQuest, ResearchGate, ScienceDirect, Scopus, Springer, Taylor & Francis Group, and some other databases. The search engines used were Fusion and Google Scholar.
    2. Search the key words with combinations of the following terms: *career development + project-based learning + collaborative learning or cooperative learning, project-based learning + corporate learning, project-based learning + effect size, project-based learning + higher education or college or university or post-secondary or postsecondary, project-based learning + achievement or learning outcome, project-based learning + meta-analysis, project-based learning + student achievement or achievement or learning outcomes, project-based learning + student performance, and project-based learning + student performance + meta-analysis*.

Inclusion and Exclusion Criteria

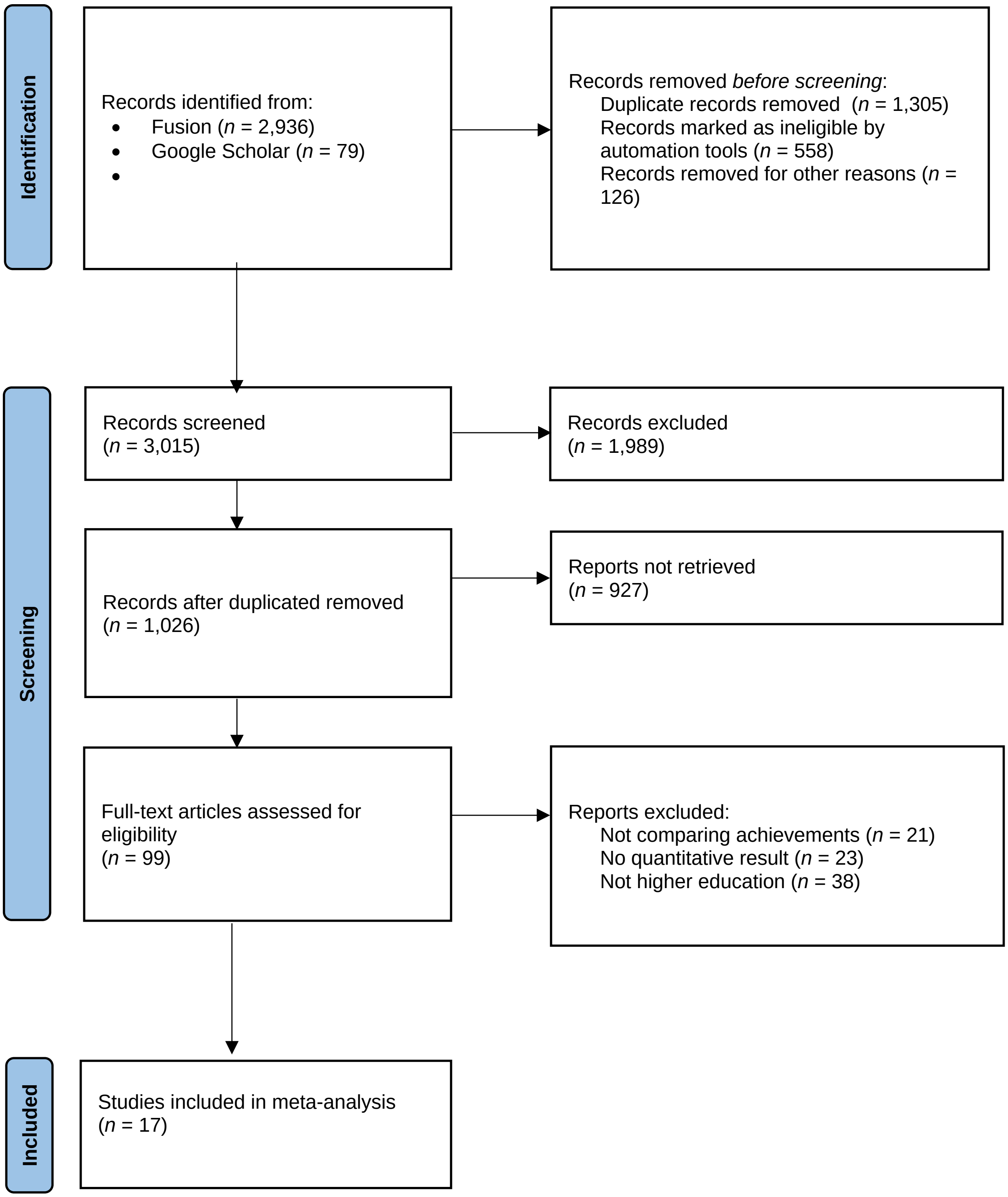

Figure 1. Flow diagram of the search, screening, and selection process

The search and selection process included an initial search and screening, applying the selection criteria, and a final selection of related studies as shown in Figure 1. This figure is based on PRISMA guideline for reporting systematic reviews (Page et al., 2020). After initial screening with the results above, the researcher established a comprehensive set of inclusion and exclusion criteria to identify eligible articles, referred to in Table 5. The following criteria were

Table 5

Selection Criteria

Criteria	Inclusion	Exclusion
Research method	Investigated project-based learning	Not focused on project-based learning in experiment
Research results	Provided quantitative data as research results	No quantitative research result
Academic achievement	Measurement including GPA, grades, test scores, or a combination	Measurement not including GPA, grades, test scores, or combination
Research type	Study had an experimental, quasi-experimental, pre-post comparison, or posttest only design	Not including any of the mentioned designs
Pre- and postexperiment design	Contained pretest to assess student prior-knowledge level before the experiment or posttest to evaluate the changes during the experiment	Not including either pretest or posttest
Participant age range	Undergraduate students	Students not in higher education
Literature type	Journal articles, dissertations, or conference presentations	Other types
Language	English	Non-English
Time period	Published between 2010 and 2021	Published outside this time period

applied to include research studies for the meta-analysis: using project-based learning as the research method; providing quantitative research results; measuring achievements including GPA, grades, test scores, or a combination; research design type; higher-education sample population; literature types; articles in English; published between 2010 and 2021. Studies that did not meet these criteria were excluded.

There were 99 articles reaching the final selection. The data extraction process included the researcher and her chair working together to identify whether the data of each article was qualified for calculating the effect size. Articles were rejected because of the following results: there was no quantitative data to collect (n = 23), studies did not investigate academic achievement as a result (n = 21), or their target population was not college students (n = 39). The final 17 articles were utilized in meta-analysis (n=17).

Publication Bias

One issue that is of concern is that the available studies may not be representative of all studies of project-based learning in higher education. Publication bias can affect the validity of the meta-analysis results because studies reporting statistically significant results are published whereas the studies reporting less than statistically significant results are not published (Card, 2012, p. 257). This problem is not unique to meta-analysis as it can arise in narrative reviews. The effect of publication bias (although a more accurate term would be general reporting bias) is that published literature does not represent all the studies that were conducted on a research topic and the available meta-analysis research results produce a stronger effect size than if all research results were considered (Card, 2012, p. 258). Research syntheses that fail to include unpublished studies may exaggerate the magnitude of the results of the investigation. The researcher accounted for this by searching for unpublished research in the form of dissertations and conference papers. Of those studies that fit the meta-analysis criteria, only one dissertation was found and no conference papers.

There are six approaches that can control publication bias, including moderator-analysis, funnel plots, regression analysis, fail-safe *N*, trim and fill, and weighted selection. The researcher used the funnel plot and fail-safe *N* to investigate the results of publication bias.

Funnel plot

Funnel plots can be an effective way to account for publication bias caused by small samples. The funnel plot has the effect sizes on the X axis and the sample size or standard error of the effect size on the Y axis. Typically, the large studies appear toward the top of the plot clustering around the average effect size. Smaller studies are at the bottom of the plot and would be spread out across the range of values, because smaller effect sizes have more sampling error. Light and Pillemer (1984) suggested that the pattern resembles a funnel, resulting in the name funnel plot. Publication bias may cause asymmetrical funnel plots as those studies in small sample sizes fall below the average effect size. Asymmetrical effect sizes, however, may be due to true heterogeneity of effect sizes, chance, sampling variation, and methodological quality as well as publication bias.

Figure 2 contains the Funnel Plot chart for the selected 17 studies. The majority of the effect sizes were in the lower right portion of the forest plot. Those with larger sample sizes were in the upper part of the plot. The studies did not follow the expected symmetry of mean effect size. The gap was to the right and not to the left where nonsignificant studies would have been if they had been located (Borenstein et al., 2009). As pointed out above, the asymmetry may be due to other factors that were investigated with the moderator variable analyses. Vevea et al. (2019) pointed out that the results of the funnel plot may be less meaningful when sample sizes are less than 20, as was the case in this meta-analysis.

Fail-safe N

Fail-safe N is an approach to evaluate the robustness of a meta-analysis to the existence of excluded studies. Fail-safe N is the number of studies that are needed to be included in the meta-analysis that would result in the average effect size becoming not statistically significant.

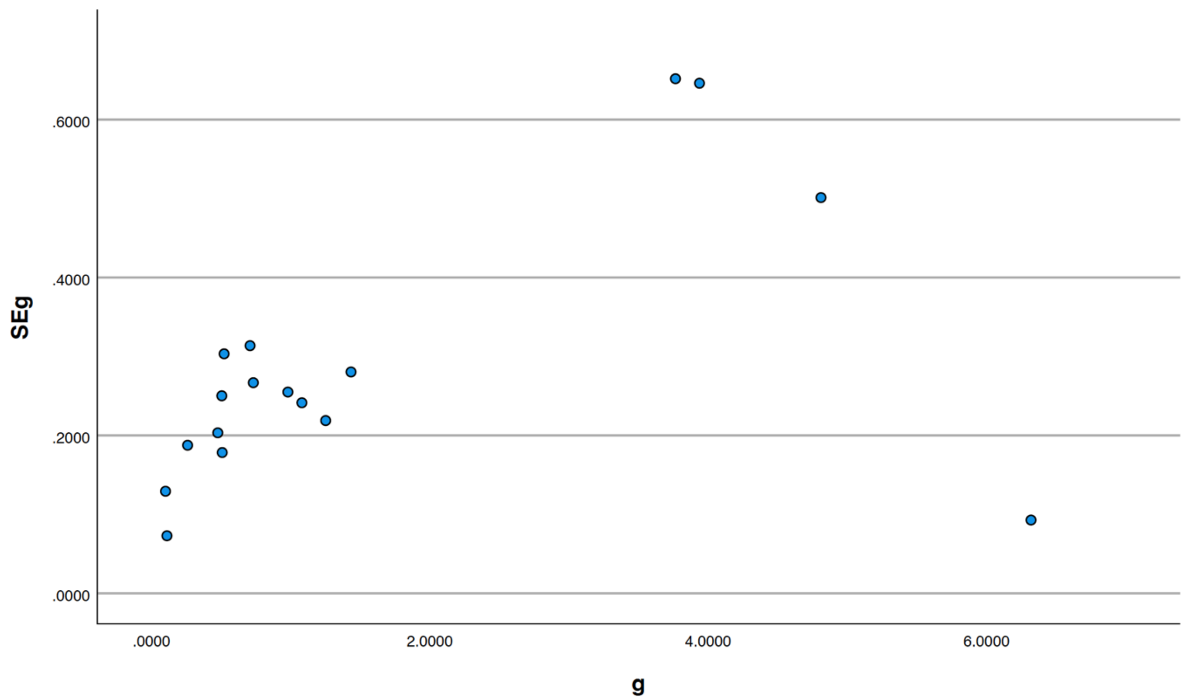

Figure 2. Funnel plot of 17 studies

The number of studies that were excluded from publication that would have an effect size of zero or not statistically significant that would need to be included in the meta-analysis is $N = k(z_c/z_\alpha)^2$-k. In this equation, *k* is the number of studies in the meta-analysis, *zc* is the combined standard normal deviate of significance across studies, and *z alpha* is threshold value of significance. Failsafe N is evaluated by using Rosenthal's (1979) recommendation equal to 5*k* + 10. The result of 5k + 10 = 95, so the fail-safe *N* should be greater than 95.

For this dissertation, *k* was equal to 17. After obtaining the *z* value associated with Hedges's *g*, the researcher obtained the result of 50.31, or 50 studies with null results. The number 50 was smaller than 95, but given the small number of published studies in 11 years publication bias was unlikely for this research study.

Instrumentation Reliability

The meta-analysis included research studies that were based on the inclusion criteria. All of the selected studies were coded according to the coding procedures that are detailed below in the coding section. Card (2012, p. 74) described how intercoder reliability is used to assess the consistency between coders and intracoder reliability to assess the consistency within the same coder. This dissertation controlled for intercoder reliability using a second coder. The researcher coded four articles for meta-analysis with a second coder. Both coders reviewed and filled in the coding forms independently and then met on Zoom® to integrate results. The second coder was the Director of the Learning Center at a Roman Catholic university. Both coders discussed any disagreements until there was complete agreement. To ensure intercoder reliability, an agreement rate was calculated using the proportion of studies that two coders assigned the same categorical code. This occurred on two occasions for the four studies. Differences in coding occurred for the geographic identification of student population worldwide, reported data format, and the understanding of students grades or scores. Both coders negotiated the differences and arrived at consistent coding results. The agreement rate was 96.74%, which is close to 100% and acceptable for the intercoder reliability. Disagreements were resolved through discussion.

Data-Collection Procedures (Coding)

The key words of initial search for the research study were listed in the Data Sources and Search Strategies section. All data were collected based on the researcher-developed coding sheet (Appendix A). The coding sheet was based on study characteristics as suggested by Card (2012, p. 66) and the moderator variables suggested by the previous meta-analyses and the review of the literature. The following sections provide additional information and background about each of the sections of the researcher-developed coding sheet

General information

The first section of the researcher-developed coding sheet, "General information," included coder name, coding date, and name of the study. The second coder had a brief knowledge of which study to code and the study's inclusion criteria.

Identification of studies

In the "Identification of studies" section, the specific identification of studies to code were deployed. Information sections included title of study, American Psychological Association (APA) citation for the study, year of publication, country of the research, type of report, and if peer reviewed.

Participant characteristics

The next section, "Participant characteristics" had coders identify participant characteristics, including gender, class level, student major disciplines, and course disciplines. Each characteristic had the number of students or percentage of the sample population reported on the coding sheet. For each study, the coder identified the number of female students as 0, less than 50%, equal or more than 50%, or not specified. College students had the following class levels of freshman, sophomore, junior, and senior.

Institution, program, and performance characteristics

The “Institution, program, and performance characteristics” section was used to identify information about college institutions and programs. Questions to answer in the section included institution type, size, public or private institution, and the learning performance measurement. Institution sizes were identified as small (1,000-2,999), medium (3,000-9,999), or large (10,000 and above). Degree levels included 2-year and 4-year programs. Colleges were divided as public and private. Coders also reviewed the learning performance measurement for pretest, if any, and posttest in each study. The performance measurements included GPA, grades, and test scores developed by researcher, teacher, or standardized test. For each study, a specific explanation of the learning performance measurement was noted during the coding process.

Research-design characteristics

The study type, such as experimental, quasi-experimental, pre-post comparison, and posttest only research, was coded in the “Research-design characteristics” section. The pretest posttest and posttest only options were compared for experimental, quasi-experimental, and non-experimental studies. Other information collected under this section included control group, sampling type, and teacher/researcher carried the experiment.

Moderator variables

The “Moderator variables” section contained five questions for the five moderator variables including technology support, project-based learning group size, experiment disciplinaries or subject matter areas, hours of instruction, and university location. Group sizes included individual, small (two to five participants), large (more than five), and not specified. Subject-matter areas were divided as STEM or non-STEM so that the design was consistent with previous meta-analysis studies published (as described in chapter I). The instructional hours within project-based learning included 2 hours or below, more than 2 hours, and not specified. After discussing university location with the other coder and the chair of the dissertation committee, the researcher included the regions Western Asia, Eastern Asia, Southeastern Asia, Europe, and North America, based on the location where the 17 studies were conducted. Appendix B contains a listing of the countries of each of university and the associated location categories.

Effect sizes and statistical reported in study

This section is based on the statistics reported in each study. Data reported within each study included means and standard deviations, effect sizes, sample sizes, raw differences, correlation coefficient, eta squared, *t*-test values, *F*-test values, and degree of freedoms. For each article, the coder selected one of four methods to report the effect size, including mean and standard deviation, standard deviation gain, *t*-test values, and *F*-test values. Details of the conversion to effect sizes are explained in *Appendix A*. All of the effect sizes were calculated by the researcher and dissertation chair to ensure consistency.

To measure the effect size, the researcher calculated Cohen's *d* based on the reported data from the 17 studies. If a study provided the means and standard deviations, the Cohen's *d* was computed manually. If a study did not provide the means and standard deviations, the Cohen's *d* was calculated by converting the data of *t* test, *F* test, or standard deviation gain depending on what statistical data the article provided. In all cases, the researcher calculated Hedges's *g* value to correct for small-sample-size bias. To interpret the size of the effect size, Cohen's (1992) criteria of .20 small, .50 medium, and .80 large was applied.

Study quality

All studies were evaluated on a scale from 0 (good quality) to 4 (poor quality). Each study was coded with one point for inadequate reporting of the research characteristics, small sample sizes, incomplete experiment procedures, poor reliability or validity, incomplete or incorrect statistic reports, or other limitations of the research study.

The study quality coding for meta-analysis is classified as "good quality" if the final score is 0. If a selected study has a score of 4, it is classified as "poor quality." A study with a score from 1 to 3 is classified as "moderate quality." \ After completing the coding process for all 17 studies, only one study was classified as "poor quality." All the other 16 articles were "moderate quality." All 17 articles had one or more limitations that are discussed in chapter V, including small sample size, no female student population, no pretest, no group size or instructional hour information, and no clear definition of measurements. After coding, the researcher collected data and reported the descriptive information in Table 6.

Sample sizes ranged from 21 to 219, which were corrected for using Hedges's *g* for the effect-size measure. Many of the studies did not report gender of participants. Seven of the studies did not report students' year in the program. All but one of the colleges was considered as large. All but one school was a 4-year college. Nine of the schools were public institutions. The most common measurement of learning performance was test scores (n = 15), with only two studies using grades. Among those that used test scores, the majority were researcher-developed (n = 12), with only one teacher-developed test.

Table 6

Descriptive Information for Qualifying Studies

Study (year)	Sample Size	Gender	College year	Type of college 1	Type of college 2	Type of college 3	Learning performance measurement
Bakar et al. (2019)	44	Not Specified	Unknown	Large	4-year	Public	Test scores (researcher developed)
Berchiolli et al. (2018)	115	Not Specified	Freshmen	Large	4-year	Private	Test scores (researcher developed)
Bilgin et al. (2015)	66	Female > or = 50%	Unknown	Large	4-year	Public	Test scores (researcher developed)
Çelik et al. (2018)	19	Not Specified	Unknown	Large	4-year	Private	Test scores (researcher developed)
De La Puente et al. (2018)	45	Not Specified	Unknown	Large	4-year	Private	Other
Hamoush et al. (2011)	27	0 < Female < 50%	Junior	Large	Not Specified	Public	Test scores (teacher developed)
Jollands & Parthasarathy (2013)	219	Not Specified	Unknown	Large	4-year	Public	Test scores (researcher developed)
Kettanun (2015)	21	Not Specified	Unknown	Medium	2-year	Public	Other
Mahasneh & Alwan (2018)	79	Not Specified	Junior	Large	4-year	Public	Test scores (researcher developed)
Mohamadi (2018)	60	Not Specified	Senior	Large	4-year	Public	Test scores (researcher developed)
Ozdamli & Turan (2017)	130	Female = 0	Unknown	Large	4-year	Private	Test scores (researcher developed)

Peng et al. (2019)	69	Female > or = 50%	Junior	Large	4-year	Private	Test scores (researcher developed)
Rahardjanto et al. (2019)	100	Not Specified	Junior	Large	4-year	Private	Test scores (researcher developed)
Razali et al. (2020)	764	Not Specified	Unknown	Large	4-year	Public	Grades
Santyasa et al. (2020)	62	Female > or = 50%	Unknown	Large	4-year	Public	Test scores (researcher developed)
Wu et al. (2018)	64	Not Specified	Unknown	Large	4-year	Private	Grades
Zhang et al. (2020)	240	Not Specified	Unknown	Large	4-year	Public	Other

Research Questions

The meta-analysis addressed the following research questions:

1. What is the average effect size of using project-based learning on academic achievement in higher education?

To what extent does technology support influence the effectiveness of project-based learning on academic achievement as a moderator variable?

2. To what extent does discipline or subject-matter area influence the effectiveness of project-based learning on academic achievement as a moderator variable?
3. To what extent does individual, small group, or large group influence the effectiveness of project-based learning on academic achievement as a moderator variable?

5. To what extent does hours of instruction influence the effectiveness of project-based learning on academic achievement as a moderator variable?

6. To what extent does university location influence the effectiveness of project-based learning on academic achievement as a moderator variable?

Data Analysis

To address the research questions, effect sizes from the studies collected for meta-analysis were analyzed. The researcher computed the average effect size of the effect size results of 17 articles to assess the effectiveness of project-based learning on academic achievement. According to Card (2012, p. 90), in order to investigate standardized mean difference between the means of two groups, Cohen's *d* should be used to measure the effect sizes. In this meta-analysis, Cohen's *d* was converted to Hedges's *g* to obtain an unbiased estimate of effect size.

Hedges's *g* was used to correct the effect sizes based on the different sample sizes within each study. The first research question was answered through the calculation of the average effect size. Testing for statistical significance, homogeneity, and analysis of variance (ANOVA) were used to explore the influence of moderator variables on academic achievement to address the second to sixth research questions. In addition to addressing these research questions, the researcher investigated potential effects from data results based on other coding questions. The

CHAPTER IV

RESULTS

This study was a meta-analysis of the effectiveness of project-based learning on academic achievement and the aspects that may affect academic achievement in higher education worldwide. Project-based learning is a student-centered approach that requires students to engage in real-world tasks. During this process, students develop a project to report to an audience, enabling the students to learn knowledge and enhance skills (Thomas, 2000). Researchers have discovered the advantages of project-based learning for improving academic achievement in specific courses. Meta-analysis is a powerful method to evaluate the effectiveness of a project-based learning approach across research studies. This research method has been utilized by different researchers many times based on various populations to quantify the effectiveness of this instructional methodology. This research study conducted a meta-analysis to integrate the studies that investigate the effectiveness of project-based learning on academic achievement in higher education worldwide.

In meta-analysis, once the average effect size is obtained and tested for statistical significance from zero, effect sizes are tested for homogeneity. If they are found to be heterogeneous, then moderator analyses are conducted for investigating the variables that may be contributing to the heterogeneity in the effect sizes. To investigate the effect of moderator variables in this meta-analysis, the following five moderator variables were considered, including technology support, group size, subject area, hours of instruction, and university location. A moderator analysis is similar to the analysis of variance (ANOVA) and is used for testing equality of the levels of the moderator variables (independent variables). In meta-analysis, the moderator analysis tests for homogeneity of average effects sizes across the categories of the moderator variable. In an ANOVA, if there are too few outcomes for one of the levels of the independent variable, including that level in the analysis is not advisable as one is capitalizing on individual variation and not level variation. The same is true for the moderator analyses in meta-analysis. Some categories that have very few effect sizes would not be included in the analysis.

Research Question 1

The effect sizes for all of the 17 studies included in the meta-analysis are listed in Table 7, along with authors and year, sample size, measurement of academic achievement, Hedges's *g*, and standard error. Sample sizes range from a low of 19 to a high of 764. Eleven of the studies used researcher-developed tests and Hedges's *g* ranges from 0.10 to 4.92.

The average effect size of 17 articles is 1.64, with a standard error of 0.42. The 95% confidence interval (CI) is (1.56, 1.72). Hence zero is not in the CI, indicating that the average effect size is statistically significant at the .05 level. This average effect size across the 17 studies is not only positive but also very large as it is greater than one, which indicates the effectiveness of project-based learning on student academic achievement in higher education. Testing for heterogeneity of effect sizes resulted in a *Q* of 3391.94, with 16 degrees of freedom that is statistically significant at the .05 level of significance. The magnitude of heterogeneity (I^2) is 0.9953, or 99%, a very large result.

Of the 17 articles, 12 of them were published between 2018 and 2020. There was only one article published in each of the years 2011, 2013, and 2017. Two articles were published in 2015. Given the larger number of articles written between 2018 and 2020 and in comparison

Table 7

Effect Sizes for the 17 Studies Included in the Meta-Analysis

Study (year)	Sample Size	Measurement	Effect size	Hedges's *g*	Standard error
Bakar et al. (2019)	44	Researcher developed test scores	0.72	0.71	0.31
Berchiolli et al. (2018)	115	Other	0.26	0.26	0.19
Bilgin et al. (2015)	66	Researcher developed test scores	0.51	0.50	0.25
Çelik et al. (2018)	19	Researcher developed test scores	3.94	3.76	0.65
De La Puente et al. (2018)	45	Grades	0.53	0.52	0.30
Hamoush et al. (2011)	27	Researcher developed test scores	0.49	0.48	0.20
Jollands & Parthasarathy (2013)	219	Other	6.34	6.32	0.09
Kettanun (2015)	21	Researcher developed test scores	4.10	3.97	0.65
Mahasneh & Alwan (2018)	79	Researcher developed test scores	1.09	1.08	0.24
Mohamadi (2018)	60	Researcher developed test scores	0.74	0.70	0.27
Ozdamli & Turan (2017)	130	Other	0.51	0.51	0.18
Peng et al. (2019)	69	Teacher developed test scores	0.99	0.98	0.25
Rahardjanto et al. (2019)	100	Researcher developed test scores	1.26	0.25	0.22
Razali et al. (2020)	764	Grades	0.11	0.11	0.07
Santyasa et al. (2020)	62	Researcher developed test scores	4.87	4.81	0.50
Wu et al. (2018)	64	Researcher developed test scores	1.45	1.43	0.28
Zhang et al. (2020)	240	Researcher developed test scores	0.10	0.10	0.13

with the years prior, there is an upward trend of popularity in research on project-based learning in higher education.

There were 12 articles investigating project-based learning in STEM programs and 5 in non-STEM programs. This question is explained with details under moderator-variable analysis.

In comparing the two institutional types, 10 studies were from public schools and 7 were from private schools. Both public and private universities utilized project-based learning in daily instruction and provided the data for educational research.

There was a range of different sampling methods among the 17 studies. Eleven of the research studies used convenience sampling for their experiment. Three studies used random sampling, and three did not specify their sampling method. It is understandable that random sampling is not always possible in educational research. Researchers likely used convenience sampling because it was easy to organize experiments and collect data. As there were only three articles using random sampling, the data were not sufficient to assess any effectiveness or differences between convenience and random sampling.

Moderator-Variable Results

To investigate the moderator variables, the researcher conducted analyses of the moderator variables including year of publication, study type, sampling, university type, and experiment instructor (teacher or researcher).

The different publication years were investigated by grouping the 17 articles in two categories: 2011-2017 and 2018-2020 (Table 8). The result of the analysis was statistically significant indicating heterogeneity for the two groupings of publication years. An alternative representation of heterogeneity is the index of I^2. For this analysis, the I^2 was 0.99, or 99%, which is large heterogeneity. Huedo-Medina et al. (2006) provided guidelines for the interpretation of I^2 as follows: 25% is a small amount of heterogeneity, 50% is a medium amount of heterogeneity, and 75% is a large amount of heterogeneity.

Table 8

Categories for Years of Publication, Associated Effect Sizes, Standard Errors, and Results of the *Q* Test Based on the Analysis of Variance for Years of Publication

Variable	*f*	%	Average Effect Size	Standard Error	95% CI	*z*
Publication Years						
2011-2017	5	29	4.10	0.07	(3.96, 4.24)	56.55*
2018-2020	12	71	0.42	0.05	(0.32, 0.52)	8.23*
Q_W = 1674.23 Q_B = 1717.71* *df* = 1						

*Statistically significant when the overall error rate was controlled at the .05 level.

The statistically significant result indicated that the five studies between 2011 and 2017 had more effective average effect size compared with more than twice the number of studies between 2018 and 2020.

The results of the heterogeneity tests for Study Design are presented in Table 9. The moderator variables that constitute sStudy dDesign were two types of studies: sampling and experiment instructor. The two tTypes of sStudies are sStudy tType I pretest-posttest with comparison group, pretest-posttest one group, and posttest only with comparison group designs and sStudy tType II experimental, comparative, and quasi-experimental. For sStudy tType I, the majority of designs were pretest-posttest with comparison group with average *g* of 0.77 (close to a large effect size). Four studies that were pretest-posttest with one group had an average *g* of 5.26 (a very large effect size). Only four studies that were posttest only with comparison group had an average *g* of 0.22 (small effect size). All three Hedges's average *g* values were statistically significant when overall error rate was controlled (Table 9). The *Q* between sStudy tType 1 was statistically significant when the overall error rate was controlled and I^2 was .99 (a large amount of heterogeneity). There was a difference between the effect sizes for pretest-posttest comparison group, pretest-posttest one group, and posttest only designs, favoring the pretest-posttest one-group design. The other two designs differed as well, given that the 95% confidence intervals do not overlap. I^2 = .98, indicating a large amount of heterogeneity.

Table 9

Categories for Study-Design Intervening Variable, Associate Effect Sizes, Standard Error, and Results of the *Q* Test Based on the Analysis of Variance for Study Design

Study-Design Variable	*f*	%	Average Effect Size	Standard Error	95% CI	*z*
Study type I						
Pretest posttest comparison group	9	53	0.77	0.06	(0.65, 0.89)	12..83*
Pretest Posttest one group only	4	24	5.26	0.08	(5.10,5.42)	65.75*
Posttest only	4	24	0.22	0.06	(0.10, 0.39)	3.67*
Q_W = 820.74 Q_B = 2,571.17* *df* = 2						
Study type II						
Experimental	2	29	1.18	0.19	(0.81, 1.55)	1.21*
Comparative	7	41	0.42	0.08	(0.26, 0.58)	5.25*
Quasi-experimental	8	47	2.10	0.05	(2.00, 2.20)	42.00*
Q_W = 3085.93 Q_B = 305.43* *df* = 2						
Sampling						
Convenience	11	65	0.37	0.14	(0.10, 0.64)	2.64*
Random	3	18	5.62	0.09	(5.44, 5.86)	62.44*
Not specified	3	18	0.51	0.14	(0.37, 0.65)	3.64*
Q_W = 528.16 Q_B = 2863.78* *df* = 2						
Experiment instructor						
Teacher	15	88	1.67	0.04	(1.59, 1.75)	41.75*
Researcher	2	12	0.92	0.23	(0.97, 1.37)	4.00*
too small to take comparison						

*Statistically significant when overall error rate is controlled at .05 level.

For study type II, both comparative and quasi-experimental studies were in the majority with only two experimental studies. The largest average Hedges's *g* was for quasi-experimental, followed by experimental and comparative; all of which were different. The fixed analysis of variance results was statistically significant indicating that comparative studies yielded the largest average effect size, experimental next, and quasi-experimental with the smallest average effect size. $I^2 = .95$, which indicated a large amount of heterogeneity. All of the average effect sizes were different as the 95% confidence intervals do not overlap. Given that there were only two experimental studies, however, interpretation of these results must be done with caution.

A review of sampling procedures resulted in three studies with random sampling and three that were not specified as to the type of sampling. The majority of the samples used convenience sampling. Both convenience and not specified sampling had the smallest average *g*. The random sampling with only three studies had a very large average *g* of 5.62. All three types of sampling were statistically significantly different from zero. The Q for sampling was statistically significant, but the confidence intervals of convenience and not specified overlap with one another but do not overlap with random sampling (Table 9). $I^2 = .99$.

All but two of the experiment instructors were teachers, and the average *g* was very large. There were only two researchers who carried out the research investigations, which was a very small number for comparative purposes. The average *g*, however, was large. The confidence intervals between the two did not overlap. The fixed effects analysis of variance was not performed as the sample size for researcher was too small (Table 9).

Study conditions was the next moderator variable investigated (Table 10). Subject-matter areas (STEM or non-STEM), instructional hours, and group size constituted study conditions. There were 11 studies based on STEM courses and 5 based on non-STEM courses (Table 10). The average *g* was very large for STEM courses and large for non-STEM courses. Both were statistically significant different from zero, and the confidence intervals did not overlap. As the Q is statistically significant, there was a statistically difference with the STEM courses with the larger average *g*. $I^2 = .99$ (large amount of heterogeneity).

The majority of hours of instruction were not specified (Table 10). Of those hours that were specified, 2 hours or below had the largest average effect size *g* of 3.85. All three average effect sizes were statistically different from zero. As there were so many studies with not specified hours of instruction, one should only consider the overlap or nonoverlap of the confidence intervals. Notice that not specified and more than 2 hours overlapped and did not overlap with 2 hours or less (Table 10).

Group sizes were categized as individual, 2 to 5 students, more than five students, and not specified (Table 11). There was one study that had one individual or 2 to 5 students. For the *Q* analysis, this study was not included. The largest average *g* was for the 2 to 5 grouping, followed by the individual or 2 to 5 student grouping. The individual group, more than five, and not specified groupings were small to large, respectively (Table 10). Although the *Q* was statistically significant, there were no differences between individual and 5 or more groupings, and both of these groupings differed from not specified and 2 to 5 groupings. $I^2 = .99$ (a large amount of heterogeneity).

There were four categories for university location: Western Asia, Eastern Asia, Europe and North America, and Southern Asia (see Appendix B for a listing of the countries within these categories). The largest average *g* was associated with Eastern Asia with five studies. The other three categories ranged from almost large, small, and small (Table 10).

Table 10

Categories for the Study Conditions Intervening Variables, Associate Effect Sizes, Standard Errors, and Results of the *Q* Test Based on the Analysis of Variance for Study Conditions

Variable	*f*	%	Average Effect Size	Standard Error	95% CI	*z*
Subject-Matter Areas						
STEM	12	65	1.71	0.04	(1.62, 1.80)	39.04*
Non-STEM	5	35	0.93	0.14	(0.66, 1.20)	6.64*
Q_W = 3361.84 Q_B = 30.10* *df* = 1						
Instructional Hours						
2 or below	5	35	3.85	0.07	(3.71, 3.99)	55.00*
More than 2	2	12	0.74	0.18	(0.39, 1.09)	4.11*
Not Specified	10	58	0.40	0.05	(0.30, 0.50)	8.00*
Q_W = 1846.07 Q_B = 1545.87* *df* = 2						
Group Size						
Individual	3	18	0.84	0.15	(0.55, 1.13)	5.60*
2-5 students	3	18	4.77	0.08	(4.61, 4.93)	59.63*
More than 5	5	35	0.63	0.10	(0.43, 0.83)	6.30*
Not specified	5	35	0.30	0.06	(0.18, 0.42)	5.00*
Individual or 2-5 students	1	04	3.93	0.64	(2.68, 5.18)	6.14*
Q_W = 5241.89 Q_B = 2150.05* *df* = 3						
University Location						
Western Asia	5	35	0.76	0.11	(0.54, 0.98)	6.91*
Eastern Asia	2	12	1.44	0.19	(1.07, 1.81)	7.64*
Europe and North America	3	18	0.22	0.09	(0.04, 0.40)	2.34*
Southeastern Asia	5	35	0.37	0.07	(0.10, 0.24)	4.63*
Q_W = 344.29 Q_B = 3047.65* *df* = 3						

*Statistically significant at .05 level

The *Q* was statistically significant, indicating differences among the categories. An inspection of the confidence intervals revealed that Eastern Asia was different from the other three categories. There was an overlap of confidence intervals for Southeastern Asia and Europeand North America. Western Asia differed from Southeastern Asia and Europe and North America as there was no overlap for those confidence intervals (Table 10). I^2 was .98 (a large amount of heterogeneity).

Institution type was analyzed, and the results presented in Table 11. There were two institutional types: public and private, with public having a very large average *g* and private with a large average *g* (Table 11). Both were statistically significantly different from zero. Also, the *Q* was statistically significant. Notice that the confidence intervals did not overlap. I^2 was 98%.

Table 11

Categories for Institution Type, Associated Effect Sizes, Standard Errors, and Results of the Q Test Based on the Analysis of Variance for Institution Type

Variable	*F*	%	Average Effect Size	Standard Error	95% CI	*z*
Institution type						
Public	10	59	1.78	0.05	(1.68, 1.88)	35.60*
Private	7	41	0.91	0.10	(0.71, 1.11)	9.10*
Q_W = 3332.59 Q_B = 59.35* *df* = 1						

*Statistically significant when the overall error rate is controlled at the .05 level.

Additional Analyses

Additional analyses were conducted based on study limitations (Table 12). There were four categories of limitations, but category 4 had only one study. Therefore, the Q analysis was based on one, two, three, and four limitations. The one study with four limitations had an average *g* of 3.75, but when combined with the four studies with three limitations, the average *g* was 0.50. The Q test was statistically significant, with all three sets of limitations differing from one another (Table 12). There was no overlap in confidence intervals. I^2 was 93%.

Table 12

Categories for Limitations and Sample Size, Associated Effect Sizes, Standard Errors, and Results of the *Q* Test Based on the Analysis of Variance for Limitations and Sample Size

Variable	*f*	%	Average Effect Size	Standard Error	95% CI	*Z*
Limitations						
1	3	18	0.86	0.14	(0.59, 1.13)	6.14*
2	9	53	2.64	0.05	(1.94, 2.14)	40.80*
3	4	24	0.43	0.10	(0.23, 0.63)	4.30*
4	1	06	3.75	0.65	(2.48, 5.02)	5.77*
3 or 4	5	29	0.50	0.10	(0.30, 0.70)	5.00*
Q_W = 3150.78 Q_B = 241.16* *df* = 2						
Sample size						
$n \leq 50$	5	29	0.85	0.14	(0.58, 1.12)	6.07*
$51 \leq n \leq 100$	7	41	1.50	0.10	(0.95, 1.35)	11.50*
$n > 100$	5	29	1.84	0.05	(1.74, 1.94)	36.80*
Q_W = 3258.66 Q_B = 133.28* *df* = 2						

*Statistically significant when the overall error rate is controlled at the .05 level.

Sample-size groups were categorized according to Baleman and Keskin (2018) for the additional analysis of sample size (Table 12). As the sample-size category increases then the average *g* also increases. The partitioning of the heterogeneous variance between and within sample-size categories indicated the location of statistically significant differences. The confidence intervals for the two smaller intervals overlapped one another. I^2 = .89.

Summary

The average effect size for the 17 studies was found to be 1.64, which is very large. The 95% confidence interval was (1.56, 1.72) and does not contain zero so the average effect size was statistically difference from zero. The test of homogeneity was statistically significant and indicated that the effect sizes for the 17 studies were not homogeneous, permitting exploration of the moderator variables.

After the moderator analyses, additional analyses were performed, investigating year of publication, study limitations, and sample sizes. All three of these variables contributed to the heterogeneity of the effect sizes as they were statistically significant. Two groupings of year of publication were assessed for differences using the analysis of variance, assuming a fixed effects model. The two groupings of year of publication, 2011 to 2017 and 2018 to 2021, yielded statistically significant differences. The 2011 to 2017 had fewer studies and a very large average effect size. Study limitations were coded as one, two, three, or four or more. As there was only one study with four or more limitations, three and four were combined. The largest average effect size was for those studies with two limitations, followed by the one-limitation category, and two-limitations category. The sample sizes were grouped according to Baleman and Keskin (2018) categories of less than or equal to 50, between 51 and 100, and greater than 100. The largest average effect size was for the largest sample-size grouping and that grouping's confidence interval did not overlap with the two smaller sample-size groupings.

Moderator analyses were conducted for study design, study conditions, and institution type. All of these analyses were found to be statistically significantly different, contributing to the heterogeneity of effect sizes.

The results are summarized in chapter V along with a discussion of the results and implications for practice and future research.

CHAPTER V

DISCUSSION, LIMITATIONS, IMPLICATIONS, AND RECOMMENDATIONS

This study was a meta-analysis of the effectiveness of project-based learning approaches on academic achievement and the aspects that may effect academic achievement in higher education worldwide. Project-based learning is a student-centered approach that requires students to engage in real-world tasks and develop a project to report to the audience, enabling the students to learn knowledge and enhance skills (Thomas, 2000). Researchers have discovered the advantages of project-based learning for improving academic achievement.

Meta-analysis is a powerful method to evaluate, quantitatively, the effectiveness of project-based learning approaches across research studies and has been utilized by different researchers many times based on various populations. Thus, the researcher conducted a meta-analysis in order to integrate the studies that investigated the effectiveness of project-based learning on academic achievement within a higher-education population worldwide.

To investigate the effect of moderator variables in the meta-analysis, five moderator variables were considered, including technology support, group size, subject area, hours of instruction, and university location in higher education.

Summary of Study

The initial search for studies yielded 3,015 total studies. After screening based on inclusion and exclusion criteria, 1,989 studies were excluded. Ninety-nine full-text articles were accepted. After excluding studies that did not involve academic achievement as the dependent variable, did not have quantitative results, or were not conducted in higher education, 17 studies remained. There were several articles that used inquiry-based learning but not specifically the project-based learning method. Many articles identified their variables as learning outcomes but did not have academic achievement as the quantitative measurement for the learning outcomes. Some articles did not have quantitative data, so they were not qualified for inclusion in the meta-analysis.

Academic achievement was measured differently across articles, but the most frequently used were grade point average (GPA), grades, and test scores. These measures are consistent with prior meta-analysis studies that investigated the effectiveness of project-based learning on student academic achievement (Aya & Soylemez, 2015; Balemen & Kelskin, 2018; Chen & Yang, 2019). Ayaz and Soylemez (2015) analyzed the results of nine studies that were based on university populations and found the average effect size as 0.68. Balemen and Keskin (2018) had 10 articles that conducted research with a university population and found the average effect size of 0.91. Chen and Yang (2019) analyzed six university-based articles and had the average effect size of 0.57. So far, this dissertation found the largest average effect size of 1.64 based upon the 17 research studies conducted with university populations.

Regarding the above studies, Baleman and Keskin (2018) did not exclude studies that were not written in English. The majority of the studies used in their meta-analysis were in a foreign language. Aya and Soylemez (2015) focused on Turkish studies that were not published in English. Chen and Yang (2019) included both studies published in English and not in English. Several of their included studies were not published in English or were not accessible.

The 17 studies that were chosen for this meta-analysis were conducted using research designs such as pre- and postcomparison, pretest-posttest one group only, or posttest only with a comparison group. Some articles were identified as experimental or quasi-experimental, but others were not. Most research in an educational setting does not involve random assignment of participants to comparison or treatment groups or random assignment of intact groups to conditions, so either experimental, quasi-experimental, or nonexperimental studies were included in the meta-analysis. The age range for the sample population was students in higher education, including freshmen, sophomore, junior, and senior students. Ages were not reported in the research studies but were approximately 18 to 21.

The screening process for the research studies involved journal articles, dissertations, conference papers, and other type of articles. All but one of the 17 studies were peer-reviewed articles. The one study was a dissertation. This meta-analysis excluded studies not published in English and those not conducted between 2010 and 2021.

Summary of Study Results

In this section, results of the meta-analysis for each of the six research questions are detailed.

1. **What was the average effect size of using project-based learning method on academic achievement in higher education?**

The average effect size was 1.64, which is a very large effect. The effectiveness of project-based learning was strong and positive, demonstrating an increase in the students' academic achievement using project-based learning.

2. **To what extent did technology support influence the effectiveness of project-based learning on academic achievement as a moderator variable?**

Technology is very important to project-based learning because they are used to continue the learning process. Within the meta-analysis, most universities used technology in the courses to support the daily educational activities. Unfortunately, this analysis was not able to be undertaken as all but one study employed technology in the project-based learning, leaving too few studies to make a comparison.

3. **To what extent did individual, small-group, or large-group size influence the effectiveness of project-based learning on academic achievement as a moderator variable?**

    Students were encouraged to do group work in project-based learning, but the studies investigated did not result in a solid preference for differing group size. Instructors decided to use either individual or group work based on the learning content and purpose. There are statistically significant differences between the effect sizes when individual student, 2-5 students, more than 5, and not specified were compared. Group size of 2-5 students has the largest effect size of 4.77.

4. **To what extent did discipline or subject-matter area influence the effectiveness of project-based learning on academic achievement as a moderator variable?**

Subject-matter areas were divided as STEM and non-STEM in this dissertation. The research results for STEM program studies were two times more effective than non-STEM studies, with an effect size of 1.71 for STEM and 0.93 for non-STEM.

5. **To what extent did hours of instruction influence the effectiveness of project-based learning on academic achievement as a moderator variable?**

Instructors preferred not to arrange long hours of instruction in project-based learning, mostly less than 2 hours per week. Researcher did not provide sufficient data to conduct an analysis for this question. Future studies should provide details regarding this variable in their reports.

6. To what extent did university location influence the effectiveness of project-based learning on academic achievement as a moderator variable?

The research results worldwide provided evidence that project-based learning is effective in increasing student academic achievement in a global context. There were more research studies found in Western and Southeastern Asia compared with the other areas in the world. It is possible that instructors or researchers at universities from these two areas may prefer to use project-based learning or classes. Alternatively, it is possible that researchers in these areas are conducting and publishing the results of project-based learning at a higher grequency. Other areas in the world have higher education courses that are using project-based learning, but they may not be researching and publishing their use of project-based learning.

Additional analyses were conducted, investigating the year of publication, study design, study conditions, institutional type, limitations, and sample size. The last three analyses yielded statistically significant differences.

The study designs that were investigated included pretest-posttest with comparison group and posttest only one-group studies. The pretest-posttest designs yielded the largest average effect size and were statistically significantly different from posttest only designs. Also assessed for contribution to heterogeneity of effect sizes were experimental, comparative, and quasi-experimental study designs. There were statistically significant differences for the three study-design types. Quasi-experimental designs had the largest average effect size, followed by experimental, and comparative with the smallest average effect size.

There were three categories of sampling within the studies: convenience, random, and not specified. The majority of the studies used convenience sampling, which had the smallest average effect size. Random sampling had the largest average effect size, and not specified was close to convenience sampling's average effect size. The 95% confidence intervals for random and the other two sampling categories do not overlap, whereas convenient and not specified overlap.

For all but two of the studies, a teacher was the primary investigator, with the other two being conducted by the researcher, which resulted in too few researcher-conducted studies to make a valid statistical comparison of the two conditions. An inspection of the 95% confidence intervals revealed that those intervals do not overlap.

Institution type of public or private was found to yield statistically significant differences. Both of the average effect sizes were large, public schools had the higher average effect size.

Publication year, study limitations, and sample size were analyzed as part of additional analyses. All were found to be statistically significant. Earlier studies had larger effect sizes, studies with only two limitations had the greatest average effect size, and as sample size increased so too did the average effect size.

Limitations

Meta-analysis is able to provide strong quantitative support for research results, but the significance may be affected by the reports of data in the obtained studies. Many papers provide limited information for the researcher to utilize. Varying completeness of information in research studies also will affect the sample sizes for analyzing moderator variables, limiting the categories that can be compared.

Several of the researchers used small sample sizes in their experiments, which were adjusted by using Hedges's *g* to correct for bias in the effect-size estimate. There were multiple variables reported in each article, which may or may not have been considered as moderator variables in this dissertation. Only the moderator variables that were reported frequently in the meta-analyses presented in chapter I were used.

To avoid any limitations coming from inconsistency in coding, the researcher collaborated with a second coder to code a sample of the studies, which was assessed by intercoder reliability.

A discussion of these results, along with recommendations for practice and future research follow in the next sections.

Discussion

According to the data-analysis results, project-based learning was effective in improving student academic achievement. Moderator variables also affected these results. What follows is a comparison of these results with the meta-analysis studies that were presented in chapter I.

The 17 meta-analysis studies varied widely in the sample sizes that were used. For example, Celik et al. (2018) had only 19 students for a sample population, but Razali et al. (2020) had 764 students for the sample population. There were three research studies with a sample size of less than 30 students. For the moderator analysis, the results of each study were pooled to calculate the effect sizes. The meta-analysis articles that were presented in chapter I did not focus exclusively on higher education. Their samples were from primary to secondary and higher education but did not report sample sizes specifically for university samples. Ayaz and Soylemez (2015) located 18 articles that had less than 50 students and 24 articles that had more than 51 students, but they did not report the sample sizes that were less than 30 students. Ayaz and Soylemez reported that there was no difference in the effect sizes among the sample-size groups. Balemen and Keskin (2018) grouped the sample sizes into three categories, small ($n \leq 50$), medium ($51 \leq n \leq 100$), and large ($n > 100$), with the largest number in the medium sample-size category. As with the Ayaz and Soylemez (2015) study, the sample sizes were not broken down by grade level. There were no differences found in the average effect sizes for the three sizes of groups, which differs with the statistically significant finding in this dissertation.

Most of the universities of the included 17 studies were identified as large universities (more than 10,000 student population or above), so the overall student populations were all large. Except for one university that did not identify as a 2- or 4-year, 15 universities were 4 year, and one was 2 year. As for the identification of public or private universities, 7 universities were private and 10 were public. There was no difference between the research results of studies from public or private universities, so this coding category was not investigated further.

As the learning performance measurement, the researcher investigated teacher- or researcher-developed test scores, grades, and others. Eleven out of the 17 studies used researcher-developed tests to identify the student academic achievement. The other research studies included one using grades, two using teacher-developed tests, and three used other measurements. Most of the studies chose researcher-developed tests to model their research on prior studies. The researcher-developed tests also had standard scoring or rubrics to help researchers of the studies obtain the test results. As the specific researcher-developed tests were replicated in more than one study, it improved the reliability and validity of the meta-analysis.

Ayaz and Solemonez (2015) were the only researchers who investigated differences in the developer (researcher, teacher, or other) of the test. There were only two of the nine higher education studies that were not researcher developed, which supports the findings of this meta-analysis.

The following sections contain the findings regarding the study conditions, study design, and additional analysis based on the research results of the 17 studies.

Study conditions

The study conditions within the 17 studies selected included technology support, subject-matter areas, instructional hours, group size, and university location. These categories were designed as moderator variables in this meta-analysis to investigate their influence on student outclomes. Technology support was used in all but one of the 17 studies so technology also was investigated as a moderator variable (see Table 13).

Technology support

Researchers of most of the studies agreed that using technology-supported project-based learning was essential for learning activities. Within the studies selected, there was a variety of technology tools used, including online searches, Learning Management System (LMS), coding software, and other technology tools. Future studies might consider comparing the use of different technology-support methods. Many of the studies used technology to support the project-based learning class activities. Bakar et al. (2019) arranged searches for information in a project-based learning warm-up activity. They also used several scaffolding activities for

Table 13

Descriptive Results for the Five Moderator Variables for Study Conditions

Moderator variables	Number of articles
Technology Support	
Yes	16
No	1
Subject-matter areas	
STEM	12
Non-STEM	5
Instructional hours	
2 hours and below	5
More than 2 hours	2
Not specified	10
Group size for project-based learning	
Individual	3
Small (2-5)	5
Large (more than 5)	4
Not specified	5
University location	
Western Asia	5
Eastern Asia	2
Europe and North America	3
Southeastern Asia	5
Other	2

teaching that involved the Internet and an online video player. Bilgin et al. (2015) found that students in project-based learning in science and technology class mentioned using the Internet and the computer for searching and material design. Celik et al. (2018) utilized software in project-based learning to teach students a programming course. The LMS appeared as technology support in some experiments as a way that instructors organized the learning process.

Mahasneh and Alwan (2018) conducted a course called "Use Computer in Education."Technology was employed in the whole lifecycle of the course. Many of the educational programs that researchers focused on required a technologically environment, which explained the high ratio of using technology in experiments.

Balemen and Keskin (2018) compared studies that used project-based learning and other techniques, but they did not clarify the other techniques or whether technology was used in the course. There were 40 studies in the project-based learning group and only 8 studies in the project-based learning and other techniques group. They found that there was no difference between the results of two groups. The studies that Balemen and Keskin selected may have had a preference of using project-based learning without other techniques. The opposite occurred with this dissertation because 16 out of 17 studies the researcher collected used technology support for the experiments.

Chen and Yang (2019) found that technology support made a difference in improving the effectiveness of project-based learning. There were 13 studies without technology support with an average effect size of 0.61 and 16 studies with technology support with an average effect size of 0.74. The researchers did not breakdown the studies with technology support by grade level. Therefore, it is difficult to know how many of the studies with technology support were within higher education. It is likely that technology support was used in the higher education studies given the prevalence of technology in higher education in the US (Chen & Yang, 2019).

Wu et al.'s (2018) study illustrated the importance of technology. Their study provided the same advantage of wireless networks and portable devices as previous studies in nursing practice courses. Enhancing network and device support reduced medical errors and provided instantaneous access to information. The real-time feedback and core knowledge support provided by such devices contributed to students' mastery and application of skills. This study also applied an interactive multimedia e-book system under a teaching strategy of project-based learning combined with authentic learning, which arranged technology support in the experiment by reducing the costs, time, and privacy concerns associated with traditional paper methods (Wu et al., 2018).

Peng et al. (2019) proposed a visualization tool for programming education. Although existing visualization-based tools for programming education focused on helping students to understand the abstract concepts and complicated behavior of programs and supporting the coding process, the visualization-based cognitive tool proposed in Peng et al.'s study focused on externalizing the complex cognitive process of completing a realistic programming project, which included coding, debugging, problem formulation, solution *planning*, and solution design.

Project-based learning is emphasized by learning experiences and is characterized by applying knowledge, management of resources, and self-directed learning. Therefore, for constructivist project-based learning, it is essential to have technological communication tools to support conversation, interaction, collaboration, sharing, construction, and creation between the teacher and learners for purposes of ongoing achievement formative assessment and feedback (Chanpet et al., 2020). The use of technology in project-based learning is essential for higher education where classes meet for once or at most three times a week for a total of 3 hours.

Subject-matter areas

When searching for articles to include in the meta-analysis, the researcher did not limit the search to a particular discipline, but the amount of STEM subject-matter areas was found to be two times more than non-STEM research studies (Table 13). Previous research has shown that project-based learning has been implemented in science (Rogers et al., 2011; Schneider et al.,

2002) and mathematics (Han et al., 2015; Holmes & Hwang, 2016), which may account for the large number of STEM studies in higher education. In this meta-analysis, the effect size was large and very large for STEM and non-STEM subject-matter areas, respectively. There also was a difference found between the effectiveness of project-based learning favoring the non-STEM areas.

Ayaz and Soylemez (2015) did not have statistically significant results between differentfields of science. Balemen and Keskin (2018) investigated differences among STEM subject-matter areas including science, chemistry, physics, and biology. Within those categories, there were 35 science articles but a limited few among the other three subject-matter areas. Balemen and Keskin (2018) also found no difference among the subject-matter area groups. Chen and Yang (2019) found a difference between the results of STEM and non-STEM subject-matter areas, with the effect in the social sciences being significantly better than that in science and mathematics. Chen and Yang's (2019) results differed from this dissertation in that STEM subject-matter areas had better effect than non-STEM studies. Jensen (2015) found that project-based learning had better effects on science and mathematics than social studies, but there was no information regarding a homogeneity test. Thus, researchers in the future should compare differences among subject-matter areas in project-based learning using a homogeneity test.

According to the research results of the 17 studies used for meta-analysis, both STEM and non-STEM research studies had positive results of using project-based learning to improve the student academic achievement. Zhang et al. (2020) found that within a chemical engineering class, a student-centered project-based learning laboratory with a real-world design, was highly beneficial for student learning. Students improved in terms of high-level design-related learning achievements and high-level skills. By using project-based learning in a nursing class, Wu et al. (2018) concluded that students acquired increased competence, self-efficacy, positive emotions, expectations, and values, leading to high learning effectiveness and achievement. Santyasa et al. (2020) found that project-based learning was better than direct instruction in achieving physics learning. Razali et al. (2020) concluded that the students achieved better performance after implementing project-based learning in the learning and teaching session of a Vector Calculus course. Rahardjanto et al. (2019) examined the effect of hybrid-project-based learning on learning achievement for an environmental knowledge course in biology education. Peng et al. (2019) used project-based learning by proposing a visualization-based cognitive tool to make the complex process of completing a realistic programming project visible to learners, which created the simple-to-complex sequencing of whole-task projects and increased the course scores for students in the experimental group.

Instructional hours

The authors of the 17 articles did not provide sufficient data to determine the number of hours per week that instructors provided instruction prior to implementing project-based learning (Table 13). Ten of the articles did not include information about instructional hours. Five studies used less than 2 hours per week on direct instruction during project-based learning. As a learning and teaching approach, project-based learning is student centered, requiring students to engage in real-world tasks and develop a project to report to an audience (Thomas, 2000). Teachers should not plan long period of instructional time during the project-based learning process. Future studies should consider monitoring the instructional hours. As the results of the other meta-analysis studies, Ayaz and Soylemez (2015) used a different dimension to identify project-based learning instructional hours. They did not find any differences between 1 to 20 hours or more than 20 hours of practicing time per week. Chen and Yang (2019) used the same categories of instructional hours as this dissertation but found opposite results. They found a difference between the weighted effect sizes of implementing project-based. More than 2 hours per week was better than that with less than 2 hours per week. This difference could be explained as teachers and students needed more time to use project-based learning than if they used traditional teaching method. As project-based learning has been popular in universities in the last 10 years, teachers and students no longer need long hours to practice this teaching modality during classroom instruction. Future studies could analyze this variable to find support for different instructional hours.

Group size

There was no obvious preference in the 17 studies for group size. According to the data analysis, however, individual or small groups made more of a difference in improving student academic achievement using project-based learning than large groups. The number of articles in each category were close to equal (Table 13). Because most experiments were based on the teaching process, instructors decided the group size based on the extent to which students were required to collaborate for learning outcomes. Thus, researchers in the future might consider individual or small groups when designing project-based learning activities. Also, there could be research surveying instructors to investigate the reasons that individual or small-group learning was more effective than the other group designs in project-based learning.

Within the 17 studies, Zhang et al. (2020) organized the project-based learning into small learning groups, with four students in each. Wu et al. (2018) organized large project-based learning groups of 8 to 10. Peng et al. (2019) did not assign the participants to groups, instead opting for individual project-based learning.

University location

The categories of university location were adjusted after the coding process. The first and second coders disagreed about splitting Southeastern Asia from Eastern Asia. The geographic definition was acknowledged, however, after searching about world regional division. The classification of the university location variable originated from the research of Chen and Yang (2019). This dissertation added one more option, Southern Asia (see Appendix B). According to the result of the moderator analysis, the average effect sizes for the studies from Western Asia and Southern Asia were greater than other parts of the world. Universities in the two areas above used and researched project-based learning within the higher education population more often. Meanwhile, the results of Southeastern Asia category differed from the other university location categories with regard to improvement of student performance; project-based learning was more effective in improving the college students' academic achievement in that location. Chen and Yang (2019) had only three categories for the school location and found a difference in results coming from the different locations. The weighted effect sizes of studies in Europe and North America and of Western Asia were greater than the effect size of East Asian studies. These results differ from this dissertation, with greater effects seen in Western and Southern Asia than the comparison locations. Both studies, however, identified a difference in the location of project-based-learning study. Studies in the future should consider the effect of geographical differences on project-based learning and the effect of differences in school competition, resources, cultural environment, and so on.

Jensen's (2015) meta-analysis compared the results of Turkey and the United States. The results indicate a larger effect among studies from Turkey. A homogeneity test result, however, was not reported.

Among the other meta-analyses described in chapter I, there were no comparisons conducted in different regions. Zhang et al.'s (2020) meta-analysis addressed the study based on the population of a North American university. Peng et al. (2019) and Wu et al. (2018) reported on experiments in East Asian universities. Rahardjanto et al. (2019), Razali et al. (2020), and Santyasa et al. (2020) were based on Southeastern Asian universities.

Additional analyses

Additional analysis was conducted to determine differences among the 17 studies beyond the five moderator variables. First, a comparison was made across the studies research design, including the selection of assessment to compare student outcomes. Studies were also compared in the ways that they sampled participants, with the majority of studies using convenience sampling, which mirrors many studies in educational research. Within the 17 studies, the primary investigator was identified to determine differences between studies conducted by teachers and researchers. Publication year was also compared to investigate differences in popularity of research on project-based learning over time. Finally, publication type, including journal articles, dissertations, and these were discussed, but not compared due to the lack of diversity in the 17 studies chosen for this meta-analysis.

Study design

This meta-analysis compared the designs of the 17 studies based on two different design groupings. The first group, studies with pretest posttest or posttest only designs were grouped as study type I. The second group, type II compared studies that used experimental, quasi-experimental, or comparison designs. Both design types were statistically significantly different, so the diverse study type designs effected the research results of the meta-analysis.

Zhang et al. (2020) used project-based laboratory processing in a pre-post comparison study for 140 students. Wu et al. (2018) used convenient sampling by collecting students from two nursing classes and randomly assigned them into the experimental (project-based learning) and control (traditional paper-presentation) groups. To compare the two groups, the researchers conducted a pre-post comparison experimental design. Santyasa et al. (2020) used a pre-post comparison quasi-experimental design to compare the effect of project-based learning and direct instruction in physics learning. Razali et al. (2020) compared learning achievement in the Vector Calculus course for two semesters using a comparison posttest only design to determine the effectiveness of project-based learning. Rahardjanto et al. (2019) used pre-post comparison quasi-experimental design to determine the effect of hybrid project-based learning in an environmental knowledge class. Peng et al. (2019) designed a pre-post comparison experimental study to identify students' achievement in the programming course.

Sampling methods

As 11 of the 17 studies used convenient sampling for the experiment designs, there was sufficient data to investigate the use of random sampling. Zhang et al. (2020) randomly assigned 140 students in a chemistry lab course into groups of four students for the project-based learning laboratory. Students were randomly assigned, but it was convenient sampling due to the use of students already enrolled within the course. Wu et al. (2018) also used convenient sampling by collecting students from two nursing classes and randomly assigned them into the experimental and control group. Santyasa et al. (2020) studied 278 students who took a physics class, so it was convenient sampling with randomly assigned groups. Razali et al. (2020) used 422 students from session 2016-2017 academic year and 342 students from session 2015-2016 academic year as the convenience sample to address the study. Rahardjanto et al. (2019) randomly selected two out of three classes (150 students) from the biology education population in a university as the convenience sampling for the study.

According to the heterogeneity test result, there was a difference among using convenience, random, or other sampling methods. Even though random sampling is not easy to conduct in social-science research studies, future studies could consider random sampling and compare different sampling methods.

Primary investigator

Fifteen of the 17 studies had teachers conducting the experiments and only two of the studies had researchers as the primary investigator. This result differed from the finding of Aya and Solyemez (2015) based on nine university studies where all but two of the nine studies were not conducted by the researcher. Aya and Solyemez is the only one of the three previous meta-analyses that compared teachers and researchers as the primary investigator. It is possible that given the popularity and increased understanding of project-based learning, instructors were more familiar with how to use the method without the assistance of a researcher. Primarily teachers are the best instructors to teach traditional or project-based learning methods for classes, in particular, several studies used STEM classes that were carried out as teacher-based experiments (Peng et al., 2019; Rahardjanto et al., 2019; Razali et al., 2020; Santyasa et al., 2020; Wu et al., 2018; Zhang et al., 2020).

Publication year

Based on the results of investigating the publication year, more studies were located at the end of the time period studied (2011 to 2020) . There were five articles collected from 2011-2017, but 12 articles collected from 2018-2020. This result showed that project-based learning has been used more frequently in educational experiments in recent years.

Publication type

Because the 17 research studies located were all journal articles, no comparison could be made with other types of research studies such as dissertations, theses, or presentations. Ayaz and Soylemez (2015) did not analyze the papers they collected by publication years but did analyze by the publication type, including master thesis, PhD dissertation, and articles. Master thesis had the highest effect size, but there was not a statistically significant difference found for the other three groups. Balemen and Keskin (2018) discussed the publication types in their meta-analysis including articles, Master thesis, and PhD dissertation. The Q test of homogeneity was not statistically significant, which differed from the finding of Ayaz and Soylemez.

Limitations resulting from studies used in the meta-analysis

All 17 studies were coded on a scale from 0 to 4 for study limitations. Each of the 17 studies were coded for inadequate reporting of the research characteristics, small sample sizes, incomplete experiment procedures, poor reliability or validity, incomplete or incorrect statistical reports, and other limitations. Based on these ratings, studies were grouped into good, moderate, or poor quality. Sixteen of the articles were coded as having one to three limitations and were grouped as “moderate quality.” One article had at least four limitations and was identified as “poor quality.” There were additional limitations in the studies other than those based on quality.

These limitations are based on the omission of information from the research articles. A list of frequency of each limitation or omission is provided in Table 14.

Table 14

Frequency of Limitations for the 17 Articles

Limitation	*F*
No gender information	7
No clear definition of project-based learning	1
No clear definition of the achievement test	1
No clear experiment or course design	2
Small sample size	4
No comparison group	4
Inconsistent sample size in pre and posttest	2
No project-based learning-group-size information	5
No information on instructional hours	10
Missing information about moderator variables	1

This study's meta-analysis provided strong quantitative support for the moderator analysis results, but investigating the heterogeneity of effect sizes was affected by the lack of information in the studies for some of the moderator variables. Due to lack of information, it was not possible to make valid comparisons across some of the moderator categories. The moderator analysis was undertaken without that category.

Implications or Recommendations for Future Research

This study provided support that project-based learning is effective in improving student academic achievement in higher education. Large effect sizes and statistically significant heterogeneity result establish a quantitative value for this claim. Some of the homogeneity tests for moderator analyses were limited because some categories could not be included in the analyses or a moderator variable could not be tested due to missing information.

Gender was one variable that could not be tested as 12 out of 17 articles that did not mention information about the gender of participants. Future research studies should include the information regarding gender composition so that it would be possible to analyze for gender differences.

The 17 research studies did not provide sufficient information about which year the college students were in. Some courses may have students from the same year in college and other courses may be mixed. The information as to the composition is useful for investigation. It is recommended that future researchers report a breakdown of the year or years that the students are in for their studies, thus allowing future researchers to analyze year in college as a moderator variable.

For finding the articles that investigated the effectiveness of project-based learning on academic achievement in higher education, the researcher screened more than 3,000 articles that resulted in only 17 useable studies for the meta-analysis. Many articles did not provide empirical data analysis to support their results. Studies in the future should collect and report quantitative data that would be used for a meta-analysis.

Whereas many of the located studies were conducted in Kindergarten (K)-12 schools, the importance of project-based learning in higher education is well documented. Therefore, if instructors are able to obtain permission to conduct research, there are many resources for publishing the results of their investigation, as can be attested by the 17 studies. Also, there are opportunities for masters and doctoral students to conduct research on project-based learning for their theses and dissertations

The courses that the researchers used to conduct the project-based learning experiments were not foundation courses in higher education. Most courses that included project-based learning activities were specialized in the third or fourth year of college. As project-based learning has been demonstrated to be an effective teaching method, instructors of all courses should consider using project-based learning methods. If such studies are conducted, then future meta-analyses could investigate learning outcomes between specialized and foundational courses in higher education.

Because 11 of the 17 studies were conducted in STEM courses, results on the effect of project-based learning on non-STEM courses were limited. Project-based learning should be effective for both STEM and non-STEM courses, so researchers in the future might consider using project-based learning for non-STEM courses. Additional studies need to be conducted in non-STEM courses to provide support for expanded instructor use of project-based learning across the disciplines.

Implications for Instruction

Project-based learning should be based on social-constructivist learning principles, in which individuals learn from their peers. Therefore, groupings of students for projects must be greater than one individual. Vygotsky's (1962) social constructivism provides the support for group collaboration in project-based learning.

As project-based learning is being used more frequently by instructors, there may be less time needed for instructing students in the method of project-based learning. If the students are new to project-based learning, as with students just beginning their studies in higher education, however, then more time is needed to orient them to college-level project-based learning.

Although the majority of studies were located in the STEM fields, there were studies in non-STEM subject-matter areas that produced relevant effect sizes, supporting the continued employment of project-based learning in areas outside of STEM. Project-based learning improves student academic performance in STEM and non-STEM subject-matter areas.

Technology has been an integral part of project-based learning, promoting effective communication between project members regarding their project collaboration. In this age of social-media use, every form of technology should be employed by instructors.

Conclusions

Based on the research results, it is concluded that project-based learning has very large effect sizes on improving student academic achievement in higher education. Technology support had a positive effect to improve student academic achievement. There was a difference between individual or small (two to five students) group size and STEM or non-STEM subject-matter areas, on the outcomes of project-based learning. Studies from the Southeastern Asian countries had the most effective results of using project-based learning in higher education. The instructional hours of project-based learning per week did not have sufficient data, but 2 or less instructional hours were the most effective compared with the other groups Thus, according to the meta-analysis result, there was a statistically significant effect of project-based learning on improving student academic achievement in higher education.

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Appendix A

Coding Sheet

Coding Sheet

1. General Information

Coder (first and last name)

Coding Date

Example: January 7, 2019

1. Identification of Studies

Title of Study

Study Number

APA Citation of Study

Year of Publication

Country of the research

Type of Report

Journal Article : 1

Book or Book Chapter: 2

Dissertation: 3

Master Thesis: 4

Private Report: 5

Conference Paper: 6

No Information: 7

Other, please specify: 8

Peer Reviewed

Yes: 1

No: 2

Unknown: 3

2. Participant Characteristics

Gender Sampling

Female (number/% of Sample)

Female = 0: 1

Female < 50%: 2

Female > or = 50%: 3

Not specified: 4

Class Sampling

Freshmen (number/% of Sample): 1

Sophomores (number/% of Sample): 2

Junior (number/% of Sample): 3

Seniors (number/% of Sample): 4

Other/Unknown (number/% of Sample): 5

Not Specified: 6

Student discipline or subject matter area

STEM (number/% of Sample): 1

Non-STEM (number/% of Sample): 2

Other, please specify: 3

Course Discipline or subject matter area

STEM (Yes or no): 1

Non-STEM (Yes or no): 2

Other, please specify: 3

3. Institution, Program, and Performance Characteristics

Institution Type - Size (small: 1, medium: 2, large: 3)

Institution Type – Degree

Community college: 1

2-Year: 2

4-Year: 3

Not Specified/Unknown: 4

Institution Type

Public: 1

Private: 2

Not Specified/Unknown: 3

Learning Performance Measurement

GPA: 1

Grades: 2

test scores

researcher developed: 3

teacher developed: 4

standard test: 5

Other, please specify: 6

Specify Learning Performance Measurement

Learning Performance Baseline Measurement

SAT Score: 1

ACT Score: 2

Placement Test Score: 3

Term GPA: 4

Cumulative GPA: 5

Previous Course Grade: 6

Other, please specify: 7

4. Research Design Characteristics

Study Type

Experimental: 1

Quasi Experimental: 2

Pre-Post Comparison: 3

Posttest only: 4

Control Group

Yes: 1

No: 2

Not Specified: 3

Sampling

Convenience: 1

Random: 2

Volunteer: 3

Purposeful: 4

Not Specified: 5

Other, please specify: 6

Who carried out the experiment?

Teacher/instructor: 1

Researcher: 2

Staff: 3

Research assistant: 4

Other, please specify: 5

5. Moderator Variables

Did the experiment have technology support?

Yes: 1

No: 2

Not specified: 3

Did students use the project-based learning approach in the experiment by individual, small group, or large group?

Individual: 1

Small Group (2-5): 2

Large Group (more than 5): 3

Not specified: 4

Is the experiment based on STEM or non-STEM discipline?

STEM: 1

Non-STEM: 2

Not specified: 3

How many hours did instructors use to teach students by project-based learning per week?

2 hours or below: 1

More than 2 hours: 2

Not specified: 3

Where is the sampled university from?

Western Asia: 1

Eastern Asia: 2

Europe and North America: 3

Other, please specify: 4

6. Effect sizes and statistically reported in study (for each option in the experiment)

Page number where the effect size data is recorded

Effect sizes

Type of data the effect size is based on

Mean, standard deviation: 1

Mean gain, standard deviation gain: 2

t-test values: 3

F-test values: 4

Cohen's *d*: 5

Hedges's *g*: 6

Other, please specify: 7

Means

Standard deviation

Raw differences

t-test value

Degree of freedom

F-test value

Degree of freedom 1

Degree of freedom 2

Eta squared

Alpha and *p* value

Correlation coefficient

Other, please specify.

Is there more effect size(s) to report?

Yes

Skip to section 7

No

Skip to section 8

7. Study quality

For each limitation you found from the study, add one point. Please decide the final score of the journal.

0 1 2 3 4

What kind of limitations does the journal have?

Inadequate reporting of the study characteristics

Small sample sizes (< 30)

Incomplete experimental procedures

Poor reliability or validity

Incomplete or incorrect statistic reports

Poor experimental design

Inadequate reporting of population characteristics

Other, please specify.

8. This is the end of the coding sheet.

Appendix B

Area and Country of the Studies Used in Meta-analysis

Area and Country of the Studies Used in Meta-analysis

Area	Country	Study (year)
Western Asia	Turkey	Bilgin et al. (2015)
	Turkey	Çelik et al. (2018)
	Jordan	Mahasneh & Alwan (2018)
	Iran	Mohamadi (2018)
	Turkey	Ozdamli & Turan (2017)
Eastern Asia	China	Peng et al. (2019)
	Taiwan	Wu et al. (2018)
Europe and North America	United States	Berchiolli et al. (2018)
	United States	Hamoush et al. (2011)
	Canada	Zhang et al. (2020)
Southeastern Asia	Malaysia	Bakar et al. (2019)
	Thailand	Kettanun (2015)
	Indonesia	Rahardjanto et al. (2019)
	Malaysia	Razali et al. (2020)
	Indonesia	Santyasa et al. (2020)
Other	Colombia	De La Puente et al. (2018)
	Australia	Jollands & Parthasarathy (2013)