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Thematic Review

Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators

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ABSTRACT

Project-based learning is generally considered an alternative to traditional, teacher-led instruction. However, there is a noticeable lack of meta-analyses with regard to determining its overall effects on students' academic achievement, and what study features may moderate the impacts of project-based learning. This study thus performed a meta-analysis to synthesize existing research that compared the effects of project-based learning and those of traditional instruction on student academic achievement. Forty-six effect sizes (comparisons) extracted from 30 eligible journal articles published from 1998 to 2017 were analyzed, representing 12,585 students from 189 schools in nine countries. The results showed that the overall mean weighted effect size (d_+) was 0.71, indicating that project-based learning has a medium to large positive effect on students' academic achievement compared with traditional instruction. In addition, the mean effect size was affected by subject area, school location, hours of instruction, and information technology support, but not by educational stage and small group size.

1. Introduction

Project-based learning (PjBL) is a systematic teaching and learning method, which engages students in complex, real-world tasks that result in a product or presentation to an audience, enabling them to acquire knowledge and life-enhancing skills (Barron & Darling-Hammond, 2008; Thomas, Mergendoller, & Michaelson, 1999, p. 1). PjBL is related to constructivism; the central activities of PjBL involve the transformation and construction of new knowledge (Oguz-Unver & Arabacioglu, 2014; Thomas, 2000). The philosophy of PjBL considers that learning is more engaged when triggered by a student's "I need to know" than by a teacher's "because you should know" (Lenz, Wells, & Kingston, 2015, p. 68). The core of PjBL is the project itself (Trilling & Fadel, 2009, p. 97). *Project* is the word that distinguishes PjBL from other instructional approaches, and this can be defined as "an act of creation over time" (Lenz et al., 2015, p. 67), involving students in a constructive investigation (Thomas, 2000). A project gives students hands-on opportunities to work with concepts from course materials, discuss their approach in peer groups, and present their work (Johnson, Renzulli, Bunch, & Paino, 2013). There are two essential components of projects (Blumenfeld et al., 1991): a question, which serves to organize and drive learning activities; and products/artifacts, which are representations of students' solutions resulting from the activities used to address the driving question. Accordingly, PjBL has several fundamental features or essential characteristics, as follows (Bender, 2012, pp. 31–32; Hallermann, Larmer, & Mergendoller, 2011, pp. 7, 86; Krajcik & Czerniak, 2014, p. 6; Krauss & Boss, 2013, p. 12; Larmer & Mergendoller, 2010): inquiry, guided by the driving question, meaning that students ask their own questions, perform investigations, and develop answers; student voice and choice, meaning that students are allowed to make some decisions about the

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products to be constructed and how they work; revision and reflection, in which students have opportunities to use feedback to make their products better, and think about what and how they learn; and a public audience, to which students present their work. In general, students work together, autonomously and purposefully, toward the completion of a project (Dado & Bodemer, 2017; Thomas, 1998). In the learning process of PjBL, students need to solve problems by defining the problem, discussing ideas, designing inquires, collecting and analyzing data, and sharing findings with their peers (Bell, 2010; Blumenfeld et al., 1991). When students collaboratively find solutions to the driving question, they develop understanding of the related concepts (Krajcik & Czerniak, 2014, p. 6). As Markham, Larmer, and Ravitz (2003, pp. 3–4) and Oguz-Unver and Arabacioglu (2014) noted, PjBL has grown in popularity because psychological research has shown that students' learning may be limited in the context of traditional direct instruction, and there is a need for education to adapt to a changing world in which learners are encouraged to use what they know to explore, create, and construct solutions in the learning process. Students in traditional instruction (TI) classrooms, on the other hand, only use the lowest levels of cognitive processing to perform basic work like reading and memorizing (Lamb, 2003; Thomas, 1998). As a consequence, students' knowledge of the subject matter may be fleeting and superficial; students cannot apply what they have learned, and are not stimulated to study on their own (Thomas, 1998). Larmer and Mergendoller (2011) explained that the difference between *projects* and home assignments, where students simply apply what they learn from TI, is that students learn the main course material from completing the project in PjBL. PjBL attempts to create a student-centered learning setting (Kokotsaki, Menzies, & Wiggins, 2016; Uziak, 2016), with the projects being central to the curriculum (Thomas, 2000).

PjBL has been widely used in various subjects. Although it has been implemented more often in science (e.g., M. A. P. Rogers, Cross, Gresalfi, Trauth-Nare, & Buck, 2011; Schneider, Krajcik, Marx, & Soloway, 2002) and mathematics (e.g., Han, Capraro, & Capraro, 2015; Holmes & Hwang, 2016), a number of instructional examples can be found in technology (e.g., Domínguez & Jaime, 2010; Mioduser & Betzer, 2007) and social sciences (e.g., Chang & Lee, 2010; Johnson et al., 2013). As PjBL is relevant to students' lives, this factor tends to increase their motivation to learn (Bender, 2012, pp. 8, 10; Blumenfeld et al., 1991; Hallermann et al., 2011, p. 11; Krajcik & Czerniak, 2014, p. 6) and interest in content (Holm, 2011) and completing the required work for the project (Bender, 2012, p. 33), which also allows them to pursue their interests (Intel Education Initiative, 2007). The benefits of PjBL include improved attitudes toward learning and the subject matter (Bender, 2012, p. 33; Thomas, 2000; Tseng, Chang, Lou, & Chen, 2013). Moreover, PjBL helps develop metacognitive skills in students, such as self-regulation and -monitoring (Thomas, 1998; Thomas et al., 1999, p. 30), as well as support self-directed and -regulated learning (English & Kitsantas, 2013; Intel Education Initiative, 2007; Markham et al., 2003, p. 7). Self-assessment and -evaluation are also emphasized for students in PjBL projects (Bender, 2012, p. 167; Thomas, 1998). It is noteworthy that a number of studies have shown that PjBL is linked with increased academic achievement (e.g., Boaler, 1998; Panasan & Nuangchalerm, 2010; Schneider et al., 2002). For instance, Boaler (1998) found that senior high school students who underwent PjBL in mathematics classes had better performance compared with those who received TI on conceptual problems. However, Markham et al. (2003, pp. 5–6) indicated that the effect of PjBL on improving academic achievement was only equivalent to or slightly better than other teaching methods, and there was not sufficient empirical data to state that PjBL is a proven alternative to those. In Thomas's (2000) classic review of PjBL, he concluded that there is a need for more empirical research reporting the effectiveness of PjBL, especially when compared with TI. Additionally, Thomas suggested that future research can explore more aspects of PjBL, including subject matter areas, duration of implementation, and under what conditions students can have the best academic achievement, because planning, implementing, and managing PjBL are all associated with student learning and achievement. Hallermann et al. (2011, p. 13) also noted that more research is needed on PjBL's effects, because PjBL is hard to pin down, much depending on the particular circumstances in a school and the quality of classroom implementation. To date, the study features deserve more attention when investigating the effects of PjBL on students' academic achievement.

Studies have recommended different numbers of hours per week during which PjBL should be conducted. For example, while Wen and Huang (2005) only proposed having one lesson (45–50 min) per week, Larmer, Ross, and Mergendoller (2009, p. 39) suggested 5 h and Tuncay and Ekizoğlu (2010) recommended more, up to 8 h. Although educators, in general, have a positive view of implementing PjBL in classrooms, some teachers or parents might think that projects expend large amounts of instructional time, and these large time blocks cover only a small amount of curriculum content (Miller, 2018; Thomas, 1998). If we have a better understanding about the effects of instructional time on student academic achievement in PjBL compared with TI, it would provide evidence in support of the amount of time that should be devoted to PjBL. In order for students to conduct PjBL effectively, teachers could provide appropriate technological support in their classrooms, such as Internet-capable devices, computer-based simulations, visualization tools, or interactive multimedia. Technology has the potential to motivate students to carry out projects and increase their interest, and can help them when doing their investigations, communicating and collaborating with peers, and gathering relevant information to generate artifacts that represent their understanding (Blumenfeld et al., 1991; Hung, Hwang, & Huang, 2012; Krajcik & Czerniak, 2014, p. 6). Applying information technology in PjBL could be effective in raising student academic achievement (Branch, 2015). Nevertheless, this emphasis on technology is not an absolute requirement in PjBL projects. While technology-based instructional options may be likewise used in TI, Bender (2012, p. 94) suggested that these are particularly appropriate in PjBL projects, as they facilitate a new teaching and learning process.

Students usually work in small groups in PjBL, as they tend to have more motivation to learn during such work, and sharing ideas and getting feedback with peers can help learners engage in reflection, extend their knowledge, and revise artifacts (Blumenfeld et al., 1991; Uziak, 2016). Learning to work together toward problem solutions is a critical factor in PjBL, and thus teachers should make efforts to facilitate appropriate collaboration and teamwork; when working in a team students are generally asked to collaboratively develop a plan of action for the development of their products or artifacts (Bender, 2012, pp. 11, 52–56), individually collect and analyze data associated with the focal topic, and collaboratively present their work to the class (Johnson et al., 2013). Nonetheless, the recommended group size for PjBL differs in different studies. Some works arranged students in groups of two to four (e.g., Schneider et al., 2002), while others used groups of six (e.g., Olatoye & Adekoya, 2010). Hwang & Lin, 1996(pp. 34, 143) suggested having three to six students in a collaborative learning group and indicated that a larger group size enables more interpersonal interactions, although the time spent on communication and coordination also increases. When group size increases, it would be more difficult to ensure that all group members contribute their share of the work and have a strong voice in team discussions (Hallermann et al., 2011, p. 68). Along these lines, Larmer et al. (2009, p. 74) suggested that a group of five or more makes it more difficult to make sure that each student contributes to the group effort, and that no one is freeloading. Favoring smaller collaborative teams, Bertucci, Conte, Johnson, and Johnson (2010) found that groups of two are suitable for students who have not learned teamwork skills. In addition, various proponents of PjBL have described different projects for different grade levels (Bender, 2012, p. 8). Many PjBL studies were designed for high school or college students (Oguz-Unver & Arabacioglu, 2014; e.g.,; Liu, 2016; Schneider et al., 2002; Xu & Liu, 2010). Although Bender stated that PjBL has been used in virtually every grade level, and Han et al. (2015) noted that PjBL has generally been more implemented in K–12 education to encourage students' deep understanding in recent years (see a complete example project for third grade, Bender, 2012, pp. 23–28; and sample projects for grades K–12, Krauss & Boss, 2013, pp. 151–171), more work needs to be done to determine and compare the effectiveness of PjBL when used with elementary or middle school students. Based on the perceived effectiveness of PjBL with regard to improving student learning and achievement, a number of Western educational organizations, such as the Buck Institute for Education (BIE) and the Partnership for 21st Century Learning (P21), have put their support behind this teaching approach. While PjBL has been applied in Asia (e.g., Jo, 2011; Xu & Liu, 2010), there has been little research examining its effectiveness compared to Western contexts. Therefore, more cross-national work is needed to allow researchers and educators to better understand the effectiveness of PjBL in different cultural contexts.

Overall, to date, few studies have used a meta-analytic framework to obtain statistical results with regard to what extent PjBL is more effective than TI in increasing students' academic achievement, and little is also known about the effect size (ES) and the moderator variables that may affect academic achievement in this context. Accordingly, this study conducted a meta-analysis to carry out a quantitative synthesis of empirical research on PjBL, exploring the effects of PjBL on student academic achievement and the factors that may affect this. Specifically, the present study attempted to address the follow two questions. First, what are the overall effects of PjBL on students' academic achievement? Second, are these effects influenced by PjBL study features such as subject area, school location, educational stage, hours of instruction, information technology support, and group size?

2. Method

This study employed a meta-analytic approach based on Hedges and Olkin’s (1985, pp. 122–128, 153–156) homogeneity procedures to answer the research questions. Furthermore, Chambers's (2004) guidelines for conducting and reporting meta-analytic research were followed.

2.1. Collecting related articles and studies

The researchers used (“project-based” OR “project-oriented”) AND (“achievement” OR “academic performance” OR “learning outcome”) as keywords, and did keyword searches of the expansive and robust databases in the social sciences, ranging from psychology to education including *EBSCOhost* (including *Academic Search Premier*, *Education Research Complete*, *OmniFile Full Text Select*, *Professional Development Collection*, *PsycARTICLES*, *Teacher Reference Center*), *ProQuest* (including *Education Database*, *ERIC*, *Social Science Database*, *Sociological Abstracts*), *ScienceDirect*, *Web of Science*, and *LearnTechLib* in January, 2017, at National Taiwan Normal University. To include more PjBL research in different cultural contexts, and with respect to our linguistic competence, keyword searches of the same meaning as the above English keywords in traditional Chinese, (“專題式” OR “專案式” OR “專題本位” OR “專題導向” OR “專題學習”) AND (“成就” OR “成績” OR “成效” OR “表現” OR “成果” OR “效果”) (“project-based,” “achievement,” “performance,” and “outcome” can have different translations in Chinese), were also done of the expansive and robust Chinese databases including *Airiti Library*, *HyRead Journal*, *ERICdata*, and *PerioPath: Index to Taiwan Periodical Literature System*. In addition, to include relevant research articles not indexed in the above databases and the grey literature that is usually inaccessible through databases and indexes, this study performed a Google Scholar search using the above English and traditional Chinese keywords (via scholar.google.com) plus “traditional instruction” (傳統教學), and viewed the article titles and meta descriptions shown on the search results pages to locate and further examine the materials not found in the previous searches, until no relevant articles (in which PjBL is compared with TI or TI is mentioned) were found on the search page. These searches were limited to research papers published by peer-reviewed journals to enhance the rigidity of data collection (Chien, Chang, & Chang, 2016). If full electronic texts were not available, the researchers used university library resources and the document delivery services like *RapidILL* and *Nationwide Document Delivery Service*, to gain the materials.

2.2. Establishing criteria for the inclusion of studies

The criteria for the inclusion of studies were as follows:

- Studies had to compare the effects of PjBL with TI on students' academic achievement. In this context, PjBL (project-based learning) is when students engage in a learning process for implementing projects, explore and solve authentic problems, and produce artifacts or make presentations in class. TI (traditional instruction) means students learn through direct instruction from teachers.

- The research method must be an experimental approach.
- The results must provide sufficient data: (a) the means, standard deviations, and sample size of the PjBL and TI groups; (b) F values and sample sizes; (c) t values and sample sizes; (d) χ^2 and sample sizes; or (e) ES and sample sizes.
- Studies had to be written in English or Chinese.

The researchers screened the collected studies according to these criteria. Based on the results of this, thirty studies, which were all journal articles published from 1998 to 2017, were eligible for the meta-analysis.

2.3. Examining publication bias

This research used Rosenthal's (1979) fail-safe number formula calculated as $[\sum_1^n Z(p_i)]^2/Z_\alpha^2 - n$ (where n is the number of studies included in the meta-analysis, $Z(p_i)$ are the z-scores for the individual significance values, and Z_a is the z-score associated with the desired α level that is usually 0.05) to examine publication bias, which takes account of the effects of non-significant, unpublished, or missing studies on the results of meta-analysis (Liao & Chang, 2013; Yeung & Nguyen-Hoang, 2016). According to Rosenthal (1979), publication bias will not affect the results if the fail-safe number is bigger than the tolerance level of $5n + 10$.

2.4. Setting up moderator variables

To determine whether the effectiveness of PjBL would be impacted by other factors, this research set six moderators (i.e., study features), which were all categorical variables (see Appendix for the complete coding table): (a) subject area (social sciences, science and mathematics, and technology and engineering); (b) school location (Europe and North America, Western Asia, and East Asia); (c) educational stage (primary school, secondary school, and college or university); (d) hours of instruction (2 h and below, and above 2 h per week); (e) information technology support (with support, and without support); and (f) group size (two to four, five and above, and one person). The first three study features were coded to detect the possible effects of different study characteristics. The last three were coded to analyze how activity design affects the influence of PjBL on students' academic achievement.

2.5. Coding of moderator variables

A researcher examined 30 studies that met the criteria and coded each according to the study features. To ensure the accuracy of the coding results, this study referred to previous meta-analyses and adopted the same research approach (Liao, 2011; Sowislo & Orth, 2013; Zhang & Xin, 2012), with a second coder independently coding 30–50% of the included studies. Therefore, 12 studies (40% of the total) on each of the study features were coded by another researcher, who had experience conducting meta-analytic research for the topics related to teaching and learning strategies. The two coders agreed on 92.31% of the 12 articles that were jointly coded. The intercoder agreement for each of the six study features, i.e. subject area, school location, educational stage, hours of instruction, information technology support, and group size, was 76.92, 92.31, 100, 100, 92.31, and 92.31%, respectively. When different codings arose, the two coders discussed and reexamined the studies until agreement was reached.

2.6. Calculating effect sizes for individual studies

Following Hedges and Olkin’s (1985, p. 104) and Rosenberg, Adams, and Gurevitch's (2000, pp. 13–15) formulas of ES, this research examined student academic achievement measured by standardized or researcher-developed achievement tests after PjBL or TI to obtain the ESs for individual studies. That is, the difference between PjBL and TI means was divided by pooled standard deviations. For studies that did not report means and standard deviations the F, t or χ^2 values were used to estimate the ES. Each ES was weighted in accordance with the sample size to derive an unbiased estimator of ES. The formula used in calculating Hedges' d is

$$d_i = \left(1 - \frac{3}{4N - 9}\right)g_i, \tag{1}$$

Here g_i refers to Hedges' g, the original ES; $N = n_1 + n_2$; n_1 is the number of subjects in the experimental group; and n_2 is the number of subjects in the control group. The correction factor multiplied by g is used to correct the small sample bias, which tends to overestimate the absolute value of the ES parameter in small samples (Borenstein, Hedges, Higgins, & Rothstein, 2009, p. 27; Rosenberg, Adams, & Gurevitch, 2000, pp. 14–15). The weighted ESs were then aggregated to obtain an overall weighted mean estimator d_+ and its variance $\sigma^2_{(d+)}$. In addition, if a study included over two comparisons, the ES of each comparison was weighted according to the reciprocal of the number of comparisons to avoid overweighing the ES for a study (cf. Liao, 2007; Waxman, Wang, Anderson, & Walberg, 1985). Finally, the 95% confidence interval (CI) of d_+ was calculated to determine whether a significant difference existed between the PjBL and TI groups. If the overall weighted mean ES d_+ is positive and the CI does not contain zero, the PjBL group is significantly superior to the TI group; in contrast, if d_+ is negative and the CI does not contain zero, the TI group is significantly superior to the PjBL group. Cohen (1988, p. 40) specified that an ES of 0.2 is a small effect, 0.5 a medium effect and 0.8, a large effect. This study used MetaWin (version 2.1; Rosenberg et al., 2000) which is a statistical software for meta-analysis, and a fixed effects model (i.e., inverse variance method) to carry out the meta-analysis.

Table 1
Study-weighted ESs and number of students, schools, and comparisons.

Authors (Year)	No. of students	No. of schools	No. of comparisons	ES
Barak and Dori (2005)	215	1	2	0.70
Baş (2011)	60	1	1	0.79
Baş and Beyhan (2010)	50	1	1	0.91
Bilgin, Karakuyu, and Ay (2015)	66	1	1	0.71
Boaler (1998)	332	2	1	0.41
Çakici and Türkmen (2013)	44	1	1	2.39
Chang and Lee (2010)	262	1	2	0.39
Cheng, Chang, Lee, and Yang (2008)	72	1	1	0.81
Chou, Huang, and Su (2009)	72	1	1	−0.23
Chung and Chen (2006)	64	1	3	0.83
Domínguez and Jaime (2010)	155	1	2	0.85
Dori (2003)	243	4	4	0.77
Eskrootchi and Oskrochi (2010)	52	1	1	1.78
Han, Capraro, and Capraro (2016)	819	59	1	0.54
Hastie, Chen, and Guarino (2017)	185	3	1	1.37
Hernández-Ramos and De La Paz (2009)	170	1	1	2.31
Hsu, Chan, and Chang (2007)	42	1	2	0.50
Karaçalli and Korur (2014)	143	1	1	1.14
Kucharski, Rust, and Ring (2005)	61	1	1	0.38
Lai and Kuo (2005)	68	1	1	0.60
Mioduser and Betzer (2007)	107	6	1	0.70
Olatoye and Adekoya (2010)	104	3	2	1.25
Özdener and Özçoban (2004)	64	1	1	1.56
Ross et al. (2001)	8,600[a]	86	1	0.70
Schneider et al. (2002)	142	1	1	0.52
Shyr (2012)	40	1	1	1.36
Su (2008)	140	1	1	0.30
Tuncay and Ekizoğlu (2010)	38	1	2	1.39
Turnbull (1999)	100	4	6	0.79
Wen and Huang (2005)	75	1	1	0.10
sum	12,585	189	46	

Note. Total N of studies = 30; total N of comparisons = 46.
[a] The number of students in this study was estimated by the number of schools (86 schools) multiplied by 100 (assuming, conservatively, each participating elementary school in Memphis had at least 100 participating students), since this paper reports the number of schools and the ES but does not provide the specific number of students.

2.7. Testing for homogeneity

This study employed Hedges and Olkin's (1985 pp. 122–128, 153–156) homogeneity procedures to determine the heterogeneity between outcomes. The formula for the homogeneity test is

$$Q = \sum_{i=1}^{k} \frac{(d_i - d_+)2}{\sigma^2{}_{(d_i)}} \tag{2}$$

When significant variation existed, the Cochran's Q statistic was applied to examine whether the overall study-weighted d_+ is affected by other moderator variables. Then the within-class variance component Q_W was calculated, and the between-class variance component Q_B was obtained by Q_T minus Q_W, where Q_T is the variance component of the overall study-weighted d_+. Finally, if Q_B showed significant variation between subsets of a moderator that has more than two subsets, then Scheffe's post hoc comparisons were carried out to account for multiple comparisons.

3. Results and discussion

The fail-safe number of this meta-analysis was 7488 and the tolerance level was 160. The fail-safe number was larger than the tolerance level; publication bias would not affect the results of this study, according to Rosenthal (1979).

3.1. Overall effects on academic achievement

Table 1 presents the calculated ESs and the number of students, schools, and comparisons in 30 studies, in which the study-weighted ESs of 29 studies (96.67%) were positive, and only one (3.33%) of them was negative. The range of the study-weighted ES was from −0.23 to 2.39, which lie within three standard deviations of the overall weighted average ES, and thus no studies were excluded. The mean weighted ES (d_+) was 0.71 (95% CI was 0.67–0.75). The results indicate that students who participated in PjBL had significantly better academic achievement than those who took part in TI, showing a medium to large positive effect on student academic achievement.

These results are not exactly the same as those in Markham et al. (2003, pp. 5–6) and Thomas (2000), who presented rather conservative arguments about the effects of PjBL compared with TI when they reviewed PjBL studies. However, it is worth noting that Markham et al.'s argument was based on the evidence gathered in the previous 10 years at the time of writing (i.e., 1993–2002), and Thomas's was mainly based on research from the 1990s. The results of the current study imply that PjBL has become more effective in recent years. There may be two reasons for this. First, more than a decade ago there were relatively few studies on implementing PjBL in classrooms, and the support resources were relatively insufficient, and thus it might be difficult for teachers to understand how to conduct PjBL effectively. This situation has changed in recent years, as the number of studies published on PjBL has grown, making it easier for teachers to adopt this approach. The relevance of time is also supported by the positive correlation between the ESs found in the reviewed studies of this study and their year of publication, $r = 0.33$, $p = .07$, reaching marginal significance and a medium correlation (0.30; Cohen, 1988, p. 287). Second, over the last decade more educators and organizations have paid attention to PjBL, such as the 21st Century Community Learning Centers, BIE, Oracle Education Foundation, and P21 (listed in alphabetical order), and these movements have also helped in the development of more effective practices. As schools struggle to teach all students in a climate of limited budgets and ever-changing technologies, PjBL has emerged as an instructional approach that results in increasing achievement and engagement for students in today's classrooms (Bender, 2012, pp. 1, 5–6). Over the past 15 years Dole, Bloom, and Kowalske (2016) and Dole, Bloom, and Doss (2017) have also seen transformations in both students and teachers, with practice moving from a teacher-centered to learner-centered pedagogy as a result of a BIE model course, in which teachers facilitate PjBL with students in elementary and middle schools. These changes indicate that PjBL is maturing in the context of teaching.

3.2. Homogeneity test and moderator analyses

The results of a homogeneity test show significant differences in the students' academic achievement, $Q_T = 184.58$, $df = 29$, $p < .001$, indicating that the differences between studies were not due to sampling errors among the same population, and thus moderator variables should be examined. Table 2 shows that subject area, school location, hours of instruction, and information technology support were significantly related to the variability in student academic achievement. The 95% CI of each subset was positive and exclusive of zero, except for "one person" in group size, indicating that students who received PjBL had higher academic

Table 2
Results for the moderator variables.

Moderator variables	Q_B	K	d_+	95% CI	Q_W	Contrast
Subject area	15.53*	30				1 > 2
1. social sciences		6	1.05	0.79–1.30	55.48*	
2. science and mathematics		11	0.64	0.54–0.74	57.84*	
3. technology and engineering		9	0.81	0.61–1.01	22.49*	
9. others		4	0.70	0.63–0.78	33.24*	
School location	23.38*	29[a]				1, 2 > 3
1. Europe and North America		10	0.71	0.66–0.76	106.05*	
2. Western Asia		10	0.93	0.77–1.09	27.03*	
3. East Asia		9	0.42	0.23–0.60	21.71*	
Educational stage	4.39	30				
1. primary schools		8	0.73	0.67–0.79	50.15*	
2. secondary schools		16	0.68	0.59–0.77	107.83*	
3. colleges or universities		6	0.57	0.36–0.77	22.21*	
Hours of instruction (per week)	11.74*	30				2 > 1
1. two hours and below		6	0.35	0.07–0.63	12.57*	
2. above 2 h		12	0.76	0.64–0.89	51.80*	
9. not specified		12	0.72	0.67–0.76	108.48*	
Information technology support	5.37*	29[b]				2 > 1
1. without support		13	0.61	0.49–0.73	59.21*	
2. with support		16	0.74	0.69–0.79	114.53*	
Group size	5.82	30				
1. two to four		11	0.82	0.69–0.95	98.84*	
2. five and above		8	0.70	0.52–0.88	33.63*	
3. one person		2	0.53	−1.01–2.07	4.76*	
9. not specified		9	0.70	0.65–0.75	41.53*	

*$p < .05$.
[a] Subsets with fewer than two valid studies were eliminated from the analysis, as one study (Olatoye & Adekoya, 2010) was conducted in Nigeria.
[b] One study (Han et al., 2016) was not specified and therefore eliminated from the analysis.

achievement than those who received TI. The following sections present and discuss the results for each moderator.

3.2.1. Subject area

Q_B was significant for subject area, and thus a difference existed between the weighted ESs. The results of post-hoc comparisons indicate that PjBL had a significantly greater effect than TI in the social sciences (including English, French, history, and geography), technology and engineering (including computer science, web design, digital logic, machine control, and mechatronics), and science and mathematics (including basic science, physics, chemistry, life science, earth science, agricultural science, and math), with these ESs in descending order. In addition, the effect in the social sciences was significantly better than that in science and mathematics.

The findings show that PjBL had significant better effects than TI in different subject areas. It is also notable that the ES in social sciences was 1.05, indicating a quite large effect. Although PjBL originated from a form of instruction stressing investigations and experiments, if used properly it might be even more effective when learning a language (e.g., Baş & Beyhan, 2010), history (e.g., Hernández-Ramos & De La Paz, 2009), or geography (e.g., Chang & Lee, 2010), as authentic projects and assessments can also be implemented in social studies and language arts (cf. Krauss & Boss, 2013, pp. 73, 87; Laur, 2013, pp. 22, 41, 48, 68, 90, 128, 132). Larmer (2015) noted that projects are effective for language learners, because reading and writing are purposeful and connected to students' personally meaningful experiences. In addition, our findings lend some credence to the notion of Markham et al. (2003, p. 6) that PjBL may not be appropriate for learning computation skills, since the effects in some science subjects, such as mathematics, were small in the current study (based on, for example, the analyses of Boaler, 1998, and Su, 2008). As noted by Yetkiner, Anderoglu, and Capraro (2008), the achievement gains in mathematics lag behind those in reading, but longitudinally the mathematics performance in PjBL outperformed than that seen with TI.

3.2.2. School location

Q_B was significant for school location, and the weighted ESs of studies in the contexts of Europe and North America and Western Asia were greater than the ES in East Asian ones. The results show that the effects of PjBL versus TI studies located in Europe and North America (including the United Kingdom, Spain, Canada, and the United States of America), and Western Asia (including Israel, Turkey, and Northern Cyprus), were significantly greater than the effect in East Asia (including Taiwan, ROC).

Although Hallermann et al. (2011, p. 10) considered that every school has a place for PjBL, this study found that the effects may be different depending on where the school is. A partial explanation for this may lie in the fact that, compared with students in East Asia, students in many Western contexts may be subject to less intense competition at school and that teachers have no need to go through designated textbooks, and so teachers and students can pay more attention to PjBL. Another possible explanation for this finding is that schools in the West may have more practical experience of PjBL and access to more supporting resources, whereas students in East Asia (especially in Taiwan) tend to have fewer experiences of collaborative learning in the classroom, as well as completing PjBL tasks, compared with students in Europe and North America. Trilling and Fadel (2009, p. 101) emphasized that learning environment and school support for PjBL are key factors in the success of this approach. Furthermore, culture may also play a part in these findings, as students in East Asia might be more accustomed to teacher-centered TI and unfamiliar with PjBL. Students who are accustomed to TI, and rarely engage in PjBL, may find it difficult to effectively control their time and gather information, and thus face more problems when working to complete a project (Barron & Darling-Hammond, 2008; Hallermann et al., 2011, p. 114).

3.2.3. Educational stage

Q_B was not significant in the educational stage, showing that there were no significant differences between the weighted ESs. In other words, the effects of PjBL versus TI conducted in primary, secondary, or college schools were not different. The participants in the studies examined in this work ranged from third-grade elementary school to senior college students.

The finding supports the argument that PjBL pertains to K–12 grade classrooms (Holm, 2011), and the initiatives proposed in Markham (2012, p. xiv) and Krajcik and Czerniak (2014, p. ix) about applying PjBL in elementary and secondary grades. It is noteworthy that the weighted ES of primary school (0.73) was the largest of all and close to the large effect. This finding echoes Hallermann et al.’s (2011, pp. 2, 14–15) initiative of integrating PjBL in K–5 classrooms and suggests that it is worth trying to introduce this teaching approach at the elementary level. This result may be explained by the fact that compared with middle and high school students, elementary students' pressure of entrance examination is relatively low; teachers and students have more time and effort to devote themselves to PjBL, and their motivation might be higher. In addition, note that educators should make adaptions to PjBL based on the students' needs according to their grades (Hallermann et al., 2011, pp. 11–12). For instance, elementary students would need more guidance from the instructor than high school or college students. Since students' academic achievement in PjBL was significantly better than that in TI in these educational stages, with medium to large ESs, it is worth working to spread the practice of PjBL from primary to tertiary education.

3.2.4. Hours of instruction

Q_B was significant in hours of instruction, and thus a difference existed between the weighted ESs. The results of post-hoc comparisons show that the effect of implementing PjBL for above 2 h per week versus TI was significantly better than that seen with less than 2 h per week.

These results may partially support Larmer et al.’s (2009, p. 39) recommendation of using PjBL for 5 h per week, although this analysis was based on 2 h of instruction. A one-shot intervention that lasts only one lecture long (50 min or less) is thus not suggested. For students and teachers used to TI, the open-ended nature of PjBL may be rather challenging at the beginning, but they would find that this approach gets easier with more experience (Barron & Darling-Hammond, 2008; Hallermann et al., 2011, p. 12; Larmer, 2015). It may be helpful not to think of PjBL as taking time away from regular courses, but consider the project work is central to the curriculum (Markham et al., 2003, pp. 7, 9). To this end, Markham et al. advised teachers to introduce PjBL in main courses with extended block scheduling, so that they could have more time to manage projects and let students learn the information and skills needed to carry out the tasks successfully. Larmer and Mergendoller (2011) also advocated distinguishing main course PjBL from short duration activities, and daily or weekly schedules can be adjusted to provide PjBL with longer and more flexible blocks of class time.

3.2.5. Information technology support

Q_B was significant in information technology support, and the weighted ES of PjBL studies with information technology support was significantly higher than that without such support. The results show that PjBL with the support of information technology had a better effect in comparison to TI than seen with PjBL without this support.

Hallermann et al. (2011, p. 28) and Larmer et al. (2009, p. 38) believed that although PjBL can take advantage of a technology-rich classroom, teachers can still implement PjBL effectively through crafted projects, even in classrooms without any technological support. Nonetheless, the results of the current study indicate that PjBL is more effective with the support of information technology. The results are consistent with Eskrootchi and Oskrochi's (2010) findings that technological support would enhance students' science learning in a PjBL setting. One reason for this could be that technology affords students multiple ways to gather information or integrate their ideas. Additionally, group members are able to contribute knowledge on shareable interfaces, and thus are better able to learn and collaborate in order to solve the problems they are dealing with (Rick, Rogers, Haig, & Yuill, 2009; Y.; Rogers & Lindley, 2004). On the other hand, computer technologies offer teachers opportunities to conduct meaningful learning activities in technology-enhanced classrooms (Hwang, Hung, & Chen, 2014). Blumenfeld et al. (1991) and Markham (2012, pp. 19, 52) encouraged teachers to use technology in PjBL classrooms, as it can not only help students to implement and present their projects, but also support learning by making information more accessible. However, successful technology use for PjBL is dependent on teachers' knowledge of the technology (Eskrootchi & Oskrochi, 2010). Teachers should not rely on technology simply because it is available or fun; instead, they should use it as a support tool for student learning (Markham et al., 2003, p. 85). In addition, the degree of technology use (i.e., the level of technology saturation) was found to be a moderator affecting learning achievement in non-distance higher education classrooms (Schmid et al., 2009), future research could explore the possible moderating effects of the degree of technology saturation, or the type of technology use, on students' academic achievement in PjBL.

3.2.6. Group size

Q_B was not significant in group size, showing that there was no significant difference between the weighted ESs. That is, the effects of PjBL versus TI were not different between PjBL groups of two to four, five and above, and one person working alone. The results also show that the effects of PjBL were significantly better than those of TI in both smaller groups (two to four people) and larger ones (five people and above).

With regard to the group size for collaborative learning, Bertucci et al. (2010) recommended grouping students who have no experience of this approach into pairs. On the other hand, Larmer and Mergendoller (2010) argued that students form teams of three or four in PjBL. More precisely, Hallermann et al. (2011, p. 68) and Larmer et al. (2009, p. 73) suggested getting students to form groups of four for PjBL. However, the results of this study show that the effects of smaller groups (two to four students) and larger groups (five to seven students in this study) were both positive. It is notable that the weighted ES of the smaller groups was a large effect (0.82), whereas a medium effect (0.70) was found for the larger groups. Additionally, these effects might be influenced by the use of information and communication technology, which could foster intra-group communication and sharing, as well as enable whole class presentations (e.g., Chang & Lee, 2010). Since the comparison between smaller and larger groups was based on the weighted ES of PjBL versus TI, future research could explore the effects of smaller and larger groups for PjBL.

4. Conclusions

This meta-analysis of 20 years of research synthesized the quantitative results comparing the effects of PjBL and TI on students' academic achievement, and investigated the study features impacting this in various educational settings. The findings present a quantitative ES estimate (0.71) based on individual studies, i.e. a medium to large and positive effect on student academic achievement in PjBL compared with TI, providing reliable evidence that PjBL is much more effective than TI with regard to enhancing students' academic achievement. The results show a greater impact of PjBL than seen in the previous reviews (Markham et al., 2003; Thomas, 2000), and thus imply that PjBL has become more effective in the 2000s and 2010s. This study suggests that PjBL could be an effective and proven alternative to traditional direct instruction. Teachers could introduce PjBL in their "main courses," as students can then be expected to have better learning outcomes than seen with TI. Teachers can first identify what topics reflect important concepts and essential information that would be taught through lectures, and then incorporate these into projects (Markham et al., 2003, p. 7). Nonetheless, even though this study's findings support the positive effects of PjBL on students' academic achievement, this does not completely negate the effectiveness of TI in this context. For example, it may be necessary to include TI to teach some basic skills during a project (Markham, 2012, pp. 17, 77; Markham et al., 2003, p. 10). It is important to bear in mind that PjBL does not have to completely replace TI (Özel, 2013), but could replace TI for a (perhaps large) portion of the whole course. For the remaining topics not incorporated in the project, instructors could consider dealing with these through TI.

In addition, the findings of this meta-analysis suggest that students' academic achievement in PjBL is not affected by educational stage and group size, but by subject area, school location, hours of instruction, and information technology support. Among these, the effect in social science courses was better than that seen in science and mathematics courses, though their effects were all better than TI. Furthermore, the effect of implementing PjBL at least 2 h per week was better than that seen with less than this, and the effect of using information technology to support PjBL was better than seen without such support. Although the effect reported in studies carried out in Western contexts was better than that seen in East Asian ones in the current study, PjBL teachers from different countries and different educational stages could pay more attention to the subject area, instruction hours, and technology support, to obtain better academic achievement among students. For example, elementary social studies lessons are worth trying to teach (and learn) with collaborative PjBL, with more than 2 h a week, in a technology-enhanced classroom. Nevertheless, as the Intel Education Initiative (2007) points out, teachers or researchers should also consider recognizing situations that make for good projects, integrating technologies where appropriate, managing student learning process, and developing authentic assessments.

Although this study focused on PjBL, the results may not be generalized to other inquiry-related alternatives to TI such as problem-based learning, discovery learning, and the inquiry methods, as they have somewhat different aims and principles to PjBL (see, for example, Lin, Chiu, Hsu, Wang, & Chen, 2018, a scientific inquiry activity focusing on inquiry questions without a project). However, it would be of interest for future research to follow the procedures of this work to analyze their effects on student academic achievement using the same moderator variables, and compare the results with those obtained in the current study. It would also be interesting to evaluate the effective degree of scaffolding/structure of the project assignment for students with different ages and levels of expertise, as success or failure may be dependent on the degree and nature of the constraints or guidelines presented to students with regard to the project, and the maximally effective degree would vary with their age and expertise. In addition, this study did not perform a meta-analysis with regard to the possible effects of PjBL compared with TI on affective outcomes (e.g. motivation, attitudes), problem-solving or collaborative skills, which are now a particular focus of educational practices in many contexts, due to the limited number of studies with sufficient data that were available for the analysis. Future research could thus use relevant keywords (e.g., project-based/oriented AND problem-solving skills OR collaborative/collaboration skills OR motivation OR attitudes) to conduct a new literature search, and use any related studies that are found for a further meta-analysis of PjBL and these skills or affective outcomes. Additionally, the keyword searches in this study were conducted in the authors' affiliation, and the research databases available in database platforms (e.g. *EBSCOhost*, *ProQuest*) are possibly somewhat different to institutions' subscriptions. Researchers who would like to replicate or extend this study are therefore recommended to perform a Google Scholar (or/and other academic search engines) search to compensate for the different search results that may be caused under such circumstances, as well as to include the eligible studies that may be missed through the database searches, as done in this meta-analysis. Finally, this work did not include any studies that were not written in English or Chinese, since the researchers' linguistic competence is limited to these two languages. Future studies could thus cooperate with researchers familiar with other languages such as Spanish, French, German, Japanese, Korean, and Nordic languages, or search using simplified Chinese, to include more PjBL studies in their works.

Declarations of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.edurev.2018.11.001.

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