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Work in Progress: An Early Look Into the Systematic Review of Project-Based Learning in Engineering Education

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Introduction

> "A review earns the adjective systematic if it is based on a clearly formulated question, identifies relevant studies, appraises study quality, and summarizes the evidence by use of the explicit methodology. It is the explicit and systematic approach that distinguishes systematic reviews from traditional reviews and commentaries" [1].

14 main types of reviews and their methodologies using the Search, Appraisal, Synthesis, and Analysis (SALSA) framework have been analyzed [2]. The authors described each review, detailing their strengths and weaknesses, and the kind of activities that the researchers undertake when searching, appraising, synthesizing, and analyzing. In describing the analysis of systematic literature review, they postulated that the aim of the researcher is to examine "what is known, what should be recommended for practice, what remains unknown, uncertainties around findings, and recommendation for future research" [2]. Undertaking a systematic review involves 6 steps. The steps include deciding to do a systematic review, identifying the scope and stating the research questions, defining inclusion criteria, finding and cataloging sources, critiquing and appraising, and synthesizing [3]. Other authors have suggested steps that are involved in conducting a systematic review [1, 4, 5, 6].

Project-based learning processes are "learning by absorption" and "learning by reflection" [7]. It has been suggested that there are 13 forms of project-based learning including "community studies, designing technological gadgets, environmental projects, expeditionary projects, field study, foxfire approach, micro-society studies, museum approach, problem-based approach, project approach in early childhood education, senior project approach, service learning, and work-based learning approaches" [8]. There is some evidence that project-based learning (PBL) improves students' involvement and academic achievement [9, 10]. Others have suggested how project-based learning can be implemented in an engineering program [11, 12, 13, 14, 15, 16]. Authors have done a review of literature and meta-analysis on project-based learning in the past [17, 18, 19, 20, 21, 22, 23, 24].

In the 1990s, the Accreditation Board for Engineering and Technology (ABET) decided to use outcomes as the basis to accredit engineering and engineering technology programs in the higher institutions of learning in the United States. Engineering Criteria EC 2000 by ABET has led to the increased emphasis on research and implementation of outcome-based learning and assessment. One of such outcome-based learning in engineering education is project-based learning. Also, based on some evidence that active learning enhances students' achievement, and facilitates students' engagement and deep processing [25, 26], instructors have been encouraged to incorporate project-based learning in their course curriculum. Although there are works of literature on project-based learning in engineering education and systematic reviews of project-

based learning in broad STEM and non-STEM programs, there is no known systematic literature review of project-based learning in the specific context of engineering education in recent times. There is therefore a need to conduct a systematic literature review of project-based learning in engineering education. The outcome of such a study will enlighten the public on the current status, future trends, and impact of project-based learning on the academic achievement of undergraduate students in the college of engineering. Hence the purpose of this study.

This study identifies and will synthesize works of literature that have researched and implemented project-based learning in engineering education. This systematic review gives a critical overview of the existing body of knowledge on the current state of research on project-based learning in and outside of the classroom environment. This work will inform researchers and instructors of the best practices in implementing project-based learning that will enhance student achievement. The study will also propose future trends and new research directions by identifying gaps in the literature. In conducting this ongoing systematic literature review, the following research questions were asked:

RQ1: What is the current status and strategies for implementing project-based learning in engineering education?

RQ2: What limitations/barriers are encountered in adopting project-based learning in engineering education?

RQ3: How has project-based learning influenced students' achievement in engineering education?

RQ4: What are the future trends and recommendations for the future directions of research for project-based learning in engineering education?

Methods

This study followed the typical process of conducting a systematic review study. The systematic review steps the authors adopted during the study include: deciding to do a review, developing research questions for the intended systematic review, stating the inclusion criteria, finding and cataloging sources, screening, critiquing, appraising, and synthesizing [1, 2, 3, 4, 5]. 5 out of these 8 steps have been completed. The completed steps include: deciding to do a review, developing research questions for the intended systematic review, stating the inclusion criteria, finding and cataloging sources, and screening the title and abstract steps for this study. This systematic review screening process was guided by PRISMA 2020, elaboration and expansion [27]. 7 databases were selected to locate articles to be used in this project. The selected databases cut across the 4 types of databases to be searched as suggested by [3] when conducting a systematic literature review study. These databases include subject-specific databases, general databases, journal databases, and gray literature databases [3]. The databases searched for this study include Education sources (EBSCO), ERIC (EBSCO), Education full text (EBSCO), Scopus, Science direct, and Dissertations/Theses: ProQuest Dissertations & Theses, and Institute of Electrical and Electronics Engineers IEEE electronic library.

The inclusion criteria for the study are: the full text in English, the publication date should be between 1990 and 2021, and the study must implement project-based learning in the college of engineering. Any project-based application outside of the field of engineering is excluded from the study. The search strategy was decided by the authors of the paper in consultation with the librarian for the department of engineering education at a western University in the United State. The first search for literature using the search strategy was developed together with the librarian and was conducted on the 31st of November, 2021. The details of the search terms, search strategies, Boolean operators as used for each of the databases, and the numbers of articles generated for each of the databases are shown in Table 1.

The articles generated from each of the databases were saved into Mendeley Desktop 1.19.5 software. The metadata of these articles was exported from Mendeley Desktop 1.19.5 as BibTex files. These BibTex files were converted to Microsoft excel comma-separated values files using the JabRef 5.5 for Windows. Once converted to Microsoft excel comma-separated-values, the metadata for the articles was accessible for analysis. The metadata excerpted include the type of article, authors of articles, year of publication, the title of the article, country where the study was done, and the abstract of the article, among others.

The imported articles were sorted alphabetically using the authors' column in the excel sheet. Duplicate articles were identified and removed from the database generated. Duplicates were identified when any two or more articles bear the same title, have the same authors' name, and were published in the same year. The review of the title and abstract were done by the author of the paper, and the paper that do not meet the inclusion criteria were screened out from the study. After reading the abstract of the paper, when the authors are unsure if the paper met the inclusion criteria, the researchers decided to assume it met the inclusion criteria. The decision of whether it will be included in the systematic review study will be made when the full text is screened for eligibility [22].

For the full-text review, the authors of this systematic review will individually review the full text, and inter-rater reliability will be calculated. Inter-rater reliability greater than 0.8 is good for the study [28]. After the inter-rater reliability exercise, the authors will reach a consensus on articles where they have discrepancies of which ones should be included in the final systematic review of the literature. Data will be extracted from eligible articles, study characteristics of articles will be coded, the papers will be assessed for quality, and the overall result that will answer the research questions will be presented.

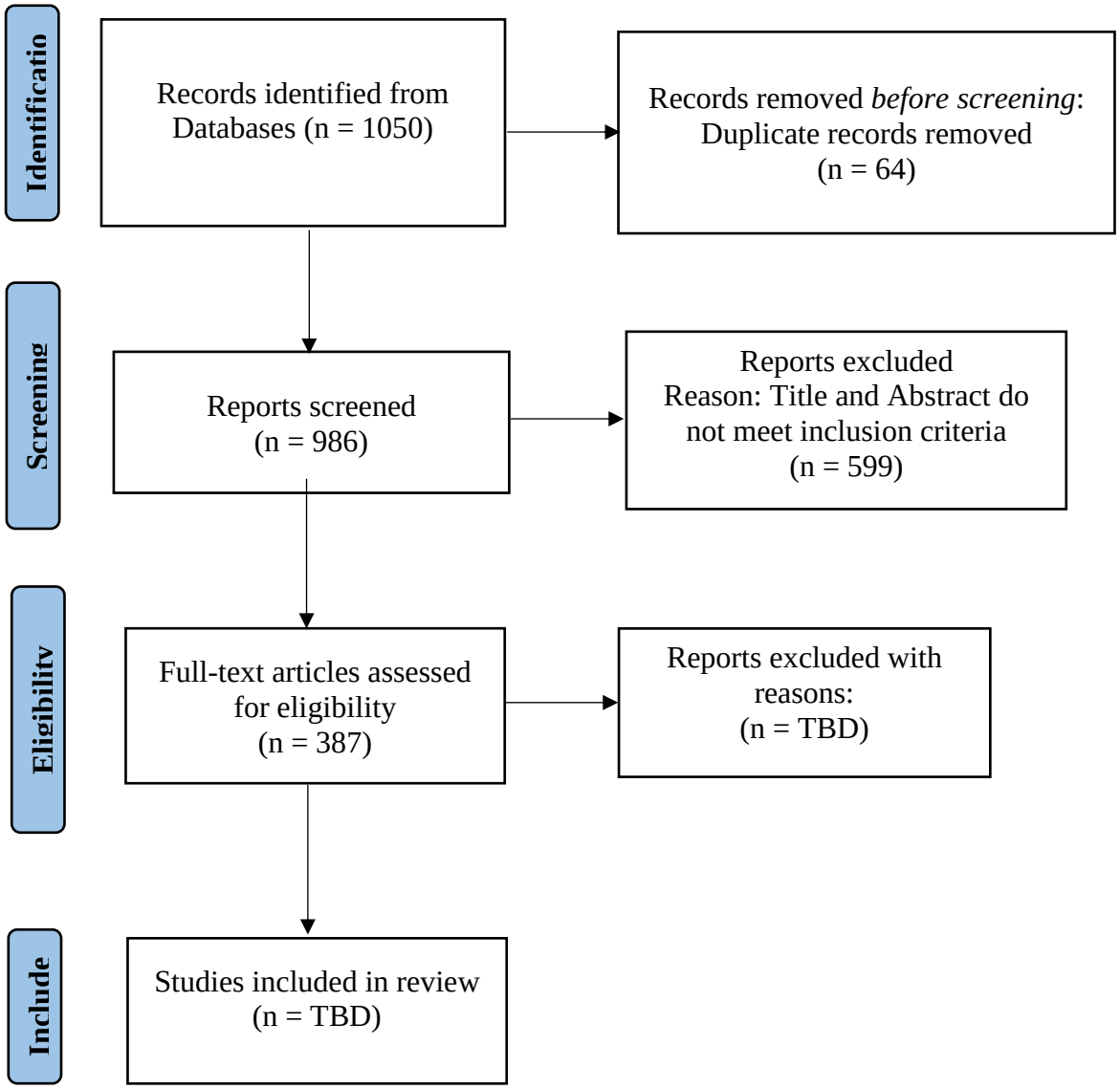

Figure 1: Adapted Work in progress PRISMA 2020 flow diagram for the systematic review of project-based learning in engineering education [27, 29, 30].

Database	Search Strategy Using Inclusion Criteria	Number
Education Source	(“Project-based learning”) AND (“student achievement” OR “academic achievement” OR “academic performance” OR “academic success” OR “scholastic achievement” OR “student performance” or “student success” OR “student outcome”) AND (college OR universit* OR undergraduate) AND (engineer* OR STEM)	54
ERIC	(“Project-based learning”) AND (“student achievement” OR “academic achievement” OR “academic performance” OR “academic success” OR “scholastic achievement” OR “student performance” or “student success” OR “student outcome”) AND (college OR universit* OR undergraduate) AND (engineer* OR STEM).	24
Education full text	(“Project-based learning”) AND (“student achievement” OR “academic achievement” OR “academic performance” OR “academic success” OR “scholastic achievement” OR “student performance” or “student success” OR “student outcome”) AND (college OR universit* OR undergraduate) AND (engineer* OR STEM).	14
IEEE Electronic Library (IEL)	("Full Text Only": "project-based learning") AND ("Full Text Only": "student achievement" OR "Full Text Only": "academic achievement" OR "Full Text Only": "academic performance" OR "Full Text Only": "academic success" OR "Full Text Only": "scholastic achievement" OR "Full Text Only": "student performance" OR "Full Text Only": "student success" OR "Full Text Only": "student outcome") AND ("Full Text Only": college OR "Full Text Only": universit* OR "Full Text Only": undergraduate) AND ("Full Text Only": engineer* OR "Full Text Only": STEM).	529
Scopus	(TITLE-ABS-KEY ("Project-based learning") AND TITLE-ABS-KEY ("student achievement" OR "academic achievement" OR "academic performance" OR "academic success" OR "scholastic achievement" OR "student performance" OR "student success" OR "student outcome") AND TITLE-ABS-KEY (college OR universit* OR undergraduate) AND TITLE-ABS-KEY (engineer* OR stem)) AND PUBYEAR > 1989 AND PUBYEAR < 2022	105
ProQuest (Dissertations & Theses)	"Project-based learning" AND ("student achievement" OR "academic achievement" OR "academic performance" OR "academic success" OR "scholastic achievement" OR "student performance" OR "student success" OR "student outcome") AND su(college OR universit* OR undergraduate) AND su (engineer* OR stem). Full text Available	90
Science Direct	(“Project-based learning”) AND ("student achievement" OR "student performance" OR "academic performance") AND (college OR university OR undergraduates) AND (engineering OR STEM)	234

Table 1: Table showing the databases searched, the searched strategy, and the number of articles per database foun

Preliminary Results

Some of the processes involved in this systematic review of engineering education have been completed [3]. A work-in-progress PRISMA 2020 flow diagram (Fig. 1) details the systematic literature review process for this study. The first search of the seven databases using the search strategy yielded 1050 articles. 54 articles from education sources, 24 articles from ERIC, 14 articles from Education full text, 529 articles from IEEE, 105 articles from Scopus, 90 articles from ProQuest, and 234 articles from science direct. 64 articles in total were duplicates, and these were removed by the researcher. The remaining 986 articles' titles and abstracts were screened using the inclusion criteria for the study. A total of 599 articles were excluded from the study since their title and abstract did not meet the inclusion criteria for the study. 387 articles met the inclusion criteria for the title and abstract screening. The full-text evaluation of the 387 articles for eligibility to be included in this systematic literature review study is ongoing.

From Figure 2, it is noted that there was no publication on Project-based learning in engineering education in the context of our study until the year 2000. This implies that published research on project-based learning in engineering education is only about 2 decades. Also, figure 2 revealed that more than 90% of project-based learning research in engineering education was undertaken about 10 years ago.

Furthermore, examining Figure 3 shows that the first published completed dissertation project in engineering education within the context of the researcher inclusion criteria occurred in the year 2021. This shows that student research work in project-based learning in engineering education is in its infancy. Also. Figure 3 provides us with the information that Journal articles followed by conference proceedings are the most utilized dissemination channel by which researchers disseminate their project-based learning outcomes in engineering education.

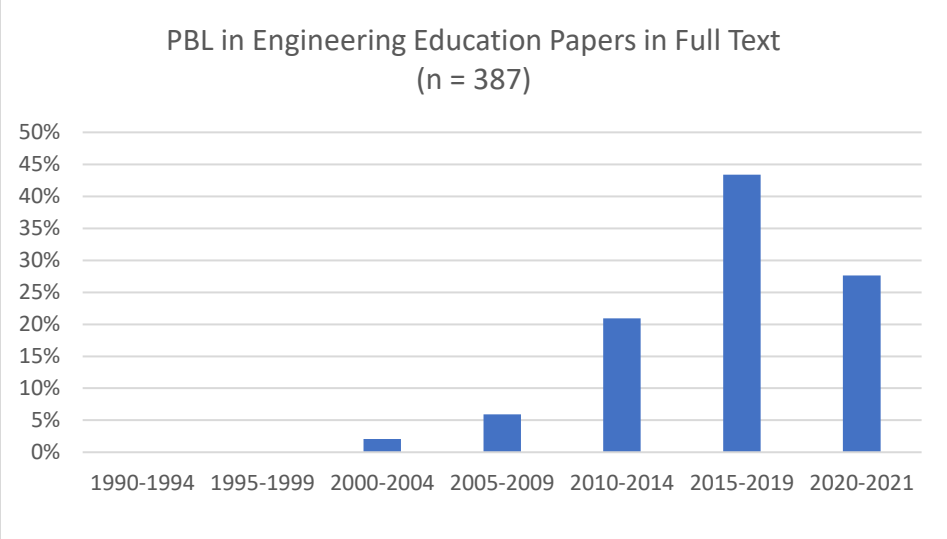

Figure 2: Related “Project-based learning engineering education papers” in engineering education as adapted [25].

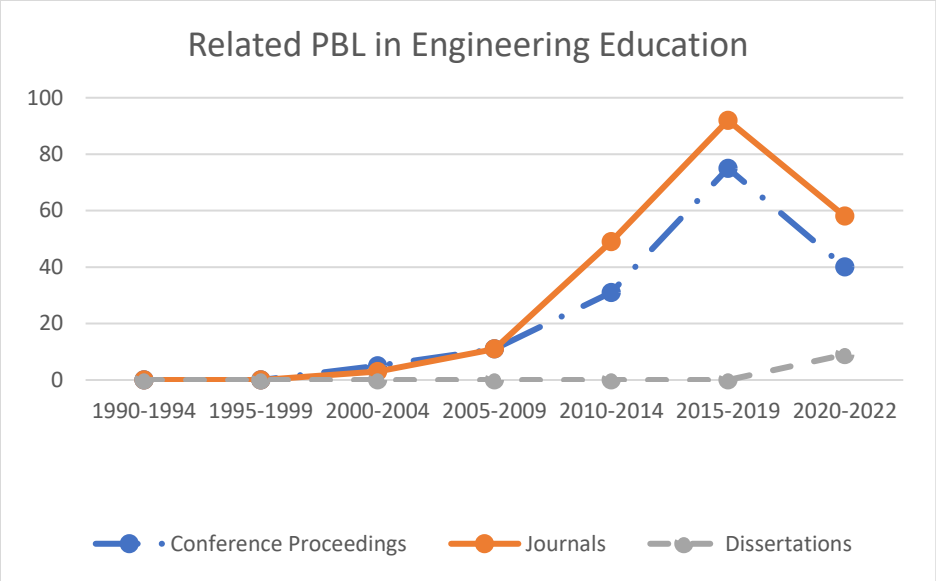

Figure 3: Related "Project-based learning (PBL) in engineering education from Journals, Conference proceedings, and Dissertation".

Limitation of the Study

Some of the papers in this initial analysis might not be exact studies on project-based learning in engineering education. The ongoing screening of the articles' full text in deciding which studies will be finally included in this systematic literature review study will provide us with more accurate details. Also, there is a possibility that some articles will be added from citation searching and reference list checking of included eligible studies.

Discussions

To provide definitive answers to the proposed research questions of this study, more work needs to be done. However, our analysis provides some tentative suggestions. Based on the preliminary outcome of this study, there is an accelerated increase in studies of project-based learning in engineering education. This provides suggestive evidence that project-based learning is an active learning process whose paradigm has come in engineering education. The authors of this study postulate that the over 90% emphasis in engineering education from the year 2010 on project-based learning must have been influenced by the Accreditation Board for Engineering and Technology (ABET) EC criteria which became effective for accrediting engineering programs from 2010-2011. ABET further emphasized that the criteria of accrediting a program will no longer be on what is being taught as input, rather it will be a showcasing of what is learned as the outcome. However, within the confines of the search strategy, inclusion criteria, and databases searched, the preliminary outcome of this systematic review shows that in the past 3 decades, only 9 published dissertations have investigated project-based learning in engineering education. Therefore, effort should be channeled towards encouraging more undergraduate and graduate students to investigate project-based learning in engineering education as their theses or dissertation.

The ongoing next phase of this systematic review is assessing and reviewing the full text of the 387 articles whose title and abstract fulfilled the inclusion criteria for this study. Once articles to be included in the systematic review are identified, citation searching and reference list checking will be done [2]. Authors will be consulted to seek additional information that may be missing from articles that are important for the review. Also, experts will be consulted to see if they have any suggestions for any additional articles that relate to this ongoing systematic review [31,32].

Study characteristics of the eligible paper for this study will be extracted and coded. From the coded information, a synthesis of the eligible study will be carried out [32, 33]. The synthesized information of this study will answer the research questions of this systematic literature review. It is hoped that this study when completed will better inform the engineering community of the current state-of-the-art of project-based learning in engineering education, the impact of engineering education on students' academic achievement, and recommend future direction for project-based learning in engineering education. The study will also contrast project-based learning in the United States to other countries.

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