International Journal of Engineering Education Vol. 36, No. 1(A), pp. 18–39, 2020
Printed in Great Britain
0949-149X/91 $3.00+0.00

Ten Years of First-Year Engineering Literature (2005–2014): A Systematic Literature Review of Four Engineering Education Journals*

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First-Year Engineering (FYE) education, while arguably established, is changing within a field that is evolving. To ensure that research is informing FYE change, there is a need for an overview of existing FYE research, which both summarizes what is known and provides direction for future research. The purpose of the review is to answer (1) What is the general landscape of FYE literature? and (2) What FYE practices are recommended or supported by the literature? Four journals were used as the source of articles. Through a three-step process, we identified 156 articles that focused on FYE that were included in the analysis. Of these, 73 were identified as research articles and both their methods and findings were explored in the study. FYE literature spans both innovative practice and research, and covers a wide-range of topics, such as *Design*, *Pedagogy & Learning Theories*, and *Skills*. Though, numerous studies document individual FYE programs, courses, or projects, many findings were limited to evaluating the activity in isolation. We did not find substantial literature examining the impact of FYE program design (e.g., matriculation decisions, course focus) on achieving engineering program outcomes. Future FYE research should more fully consider the theory and research designs used to promote generalizability and transferability of study findings beyond a single FYE experience or university.

Keywords: systematic review; first year; evidence-based practice; research methods

1. Introduction

An outcome of the 1990 ASEE Engineering Deans Council Pipeline Implementation Committee assembly was the identification of the need for the enhancement of the First-Year Engineering (FYE) experience [1]. The committee called for engineering programs to expose students to a variety of engineering experiences as well as the types of opportunities in engineering [2]. Engineering programs responded by introducing new courses and revising the objectives, credit hours, and approaches of existing engineering courses [2]. Courses were designed based on topics instructors at discrete institutions believed necessary for an FYE course [3]. Through their process of developing a classification for FYE courses, Reid, Reeping, and Spingola (2018) found that FYE courses varied considerably: FYE courses focused on academic success (e.g., time management [5]), communication (e.g., writing [6]), engineering design (e.g., design fundamentals [7]), engineering knowledge (e.g., soldering [8]), the engineering profession (e.g., engineering disciplines [9]), engineering professional skills (e.g., teaming [10]), global interests (e.g., concern for society [11]), and/or math skills (e.g., calculus [12]). Within the Unite States alone, nearly three-fifths of engineering programs have established a FYE course [13].

Though FYE is often viewed as an established success, FYE courses and programs are continuing to change within a wider engineering education field that is also changing. New or revised FYE courses are introduced each year [14–17]. Multiple calls for change have resulted in colleges and departments of engineering taking a retrospective position, considering their degree program curriculum, and then acting on ways they could revolutionize, or at least improve, their units. Within the United States, calls for engineering curricula change have come from the National Academy of Engineering [18], the National Science Board [19], Neilsen [20], and the National Science Foundation (2014). World-wide, FYE change has been motivated by calls such as the United Nations Decade of Education for Sustainable Development (DESD) 2005–2014 (e.g., [22]) and Accreditation Board for Engineering and Technology criteria (e.g., [23]).

Within the wider field of engineering education, FYE education has played an important role. Today, FYE subjects remain critical discussion topics, as is evident from the 58 papers presented at 11 technical sessions sponsored by the First-Year Programs Division at the 2017 American Society for Engineering Education (ASEE) Annual Conference and Exposition [24] and the increased participation at both the First Year Engineering Experience

* Accepted 14 September 2019.

(FYEE) and the European First Year Experience (EFYE) conferences. FYE is a significant topic area when discussing engineering student development because it impacts student motivation (e.g., [25]), teaming skills (e.g., [26]), engagement in learning (e.g., [27]) and, ultimately, retention (e.g., [28]). Despite the recognized importance of FYE in terms of both engineering education and research, no formal review of FYE literature has been conducted.

As engineering programs address the status of their first-year engineering curricula, it is important for existing models to be considered in order to prevent course developers from "reinventing the wheel" [3]. In her *Journal of Engineering Education* guest editorial, Watson [29] states the importance of research for changing and improving engineering education, commenting that change must be consciously designed based on what is known from research. To ensure that research is informing FYE development and change, there is a need for an overview of existing FYE research, which both summarizes what is known and provides direction for future research. The systematic literature review presented in this paper addresses that need.

2. Purpose

The purpose of our systematic literature review is to describe the state of knowledge of research related to FYE students and programs and to provide direction for future FYE research. Our purpose is consistent with typical rationale for conducting a literature review [30, 31]. This review focused on all types of FYE programs. We did not limit ourselves to first-year programs based on content (e.g., student success versus engineering design) or structure (e.g., discipline-specific versus common first-year programs). Our review used broad search terms, as described in Step 1 of the Methods Section to ensure we captured research from the many types of FYE experiences.

Our purpose is important for two reasons: Petticrew and Roberts [32] explain that systematic reviews are warranted when (1) "it is known that there is a wide range of research on a subject, but where key questions remain unanswered" and (2) "when a general overall picture of the evidence in a topic area is needed to direct future research efforts" (p. 21). The FYE community investigates a wide range of topics (e.g., student motivation to pursue engineering degrees [33], changing departmental cultures [34], and reasons why students leave engineering [35]) within a wide variety of FYE programs (e.g., direct matriculation, common first year – see discussion in Orr et al., [36]) that provide instruction for a diverse set of content areas (e.g., engineering design, academic advising – see discussion in Reid et al., [3]). With this in mind, it is necessary to understand the landscape of the literature to better understand the progress and importance of FYE work in engineering education.

Researchers have explored other areas of interest in engineering education through systematic literature reviews. The article by Borrego, Foster, and Froyd [37] was a systematic literature review of systematic literature reviews in engineering education and included 49 review articles published since 1990. Since this publication, the number of systematic literature reviews has expanded. For example, an article by Brown, McCord, Matusovich, and Kajfez [38] detailed the use of motivation theory in engineering education work, finding that 52% of gathered articles, ranging from 2009 to 2012, did not use a motivation framework, theory, or construct definition despite the article stating that motivation was studied. The Brown et al. [38] article served as a catalyst for the 2017 American Society for Engineering Education workshop on Deconstructing and Assessing Motivation [39] which aimed to bolster practitioners' and researchers' use of motivation in their work. Additionally, Bodnar, Anastasio, Enszer, and Burkey [40] reviewed literature on games used as teaching tools in undergraduate engineering education, highlighting the positive impact games can have on learning and attitudes along with the need for a more systematic assessment related to their use. Their research emphasized an important impact of these tools and a potential area for improvement. Through our systematic review, we aim to do the same. We want to provide the field with a better understanding of FYE literature while identifying opportunities for future work.

We used the following overarching and sub-research questions to frame our review of FYE literature:

1. What is the general landscape of FYE literature?
   (a) What trends exist regarding publishing venues for research and practice in FYE literature?
   (b) What theoretical frameworks have been used to study FYE?
   (c) What research methods have been used to study FYE?
2. What FYE practices are recommended or supported by the literature?

Since first-year courses are often used as an example of an area of engineering education that has been heavily researched, we believe it is important to develop a clear understanding of what has been researched, the theories that have been used to frame FYE research studies, and the types of

Table 1. Ratings for Engineering Education Journals

Journal	***JEE***	***AEE***	***EJEE***	***IJEE***
2014 Impact Factor[1]	2.059	N/A	N/A	0.36
2014 Source Normalized Impact per Paper (SNIP)[2]	0.427	2.213	1.385	1.86
2014 SCImago Journal Rank (SJR)[2]	0.152	0.23	0.419	0.314

[1] http://www.researchgate.net
[2] https://www.scopus.com/source/eval.url

investigations (qualitative, quantitative, or mixed methods) that have been utilized to generate FYE knowledge. Theories, research questions, and study design are all inextricably linked. Identifying theories provides insight into study constructs and perspectives of viewing FYE. By summarizing the types of research methods employed, we illuminate gaps in the ways researchers have posed and answered research questions about FYE. By summarizing what is known about research surrounding FYE, we position the community to identify more meaningful topic areas for future research and development. We highlight important aspects of FYE that are linked to literature and are pertinent to administrators or practitioners who are instituting or revising an FYE program, course, or project.

3. Methods

We conducted a systematic literature review following the general procedures outlined by Gough, Thomas, and Oliver [41] and the engineering education-focused procedures outlined by Borrego, Foster, and Froyd [31]. While there are a variety of publishing venues for engineering education work outside of the engineering education field, this literature review strategically examines articles from four engineering education specific journals:

- *Advances in Engineering Education (AEE)*
- *European Journal of Engineering Education (EJEE)*
- *International Journal of Engineering Education (IJEE)*
- *Journal of Engineering Education (JEE)*

The journals selected for review cover a breadth of publishing venues specifically in engineering education, have been publishing for at least 10 years, and have a top-rated h-index in the field [42]. *JEE* is a research journal published by the ASEE whose charge is "to cultivate, disseminate, and archive scholarly research in engineering education" [43]. *AEE* is also published by the *ASEE* and is a younger counterpart to *JEE*. Its mission is to publish the innovations made in engineering education practice [44]. In their guest editorial outlining the differences between *JEE* and *AEE*, Shuman, Besterfield-Sacre, and Litzinger [45] acknowledge that while *AEE* is more focused on applications, *AEE* is not "applications without research" (p. 225). Both the *IJEE* and *EJEE* were chosen to add an international viewpoint to the FYE research that will be analyzed. To give the reader an indication of the reputation and importance of the journals, various ratings, if available, are given in Table 1.

While engineering education conferences (e.g., ASEE Annual Conference and Exposition, Australasian Association of Engineering Education (AAEE) Annual International Conference, European First Year Experience (EFYE) Conference, Frontiers in Education (FIE) Conference, First Year Engineering Experience (FYEE) Conference) also provide venues for publication and have articles that could be used or analyzed, we considered articles from conferences outside the scope of this review. This review is concerned with examining peer-reviewed research-based articles. While some conference papers do fit within that scope, many conference publications are not subject to rigorous peer-review or are not research-based. In addition, many conference papers are not indexed, and conference website search tools are not robust enough to ensure that all relevant articles are identified. In the future, an additional review can examine the multitude of conference articles and compare conference trends to peer-reviewed journal trends identified in this review.

Past systematic literature reviews in engineering education have taken a similar approach of scoping their search to a selection of journals (e.g., [38, 46]). Others (e.g., [37, 40, 47–49]) have used a wider set of journals by searching through journal databases (e.g., Academic Search Complete, ERIC, Scopus) without limiting their search to a pre-determined set of journals. We chose the four engineering education-specific journals because we are surveying what engineering education *researchers* have investigated with regard to FYE. While some FYE studies may be published in other journals, namely discipline-specific engineering education journals, the four journals we selected represent focused engineering education publishing venues used by the research community. With the increasing interest in expand-

Table 2. Distribution of Articles by Journal

Number of articles . . .	*JEE*	*AEE*	*EJEE*	*IJEE*	Total
Step 1: Identified by search terms	59	73	97	498	727
Step 2: Eliminated by search term location	23	62	48	400	533
Step 3: Eliminated by search term usage	7	4	8	19	38
Articles included in and analyzed for literature review	29	7	41	79	156

ing and intersecting discipline-based education research, we believe we must first understand our specific discipline before we can meaningfully engage with those influencing education more broadly.

We searched for FYE articles that were published in the timeframe from January 2005 through December 2014 (10 years). We initiated our search from the year 2005 due to its significance in the shift of the engineering education community towards more rigorous research. The shift occurred in conjunction with the establishment of engineering education departments, which created tenured engineering education faculty positions [50]. It is also documented by the 2003 announcement of a new mission of *JEE* "to serve as an archival record of scholarly research in engineering education" [51, pp. 1] and the January 2005 *JEE* special issue, *The Art and Science of Engineering Education Research*, which was planned as "a special celebration issue that would review the current state of scholarship in key areas of engineering education" [52, pp. 8]. By initiating our literature search in 2005, we review articles that were published after the shift towards more rigorous research in the field, and we begin where the 2005 special issue summaries ended. For those reading this paper shortly after the review period, we hope this work provides inspiration for new areas of work related to FYE where the gaps in past FYE serve as inspiration to concepts yet to be explored. For those reading this paper significantly after this 10-year period, we believe this review will serve as a snapshot of FYE education during this time that may be helpful for a historical perspective on the field where conclusions can be drawn related to progress and change. Regardless of the reader, we believe that insights about FYE during this time period can be gleaned from this work which will enhance FYE literature as a whole.

3.1 Step 1: Search Terms, Search Term Refinement and Article Identification

Academic Search Complete was used to search *JEE* and *EJEE*. For *IJEE and AEE*, searches were performed using the search toolbar, abstracts, and other information posted on the *IJEE* and *AEE* websites. Initially, we searched using the following search terms: "first-year engineering", "first year engineering", and "freshman engineering". We examined our initial set of articles individually to search for appearances of our search terms and, importantly, we noted that several articles that appeared to be relevant for answering our literature review research questions did not include our search terms in their entirety. For example, many of the articles included "first-year" but not "first-year engineering." Therefore, we revised the set of search terms to "first year", "first-year", "freshmen", and "freshman." The number of unique articles that were identified with revised search terms was 727, with the distribution of articles by journal given in Table 2. The new search terms gave our searches more breadth and increased our confidence that we captured all relevant articles from the selected journals. Simultaneously, the new broad search terms generated a need to carefully examine the identified articles' primary focus for fit for this review.

3.2 Step 2: Elimination of Identified Articles Based on Article's Focus: Search Term Location

To determine if an article identified by our search terms was relevant for this review, we examined an individual article using inclusion criteria. Our first inclusion criterion was the search term *location*: we examined whether a search term appeared in a significant location within an article, such as the article's title, abstract, or keywords, which indicated the article's focus. These locations were chosen because words found in these three locations are likely to be the focus of an article or have a strong impact within the article itself. All articles were examined individually, and if any of the search terms appeared in any one of these three locations, the article was tagged for inclusion. Based on *location*, we eliminated 533 articles (23 *JEE*, 62 *AEE*, 48 *EJEE*, and 400 *IJEE* articles), leaving 194 to be assessed in Step 3 (see Table 2). Due to the large number of eliminations for *IJEE*, we examined the *IJEE* article elimination further. We noted that the reason for the high number of eliminations of *IJEE* articles was that the initial search method included articles where search terms appeared only in the eliminated *IJEE* article's bibliography. Therefore, all the 533 eliminated articles remained eliminated.

3.3 Step 3: Elimination of Identified Articles Based on Article's Focus: Search Term Usage

In Step 3, article abstracts and, when necessary, entire articles were examined for search term *usage*. Both authors of this FYE review scrutinized every article that passed the Step 2 elimination to determine if the search term usage within a given article clearly indicated an investigation of FYE programs, students, or activities. If the search term usage was clearly related to FYE, the article was included for Step 3 processing. If an article was clearly unrelated to FYE, the article was eliminated. For example, several articles that were eliminated during Step 3 processing used the key word "first year" in reference to first year graduate students (e.g., [53]). In the case that articles that did not clearly fit into either category (i.e., clearly about FYE or not), as indicated by a flag by one reviewer or a mismatched classification between reviewers, the final classification was discussed. The criterion used during all discussions was that, to proceed to our analysis phase, an article must (1) collect principal rather than ancillary data from FYE students/programs, or (2) draw conclusions about FYE students/programs. For example, one article excluded after discussion examined faculty acceptance and the impact of service learning integrated throughout the curriculum [54]. Though FYE students were surveyed, the survey served as an initial pre-test data point and convenient comparison point for surveys administered to students across all engineering years. Duffy and his coauthors' conclusions focused on the benefits of and tips for integrating service learning across the curriculum. As a second example, we excluded an article that detailed developing and testing a framework for formative feedback provided to design teams [55]. To develop the framework, Diefes-Dux and coauthors examined instructor feedback provided by graduate students to design teams, which unrelatedly were FYE design teams. The conclusions focused on the utility of the framework for identifying patterns in and improving formative feedback. During Step 3, we eliminated 38 articles (seven *JEE*, four *AEE*, eight *EJEE*, and 19 *IJEE* articles), which resulted in a group of 156 articles relevant for answering our research questions. Table 2 provides details of article counts by journal for each search and elimination step.

3.4 Validity, Reliability and Limitations

In their 2014 article, Borrego et al. [31] provide a review of validity and reliability considerations related to systematic reviews and limitations of such a study. We have framed this section around their recommendations and insights addressing both the study's bias and quality.

We acknowledge the bias present in our work as it relates to systematic reviews in general and our bias as researchers. First, as Borrego et al. [31] explained, published papers tend to present positive research results opposed to failures. We recognize that unsuccessful programs and projects related to FYE may not be included, which limits the scope of the findings. Second, we did limit our study to four engineering education journals which excluded discipline-specific engineering education journals (e.g., *IEEE Transactions on Education*, *Chemical Engineering Education, Journal of Professional Issues in Engineering Education and Practice*), educational journals more broadly (e.g., *Journal of Higher Education*, *International Journal of Educational Research*, *Journal of College Student Development*), and FYE conferences (e.g., EFYE Conference, FYEE Conference, etc.). As noted in the Methods section, we realize this approach limits our findings to the work presented only in four journals. This limits the reach of our work and places a bias in our findings towards these publishing venues opposed to others. However, even with these limits on scope, we have still captured a core of published FYE articles, and this review does provide meaningful results and areas of future work. Finally, we note that this review examined a decade of publications (2005–2014), which excludes the most recent FYE publications. Excluding these publications is a limiting factor and should be considered when reviewing the findings. With these biases in mind, we tried to preserve the quality of our study by including "consistency and transparency in selecting and reporting procedures for every step of the review" throughout this manuscript [31, pp. 63]. We believe the detail provided in this manuscript about our process supports the validity of this work. We also established reliability by having a minimum of two engineering education research experts involved in applying the inclusion and exclusion criteria throughout the review. This "collaborative process" [31, pp. 63] ensures that agreement was met between researchers about the articles. We also employed a final checking phase to this work where a third researcher, who was not familiar with this study, reviewed 11 randomly selected articles from the appendices. Their findings aligned with the original findings further supporting the reliability of this work. While bias cannot be eliminated from any study, we believe the results of this review are scoped to fit within the bounds of our bias. Additionally, we believe the quality of this work, both the validity and reliability, was maintained through the presentation of a detailed process and multiple researchers applying the inclusion and exclusion criteria.

4. Results

Once the articles were collected, we used the data to answer each of our research questions (RQ). Below we provide the results for each question highlighting the major trends we observed.

4.1 Landscape of FYE Literature (RQ 1)

To understand the current FYE landscape (RQ 1), we classified each of the 156 articles into four categories: Scholarship of Teaching and Learning (SoTL), Engineering Education Research with Theory (EER-T), Engineering Education Research guided by a Research Question (EER-RQ), and Engineering Education Research that includes both Theory and a Research Question (EER-TRQ). All articles examined during this review were published in nationally and internationally recognized peer-reviewed journals. We note that in no way are we judging the quality of work reported. Rather, we recognize that in engineering education literature, two equally important and interdependent categories of literature exist: practice and research. These two categories are evident in differences between the more research-focused mission of *JEE* and the more practice-focused mission of *AEE*. Since none of the journals explicitly exclude any one category and articles can focus on both research and practice, to investigate FYE literature trends in journals, we found it important to consider publication patterns for both practice-focused and research-focused articles. Streveler, Borrego, and Smith [56] make the excellent point that these two realms are less like binary silos and should be thought of more like a continuum with rigorous engineering education research and excellent teaching as opposing endpoints, which is why we classified articles into four categories instead of two. Our categorization also supports the importance and interdependence inherent in the research-to-practice cycle discussed by Jamieson and Lohmann [57], as adapted from Booth, Colomb, and Williams [58]. Further, in some cases there is value in separating what is known as a result of reports and assessments of FYE implementations (practice-focused) and what is known as a result of a systematic research evaluation (research-focused).

We operationalized our practice-focused and research-focused categories from definitions originally reported by Streveler, Borrego, and Smith [56], examined by engineering faculty as part of a 2005 Rigorous Research in Engineering Education workshop [59], and adapted as a resource for engineering educators beginning engineering education research [60]. Importantly, these authors noted that the 2005 workshop participants were relatively accepting of the definitions. In our case, we relied on the adapted definition of SoTL to identify practice-focused articles as those that inform others of FYE programs, activities, or outcomes, and involves an investigation or assessment. To identify research-focused articles, we relaxed the adapted definition of "engineering education research" to those that state at least one *research* question (not an *assessment* question) or hypothesis or mention a theory, theoretical framework, or conceptual framework. An example research question is "When presented with an engineering design task, do first-year engineering students gather information from a variety of high-quality sources and document and use gathered information to support design arguments and decisions?" [61]. In that question, the work in a particular class and student learning are not the focus. An example assessment question is "What impact did the market game have on students' perceptions of engineering entrepreneurship?" [62]. While this question provides valuable insights on engineering entrepreneurship, it is focused on students' learning related to a specific course project which falls into the assessment category. We acknowledge that drawing this distinction may not capture all the nuances of educational research (e.g., conducting translation research which applies theory to practice to improve education may be categorized as assessment based on the phrasing of the questions); however, we are trying to better understand the research directly related to FYE students and programs and to provide direction for future FYE research. We believe our effort to identify FYE research through our *assessment* and *research* classifications is an appropriate starting point for discussing FYE research.

Since we did not require both theory and research question components for our *research* classification, we included three research-focused classifications (EER-T, EER-RQ, and EER-TRQ) in our classification schema to account for the component(s) an article contained. References for these papers can be found in the appendices along with a notation about including a research question and/or theory, the methods used for those with a research question, and purpose of the article. We did not evaluate the use of theory within an article; rather we set the inclusion criteria as any mention of a theory. Notably, this research definition is less strict, meaning we required theory or research questions opposed to those given by Streveler et al. [56], which requires the theory to be used to frame research questions and interpret results. As in previous elimination phases, all articles were reviewed by a minimum of two engineering education experts

Table 3. Summary of Article Classification Category Definition

Category	Minimum criteria for inclusion in category	Used for Research Question (Number)
Scholarship of Teaching and Learning (SoTL)	Peer-reviewed FYE-focused journal article published in selected engineering education journal from 2005–2014	1a, 2
Engineering Education Research with a Theory (EER-T)	Peer-reviewed FYE-focused journal article published in selected engineering education journal from 2005–2014 that mentions an educational or learning theory	1a, 1b, 2
Engineering Education Research with a Research Question (EER-RQ)	Peer-reviewed FYE-focused journal article published in selected engineering education journal from 2005–2014 that includes at least one research question	1a, 1c, 2
Engineering Education Research with a Theory and a Research Question (EER-TRQ)	Peer-reviewed FYE-focused journal article published in selected engineering education journal from 2005–2014 that mentions an educational or learning theory and includes at least one research question	1a, 1b, 1c, 2

Table 4. Trends by Publishing Venue

Number of articles . . .	*JEE*	*AEE*	*EJEE*	*IJEE*	Total
SoTL	4 (14%)	4 (57%)	27 (66%)	48 (61%)	83 (53%)
EER-T	0 (0%)	1 (14%)	4 (10%)	5 (6%)	10 (6%)
EER-RQ	18 (62%)	0 (0%)	9 (22%)	21 (27%)	48 (31%)
EER-TRQ	7 (24%)	2 (29%)	1 (2%)	5 (6%)	15 (10%)
Total number of articles	29	7	41	79	156

and any mismatches between reviewer ratings were discussed. In the few instances where there was no consensus, which always involved interpretation of research versus assessment questions, we classified the article as research-based so it could be included in further stages of our analysis. Our category definitions are summarized in Table 3. We examined 156 articles and categorized 83 articles as SoTL and 73 as EER (10 as EER-T, 48 as EER-RQ, and 15 as EER-TRQ).

4.1.1 Publishing trends for research and practice in FYE Literature (RQ 1a). In order to examine publishing trends for FYE research and practice (RQ 1a), we examined our classification results by journal and over time. The classification distribution is illustrated in Table 4 and the time classification in Fig. 1. *IJEE* had the most articles in this study, 79 out of the 156 total, demonstrating its publishing impact in the field related to FYE. *JEE*'s aim to "cultivate, disseminate, and archive

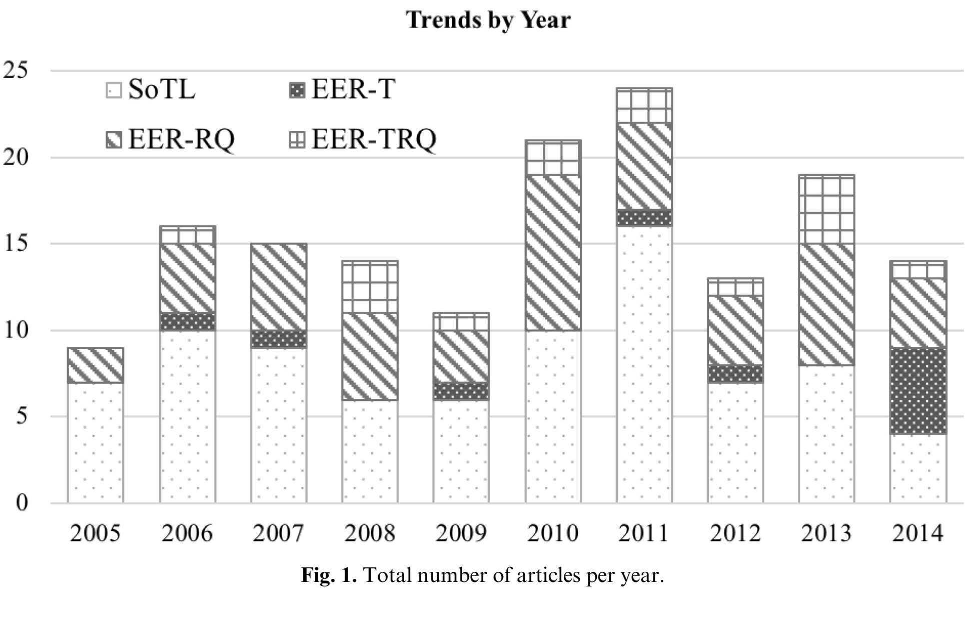

Fig. 1. Total number of articles per year.

scholarly research in engineering education'' [63] is reflected in the sample where 86% of its FYE articles classified as research were from *JEE*. *AEE*, *EJEE*, and *IJEE* articles were more balanced between SoTL and EER. Notably, if we abide by the stricter Streveler et al. [56] definition of engineering education research, requiring both a theoretical framework **and** research questions (EER-TRQ), only 10% of the articles reviewed would be considered research articles. Related to time, we note that the highest number of FYE articles were published in 2011. EER-T were published 0–1 times per year with the exception of 2014, which had five articles. An average of five EER-RQ articles were published each year with a single year maximum of nine in 2010.The largest number of EER-TRQ articles were published in 2013.

4.1.2 Theoretical frameworks used to examine FYE (RQ 1b). Out of the 156 articles that were reviewed, only 25 had any mention of a guiding theory or conceptual framework (EER-T and EER-TRQ). Some of these articles used specific frameworks in their study, such as Tinto's Interactionalist Theory (e.g., [28]), while others were more general in their approach. For example, a more general concept or theory that was mentioned in 6 of the articles (5 of which were from *JEE*) was self-efficacy. Self-efficacy was the most commonly used theory or theoretical framework. In some articles, self-efficacy was paired and explained with other theories such as Expectancy-Value (e.g., [64]) while other articles used the theory as a standalone guiding concept (e.g., [65]). The other theories and conceptual frameworks that were used were only applied in one out of the 25 articles, except for the idea of constructivism which appeared in four articles and Piaget's work which was referenced in two articles. A comprehensive list of the theoretical frameworks that were used in the articles can be found in Table 5.

4.1.3 Research methods used to examine FYE (RQ 1c). To understand what research methods have been used to study FYE (RQ 1c), which provides insight into the types of research questions posed in FYE studies, we examined the 63 EER-RQ and EER-TRQ articles (note, we did not examine the methods for the EER-T articles). First, we searched each article for the keywords ''quantitative'', ''qualitative'', and ''mixed''. When articles included both ''quantitative'' and ''qualitative'' in the text, we noted this as ''Both'' in the appendices. We chose ''mixed'' opposed to ''multi'' to capture the articles that used combined approaches opposed to multiple qualitative or quantitative components. For articles where the method type was not explicitly stated, one of the authors examined the methods and analysis sections to identify the type of methods. For validity purposes, the classification included an explanation for the expert's reasoning (e.g., a comparison of average quiz grades would warrant a quantitative classification) and the other author reviewed the methods classification and reasoning. Further, in the appendices, we identify articles for which we made a method determination with a NS tag indicating ''Not Stated''. Only 54% of the 63 articles explicitly stated the methods employed. Of the remaining 29 articles (46%) subject to expert classification, all but two were quantitative articles. The article counts for each method are summarized in Table 6. Quantitative methods were the methods of choice when investigating FYE. *EJEE* was the only journal with a balanced representation of methods: *EJEE* articles included 40%

Table 5. Theoretical and Conceptual Frameworks from Literature Review*

Self-Efficacy (6)	Identification with Academics	Significant Learning
Constructivism (4)	Information Literacy Model	Situated Cognitive Theory
Piaget Learning Theory (2)	Information Processing Theory	Social-Cultural Constructivist Theory (Vygotsky)
Bloom's Taxonomy	Kano Model of Quality (QFD)	Theory of Learning for Discovery
Connectivism	Kolb's model for experiential learning	Theory of Transformational Play
Ecological Theory	Kuhlthau's ISP model	Tinto's Interactionalist Theory
Epistemic Frame Theory	Metacognition	Triarchic Theory of Human Intelligence
Expectancy-Value Theory	MUSIC Model of Academic Motivation	Variation Theory of Learning
Hackman Model of Effective Teams	Pedagogies of the Co-Association	Significant Learning
	Self-Regulated Learning	

* (#): If more than one, number of articles that identified the theoretical framework

Table 6. Research Methods by Publishing Venue

Number of articles . . .	*JEE*	*AEE*	*EJEE*	*IJEE*	Total
Quantitative	16 (44%)	2 (100%)	4 (40%)	15 (58%)	37 (59%)
Qualitative	4 (16%)	0 (0%)	3 (30%)	4 (15%)	11 (17%)
Mixed or both quantitative and qualitative	5 (20%)	0 (0%)	3 (30%)	7 (27%)	15 (24%)

Table 7. Data Collection Method by Publishing Venue

Number of articles using . . .	*JEE*	*AEE*	*EJEE*	*IJEE*	Total
Survey	17	0	6	16	39
Student performance data (e.g., assignment grades, course grades)	4	1	2	12	19
Interviews	2	0	4	2	8
Pre/post tests	3	0	2	1	6
Student attributes (e.g., high school GPA, ACT/SAT scores, enrollment trends)	1	1	0	3	5
Expert evaluation	4	0	0	0	4
Observations	2	0	0	1	3
Focus groups	0	0	1	2	3
Verbal protocol analysis of design thinking	0	0	0	2	2
Think aloud	1	0	0	0	1

quantitative, 30% qualitative, and 30% mixed or both. *JEE, AEE*, and *IJEE* contained 58% to 100% quantitative articles from the EER set of articles with research questions.

For our second step in the analysis of the methods for the 63 articles containing research questions, we examined the types of data collection methods employed. We acknowledge that data collection methods are dependent on research questions posed. However, by examining data collection methods, we generate insight into the homogeneity of research questions and methods. Each data type has limitations, which are magnified for homogenous methods. Table 7 details the frequency of articles by journal that used surveys, student performance data (e.g., test grades, assignment grades), interviews, pre/post tests, student attributes (e.g., high school GPA, standardized test scores, enrollment trends), expert evaluation, observations, focus groups, verbal protocol analysis of design thinking, interviews, and think aloud. The column labeled *Total* shows the number of articles that used the given method. We note that 18 of the articles used more than one data collection method. Data collection methods were predominately quantitative, which is consistent with our findings related to method type (Table 5). The most common data collection method, surveys, was utilized for both quantitative and qualitative data collection. In 20 articles, surveys were the only data collection method.

4.2 FYE Recommendations (RQ 2)

To understand the recommendations and findings of the articles and their impact on FYE, we initially focused on organizing articles based on the author stated purposes within the articles. Grouping articles by research purpose would allow us to synthesize findings into recommendations. If a purpose was given in the article abstract, that statement was used; however, many times a direct purpose statement was not available in the abstract. In the latter case, the two authors independently read the abstract and each crafted a purpose statement for the article. Then, one of the authors read both purpose statements and crafted a combined purpose. If the two independently created purposes were significantly different, the two authors discussed the abstracts to reach consensus on the purpose of the article based on the abstract alone. We chose to develop purpose statements from the abstracts because the abstract is the authors' own summary of their work. We believed focusing on the abstract would help us understand the primary ideas the FYE paper authors wanted readers to understand about their work.

Once each article had a purpose statement, the statements were open coded to develop larger categories. Our initial process included one researcher reviewing all statements and noting a major topic for each paper. These topics became the original codes. After multiple rounds of coding

Table 8. Article Categories and Purposes

Category	# Articles	Articles that cover topics related to . . .
Design	30	General design topics or projects and reverse engineering
Skills	29	Professional skills such as writing ability and technical communication in general, problem solving, creativity and innovation, and other technical skills
Pedagogy and Learning Theory	29	Specific theories such as the How People Learn framework, rubrics, or approaches to teaching such as problem-based learning
Instructor and Peer Interaction	18	Learning communities, teamwork, feedback, and mentoring
Societal and Global Issues	18	Community engagement efforts, service projects with other countries, and efforts to increase awareness of sustainability or similar concepts
Academic Performance	16	Grades, learning in general, and misconceptions
Other STEM Subjects	15	FYE students and math, physics, nanotechnology, etc.
Technology	15	Online learning, technology infused or enriched classrooms, and teaching a variety of programming languages and skills
Retention/Persistence/Diversity	12	Retention and persistence through undergraduate education, transitions from high school to college, and issues of diversity as they relate to retention and persistence
Motivation	8	Motivation theories (e.g., self-efficacy)

which including adding and collapsing codes to allow the major groupings to surface, 10 major code categories emerged (Table 8). All articles have been associated to zero, one, or two of the categories, where 15 of the 156 articles did not map to a major category, 92 mapped to one, and 49 mapped to two. Of the 15 articles that did not map, 10 were SoTL, four were EER-T, and one was EER-RQ, while none were EER-TRQ. Note that only the five EER articles are listed in Appendix A and B with "No Mapped Categories".

In order to identify FYE literature topic gaps and to understand how the purposes of the articles relate to the various journals, we created radial diagrams that map the categories. Fig. 2 contains a map for all the articles that received at least one category, and Fig. 3 contains maps of article categories by journal. The radial diagrams provide a quick overview of topic areas with significant versus limited literature. Also, in these diagrams an open, more circular shape conveys a balance across the various purpose. A more closed shape depicts a focus in select areas which may be attributed to the journals focus or audience. Based on these figures, the most common purposes across all articles relate to *Design, Skills*, and *Pedagogy* & *Learning Theories*. The least common purpose relates to *Motivation* with only eight articles mapping to the

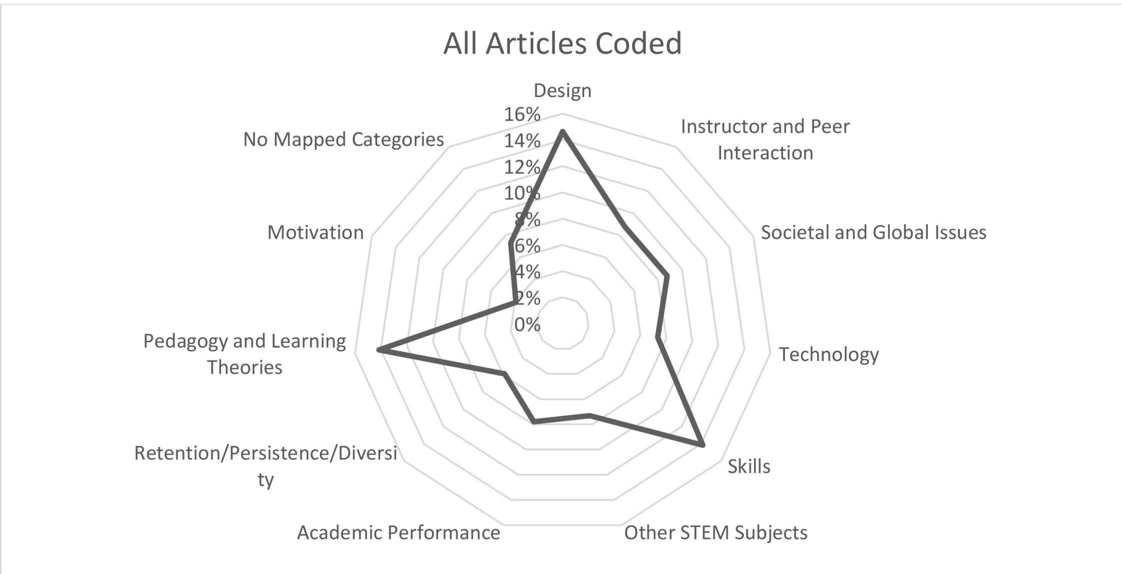

Fig. 2. Article Categories and Purposes across All Journals.

Fig. 3. Article Categories and Purposes Broken Down by Journal.

category. By journal, the most common purposes were: *JEE – Skills* (18%), *AEE – Pedagogy & Learning Theories* (36%), *IJEE – Design* (21%), and *EJEE – Skills* and *Pedagogy & Learning Theories* (each at 19%).

To identify recommendations from existing FYE literature, we extracted key conclusions from each of the research articles (EER-T, EER-RQ, and EER-TRQ). We organized the extracted conclusions using our ten categories. We examined these conclusions by category in order to synthesize the conclusions into recommendations. We excluded SoTL articles from our conclusion summary because more than 50% of the SoTL articles' purposes were to "describe" or "present" the details of a course, program, or activity. Those articles, and many other SoTL articles, did not contain conclusions beyond noting that the course, program, or activity was a success. We identified ten recommendations from existing FYE literature. Recommendations based on key conclusions from the research articles (EER-T, EER-RQ, and EER-TRQ) include:

4.2.1 Design should occur in the first year, and students should engage in design multiple times throughout their degree program. During students' first year, they often take courses outside of engineering. Open-ended design problems help students integrate knowledge from seemingly separate courses [66]. However, student attitudes towards design activities are durable and resistant to change over the course of a semester, which lessens the impact of a single semester of FYE design [67]. Incorporating design activities multiple times throughout a degree program is further supported by results indicating students become more innovative, confident, and competent in engineering design over the duration of their degree program [68], with seniors considering more factors during the problem-scoping phase of design [69]. Further, activities where students disassemble, analyze, and assemble may mitigate issues due to poor instruction [70].

4.2.2 Design can be used during the first year to teach practical and professional skills if integrated into the design problem as a fundamental aspect rather than appearing as an afterthought. Design experiences are credited with helping students learn to explore more creative solutions to problems [71], [72], improve time management [73], prepare for global engineering [74], and foster sustainability-related engineering skills [75]. An initial phase of product dissection can result in improved product functionality [72]. Project management incorporated into the overall design process can focus student attention on monitoring and managing how work is proceeding [73], a skill that will aid them well as practicing engineers.

4.2.3 Creative grading that provides timely feedback can improve student learning. Papers reported positive experiences when experimenting with student grading as feedback mechanisms for students. Examples include using zero weighted exercises combined with students interacting with tutors [34], providing meta-level feedback during problem solving activities [76], and employing structured pairing to promote learning between laboratory partners [77]. Beyond directly assisting students with their own learning, creative assessments can drive change to improve learning at an institutional level. In one example, a comprehensive, multiple choice mastery exam given to all FYE students was shown to be a mechanism for engaging faculty in science, mathematics, and engineering to focus on creating more formal linkages between classes [78]. Using creative grading as feedback for students and instructors produced positive results with regards to student learning.

4.2.4 Level of awareness of societal and global issues depends on individuals' prior experiences. There have been repeated calls for more globally minded engineers (e.g., [79–81]), and FYE studies have begun to explore these considerations. When integrating activities focused on societal and global issues into FYE courses, engineering educators must be mindful that environmental awareness and knowledge of sustainability practices are influenced by individual experiences and location [82]. Similarly, different levels of cultural awareness and appreciation exist and global educational experiences should be designed accordingly [83].

4.2.5 Technology can support FYE students during learning processes. Online tutorials [84], a virtual internship [25], and a game [85] all resulted in increased student learning and engagement with course material. However, engineering educators should be mindful that when designing student experiences utilizing technology, the experiences of student volunteers can differ significantly from the experiences of students in a required course [86]. In a world where technology is constantly changing, these studies show promise for the use of new technologies but also highlight potential challenges that must be considered.

4.2.6 Engineering educators have documented numerous positive results in implementing pedagogical changes or evidence-based practices. Research articles reviewed for our study that documented conceptual learning gains were observed when modeling and simulation activities were added to a mathematics course [87]. Integrating peers and friends as course mediators was effective support for students struggling in a spatial skills course [88]. Project-led education [27] and problem-based projects [84] have been successfully implemented to enhance FYE.

4.2.7 To improve FYE courses and programs, educators must consider students' full educational experience. Numerous studies in other STEM disciplines were conducted with FYE students as participants. FYE articles discussed research in mathematics education (e.g., [66, 87, 89, 90]), physics education (e.g., [91–93]), and interdisciplinary engineering (e.g., [94]). Learning processes for discipline-specific topics (e.g., nanotechnology [95]) were also investigated. We believe integrating findings from these studies with findings from studies examining learning in engineering contexts will maximize the impact on FYE student learning. Importantly, future FYE researchers should look beyond engineering education journals for literature published in discipline-specific and STEM journals.

4.2.8 Quantitative scores and metrics can predict engineering academic performance and career paths. From the perspective of predicting potential performance in an engineering degree program, predictors of success include quantitative skills (e.g., ACT Math scores) and confidence in quantitative skills [96], high school GPA in natural science and mathematics courses [97], data regarding the completion of advanced mathematics prior to entering an engineering program [35], and attendance at peer-led study sessions [26]. High school academic achievement and commitment to one's career and goals can predict retention to the second year [28]. Finally, expectancy-related constructs are better for predicting achievement but value-related constructs, are better at predicting career plans [64]. Prediction results have been used to establish admission criteria and promote behaviors associated with persistence.

4.2.9 FYE student motivation has been linked to academic success. Self-efficacy, expectancy, and value constructs have been investigated. Self-efficacy is by far the most prominent motivation construct investigated in FYE studies. Promisingly, many of the FYE results show positive gains in student self-efficacy. Examples include Hutchison, Follman, Sumpter, and Bodner's [98] study identifying factors that influenced students' self-efficacy beliefs, Hutchison-Green, Follian, and Bodner's [65] finding that self-efficacy for novices (e.g., FYE students) is significantly influenced by vicarious experiences, and Purzer's [99] work linking self-efficacy to academic achievement. Beyond self-efficacy theory, Jones, Osborne, Paretti, and Matusovich [100] validated the MUSIC Model of Academic Motivation with FYE students and concluded that it could be used in curricula design to foster academic outcomes and career goals. Jones' prior work recommended using both expectancy and value related motivational constructs as they predicted different outcomes [64], and both are incorporated into the MUSIC Model.

4.2.10 Interventions have mixed impact with regards to increasing FYE students' self-efficacy. A mathematics course for FYE was successful at increasing mathematics problem solving self-efficacy but not mathematics course self-efficacy [89]. In another study, supportive comments from team members did not impact students' self-efficacy [99]. However, FYE students were more receptive to advice from upperclassmen (i.e., experienced students) [101], which could be one potential way to increase self-efficacy or confidence. Another potential intervention could target improving self-efficacy before FYE students enrolled in a university. By developing K-12 technology and/or engineering teachers, students have an engineering experience prior to the first year [33].

5. Discussion

The analysis conducted through this systematic literature review provides a baseline understanding about the articles that have been published about FYE in engineering education-focused journals from 2005 through 2014. Our goal is to help researchers and practitioners understand past studies and their findings to highlight important take-aways and gaps. In sections 5.1–5.5, we highlight broad trends that emerged during our analysis of these FYE articles. In sections 5.6 and 5.7, we identify needs that should be addressed by future FYE investigations.

5.1 What is the General Landscape of FYE Literature? (RQ1)

Engineering education, like many discipline-specific education fields, grew out of practice. Accordingly, the highest number of articles in our analysis (53%) were practice-based articles while only 9.6% of the articles were categorized as EER-TRQ, meeting the more stringent definition of Engineering Education Research published by Streveler et al. [56]. When we first began this investigation, we anticipated that we would see an increase in the number of EER-TRQ articles over time due to the calls for including theories and research questions in engineering education research reporting. However, the article counts did not support this expected result, as shown in Fig. 1. It would be interesting to examine engineering education research literature outside of the FYE domain to identify whether there has been a reporting shift as the field continues to develop. It is also possible that such a shift is present in other publishing venues, including conference publications, which were outside our scope.

5.2 What Trends exist regarding Publishing Venues for Research and Practice in FYE Literature? (RQ1a)

We noted that all journals examined had a balance of practice-focused and research-focused FYE articles with *IJEE* having the most FYE articles in this study. When comparing *JEE* and *AEE*, it does appear that *JEE* is publishing more of the research-focused articles while *AEE* publishes more practice-focused articles. Similarly, *IJEE* and *EJEE* are publishing more practice-focused articles than *JEE* and *AEE*. By far, *JEE* has the fewest percentage of practice-focused FYE articles.

5.3 What Theoretical Frameworks have been used to Study FYE? (RA1b)

Only a small percentage (16.6%) of the articles in this review mentioned the use of a guiding theory or theoretical framework. The limited use of theory aligns with the findings of Brown, McCord, Matusovich, and Kajfez [38] who completed a systematic review of motivation articles in engineering education literature. Brown and his coauthors found that the articles they reviewed employed a limited number of theories. In our review of FYE papers, we identified a wider range of theories, but a majority of the theories were used in a single study with Self-Efficacy (six articles), Constructivism (four articles), and Piaget Learning Theory (two articles) used more than once. We encourage new researchers to examine articles that do incorporate a theory for examples of how to incorporate theory in their own work. Applying a variety of theoretical lenses to FYE research will help create a more complete understanding of FYE practices. Such expansion will allow FYE research to create a broader impact and withstand critical examination.

5.4 What Research Methods have been used to Study FYE? (RQ1c)

Engineering education researchers default to quantitative methods. We see that in these results based on the number of articles that are quantitative (see Table 6). The higher representation of quantitative work in the literature is consistent with past engineering education research (e.g., [102]). Through our work, we also determined that researchers using qualitative and mixed methods approaches explicitly state their approach while quantitative researchers do not (see Table 6). We suspect that this is due to the long-standing use of quantitative techniques in the field and in traditional engineering. While qualitative and mixed methods approaches are used, they are newer approaches when compared historically to quantitative work. We urge all researchers to clearly state their approaches in their articles. Doing so not only helps readers understanding the approach to the work, it also impacts the worldview or ontological perspective used for the study, which can inform the discussion and conclusions.

By further exploring the methods, we determined that surveys were the most popular data collection method. Sixty-three percent of the articles used some form of survey, with 33% of the articles using surveys exclusively: nine in *JEE*, nine in *IJEE*, and three in *EJEE*. Surveys were used in eight qualitative studies, 19 quantitative studies, and seven mixed-methods studies. Some of the survey-only articles used a previously validated survey instrument (e.g., [100]), while many other articles contained no discussion of survey validation.

Further, we rarely observed discussion related to the limitations of surveys. While surveys are an appropriate data collection method in many instances, it is important for researchers conducting survey-only studies to consider the limitations of using surveys. For example, surveys administered at the end of the semester may allow too much time to pass between behavior and measurement, which will result in substantial measurement error [103]. In addition, when surveys address topics considered less desirable, respondents may underreport those behaviors as respondents may perceive a threat and may be less likely to report participation in that activity [104, 105]. With the popularity of surveys for data collection, it is important that researchers conducting studies and researchers relying on conclusions from survey-only studies consider the reliability, validity, and trustworthiness of the data driving study conclusions.

5.5 What FYE Practices are Recommended or Supported by the Literature? (RQ2)

The literature supports that FYE education is one place that engineering educators can readily and consistently incorporate activities to improve student outcomes. We reviewed numerous articles that described or presented details of programmatic enhancements. First-year engineering literature is ripe with examples of successful research-informed practices and new curricula adoptions. We reviewed numerous articles that supported incorporating design within FYE. There are also recommendations for how to leverage design education to teach both practical and professional skills by integrating the topics as fundamental elements. However, many reports of beneficial activities were not FYE-specific. For example, using tutors, additional feedback, structured partnerships, and other creative grading to support student learning could be employed in all years of an engineering program. Similarly, beneficial technology such as online tutorials, virtual internships, and games could be useful in upper-level courses. While the literature contains numerous success stories, it often seems as if FYE courses or students were studied out of convenience rather than for purposes unique to FYE students or with specific concern for FYE practices.

We did not find research examining the impact of FYE structure, timing, and content on engineer formation. Numerous studies documented individual programs, courses, or projects within FYE. Many of those studies were geared towards innovations in teaching or focused on the results of a single program. While studies driving instructional improvement are valuable and essential to the engineering education community, they do not provide a research-based understanding of FYE across a variety of contexts. For administrators and educators who are designing and improving FYE education, the literature currently provides insight about *what* exists. We know the details of various design projects integrated into FYE courses. We know that some FYE courses leverage community-focused assignments or service-learning projects. We know that some FYE programs are structured as common or general engineering while some are structured as discipline-specific. We know that some FYE programs are a single-semester while some are multiple semesters, and some students complete FYE courses in their freshman year, while some take them in their junior year. We know that some courses focus on advising and student success topics while some focus on engineering technical knowledge. The list goes on. We did not find research comparing elements of FYE education and their impact on student development. We did not find replication studies verifying research findings for different FYE programs, institutional cultures, geographic locations, or student populations. For faculty and administrators designing new FYE programs and courses, the literature does not answer questions concerning how details of FYE program design, including matriculation structure, course timing, and course focal topics impact engineering student formation.

5.6 Need for Theoretical Framing and Attention to Study Design

We recognize the importance of practice-focused SoTL studies but simultaneously recognize the need for research studies to build general knowledge for FYE. Overall, the research papers reviewed were undertheorized: majority of the papers had no mention of a theory. EER-RQ papers comprised 63% of the EER papers. Many papers in the EER-T or EER-TRQ categories mentioned a theory in one section, such as the lit review, but did not use that theory to inform the data collection, methods, or analysis. We were very liberal in our definition of "theory" and still observed its minimal use. This finding is not surprising as there have been many articles that encourage the greater use and need for additional understanding of theory in the field. To further enhance FYE research and draw connections between engineering education and other social sciences, researchers should pay more attention to their use of theory for informing their study and reporting results in this space as well. As stated by Streveler and Smith [106], "In order to increase significance and generalizability of engineering education research, the work must be tied to the appropriate educational, psychological, or sociological theory" (p. 104). This holds true for all of engineering education research, including FYE.

Research studies need to have a central research question that is informed by theory and drives the study design so that results are produced and interpreted based on the theory that is employed. Only 10% (15) of the articles met the EER-TRQ definition. Papers that fit in other categories are important, and it is not our intention to discredit the need and importance for innovative practice papers about FYE. While it is encouraging to read practice-based articles and revel in the successes of courses and programs, transferable and generalizable research is needed to help readers implement successes at their own institutions. Engineering educators engaged in the SoTL could consider action research as an inquiry method to pair innovative practice with research techniques. Although there has been significant work in the FYE context, using formal research methods will aid with generalization and transferability of results to other institutional contexts.

5.7 Need for Holistic FYE Research to inform FYE change

Engineering education as a research field is continuing to grow and evolve. As engineering education changes, so does FYE education. Past studies related to FYE have laid a foundation for growth, but we believe that there are many questions to be answered in this domain to ensure that engineers are being prepared for successful educational and career experiences. Whether engineering administrators or educators are modifying existing or creating new FYE courses, programs, and experiences, they are making decisions with regards to FYE education. With regards to matriculation, future researchers could investigate questions such as, "What are the benefits of a direct matriculation FYE program versus a program where engineering degree choice occurs following a year-long general engineering program?" and "Is there impact on technical or professional skill development, motivation to pursue an engineering degree, or diversity by delaying engineering discipline decisions?" With regards to timing, unanswered questions include, "Should transfer students take the same FYE course as entering freshmen, have their own FYE course, or be exempt from FYE courses?" or "How do FYE courses help transfer students integrate into the institution's engineering culture?" Finally, with regards to course focal topics, future research could address, "What are the long-term impacts on engineering students who enroll in a FYE course more focused on student success and advising versus a course more focused on engineering technical knowledge?" We acknowledge FYE education is often dependent on the history, design, and political structure of the host institution. However, it remains important to examine how elements of FYE education that educators and administrators can control either support or fail to support engineering students' formation as engineers. There is a need for studies examining how FYE changes impact student's engineering development, community, influence attrition and retention, and effect engineering skill development.

6. Conclusions

The purpose of this systematic literature review is to describe the state of knowledge of FYE research so that those teaching in this domain have a synthesized understanding of what information is available and to provide direction for future research studies. We reviewed 156 articles focused on FYE that were published in either *AEE*, *EJEE*, *IJEE*, or *JEE.* We identified both innovative practice-focused and research-focused articles. We noted that majority of the reviewed articles described or presented details of specific programmatic enhancements (e.g., a single course activity). Many articles lacked theoretical framing that is needed to promote generalizability or transferability of results beyond a single course, an institution, or a set of students. We found limited research to inform the holistic design of FYE programs with regards to matriculation, program timing, and course focal topics. Based on our analysis, FYE has been studied extensively; however, additional research into FYE is needed to inform change as the field continues to grow. Going forward, future researchers should consider theoretical framing, study design, and holistic FYE research to inform change.

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Appendix A

EER-T Papers – ordered by Journal, Year, Author Last Name

Journal	Authors (Year). Title	Research Question or Theory	Methods Used	Categories
AEE	Chesler, Arastoopour, D'Angelo, Bagley, and Shaffer (2012). Design of a professional practice simulator for educating and motivating first-year engineering students	TY (Epistemic Frame Theory)	–	Technology
EJEE	Potter, Van Der Merwe, Kaufman, and Delacour (2006). A longitudinal evaluative study of student difficulties with engineering graphics	TY (Piaget Learning Theory)	–	Skills, Pedagogy and Learning Theories
EJEE	Ingerman, Berge, and Booth (2009). Physics group work in a phenomenographic perspective – learning dynamics as the experience of variation and relevance	TY (Variation Theory of Learning)	–	Instructor and Peer Interaction, Other STEM Subjects
EJEE	Grigg and Benson (2014). A coding scheme for analysing problem-solving processes of first-year engineering students	TY (Triarchic Theory of Human Intelligence)	–	Skills
EJEE	Missingham and Matthews (2014). A democratic and student-centered approach to facilitating teamwork learning among first-year engineering students: A learning and teaching case study	TY (Social-Cultural Constructivist Theory (Vygotsky))	–	Pedagogy and Learning Theories
IJEE	Ogot and Okudan (2007). A student-centered approach to improving course quality using quality function deployment	TY (Kano Model of Quality (QFD))	–	No Mapped Codes
IJEE	Al-Arfaj (2011). Scientific reasoning abilities of undergraduate science and engineering students at King Faisal University	TY (Piaget; Bloom's)	–	Skills
IJEE	Hadley (2014). Teaching teamwork skills through alignment of features within a commercial board game	TY (Theory of Transformational Play)	–	Instructor and Peer Interaction, Technology
IJEE	Mugisha, Doungmo Goufo, and Mogari (2014). Analysis of the performance of first year students in calculus	TY (Constructivism)	–	Instructor and Peer Interaction, Other STEM Subjects
IJEE	Quintana, Saez, and Fernandez (2014). Use of PLE-Portfolio to assess the competency-based learning through web 2.0 in technical engineering education	TY (Socio-Constructivism, Theory of Learning for Discovery, Significant Learning, Connectivism, and Pedagogies of the Co-Association)	–	Academic Performance

Note: NS is "Not Stated"; "–" is noted for Methods Used since methods were not explored for EER-T (theory only) articles.

Appendix B

EER-RQ Papers – ordered by Journal, Year, Author Last Name

Journal	Authors (Year). Title	Research Question or Theory	Methods Used	Categories
EJEE	Concetta-Capizzo, Nuzzo, and Zarcone (2006). The impact of the pre-instructional cognitive profile on learning gain and final exam of physics courses: A case study	RQ	Quant	Other STEM Subjects, Academic Performance
EJEE	Garmendia, Guisasola, and Sierra (2007). First-year engineering students' difficulties in visualization and drawing tasks	RQ	Qual	Skills
EJEE	Garmendia, Guisasola, Barragués, and Zuza (2008). Estimate of students' workload and the impact of the evaluation system on students' dedication to studying a subject in first-year engineering courses	RQ	Mixed	Academic Performance
EJEE	Sahin (2010). The impact of problem-based learning on engineering students' beliefs about physics and conceptual understanding of energy and momentum	RQ	NS (Quant)	Other STEM Subjects, Pedagogy and Learning Theories
EJEE	Alpay, Cutler, Eisenbach, and Field (2010). Changing the marks-based culture of learning through peer-assisted tutorials	RQ	Mixed	Instructor and Peer Interaction,
EJEE	van Hattum-Janssen, and Mesquita (2011). Teacher perception of professional skills in a project-led engineering semester	RQ	Qual	Other STEM Subjects
EJEE	Cole and Spence (2012). Using continuous assessment to promote student engagement in a large class	RQ	Both	No Mapped Codes
EJEE	Alpay (2013). Student attraction to engineering through flexibility and breadth in the curriculum	RQ	NS (Quant)	No Mapped Codes
EJEE	Fernandes, Mesquita, Flores, and Lima (2014). Engaging students in learning: Findings from a study of project-led education	RQ	Qual	Pedagogy and Learning Theories
IJEE	Wallin, Carlsson, Ross, and El Gaidi (2005). Learning MATLAB: Evaluation of methods and materials for first-year engineering students	RQ	NS (Quant)	Technology
IJEE	Walker, Cordray, King, and Brophy (2006). Design scenarios as an assessment of adaptive expertise	RQ	NS (Quant)	Design
IJEE	Zastavker, Crisman, Jeunnette, and Tilley (2006). 'Kinetic sculptures': A centerpiece project integrated with mathematics and physics	RQ	Both	Design, Other STEM Subjects
IJEE	Bernold (2007). Early warning system to identify poor time management habits	RQ	NS (Quant)	Skills
IJEE	Atman, Yasuhara, Adams, Barker, Turns, and Rhone (2008). Breadth in problem scoping: A comparison of freshman and senior engineering students	RQ	Quant	Design
IJEE	Cardella, Atman, Turns, and Adams (2008). Students with differing design processes as freshmen: Case studies on change	RQ	Both	Design
IJEE	Allen, Crosky, McAlphine, Hoffman, and Munroe (2009). A blended approach to collaborative learning: Making large group teaching more student-centred	RQ	NS (Quant)	Technology, Pedagogy and Learning Theories
IJEE	Strobel, Hua, Fang, and Harris (2010). Not all constraints are equal: Stewardship and boundaries of sustainability as viewed by first-year engineering students	RQ	Qual	No Mapped Codes
IJEE	Cardella, Hoffmann, Ohland, and Pawley (2010). Sustaining sustainable design through 'normalized sustainability' in a first-year engineering course	RQ	NS (Quant)	Design, Societal and Global Issues
IJEE	Malik, Koehler, Mishra, Buch, Shanblatt, and Pierce (2010). Understanding student attitudes in a freshman design sequence	RQ	Quant	Design
IJEE	Moore and Hjalmarson (2010). Developing measures of roughness: Problem solving as a method to document student thinking in engineering	RQ	Both	Other STEM Subjects
IJEE	De Winter and Dodou (2011). Predicting academic performance in engineering using high school exam scores	RQ	NS (Quant)	Academic Performance, Retention/Persistence/Diversity
IJEE	Ciufo (2011). Analysis of first-year student performance in an engineering program	RQ	NS (Quant)	Academic Performance, Retention/Persistence/Diversity
IJEE	Jesiek, Shen, and Haller (2012). Cross-cultural competence: A comparative assessment of engineering students	RQ	NS (Quant)	Societal and Global Issues

IJEE	Daly, Christian, Yilmaz, Seifert, and Gonzalez (2012). Assessing design heuristics for idea generation in an introductory engineering course	RQ	NS (Quant)	Design
IJEE	Tolbert and Daly (2013). First-year engineering student perceptions of creative opportunities in design	RQ	Both	Skills
IJEE	Loui, Robbins, Johnson, and Venkatesan (2013). Assessment of peer-led team learning in an engineering course for freshmen	RQ	Both	Skills, Retention/Persistence/ Diversity
IJEE	Shelby, Ansari, Patten, Pruitt, Walker, and Wang (2013). Implementation of leadership and service learning in a first-year engineering course enhances professional skills	RQ	Qual	Societal and Global Issues, Skills
IJEE	Haase, Chen, Sheppard, Kolmos, and Mejlgaard (2013). What does it take to become a good engineer? Identifying cross-national engineering student profiles according to perceived importance of skills	RQ	NS (Quant)	Skills
IJEE	Maeda, Yoon, Kim-Kang, and Imbrie (2013). Psychometric properties of the revised PSVT:R for measuring first year engineering students' spatial ability	RQ	NS (Quant)	Skills
IJEE	Fila and Loui (2014). Structured pairing in a first-year-electrical and computer engineering laboratory: The effects on student retention, attitudes, and teamwork	RQ	Mixed	Instructor and Peer Interaction
JEE	Shiavi and Brodersen (2005). Study of instructional modes for introductory computing	RQ	Quant	Technology, Pedagogy and Learning Theories
JEE	Rayne, Martin, Brophy, Kemp, Hard, and Diller (2006). The development of adaptive expertise in biomedical engineering ethics	RQ	NS (Quant)	Retention/Persistence/Diversity, Pedagogy and Learning Theories
JEE	Reisslein, Sullivan, and Reisslein (2007). Learner achievement and attitudes under different paces of transitioning to independent problem solving	RQ	NS (Quant)	Skills, Academic Performance
JEE	Kilgore, Atman, Yashara, Barker, and Morozov (2007). Considering context: A study of first-year engineering students	RQ	Mixed	Design
JEE	Atman, Adams, Cerdella, Turns, Mosborg, and Saleem (2007). Engineering design processes: A comparison of students and expert practitioners	RQ	Quant	Skills
JEE	Qualters, Sheahan, Mason, Navick, and Dixon (2008). Improving learning in first-year engineering courses through interdisciplinary collaborative assessment	RQ	Quant	Instructor and Peer Interaction, Pedagogy and Learning Theories
JEE	Veenstra, Dey, and Herrin (2008). Is modeling of freshman engineering success different from modeling of non-engineering success?	RQ	NS (Quant)	Academic Performance, Retention/Persistence/Diversity
JEE	Charyton and Merrill (2009). Assessing general creativity and creative engineering design in first year engineering students	RQ	NS (Quant)	Skills
JEE	Moreno, Reisslein, and Ozogul (2009). Optimizing worked-example instruction in electrical engineering: The role of fading and feedback during problem-solving practice	RQ	NS (Quant)	Instructor and Peer Interaction, Academic Performance
JEE	Verleger, Diefes-Dux, Ohland, Besterfield-Sacre, and Brophy (2010). Challenges to informed peer review matching algorithms	RQ	Quant	Instructor and Peer Interaction
JEE	Heller, Beil, Dam, and Haerum (2010). Student and faculty perceptions of engagement in engineering	RQ	NS (Qual)	No Mapped Codes
JEE	Meyers, Silliamn, Gedde, and Ohland (2010). A comparison of engineering students' reflections on their first-year experiences	RQ	NS (Quant)	Instructor and Peer Interaction
JEE	Dalrymple, Sears, and Evangelou (2011). The motivational and transfer potential of disassemble/analyze/assemble activities	RQ	NS (Quant)	Design
JEE	Taraban (2011). Information fluency growth through engineering curricula: Analysis of students' text-processing skills and beliefs	RQ	Quant	Skills
JEE	Genco, Holtta-Otto, and Conner (2012). An experimental investigation of the innovation capabilities of undergraduate engineering students	RQ	NS (Quant)	Skills
JEE	Diefes-Dux, Hjalmarson, and Zawojeski (2013). Student team solutions to an open-ended mathematical modeling problem: Gaining insights for educational improvement	RQ	NS (Qual)	Pedagogy and Learning Theories
JEE	Weber, Strobel, Dyehouse, Harris, David, Fang, and Hua (2014). First-year students' environmental awareness and understanding of environmental sustainability through a life cycle assessment module	RQ	Mixed	Societal and Global Issues

JEE	Doerr, Arleback, and Staniec (2014). Design and effectiveness of modeling-based mathematics in a summer bridge program	RQ	Both	Other STEM Subjects, Pedagogy and Learning Theories

Note: NS is "Not Stated" followed by the methods designation assigned in parentheses.

Appendix C

EER Papers – ordered by Journal, Year, Author Last Name

Journal	Authors (Year). Title	Research Question or Theory	Methods Used	Categories
AEE	Veenstra, Dey, and Herrin (2009). A model for freshman engineering retention	RQ & TY (Tinto Interactionalist Theory)	NS (Quant)	Retention/Persistence/ Diversity
AEE	Grantham, Kremer, Simpson, and Ashour (2013). A study on situated cognition: Product dissection's effect on redesign activities	RQ & TY (Situated Cognitive Theory)	Quant	Design, Pedagogy and Learning Theories
EJEE	Kolari, Savander-Ranne, and Viskari (2008). Learning needs time and effort: A time-use study of engineering students	RQ & TY (Constructivism, Information Processing Theory)	NS (Quant)	Skills
IJEE	Luechtefeld, Baca, and Watkins (2008). Training for self-managed student teams	RQ & TY (Hackman Model of Effective Teams)	NS (Quant)	Instructor and Peer Interaction
IJEE	Gerber, McKenna, Hirsch, and Yarnoff (2010). Learning to waste and wasting to learn? How to use cradle to cradle principles to improve the teaching of design	RQ & TY (Kolb's Model for Experiential Learning)	Qual	Design
IJEE	Brown and Burnham (2012). Engineering student's mathematics self-efficacy development in a freshmen engineering mathematics course	RQ & TY (Self-efficacy)	Mixed	Other STEM Subjects, Motivation
IJEE	Lawanto, Butler, Cartier, Santoso, and Goodridge (2013). Task interpretation, cognitive, and metacognitive strategies of higher and lower performers in an engineering design project: An exploratory study of college freshmen	RQ & TY (Metacognition; Self-regulated Learning)	Qual	Design
IJEE	Jones, Osborne, Paretti, and Matusovich (2014). Relationships among students' perceptions of a first-year engineering design course and their engineering identification, motivational beliefs, course effort, and academic outcomes	RQ & TY (MUSIC Model of Academic Motivation)	NS (Quant)	Motivation
JEE	Hutchison, Follman, Sumpter, and Bodner (2006). Factors influencing the self-efficacy beliefs of first-year engineering students	RQ & TY (Self-efficacy)	Qual	Motivation
JEE	Hutchison-Green, Follian, and Bodner (2008). Providing a voice: Qualitative investigation of the impact of a first-year engineering experience on students' efficacy beliefs	RQ & TY (Self-efficacy)	Qual	Motivation
JEE	Jones, Paretti, Hein, and Knott (2010). An analysis of motivation constructs with first-year engineering students: Relationship among expectancies, values, achievement, and career plans	RQ & TY (Self-efficacy, Expectancy Value, Identification with Academics)	NS (Quant)	Retention/Persistence/ Diversity, Motivation
JEE	Fantz, Siller, and DeMiranda (2011). Pre-collegiate factors influencing the self-efficacy of engineering students	RQ & TY (Self-efficacy)	NS (Quant)	Motivation
JEE	Purzer (2011). The relationship between team discourse, self-efficacy, and individual achievement: A sequential mixed-methods study	RQ & TY (Social Cognitive (Self-efficacy) and Social Constructivist)	Mixed	Instructor and Peer Interaction, Motivation
JEE	Weber, Dyehouse, Miller, Fang, Hua, and Strobel (2013). Impact of household location on first-year engineering students' environmental awareness and resistance to change	RQ & TY (Ecological Theory)	Quant	Societal and Global Issues
JEE	Wertz, Purzer, Fosmire, and Cardella (2013). Assessing information literacy skills demonstrated in an engineering design task	RQ & TY (ISP and Information Literacy Model)	Mixed	Skills

Note: NS is "Not Stated" followed by the methods designation assigned in parentheses