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SURVEY

A Systematic Literature Review of Entrepreneurial Education in Electrical, Electronic, and Computer Engineering Curricula

JONATHAN W. BROWNING, (Member, IEEE), AND JOHN BUSTARD
School of Electronics, Electrical Engineering and Computer Science, Queen's University Belfast, BT9 5BN Belfast, U.K.
Corresponding author: Jonathan W. Browning (j.browning@qub.ac.uk)

ABSTRACT This study contributes to entrepreneurship education within electrical, electronic and computer (EEC) engineering curricula by providing a comprehensive overview of the teaching methodologies and assessment designs currently employed by educators. We explore the challenges faced by both EEC engineering educators and students in entrepreneurship education. This study is motivated by the need to understand the landscape of entrepreneurship education within EEC engineering curricula. This will benefit those who are starting an entrepreneurship course or reflecting on their course design and delivery. The following research questions are examined in this study: Is the need for entrepreneurship education in EEC engineering curricula based on development of soft skills and/or economic need?; What teaching methods are used within entrepreneurship teaching for EEC engineering students?; How are the students assessed within EEC engineering entrepreneurship education? Does EEC engineering entrepreneurship education vary based on country?; What challenges do students encounter participating in EEC engineering entrepreneurship?; What challenges do educators encounter in delivering EEC engineering entrepreneurship?; This study adopted a systematic literature review approach. The findings revealed that project-based learning is the most popular method of curriculum delivery along with lectures, while, a business plan, pitch, and prototype product are common components in assessment. The study also highlighted the United States of America as being well established in this field compared to other countries. The administrative challenge to educators was discussed but there are new opportunities, such as experiential based learning, which has started to be adopted.

INDEX TERMS Engineering education, entrepreneurship, higher education, student experience, systematic literature review.

I. INTRODUCTION

Within the rapidly evolving sphere of electrical, electronic and computer (EEC) engineering higher education, the integration of entrepreneurship within the curricula has garnered considerable interest [1]. This focus is not just a trend but a response to the growing demand for engineers to exhibit essential soft skills, such as creativity, problem-solving, and communication [2]. The incorporation of entrepreneurship education in EEC engineering curricula clearly aligns to promotion of these skills among students [3]. Specifically, it can foster behavioral competencies, such as opportunity recognition and attitudinal competencies, including resilience and self-efficacy [4], [5]. As educators consider integrating entrepreneurship courses into EEC engineering curricula, understanding the underlying motivations and the unique competencies associated with entrepreneurial success becomes imperative. Designing such courses, however, presents its challenges, especially when determining the optimal delivery method and assessment design.

The existing literature on entrepreneurship education within engineering curricula has predominantly examined specific facets, such as gender [6] or discipline-specific courses [7]. However, these studies often focus on isolated

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aspects, leading to an incomplete understanding of the broader landscape. The primary objectives of this study are the following: Firstly, to provide a comprehensive overview of entrepreneurship education within EEC engineering curricula, thereby filling an existing knowledge gap. Secondly, to serve as a reflective tool for educators, aiding them in refining their approach to entrepreneurship courses within those specific engineering programs. Thirdly, to explore the opportunities and challenges in entrepreneurship education within EEC engineering curricula. This includes examining the role of experiential learning, industry partnerships, online learning platforms, and artificial intelligence. Lastly, pinpoint areas that require additional research, setting the stage for subsequent studies in the field. By addressing these objectives, this study enhances the understanding of entrepreneurship education in EEC engineering and guide future research directions.

This study employs a systematic literature review (SLR) methodology, analyzing relevant publications from two major databases. The selection of publications was based on predefined inclusion and exclusion criteria, ensuring a comprehensive and objective analysis. The quality of the selected papers was assessed based on their scientific rigor and methodological soundness. This is discussed in an analysis before the research questions are investigated.

The remainder of the paper is organized as follows: In Section II, we briefly summarize previous studies. The methodology adopted in this work, including research questions, is described in detail in the following section. Section IV describes the application of the methodology, along with quality assessment results and the protocol limitations. The results for each of the five key research areas are presented in Section V. In Sections VI and VII, the opportunities, and possible avenues for future work are presented, respectively. Lastly, Section VIII outlines our concluding remarks.

II. RELATED WORK

In the broader domain of engineering entrepreneurship education, significant research has been conducted. A literature review leveraging the Webibliomining model aggregated key references in this area [8]. However, its utility is limited due to its outdated nature and lack of specificity to targeted research questions. Contrasting this, a study focused on the gender aspect in entrepreneurship education [6] aimed to enhance female participation but did not consider factors such as course locations or global curriculum differences.

In [9], a new taxonomy for categorizing entrepreneurship education in engineering, based on authenticity and derived from empirical research across Nordic universities, was proposed. This taxonomy, however, might face limitations in its broader applicability, considering its sample size and generalization across engineering disciplines. The work in [7] particularly targeted entrepreneurship education within software engineering, revealing a lack of consensus on the educational tools and methodologies. The narrower scope of this study, compared to the broader inclusion of electrical and electronic engineering as in this SLR, may explain the absence of consensus. Nonetheless, the study highlighted challenges in providing real-world experiences and suggested local ecosystem engagement as a solution.

In [10] the author addressed the inadequacies of traditional computer engineering curricula by proposing an integrated approach that combines content-based and problem-based learning. This approach aims to develop both technical and soft skills necessary for contemporary engineering challenges. Although not specifically focused on entrepreneurship, the lessons learned from the work can clearly be applied to entrepreneurship education. In mining engineering, a shift towards more dynamic, interdisciplinary methods in entrepreneurship education was advocated, focusing on experiential learning methods like the conceive-design-implement-operate framework [11]. Though a novel framework was created, it could be viewed as a variation of project-based learning (PBL). Similarly, [12] emphasized the need for a fundamental transformation in engineering education, aligning with the Fourth Industrial Revolution's demands, particularly in interdisciplinary learning and creative, critical thinking.

Further exploration of entrepreneurship in civil engineering programs, was conducted in [13]. This study emphasized the development of entrepreneurial skills, including lateral thinking and understanding of the entrepreneurial cycle. Additionally, [14] advocated for a holistic approach to curriculum development in computer engineering, utilizing the Y-chart methodology to integrate foundational knowledge with practical application. Yet, there is no clear evidence of the effectiveness of the adopted methodology presented.

The current state and evolution of entrepreneurship education within engineering programs were comprehensively reviewed in [1], highlighting historical developments and current challenges. This was complemented by [15], which reviewed the assessment of entrepreneurship education, advocating for the development of theory-based assessment tools tailored to engineering-specific entrepreneurship outcomes. Finally, [16] discussed the challenges in technological entrepreneurship education, underscoring the necessity for a unified definition of entrepreneurship and a versatile educational approach.

These related works summarize the dynamic nature of entrepreneurship education in engineering, without typically looking at the specifics of EEC engineering. They highlight the imperative for practical learning experiences, and continual curriculum adaptation. Additionally, they emphasize the importance of ongoing assessment and refinement of educational strategies to ensure their effectiveness and relevance in preparing engineering students for future challenges.

III. METHODOLOGY

The research protocol adopted in this review follows the guidelines for a general SLR as proposed by Kitchenham

TABLE 1. The KAs and associated RQs.

Key area	Research question	
KA1	RQ1a	Does the paper highlight the need for entrepreneurship education in EEC engineering curriculum based on development of soft skills?
	RQ1b	Does the paper highlight the need for entrepreneurship education in EEC engineering curriculum based on economic need?
KA2	RQ2	What teaching methods are used within entrepreneurship teaching for EEC engineering students?
KA3	RQ3	How are the students assessed within EEC engineering entrepreneurship education?
KA4	RQ4	Does EEC engineering entrepreneurship education vary based on country?
KA5	RQ5a	What challenges do students encounter participating in EEC engineering entrepreneurship?
	RQ5b	What challenges do educators encounter in delivering EEC engineering entrepreneurship?

and Charters [17]. The SLR guidelines by Kitchenham and Charter, was chosen because it has been highly adopted [18], [19], and is applicable to computer engineering, and more broadly electrical and electronic engineering, within which this SLR is also concerned. A quality assessment has been conducted similar to [18], which followed the guidelines in [17], along with a brief meta-analysis.

A. RESEARCH QUESTIONS

To structure the RQs for a high-quality analysis of results, a set of seven RQs was divided into five categories, as show in Table 1. The key areas (KAs) and related RQs were created based on a review of EEC engineering entrepreneurship literature. The KAs are as follows:

1) motivation for entrepreneurship within EEC engineering curricula;
2) EEC engineering entrepreneurship course design and delivery;
3) assessment methods within EEC engineering entrepreneurship courses;
4) variation of EEC engineering entrepreneurship across the globe;
5) challenges facing students and educators within EEC engineering entrepreneurship education;

Accordingly, the KAs of the RQs relate as following: 1) KA1 - motivation (RQ1a and RQ1b); 2) KA2 - curriculum design and delivery (RQ2); 3) KA3 - assessment methods (RQ3); 4) KA4 - variation by country; 5) KA5 - challenges for students and educators (RQ5a, and RQ5b).

B. SEARCH PROCEDURE

It was essential to create a database query that would be comprehensive to include all relevant papers. Therefore, all synonyms and related terms of interest to the KAs were clearly defined as shown in Table 2. The first column in Table 2 gives variants of the terms related to engineering. The terms in the second column refer to entrepreneurship. The third column contains terms that relate to education.

TABLE 2. Database search terms.

Term 1	Term 2	Term 3
Engineering*	Entrepreneur*	Education*
	Innovation	Curricul*
	Startup	Program*
		Graduate*
		Student*

TABLE 3. Inclusion and exclusion criteria.

	Round 1 (title)	Round 2 (duplicates)	Round 3 (abstract)	Round 4 (article)
Inclusion criteria	Indicates that the paper talks about engineering entrepreneurship education.	-	Indicates it does address the research questions.	-
Exclusion criteria	Indicates that the paper does not talk about engineering entrepreneurship education.	Duplicates excluded.	Indicates it does not address the research questions.	Not written in English.
			Not available.	Incomplete.
			Not a research article.	Not related to electrical, electronic or computer engineering.
			Work in progress.	
			It is a survey, SLR or meta-analysis.	

The queries were searched for in all metadata within each database.

There were two databases chosen to have the search query applied to, which are the following: Institute of Electrical and Electronics Engineers (IEEE) Xplore Digital Library [20], hereby known as IEEE Xplore, and the Association for Computing Machinery (ACM) Digital Library [21], hereby known as ACM. These databases were chosen because they are most relevant to the area of research (i.e., EEC engineering) and are full-text databases.

C. SELECTION CRITERIA AND PROCEDURE

Considering how much is published in this research area in both of the chosen databases, the first 1000 relevant publications in each were considered. Any prior For primary studies selected for further analysis, inclusion and exclusion criteria were defined for four rounds, as shown in Table 3.

The first round considers the title of the publications. The second round removes any duplicate results. The third round applies the criteria to the abstract and the last round removes articles not written in the English language or are incomplete. One researcher carried out the selection process for each publication. As noted in Kitchenham and Charters' guidelines [17], the results of inclusion and exclusion was discussed with another researcher to ensure consistency of inclusion/exclusion decisions.

D. QUALITY ASSESSMENT

The quality of the selected papers was assessed based on criteria adopted from Kitchenham and Charters' guidelines [17], focusing on the methods utilized and their scientific rigor. For primary sources based on field studies (qualitative and quantitative approaches), the criteria were:

1) How well was the data collection carried out?
2) How well was the approach to, and formulation of, the analysis conveyed?
3) How well were the contexts and data sources retained and portrayed?
4) How clear and coherent were the links between data, interpretation, and conclusions?

For primary sources that were theoretical based, the criteria were:

1) How well did the analysis address its original aims and objectives?
2) How has knowledge or understanding been extended by the research?
3) How well was diversity of perspective and context explored?

The assessment was performed by one researcher, and each paper was scored on the scale (for each criterion):

- 1 - very poorly;
- 2 - poorly;
- 3 - reasonably;
- 4 - well;
- 5 - very well.

The scores for each question were averaged to give the final score for each paper. The results of this was discussed with another researcher to ensure objectivity.

E. DATA COLLECTION AND ANALYSIS

The following data was extracted from each study and recorded in a spreadsheet:

- Database name;
- Title, keywords, authors, publication name, type (journal article or conference proceedings), publication year, abstract, and digital object identifier (DOI);
- Scientific method (qualitative and/or quantitative approach, or theoretical);
- Summary of the study;
- Answer to each research question;
- Quality assessment (QA) score;

One researcher extracted the data and then discussed it with another researcher to ensure consistency and agreement [17].

IV. METHOD APPLICATION

A. SEARCH AND SELECTION RESULTS

An initial search of the databases was made on May 23, 2023. This yielded 42,616 and 75,945 results respectively, from IEEE Xplore and ACM. Due to the volume of publications available, an additional constraint was set for the search that the first 1000 relevant results should be included in the analysis, regardless the year of publication. The inclusion and exclusion rounds followed, with overview details provided in Sankey diagram shown in Fig. 1. For clarification to the reader, 1,294 publications were excluded in round 1, and 2 publications were excluded in round 2. In round 3 of the inclusion and exclusion process there was the following exclusions: 535 publications were not relevant; 13 publications had no abstract; 23 publications were not a research article; 35 publications were work in progress; and 4 publications were a survey, SLR or meta-analysis. In round 4, 2 publications were excluded for having incomplete articles, 2 were excluded for not being written in English, and 5 were excluded for not relating to electrical, electronic or computer engineering. The final total at the end of the inclusion/exclusion process was thus 84 primary sources (research articles).

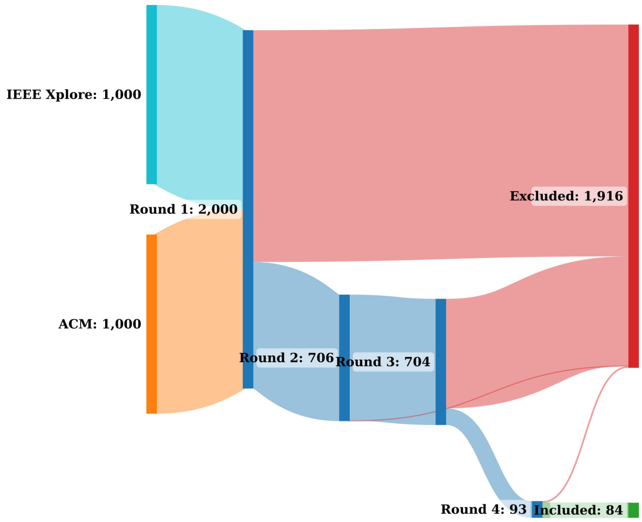

FIGURE 1. Sankey diagram of inclusion and exclusion process.

To understand the trend of publication within this area a count plot of the number of publications per year is shown in Fig. 2. From the figure it is evident that the number of publications has steadily increased since 2010. It should be noted that the number of publications appears lower for the year 2023 but that is most likely due to the database search taking place in May 2023. Therefore, it is likely that the publication count for the year 2023 will be the greater. The overall trend of increasing publications indicates that interest and inclusion of entrepreneurship education for engineering students in higher education is increasing.

B. QUALITY ASSESSMENT RESULTS

To assess the quality of the selected primary studies a series of questions was answered, as detailed in Section III-D. This information can be of interest to the education community.

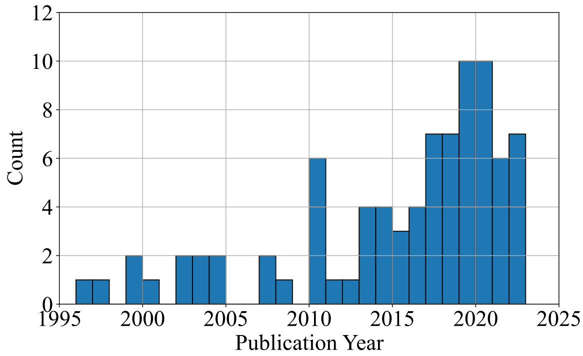

FIGURE 2. **Count plot of the year of publication for the selected primary sources.**

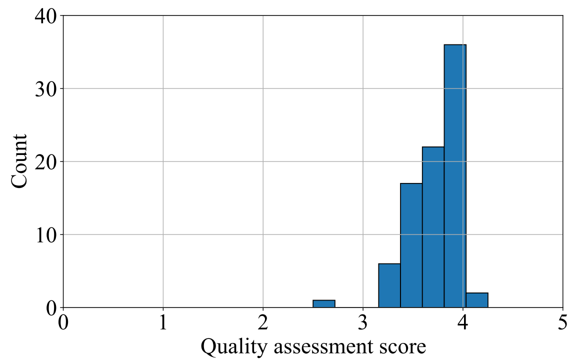

FIGURE 3. **Count plot of the QA score for the selected primary sources.**

A histogram of the QA scores of the selected primary sources is provided in Fig. 3. It is clear from the figure that the lowest QA score was 2.5 out of a possible 5. Therefore, no papers were excluded at this stage based on the QA score. Furthermore, the figure shows that the QA scores were predominantly between the range of 3 to 4, which is a relatively good score. This is expected since all the primary sources, were published in peer-reviewed scientific journals or conference proceedings.

The average QA score per publication year is provided in the form of a bar chart in Fig. 4. This shows that the average QA score has not varied significantly since 2010. Equally, the increased variation before 2010 could be the result of less publications within the area as shown in Fig. 2.

C. PROTOCOL LIMITATIONS

This SLR is limited based on the search coverage and possible biases introduced during the study selection, data extraction, and analysis. These limitations were addressed by having a second researcher discuss the results of each stage to ensure consistency and appropriate decision making [17].

There is a limitation regarding the fact that some of the research questions are not binary or objective. This lead to categorization of the primary studies. However, the interpretation of this may not be definitive. Equally, there was relatively large number of research questions considered, which made the study more difficult. However, hopefully

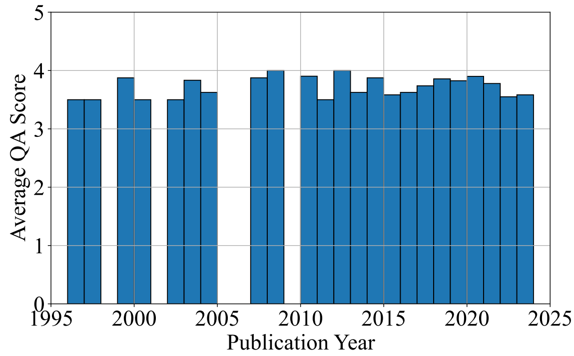

FIGURE 4. **Bar chart of average QA score per publication year.**

TABLE 4. **Categorization of soft skill motivation.**

Category	References	Total
Entrepreneurial mindset	[22]–[46]	25
Teamwork (multi-disciplinary) and collaboration	[24], [32], [40], [41], [47]–[52]	10
Creativity	[28], [34], [36], [53]–[56]	7
Leadership	[28], [29], [36], [53], [56]–[58]	7
Communication (oral and/or written)	[24], [50], [52], [59]–[61]	6
Critical thinking	[42], [50], [52], [62]	4
Management	[57], [59]–[61]	4
Problem-solving	[50], [52], [62], [63]	4
Problem and opportunity identification	[23], [64]	2

this is of benefit to the reader as it covers a wide range of topics from an educators perspective of EEC engineering entrepreneurship education.

V. RESULTS

A. KA1 - MOTIVATION

1) RQ1A

Out of the 84 primary sources included within this study, 41 did not emphasize the need for entrepreneurship education within EEC engineering curricula as a means to improve students' soft skills (i.e., non-technical degree-specific skills). The remaining 43 primary sources that did highlight soft skill development were categorized into key areas that were prevalent and are summarized in Table 4. It is worth noting that primary sources can highlight multiple soft skills as motivation. From the table, it is evident that fostering an entrepreneurial mindset in students is a dominant motivator for the inclusion of entrepreneurship education. An entrepreneurial mindset can be defined as being resilient, resourceful, and solution orientated, even when facing adverse odds. To a lesser extent, the promotion of teamwork and creativity within the students is also shown to be common soft skill motivators.

2) RQ1B

Out of the 84 primary sources included within this study, 46 did not highlight the need for entrepreneurship education within EECengineering curricula based on economic need.

TABLE 5. Categorization of economic motivation.

Category	References	Total
Economic growth	[30], [36], [41], [65]–[77]	16
Globalization	[33], [37], [49], [78]–[83]	9
Job creation	[28], [29], [66], [67], [84]	5
Labor market	[42], [50], [61], [85]–[87]	6
Venture creation	[28], [88], [89]	3
Knowledge economy	[90]	1
Sustainability	[91]	1

The remaining 38 primary sources that did highlight an economic need were categorized into key areas that were prevalent and are summarized in Table 5. It is worth noting that primary sources can highlight multiple economic categories as motivation. From the table, it is clear that the most prevalent economic motivation mentioned was that of economic growth. Job creation was differentiated from the labor market, since labor market can refer to unemployment, and the lack of appropriately skilled individuals to fulfill jobs, while job creation specifically refers to the creation of new jobs. Both of these are clear motivators though to a lesser extent when compared to globalization. In this study globalization is used to refer to global economies at a macro level and the ability of job seekers to travel the globe in response to economic circumstances. Interestingly, only one primary source mentioned the knowledge economy and one mentioned sustainability. Therefore, it is evident that though sustainability can be linked to entrepreneurship, within engineering curricula it is not typically used as motivation.

3) SUMMARY

Based on the results of both research questions in this KA, there is a higher proportion of primary sources that motivate entrepreneurship courses for engineering students based on soft skills instead of an economic need. Furthermore, there are 11 primary sources that mention both soft skills and economic need as motivation. There are a large proportion (i.e., 40/84) of primary sources that do mention an economic need and those that include economic growth, job creation and venture creation have a total of 24. Despite this, no papers included an investigation of whether any teaching had a meaningful impact on the number of students that decided to become entrepreneurs. In comparison there was clear measurement of the positive impact on soft skills. Further results of how these motivations vary based on geographic location is discussed in Section V-D.

B. KA2 - CURRICULUM DESIGN AND DELIVERY

The teaching methodology utilized within curriculum delivery was extracted from the primary sources with 18 of the 84 sources not detailing a particular method, possibly because it was not relevant to the study. The results of this extraction and categorization are shown in Table 6. It should be noted that primary sources can utilize multiple methods and so can appear in multiple rows of the table, therefore,

TABLE 6. Categorization of teaching methods.

Category	References	Total
Project-based learning (PBL)	[22], [24], [27], [31], [35]–[37], [39], [43], [44], [55], [64], [66]–[69], [73], [74], [79], [80], [82], [86], [87], [91]–[98]	31
Lectures	[24], [35], [39], [42]–[44], [50], [60], [63], [73], [80], [86]–[89], [91], [96], [98]	18
Problem-based learning (PrBL)	[40], [49], [50], [60], [61], [76], [89], [99]	8
Guest lectures	[35], [36], [43], [50], [55], [68], [69], [95]	7
Extracurricular	[25], [59], [62], [72], [81], [84], [100]	7
Case studies	[39], [46], [69], [73], [80], [87]	6
Lean	[26], [78], [83], [89], [96], [101]	6
Challenge-based learning (CBL)	[26], [47], [54], [101], [102]	5
Simulation	[29], [44], [57], [61], [103]	5
Agile	[26], [89], [96]	3
Learn by doing	[63], [77], [78]	3
Workshops	[60], [91]	2
Design thinking	[78], [92]	2
Integrated in multiple modules	[23], [53]	2
Debate-based learning	[58]	1
Story-based learning	[45]	1

the overall total is greater than the total number of primary sources. It is clear that PBL is the most popular method of curriculum delivery along with lectures. However, it should be noted that there was a correlation between these two categories. This indicates that both methods are typically used together when delivering entrepreneurship education to EEC engineering students. The lectures can provide the students with a basis of knowledge, particularly around business aspects, which they can apply within their projects. The differentiation between lectures and guest lectures is drawn as guest lecturers typical involve external speakers from the local entrepreneurial ecosystem or have a background in marketing, or finances, which is not the background of the educator running the course. Therefore, this is utilized to facilitate the understandable gap in their expertise and to foster links to external organizations.

From Table 6 it is shown that primary sources that utilize agile and/or lean startup methods are predominantly from a computer engineering background. This would be expected since those methodologies are closely aligned to that particular field. Although not the target of this study a number of primary sources are extracurricular focused. These have been included for the benefit of the reader and are shown within the table. Five of the primary sources utilized a simulation-based method to teach entrepreneurship. This can typically involve members of the teams picking roles and being presented with information and then during the simulation they make decisions. However, this method does not give the students an opportunity to explore their own ideas or address a real-world problem. Therefore, it limits their capacity to engage with extracurricular activities that often align with entrepreneurship courses.

By far the most used method to teach entrepreneurship to engineering students is PBL. This can involve student teams being informed what is the final expected output by the end of the course and being guided on identifying a problem, proposing a solution, and building a business proposition around that. This gives students an opportunity to actively work on their problem-solving skills and creativity. Guest lectures from experts in the local ecosystem can be utilized to further enhance the learning, apart from lectures from academic staff. A similar approach is problem-based learning (PrBL). In this case, students can be presented with a defined problem that does not have a single answer from the outset that students must create a solution and business around. This saves time as students do not have to identify a problem as with PBL. However, this is a trade-off between saving time and students losing the opportunity to gain experience of problem identification. A newer method, that is a special case of PrBL, is called challenge-based learning (CBL). Although, in Table 6 only 5 studies were found to implement it, this is not surprising since it is relatively new compared to PBL. CBL offers a clear framework that presents students with a broad idea to engage them first, then it presents them with questions which relate the broad idea before moving onto presenting them with a clear challenge that relates to the previous two steps and has the students create a solution to the challenge. A key aspect of it is the students documenting their thoughts, research, ideas, and reflections during the learning process, which can form part of the assessment. CBL, therefore negates the missing aspect of PrBL not introducing the students to problem identification. This is achieved through the students connecting a broader problem to themselves or their local community before presenting them with a predefined challenge.

There are two outlier methods, which use different delivery methods than the predominant PBL, PrBL, and CBL approaches, which are story-based learning [45], and debate-based learning [58]. In story-based learning the students read a chapter each week from a prescribed text, with online quizzes about the reading. They answer questions in teams each week and then submit a personal reflection based on set questions. This required the staff member to be highly knowledgeable about the prescribed text. In the debate-based learning approach, student teams partake in a structured debate with opposing views in front of the entire class. After this, both teams jointly create a report, describing both teams' views and a reconciliation. The reconciliation section is the core aspect of the report as it deals with what was learned from the debate and reflections afterwards. Both of these methods are uncommon, since they do not create a product to a problem.

Lastly, an approach that is more generalized involves the embedding of entrepreneurship activities within multiple modules throughout a degree course [23], [53]. However, a critique of this is that many aspects already involved in teaching and assessment can just be thought of as entrepreneurial training when considering them through that lens. Yet is that truly instilling an entrepreneurial mindset in students? If these skills are already adequately being addressed throughout their degree entrepreneurship courses serve little to no purpose within EEC engineering curricula. But considering that so many engineering curricula do include entrepreneurship courses, it demonstrates that though aspects of entrepreneurship can be developed throughout a degree pathway, the pinnacle of this is demonstrate of those skills within a single course in the latter end of the students' degrees.

TABLE 7. Categorization of assessment methods.

Category	References	Total
Pitch	[22], [24], [37], [44], [52], [57], [60], [63], [66], [67], [73], [76], [79], [82], [86], [92], [95], [101]	18
Prototype	[26], [43], [52], [55], [74]–[76], [79], [82], [86], [89], [92], [95]–[98], [101]	17
Business plan	[22], [24], [25], [44], [57], [60], [63], [66], [67], [69], [79], [82], [86], [95]	14
Report	[37], [38], [40], [43], [52], [58], [64], [76], [87], [94], [98]	11
Presentation	[27], [38], [40], [43], [55], [60], [64], [89], [93], [96], [98]	11
Peer assessment	[35], [43], [44], [55], [57], [60], [94]	7
Poster	[37], [55], [82], [86], [87]	5
Formative assessment	[23], [26], [39], [75]	4
Essay	[27], [87], [90]	3
Self reflection	[35], [45], [55]	3
Business model canvas	[73], [74]	2
Exam	[60], [87]	2
Advertising material	[55]	1
Blog	[87]	1
Idea generation and evaluation	[50]	1
Instructor assessment	[55]	1
Patent application	[97]	1
User requirements document	[93]	1
Video	[27]	1

C. KA3 - ASSESSMENT

Out of the 84 primary sources included within this study, 41 did not specifically indicate how they assessed students. The 43 primary sources that did highlight assessment were categorized into key areas that were prevalent and are summarized in Table 7.

It should be noted that predominantly the primary sources did not give specific details about how assessment occurs, such as the weighting of multiple components or how they dealt with awarding individual marks if group work was taking place. However, there are some exceptions to this, such as [44], [52], [55], and [57] where they detailed the percentage each component was worth. Furthermore, details of any rubrics applied to assessment was not found in any of the primary sources.

It is evident from Table 7 that the most common methods of assessment are a pitch, prototype, business plan, report and presentation. There is a distinction here between a pitch and a presentation, as a pitch would typically follow a structure that is relatively common when starting a business. However, presentation is used here as a more generic term that could represent presenting a project or other work completed by the students. Similarly, a business plan is a specified document, whereas a report is more generic and could be technical in nature. Notwithstanding, it is clear that a prototype, business plan (or some form of report) and a pitch (or some form of presentation) are the most common assessment methods and they are often compulsory components. Posters and peer assessments are also used to a lesser extent. Unsurprisingly, exams are not a common method of assessment, which would be expected given they are not typically used to evaluate learning objectives through projects. There was one notable primary source that used an innovative method of peer assessment based on a dividend [55]. This novel method has altered a typical peer assessment to suit the learning of the course.

Only one source used a patent application as a method of assessment, which could indicate that it is difficult method to measure students' learning. It would require a large proportion of students time spent researching and understanding the field of existing patents in order to identify a gap before attempting to write one. Writing a patent application is not a small task, which a patent attorney would typically write. Therefore, this assessment would possibly be to the detriment of achieving other learning objectives surrounding entrepreneurship. The lack of uptake of studies using videos to assess students could also indicate that the interpersonal skills encouraged through entrepreneurship is highly valued and that videos does not facilitate the learning objectives typically set out in entrepreneurship courses.

D. KA4 - GLOBAL VARIATION

Firstly, the location of where the primary studies took place is plotted as a global heat map in Fig. 5. It is clear from this plot that 38 of the 84 primary studies took place in the United States of America (USA). A reason for this is because the USA started the introduction of entrepreneurship courses within engineering degrees much earlier than compared to other countries that have adopted it relatively more recently. Notwithstanding this the global heat map is now shown again in Fig. 6, which does not include the USA, making it easier to view the global variation. There is a spread across key countries such as Canada and Brazil in the North and South American continents, respectively. Within the Asian continent there is a concentration of studies taking place within China, though there are still some studies that have taken place in Malaysia and Indonesia. There is a spread of studies across the European continent, which is in contrast to the African continent, that only had one primary study, which took place in Egypt.

TABLE 8. Relative frequency per country of primary studies with soft skills as motivation.

Country	Relative frequency	Count
Argentina	1.00	1
Australia	1.00	1
Chile	1.00	1
Egypt	1.00	1
Ireland	1.00	1
Latvia	1.00	1
Philippines	1.00	1
Sweden	1.00	1
Thailand	1.00	1
United Kingdom (UK)	1.00	2
Brazil	0.75	4
Portugal	0.67	6
China	0.60	5
Italy	0.50	2
United States of America (USA)	0.50	38
United Arab Emirates (UAE)	0.33	3
Norway	0.25	4

Secondly, the variation of the motivation for these courses (i.e., KA1) across the globe is examined. For primary studies that mentioned soft skills as motivation, the relative frequency per country, along with the count of primary studies for each country is provided in Table 8. However, this is susceptible to the fact some countries have a low number of sample points, which has results in a number of countries having a relative frequency of 1.

The relative frequency per country for studies that mentioned economic motivation is provided within Table 9. This table is susceptible to there being countries with a relative frequency of one due to the a small country sample count. The results of both tables are not mutually exclusive as studies can mention both soft skills and economic need as motivation, such as Ireland. Yet, most countries with a relative frequency of 1 in either Table 8 or 9 do not appear in the other table (i.e., if a country has a relative frequency of 1 in Table 8, it most likely will not appear in Table 9). The United Arab Emirates (UAE) and Norway both have a higher relative frequency in Table 9, compared to Table 8, which suggests that economic need is more likely to be the motivation for entrepreneurship courses there compared to the development of engineering students soft skills. Yet, this is in contrast with the USA, which has a higher relatively frequency in Table 8 compared to Table 9. This indicates that in the USA the development of engineering students soft skills is more likely to be the motivation. Whereas, entrepreneurship courses in Indonesia have a similar likelihood of being motivated by soft skill development or economic need. It is interesting to note that whilst neither of these motivations was mentioned for the single study in South Korea, the students found the entrepreneurial mindset and individuality of entrepreneurship teaching culturally difficult to adjust to, compared to students within the USA [92].

Lastly, the curriculum delivery method (i.e., KA2) across the globe is investigated. Table 10 shows the relative frequency per country of the main curriculum delivery method utilized. The four main methods are provided as identified in Table 6, all other methods are grouped into the

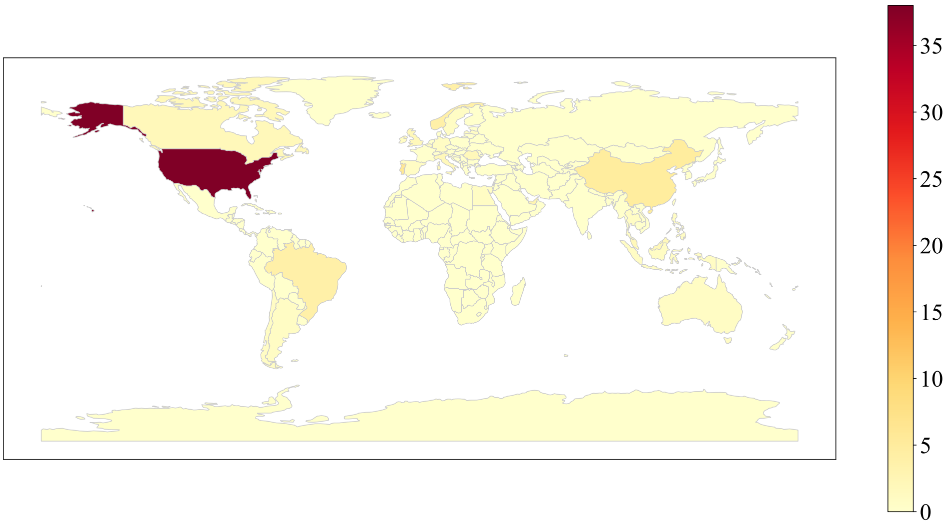

FIGURE 5. Global heat map of the locations of where the primary studies took place.

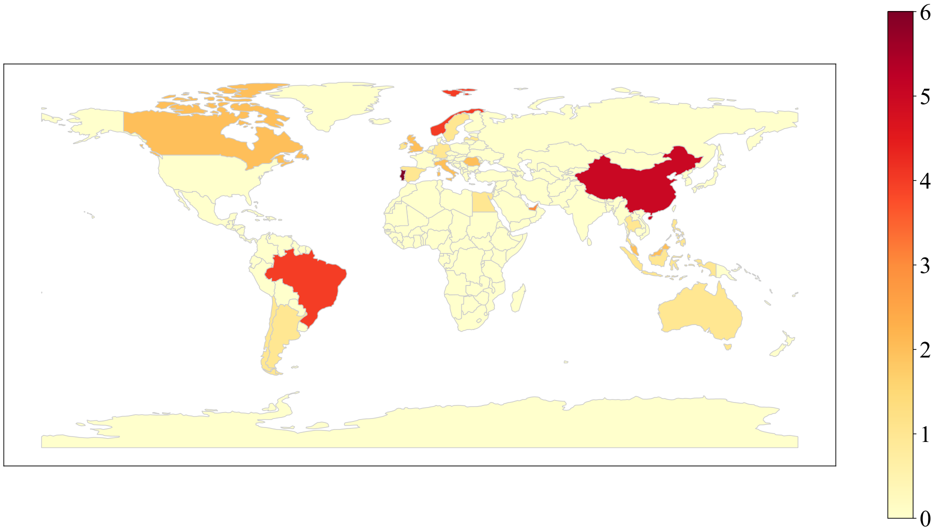

FIGURE 6. Global heat map of the locations of where the primary studies took place, excluding those located in the USA.

other category. It should be noted that not all primary studies have a curriculum delivery method mentioned. Similar to the previous tables within this section, countries with 1 as the relative frequency typically have only a small number of studies. However, there are some interesting insights to note. Brazil is shown to likely use CBL, whilst China and Portugal favor PrBL. Both the UAE and USA are likely to utilize PBL compare to the other methods. Overall, it is still evident that across the globe PBL is the dominant teaching delivery method.

E. KA5 - CHALLENGES

1) RQ5A

The challenges students face vary depending on the teaching method employed. For instance, when simulations or game are used, students often find that the game may not always engaging [103]. More importantly, they find that the choices within the simulation/game do not mirror real-world business outcomes, making interpretation of results challenging. This issue is further emphasized by students' desire for more dedicated debriefing time to better understand the outcomes [29].

As noted in Section V-B, PBL, being the most prevalent method, presents several challenges faced by students. A significant workload is often associated with this learning style in entrepreneurship courses, typically involving a business plan, and a pitch as part of the assessment [22]. When PBL is implemented within group work, students often find navigating team dynamics challenging [63], especially within the context of a multidisciplinary team [24]. Generally,

TABLE 9. Relative frequency per country of primary studies with economic need as motivation.

Country	Relative frequency	Count
Canada	1.00	1
Germany	1.00	1
Indonesia	1	1
Ireland	1.00	1
Malaysia	1.00	1
Romania	1.00	2
United Arab Emirates	1.00	3
Portugal	0.83	6
China	0.60	5
Norway	0.50	4
USA	0.39	38
Brazil	0.25	4

TABLE 10. Relative frequency per country of primary studies with a main curriculum delivery method mentioned.

Country	PBL	PrBL	CBL	Simulation	Other
Argentina	-	-	-	-	1
Australia	-	1	-	-	-
Belgium	-	-	1	-	-
Brazil	0.25	-	0.75	-	-
Canada	-	-	-	-	1
Chile	1	-	-	-	-
China	0.33	0.67	-	-	-
Egypt	-	-	-	-	1
Germany	-	-	-	-	1
Indonesia	1	-	-	-	-
Ireland	-	-	-	-	-
Italy	-	-	-	0.5	0.5
Latvia	1	-	-	-	-
Malaysia	-	-	-	-	1
Norway	1	-	-	-	-
Philippines	-	-	-	-	1
Portugal	-	0.75	-	-	0.25
Romania	1	-	-	-	-
South Korea	1	-	-	-	-
Spain	-	-	1	-	-
Sweden	1	-	-	-	-
Thailand	-	-	1	-	-
UAE	0.67	-	-	0.33	-
UK	0.5	-	-	0.5	-
USA	0.57	0.07	-	-	0.37

teams are expected to meet outside of scheduled classes, leading to difficulties in arranging meetings amidst busy and conflicting schedules [52]. As with any group work assignments, students strongly dislike those within a group who are deemed to be "free-riders" [58], i.e., those who are perceived to contribute less or not fully engage with their respective team. This issue can be exacerbated if the teams are too large, leading to further team dynamic issues [58]. The generation of novel ideas also poses a significant challenge to students, since PBL is open-ended [35], [86]. This is unsurprising given that undergraduate students in higher education have limited real-world working experience to draw upon. As a result, they have a limited perspective to generate ideas and it requires more effort in seeking out people to interview to understand the problems they face. This can lead to further issues of students finding it difficult to relate to the problem and trying to empathize with their possible users if they are far removed from them [78]. Students can find that there is a larger technical leap that is expected of them than what they anticipated [24], [35], [52]. Students expect that their lecturers are experts in the topic they are teaching them. However, this is not necessarily the case when teaching an entrepreneurship course in an EEC engineering pathway, leading students to criticize this as they believe the their lecturers do not have sufficient knowledge and that the course is not well-organized [66].

Students also raise challenges or issues regarding assessment. For instance, if there are multiple expected outputs expected but only individual and peer assessment are evaluated, it leads to student frustration [35]. This is expected since the learning objectives could not adequately assessed via individual and peer assessment alone, leading to decreased student satisfaction. Students can find assessment feedback to be overly negative, especially if they have created a solution and presented it [33], [101]. This could be due to them being more personally invested in their project and thus taking negative feedback personally. Students can perceive entrepreneurship teaching as not being grounded enough in the real-world, and thus perceive it as being less relevant to them [45]. Even when using case studies, they must remain relevant and up-to-date for the students to find them engaging and worthwhile [60].

2) RQ5B

From an educator's perspective, there are also challenges around students teams, as noted by students. For instance, team formation and monitoring can be challenging, though it has been found that teams with 4 to 5 members tend to work better [47]. Promoting teamwork among multidisciplinary teams can increase difficulty and workload [22]. A simple solution is to include more teaching members, but this can add further complexity if they are from different faculties and/or offer conflicting advice to students [22]. Justifying the requirement for more teaching staff is not an easy administrative feat to achieve [24], [97]. Other administrative challenges to contend with include timetabling [86], funding [99], and only having one semester to teach it not being long enough [52]. If using a PBL approach, when the student cohort is large then it poses a problem of increased volume trying to manage many student projects and assessing them appropriately [68], [97]

For educators from an EEC engineering background, teaching entrepreneurship poses a steep learning curve since it involves so many broad elements, including business and finance [24], [36]. It can be beneficial to utilize experts from the local entrepreneurship ecosystem or student alumni, but this puts a greater workload on staff involved [33], [89]. Utilizing external experts and partnerships should also be considered carefully and this can create unease for educators that are unfamiliar with this [80]. If external stakeholders are used to present challenges for students to solve or to act as possible users/customers this can also prove difficult to find, especially for a significant volume of projects and on a yearly basis [35], [47], [67], [78].

Assessment creates its own set of challenges from an educator's perspective. There is a need for the assessment plan to have a degree of flexibility [99]. For those utilizing group work, there is difficulty in assigning students individual marks, though peer assessments go someway to helping with this [82]. If there are multidisciplinary teams then the students tend to stick to areas they are comfortable with and possibly miss valuable learning opportunities, such as engineering students doing only technical work [79]. There is also a need for entrepreneurship courses to be appropriately accredited, since there is typically a substantial workload involved, it needs to be accredited as such [25].

If using a simulated game, this creates just as many challenges as it solves. For instance, it can be difficult to debrief the results to students as it can be complex with a huge amount of data available that needs interpreted [103]. As an educator you also have less control over the learning process and can't predict the outcomes of the simulation [29], which creates uncertainty. Furthermore, the simulation is only as good as the learners' level of problem-solving and critical reflection [29].

3) SUMMARY

Considering the challenges faced both my students and educators there are very clear similarities. These can be thought of as two sides of the same coin.

Firstly, students find group work difficult to organize and deal with team dynamics. However, educators also find creating student teams and managing them to be difficult. The "free-riders" in teams is a problem for both educators and students, the latter has to deal with this in practical terms, whilst the former has to be able to assess them somewhat individually so they don't obtain inflated marks due to the work of other team members.

Secondly, students perceive there to be a high workload associated with entrepreneurship modules in terms of assessment. Yet, educators involved also have a high amount of administrative work in order to curate such courses, such as using case studies, external speakers, predefined challenges, simulated games, external stakeholder, or having multiple educators on the same course.

Lastly, students from an EEC engineering background tend to have little to no experience in business and finance. These topics are often introduced to them through entrepreneurship courses. Yet, educators on these courses can also feel uneasy about leading these courses as it might not be their background, which is technically based.

VI. OPPORTUNITIES

The escalating interest in entrepreneurship education within EEC engineering curricula, as depicted in Fig. 2, opens up numerous opportunities for both educators and students.

A. MULTI-DISCIPLINARY COLLABORATION

While not explicitly examined in this study, some EEC engineering curricula in the USA offer entrepreneurship courses through collaboration with business schools within the same institution. This approach equips EEC engineering students with a comprehensive understanding of both technical and business aspects, particularly with educators from a business school delivering the business component. However, this model has not been widely adopted in other countries. One possible reason could be due to the administrative burden such collaborations entail [22]. Moreover, with staff members from different schools/faculties, students may receive conflicting advice [22]. Therefore, it is crucial to maintain clear and frequent communication among all teaching staff involved, ensuring consistency and clarity on the work and expected outcomes from students. This approach would provide students with a more rounded experience and reduce the burden on teaching staff from an engineering background, as they would not be expected to have an in-depth understanding of the business side of such as course in depth if another staff member involved is leading that aspect.

B. EXPERIENTIAL LEARNING

Compared to the norm of PBL and PrBL, CBL is a relatively new entrant in the arena of entrepreneurship education within EEC engineering curricula. This form of experiential learning can offer greater insights to students through consistent self-reflection. Further extracurricular opportunities, such as internships, innovation labs, and startup incubators can foster an entrepreneurial mindset in students. These opportunities can complement an entrepreneurship course, but to reap greater benefit, courses should be aligned with them. This alignment cab be achieved through assignments and deadlines, coinciding with the deadlines for competition and and incubator applications. Thus, students do not face a substantially increased workload by participating in extracurricular entrepreneurship activities. However, the opportunities and validation these activities offer to students are substantial and ultimately aid them within the entrepreneurship course. The synergy between both a credited course and extracurricular activities is clear and enhances the student experience.

C. INDUSTRY PARTNERSHIPS

Collaborations with industry can provide students with practical insights and networking opportunities. Industry professionals can contribute to the curriculum as guest speakers, mentors, or judges for project assessments. However, this does pose an increased workload for educators. But the added benefit from fostering connections with the local entrepreneurship ecosystem can benefit the students in the long term. That inherent knowledge of the local entrepreneurship ecosystem can benefit the students in the long term as well, long after they graduate. As they would understand who to contact and what to do if they wanted to create a venture at a later date, after the completion of the course.

D. ONLINE LEARNING PLATFORMS

The rise of digital learning platforms due to the impact of the Covid-19 pandemic is clear [104]. Yet the benefits they offer as a resource to entrepreneurship courses could be further exploited. For instance, lectures and all material can be stored there, along with individual spaces for student teams to store and track their work. This means it is much easier as an educator to monitor teams progress and assess their team dynamics and individual contributions to projects. Furthermore, since students within teams can struggle to arrange meetings outside set class hours, an online learning platform can offer them the ability to meet online, making it more accessible to everyone.

E. ARTIFICIAL INTELLIGENCE

Generative artificial intelligence (AI) has brought about a paradigm shift in various sectors, and education is no exception. In the context of entrepreneurship education within engineering curricula, AI presents a plethora of opportunities to both students and educators. Students can be taught to leverage generative AI in entrepreneurial ventures. For instance, they can learn how to use AI for market research, customer segmentation, product development, and operational efficiency. This practical understanding of AI can give them a competitive edge as future entrepreneurs. AI can be integrated into existing curriculum delivery, such as PBL, PrBL and CBL. Students can even be tasked with developing AI-based solutions to real-world problems. As generative AI becomes more prevalent, there's a growing need for entrepreneurs who understand not just the technical aspects of AI, but also the ethical implications. Entrepreneurship courses can incorporate lectures on AI ethics, promoting responsible innovation among future engineers.

VII. FUTURE WORK

While the opportunities are promising, there is still many avenues to investigate in regards to entrepreneurship teaching offered to EEC engineering students.

Previous work has already identified competencies and learning outcomes [105], but translating these into appropriate teaching methods and assessment strategies requires more research. Particularly, to determine the efficacy of curriculum delivery and assessment. As entrepreneurship education may be outside the comfort zone of many EEC engineering educators, there is a need for professional development programs to equip them with the necessary skills and knowledge. This can help to ease the burden and increased stress when newly appointed to teach such as course.

Future work should also focus on strategies to increase student engagement and interest in entrepreneurship education. This could involve exploring the role of extracurricular activities, student clubs, and competitions, to augment entrepreneurship courses offered. The utilization of AI within entrepreneurship courses need to be further developed. This could offer benefits to the students with the option of making viable prototypes that include AI. However, it could go beyond this by helping the students identify problems and understand their potential customers better.

Lastly, there is a need for longitudinal studies to assess the impact of entrepreneurship education on EEC engineering students' career outcomes and entrepreneurial activities post-graduation. Further, such investigations should assess the impact of students' behavioral competencies developed from entrepreneurship education on their professional careers. This is essential to help determine, which teaching methods are deemed successful through the lens of improving behavioral competencies as part of long-term professional development. So far it is typically assumed entrepreneurship education for EEC engineering students has benefit and many have stated there is an economic need, with little to no evidence to back up such motivations. Therefore, more work is required to determine if entrepreneurship courses offered to EEC engineering students does have a long-term impact on the economy.

VIII. CONCLUSION

This work has reviewed and elucidated the landscape of entrepreneurship education within EEC engineering curricula. A SLR was conducted, the results of which have been presented, providing a comprehensive overview of the key teaching methodologies currently employed by entrepreneurship educators, with PBL, PrBL and CBL being highly popular. This serves as a valuable resource for educators seeking to enhance their curriculum design.

The scope of this study was further broadened to encompass an investigation of the variation of teaching methodologies applied across the globe. The study has also identified and discussed the key challenges and issues faced by entrepreneurship educators within EEC engineering curricula, providing a foundation for future work aimed at addressing these challenges. These include, but are not limited to, difficulties in team formation and monitoring, administrative hurdles such as timetabling and funding, and the steep learning curve faced by educators from an engineering background when tasked with teaching entrepreneurship, a field that encompasses a broad array of elements including business and finance. Furthermore, challenges faced by students were also examined.

Looking towards the future, this study has identified several promising avenues for further research. There is a need for more research aimed at translating the key competencies and learning outcomes into effective teaching methods and assessment strategies, as identified in this study. The development of professional programs aimed at equipping educators with the necessary skills and knowledge to teach entrepreneurship effectively is also a priority. Furthermore, strategies aimed at increasing student engagement and interest in entrepreneurship education warrant further exploration. This could involve a more in-depth investigation into the role of extracurricular activities, student clubs, and competitions in augmenting entrepreneurship courses. The potential for integrating AI into entrepreneurship courses also presents an exciting opportunity for future research. Finally, this study found the need for longitudinal studies aimed at assessing the long-term impact of entrepreneurship education on EEC engineering students' career outcomes and entrepreneurial activities post-graduation. It is hoped that the findings and future research directions outlined herein will serve as a catalyst for further advancements in EEC engineering entrepreneurship education.

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JONATHAN W. BROWNING (Member, IEEE) received the M.Eng. degree in electrical and electronic engineering and the Ph.D. degree in electrical engineering from the Queen's University of Belfast, U.K., in 2017 and 2022, respectively.

From 2021 to 2023, he was a Connected Learning Tutor with the School of Electronics, Electrical Engineering and Computer Science, Queen's University of Belfast, where he has been a Lecturer (Education) with the School of Electronics, Electrical Engineering and Computer Science, since 2023. His research interests include entrepreneurship education and engineering and computer science education in general.

JOHN BUSTARD received the B.A. degree in computer science from the University of Cambridge, in 2000, and the Ph.D. degree in computer vision from the University of Southampton, in 2010.

He joined the School of Electronics, Electrical Engineering and Computer Science, Queen's University of Belfast, in 2014, as a Lecturer. His research interests include computer vision, professional ethics, and education.