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A systematic literature review on final year capstone project in an engineering curriculum

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Abstract: The capstone project course, typically offered in the final year of undergraduate studies, is a key part of engineering education that focuses on hands-on learning. These projects give students the chance to tackle real-world problems using the technical skills and soft skills they have developed during their studies. The main goal is to apply practical engineering methods to solve actual client needs, helping students transition from academic learning to professional practice. This study reviews research on final-year capstone projects from 2015 to 2024 across various engineering subjects. We also note the growing use of capstone projects in non-engineering programs, showing a trend toward experiential learning in higher education. By synthesizing the existing literature, this review highlights the benefits, challenges, and best practices associated with capstone projects. It provides valuable insights for researchers, educators, and curriculum developers who aim to enhance engineering education and improve student outcomes through effective capstone project integration and implementation.

Keywords: *Capstone course, Capstone design project, Capstone project, Final performance Project, Final year project.*

1. Introduction

Engineering design is mostly about finding solutions to problems. Engineers' main job is to use their science and engineering knowledge to figure out how to analyze, design and fix technical problems as well as real- life problems. Also, engineers should be able to come up with solutions based on improved ideas while staying within the limits of what is needed and what can be done [1]. Designing a problem presents difficulties like getting the right understanding of the problem, listing the needs, and working within the allotted time and money, all of which are necessary for the final answer. Engineering education tries to help students get better at these important skills so they can solve problems with confidence and success [2, 3]. A capstone project is a comprehensive educational endeavour typically undertaken during a student's last school year. Undergraduate engineering students engage in projects similar to those they may face in professional engineering environments post-graduation. Organizations such as ABET, Washington Accord, and ACM-IEEE provide capstone course structure as a part of engineering degree programs [4-6]. This type of project enables students to utilize the knowledge and abilities, both technical and interpersonal, acquired during their degree program. Engineering capstone projects typically involve open-ended proposals necessitating study, design, execution, and testing of a prototype, along with the documentation of outcomes. These

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projects may be executed alone or collaboratively. The work may be academic, initiated by either the student or an academic instructor, or it may be industry-based, tackling a real-world issue[7, 8].

The Accreditation Board for Engineering and Technology (ABET) provides the accreditation of engineering educational programsAccreditation Board for Engineering and Technology [4] upon successful fulfilment of criteria set by ABET. From the several criteria set by ABET, the specific interest of this research is criterion 3, which is established for Program Outcomes and Assessment. It consists of 11 requirements that baccalaureate degree programs must demonstrate graduates possess. From the 11, the three requirements most relevant to this research state: (1) an ability to design a system, component, or process to meet desired needs. (2) an ability to identify, formulate, and solve engineering problems. (3) an ability to communicate effectively[9]. The criteria mentioned above highlight the significance of problem-solving abilities and the capacity to develop a solution that fulfills specified criteria as essential skills that engineering graduates should possess. Moreover, the pupils must possess the ability to proficiently articulate their comprehension of the problem, prerequisites, and the formulated solutions. Frequently, this information is conveyed through various mediums like presentations, executive summaries, or design reports.

The Washington Accord International Engineering Alliance [6] adopts 12 graduate attributes to safeguard the standards of engineering education. The graduate attributes explicitly describe the expected competencies in technical knowledge, skills, and professional behaviors among graduates; an engineering program that meets the standard is accredited. The training in a four-year engineering program, however, has compartmentalized this technical knowledge and those professional behaviours into courses (i.e., modules)[10]. It is common for engineering programs to complete a capstone design project for final-year or senior-year students. The capstone design project requires students to integrate all knowledge they have acquired from the engineering program to solve real-world industrial design problems. Capstone design projects are usually a form of project-based learning in which students achieve a shared goal through collaboration in groups [11]. The Washington Accord defines these professional behaviours as ethics, teamwork and leadership, communication skills, and lifelong learning. In the real world, employers demand professional behaviours such as the ability to communicate, to be a team player, to be proactive in solving problems, and to show management skills [12]. In addition to the aforementioned accreditation, each nation possesses its own distinct accreditation process that aligns with the aforementioned standards. The current capstone project program engages multiple academic institutions and companies from around the world, allowing multiple departments (Computer Science, Software Engineering, Electrical Engineering, Mechanical Engineering, Agricultural Engineering, Marketing, and Journalism) to engage in a highly efficient manner.

There are various types of Capstone projects. Some are industry-sponsored, and some are faculty-sponsored. Morsy, et al. [13] focusing on student collaboration and the impact of industry versus faculty sponsorship. Results show that industry-sponsored projects excel in overall execution and professional skills development, while faculty-sponsored projects better foster teamwork and communication. Each model has unique strengths and weaknesses, suggestingthat an integrated approach combining elements from both could provide students with a more comprehensive and enriching educational experience. Kim, et al. [14] analyzed factors influencing student project team performance in industrial and management engineering capstone design courses. It examined various independent variables, including academic achievement, multi-disciplinary ability, project subject, team composition, individual initiative, communication, and teamwork, against team performance metrics. The research found that better academic achievement and teamwork positively affected performance, aligning with previous studies. However, contrary to expectations, teams with corporate topic knowledge or diverse majors showed negative effects on performance. Shakil and Denny [15] acknowledge the challenges of managing large capstone courses and detail their iterative improvements to enhance student engagement and motivation. Using end-of-course surveys and students' written reflections for assessment, they offer insights and recommendations for educators designing new capstone courses or scaling existing ones. The report emphasizes the value of these courses in CS education and the need for effective management strategies as they expand in size and complexity. Davis, et al. [16] explores the implementation and sustainability of geriatrics focused capstone projects developed by faculty as part of a Faculty Development Program (FDP). Through thematic analysis of interviews with 17 faculty scholars, the study identifies key factors influencing project implementation and sustainability, including supportive and hindering elements, the enhancement of pedagogical skills, and the impact on career development.

The study Znidi, et al. [17] compares online and face-to-face (F2F) instructional methods in Capstone Senior Design projects for engineering students. It finds that while both methods are equally effective overall, F2F enhances teamwork, and online settings excel in mentorship. The study suggests integrating both approaches to improve educational strategies and better prepare STEM students. The studyPolk and Hart [18] addresses the challenge of providing adequate mentorship to large engineering capstone cohorts by assigning Team Mentors (TMs) from various sources, including faculty, graduate students, and external engineers. An analysis of 2,637 evaluations across 285 projects shows that TMs are generally rated highly, with minor differences between mentor groups. This study Kim and Wi [19] explores the emotions of students participating in a capstone design course, using sentiment analysis and surveys to identify factors influencing these emotions. The research found that positive emotions were strongly linked to group interaction with teaching staff, while factors like course organization and the need for knowledge from other majors negatively affected emotions. The paper Howell and Aryal [20] presents a method that converts Harvard Business Cases into quasi-internships for information systems capstone courses, improving career readiness and flexibility. This approach overcomes the limitations of traditional internships, offering meaningful experiences aligned with students' career goals, regardless of their background. Positive feedback suggests the model is effective and adaptable for other courses, potentially increasing internship opportunities and industry connections.

In this article, we propose a systematic literature review of final-year capstone projects, focusing on their historical background and current trends. We gathered papers on this topic from 2015 to 2024. Additionally, we discuss relevant knowledge and capstone projects proposed by various universities and countries. We also explore different engineering curricula, and the accreditation institutes commonly used across countries. Furthermore, this review provides valuable insights for researchers, educators, and curriculum developers aiming to enhance engineering education and improve student outcomes through the effective integration and implementation of capstone projects.

The subsequent sections of the article will be outlined in the following manner. Section 2 presents an overview of the capstone project, encompassing its criteria and other essential aspects. Section 3 describes the research methodology of our review paper. Section 4 describes the results obtained from the study. Section 5 discuss the research questions. Section 6 describes the possible future research direction for future researchers, and Section 7 describes the threat to the validity of our research paper. Finally, section 8 concludes the paper.

2. Final Year Project in Engineering Curricular

In the engineering curriculum, introducing a final-year project is standard practice. With the assistance of a supervisor and the concepts and knowledge gained during engineering school, the future engineer is expected to tackle engineering problems and find solutions [21]. The project, which is the culmination of the engineering degree program, requires the student to synthesize the knowledge they have learned in order to use it to solve an engineering problem within or across disciplines [22]. It also serves as a means of acquiring a variety of skills necessary for engineering graduates. In the engineering curriculum, designing a project is typically and preferably the final year assignment. It is the completion of all the topics covered in numerous engineering curriculum courses in certain fields [22, 23]. It is meant to be a significant learning opportunity and a fulfilling endeavor for the staff members, such as the supervisor, as well as the students.

2.1. Project Requirements

The final year project in engineering discipline distinguishes itself from other conventional engineering courses in the curriculum due to its focus on an open-ended problem. This problem may offer multiple solutions or design possibilities [24]. Furthermore, it distinguishes itself from other courses by offering a genuine possibility for individual learning [25]. The project should additionally aim to bridge the divide between theoretical academic study and the practical implementation of such knowledge within the context of engineering practice. To fulfil the aforementioned needs, the optimal design project must meet the following criteria [23]:

- The project necessitates an integrative approach, wherein the student is required to combine the knowledge and concepts from several disciplines within specific fields of engineering.
- Every project necessitates a significant level of analysis, as the process of synthesis typically demands it.
- The project necessitates the incorporation of significant synthesis, wherein a range of possibilities must be thoroughly examined, assessed, and ultimately, the most appropriate solution chosen.
- The presentation, which encompasses a written report, a drawing, and an oral presentation, should adhere to professional standards in terms of quality.

Depending on the field of engineering, there may be extra criteria as well. Furthermore, there exist supplementary prerequisites that vary based on the particular field of engineering. Additional necessities shared by all branches of engineering are the following:

- Economic analysis - Cost analysis is an essential component of any item's design, regardless of whether it is a single or mass-produced item.
- Safety analysis - There are few, if any, products that will not have an impact on safety. Safety is not some arcane, meaningless requirement that should be avoided at all costs but rather a significant matter that every engineer must address.
- Final evaluation - The proposed design's final evaluation should be a critical self-evaluation of teamwork. This evaluation should take into account how good the design is, what would be required to finish the design, and what improvements could be recommended to improve the design.
- Environmental impact - Environmental challenges have become critical, and any engineering solution's environmental repercussions (good or bad) should be properly evaluated and addressed.
- Social impact – it may be considered an aspect of environmental effects; however, it can also be examined independently regarding the impact of engineering solutions on community dynamics and the welfare of individuals and families.

The standard design project might be done in a certain sequence [26]. Three major steps can be identified:

- An algorithmic method to design, cost calculation, and economic evaluations would result from the first step, which includes defining and identifying problems, making proposals, searching, and optimization approaches.
- Step two provides a comprehensive design experience overseen by experts. In this stage, the project's real design is the focus.
- Step three comprises finishing the design project, managing design liabilities, preparing design presentations, writing design reports, evaluating design, and creating design manuals.

In addition to its instructional value, the project holds significance for students because it may lead to other benefits like improved employment opportunities or exclusive recognition [27]. A summary of some of the things that students should think about is provided below:

- A student who completes a project well develops self-confidence, which benefits him or her in other areas of work and is noticed by hiring managers.
- A lot of students write quick summaries of their projects and bring these documents to interviews. This endeavor may have a big impact.
- National awards for student design projects are given in certain countries. Many students have projects that are qualified for entry to these contests each year. The prizes are big, but the influence on one's resume is more essential.

The assignment should ideally be completed in groups to offer students teamwork skills[28]. It would also facilitate communication with the supervisor and allow for the open sharing of ideas among peers[29]. Team projects provide opportunities to get expertise in resolving team issues and working with people who are not necessarily friends [30].

Teaching or supervising a final-year project, on the other hand, is not without difficulties for academic staff and must be approached with caution [7]. There are various issues associated with project launching and supervision, and the following items, in particular, require close attention from staff:

- The project scope must be defined and chosen with caution.
- propriate scheduling of time and resources.
- Efficiently handling uncertainties associated with the project's open-ended nature.
- A method that successfully resolves conflicts.

It is only strongly advised—though generally not a legal requirement—that the final-year projects originate from the industry. Such projects have the advantage of adding a new flavour to the course because the students are actually working on real-life engineering problems and have direct interaction with professionals from the industry, notwithstanding the possibility of some management challenges.

2.2. Capstone Purpose in Literature

Lee discusses capstone purpose details in Lee and Loton [31]. Here are the details of that purpose.

2.2.1. Knowledge and Skills

One of the most prominent issues concerning capstone objectives in literature is the creation, application, and evaluation of discipline knowledge. Most authors think that the integration or synthesis of previously acquired knowledge should be the main emphasis of capstone projects rather than the imparting of new topic knowledge. Furthermore, even if previous knowledge may be reviewed during the capstone experience, the majority of authors view this as a mostly integrative and expanded process rather than a remedial one [32]. Capstone projects often require "attainment of higher order knowledge and critical analysis" in addition to the integration of previously acquired knowledge. In general, analysis refers to a topic, problem, or challenge examination and thorough research that serves as the foundation for a response [33].

The case literature frequently addresses the application of knowledge and the development of technical skills, whether the focus is purely on the intellectual challenge of synthesis and analysis, includes practical applications like creating an artifact, or involves more field-based applications like industry projects and placements. Authors of Khmelevsky [34] research-focused curricula are used to integrate technical skills and knowledge, and in Martonosi and Williams [35] a capstone research project is outlined that uses statistical skills to analyze and understand the creation and evaluation of international business knowledge.

The literature also emphasizes the attainment of high-level capacity in what is generally seen as employability skills. These abilities include decision-making, creativity, critical thinking, communication, management (particularly project management), and cooperative problem-solving[36]. The acquisition of these skills is typically identified in case research as occurring through team-based learning. These abilities definitely seem to have been used specifically in a lot of capstone projects. In their research of capstones at American liberal arts institutions, they discovered that the majority of students thought their capstone experiences had enhanced their communication and project management abilities.

2.2.2. Preparation For the Next Stage of the Student Journey

In studyLee and Loton [31] "connections between the academic major and the work world" and "career preparation and pre professional development" were ranked second and third among capstone purposes, respectively, after integration and synthesis of academic studies, in addition to skills that may be relevant to future employment. Undoubtedly, a lot of authors believe that capstone projects help students get real-world experience in a professional setting while also preparing them for when they join the job. Often, this application takes the shape of a project or placement-related simulated or actual conversation with a client. Several writers discuss the value of giving students networking chances and proof of the kinds of skills employers look for; these things can also help students' portfolios and resumes. Recently, there has been a strong emphasis on the formation of a professional identity through capstone experience, which is frequently associated with the idea of transition and the enhancement of employability skills.

Equally frequently mentioned as an organizing element in capstone curriculum design is the acquisition of research skills and integration into research cultures, which are connected to either post-graduate study or future research professions. Capstones are the place where "all the skills of research developed in earlier work should be assembled in a project that demands the framing of a significant question in a community of senior researchers, graduate students, and undergraduate peers," according to the Lee and Loton [37] which serves as an example of this focus. As a result, the expected next step for graduates differs throughout works of literature; some are clearly intended to help them enter the workforce, while others are more focused on scholarly research or additional study. Although employability and research skills are not always mutually exclusive aims, there will probably be distinct variances in curriculum emphasis in cases where one is expressly given preference.

2.2.3. Personal Attributes and Development

The literature on capstones also extensively involves the dispositional and personal components of student development, which are commonly referred to as characteristics. Many authors contend that the development of personal qualities like independence, accountability, resilience, self-efficacy, and confidence is the express goal of capstones and that this is how they should be created[38]. An empirical study by Schermer and Gray [39] revealed a widespread belief that capstones foster resilience, self-awareness, and independence. They contend that the size and complexity of capstone projects foster confidence-building, with students frequently concluding that they are "capstone confident that they can achieve more than they thought". Through the consolidation of students' lifetime learning abilities, such as resilience, self-confidence, and self-efficacy, as the cornerstone for their future professional and personal lives, a good capstone experience aids transition. In summary, existing literature indicates capstones are intended to cultivate students' personal attributes and self-concept in addition to their knowledge and skills. However, more empirical research is needed to substantiate these perceived benefits and evaluate capstone designs for achieving dispositional development.

2.2.4. Quality Assurance and External Drivers

In scholarly discourse, two distinct approaches concerning capstones are identified in the realm of quality assurance. The first centers on external quality review, where capstones are perceived as a pivotal data source for evaluating program quality and assessing student achievement. This evaluation occurs through benchmarking and audit activities, as recognized by various scholarly sources[40]. Concurrently, a substantial body of literature suggests that assuring graduate quality is the primary aim of capstones. The fundamental premise is that capstones serve as a culmination, testing the knowledge and skills acquired throughout a program via reiteration, synthesis, and application. Consequently, the capstone is perceived as an inherent test of graduate quality and their preparedness to transition to the next phase [41]. This perspective often instigates a debate regarding the purpose of capstones, whether they should primarily conclude and validate a program of study or offer avenues for personalized personal and professional development [42]. Furthermore, many institutions worldwide have formalized capstone requirements in their policies and strategic plans, motivated by professional accreditation demands or recommendations in national or discipline-based reviews and reports[43].

Beyond the academic confines, capstone projects potentially offer benefits to universities. While less emphasized in recent literature, there is evidence suggesting that students contribute to staff research activities in various capacities, such as research partners, apprentices, assistants, or interns[44]. Industry-focused capstones, particularly those involving student placements or projects with external partners, yield institutional and staff benefits through partnership development with external organizations[45]. Additionally, they serve to counter perceptions that university programs have limited relevance to employability[46].

3. Research Methodology

The systematic literature review (SLR) addresses specific research questions, while a broad survey study provides a general overview of the topic. The SLR methodology encompasses several distinct steps, which can be grouped into three main stages: planning, implementation, and reporting[47]. This paper aims to present a comprehensive analysis of the final year capstone project and explain the specific engineering discipline used in this endeavor. The SLR process facilitates the identification of available studies within the field of final-year capstone projects and assists in answering various research questions. The various stages of a systematic literature review are illustrated in Figure 1.

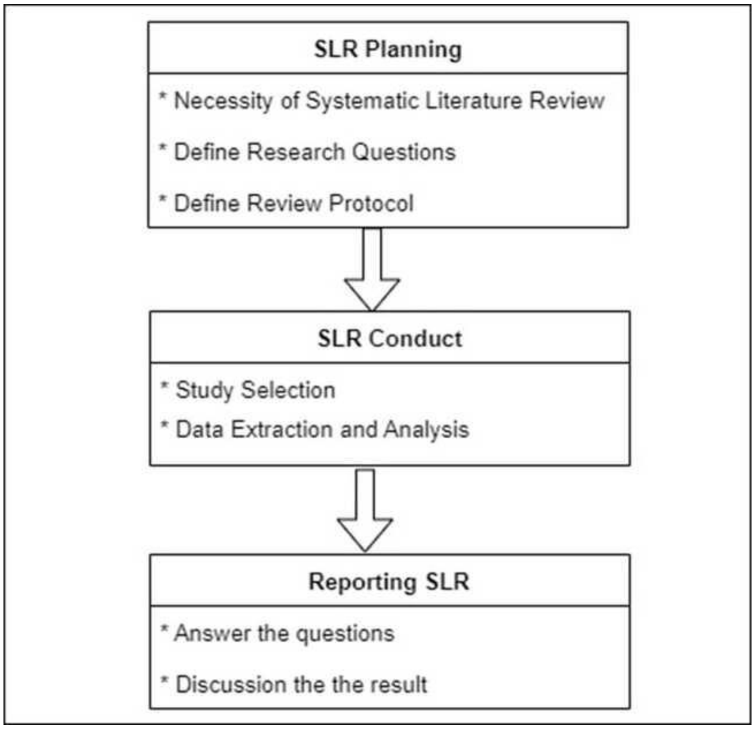

Figure 1.
SLR Process.

3.1. SLR Planning

The SLR's goal and research topics are set in the planning phase of the review. In addition, a precise review methodology is created. It entails creating a search procedure approach as well as the research's inclusion/exclusion guidelines.

3.1.1. Necessity of Systematic Review

The most comprehensive evidence from the current literature must be accumulated. The Systematic Literature Review (SLR) approach is deemed the most efficient method for collecting and examining evidence from primary sources. Additionally, the importance of the different methodologies employed to address each research query is thoroughly evaluated. This task is performed in compliance with the guidelines outlined inKeele [48].

3.1.2. Research Questions

This systematic literature review systematically organizes and categorizes the existing literature on the final year capstone project. The purpose of this review is to critically examine the current research in order to identify potential opportunities, recognize areas of deficiency, and formulate new research avenues for future studies. Developing clear and concise research questions is a crucial component of a systematic literature review; thus, a series of research questions were devised and incorporated into the collected data to conclude the systematic literature review.
RQ1: How many countries and universities are involved in researching final-year capstone projects?
RQ2: How many engineering subjects include the final year capstone project?
RQ3: Which accreditation bodies are involved in the accreditation for the currently available capstone projects?
RQ4: How long are capstone courses, and what are the benefits or drawbacks of a specific duration?

3.1.3. Research Protocol

The protocol for conducting this systematic literature review is outlined in the subsequent section. The protocol includes a comprehensive description of the search process, the selection criteria for studies, and the methodology used for data analysis.

Search Process: As the focus of this review is on the final year capstone project, a well-constructed search string is needed to identify relevant references in the literature. The search string should consist of a few crucial terms. Those are "Capstone Project/Final year project/ Final year capstone projects/ Senior design projects/ Capstone course".

Google Scholar: 607 Results for: [All: "Capstone Project"] OR [All: "Final year project"] OR [All: "Final year capstone projects"] OR [All: "Senior design projects",] OR [All: "Capstone course"] AND [E-Publication Date: (01/01/2015 to 31/12/2024).

Springer: Capstone Project, Final year project, Final year capstone projects, Senior design projects, Capstone course. Showing 1-20 of 1,416 results.

IEEE Explore: Showing 1-25 of 277 results for ("All Metadata":"Capstone Project") OR ("All Metadata":"Final year project") OR ("All Metadata":"Final year capstone projects") OR ("All Metadata":"Senior design projects") OR ("All Metadata": "Capstone course") Filters Applied: 2015 - 2024.

Science Direct: 790 results were obtained using Capstone Project, Final year project, Final year capstone projects, Senior design projects, Capstone course, and search string from 2015 to 2024.

ACM Digital Library: 481 Results for: [All: Capstone Project, Final year project, Final year capstone projects, Senior design projects, Capstone course] AND [E-Publication Date: (01/01/2015 to 31/12/2024)].

3.1.4. Selection of Studies

This study performed a primary search utilizing online research databases such as Springer, IEEE, Science Direct, and ACM, as well as conference proceedings, e-journals, and review articles. The research team employed Google and Google Scholar to access the research databases. Various types of publications and contributions were considered, including journals, conferences, peer-reviewed books, workshops, and Internet publishing. The search criteria werebased on the title, abstract, keywords, and full text of the collected articles, and studies were selected for Systematic Literature Review (SLR) based on the inclusion/exclusion criteria outlined in Table 1.

3.1.5. Criteria For Inclusion and Exclusion

We established some inclusion and exclusion criteria to employ the most important findings in our research. The first inclusion criterion was formed by perusing the science discipline for search terms that appeared in titles, abstracts, and keywords in research articles; recognition of useful ones was found. Papers published in non-English written studies, on the other hand, must be excluded. Papers will be screened for SLR using the inclusion/exclusion criteria shown in Table 1.

Table 1.
Inclusion and Exclusion Criteria.

Sl	Inclusion Criteria	Exclusion Criteria
01	The search string is fulfilled by research publications	Papers that are unrelated to the capstone project or course
02	journals, conferences, Workshop Papers, book chapters	Personal blogs, webpages, and PowerPoint presentations
03	All studies that have been published in the English language	Papers are not in Full text from
04	Take a look at papers that reference the capstone/final year project	Duplicates studies
05	Full-text papers	studies with no involvement/ Contribution on FYCP
06	Publication Date From 2015 until 2024	

3.2. SLR Conduct

3.2.1. Selection of the Studies

The query returns a large number of potential research articles, such as scholarly articles, research articles, and book chapters. In the first stage of the search, prospective studies were gathered from interactive web libraries. We were required to critically analyze and investigate each collected work in order to achieve good and precise answers to the specific study questions. As a result, the inclusion criteria process was created to be scrutinized. The PRISMA is used to identify research articles from search queries. The selection procedure for primary studies, according to PRISMA 2020Page [49] consists of three stages: identification, screening, and inclusion. Throughout the initial stage, all studies are discovered by exploring online databases using the search phrase.

4. Result

4.1. Result of the Search

The selection procedure for primary studies, according to PRISMA 2020, has three parts: identification, screening, and inclusion. During the first stage (identification), all studies are discovered by searching online databases with the search keyword. From the 3,571 studies discovered in the identification stage, 189 duplicates have been eliminated. In the second step, 1332 records are deleted in the screening step based on the exclusion criterion. 145 papers could not be retrieved because the database does not allow us to download them. After that, 1261 articles were deleted in the screening step after reading the title and abstracts. Finally, 282 papers were discarded due to poor quality and clarity. After examining all 201 publications, the ranking system for this SLR was determined to be 42 articles. To keep each research at every level, both authors must share the same opinion throughout the selection process. If there are disagreements about the preliminary investigation, the third author decides whether to keep it in this step of the selection process.

4.2. The Number of Papers Based on Different Curricula

4.2.1. Aerospace Engineering

Taheri, et al. [50] explored the assessment methods employed to measure the effectiveness of student learning in an aerospace capstone project within the NSERC Chair in Aerospace Design Engineering (NCADE) program at Concordia University. Utilizing a deep learning approach, the capstone project aims to enhance students' application of engineering knowledge to real-world problems. The assessment methods examined include the Study Process Questionnaire (SPQ), Approaches to Study Inventory (ASI), Concept Mapping Technique (CMT), and Recursive Object Model (ROM). The focus is on evaluating students' learning in both cognitive (knowledge and skills) and affective domains. The paper not only investigates these assessment tools but also discusses their implementation for ongoing continuous improvement throughout the capstone project. This research contributes to the literature by providing insights into effective assessment strategies for evaluating deep learning outcomes in aerospace capstone projects.

Gutierrez, et al. [51] discussed the implementation of a final year undergraduate engineering capstone project by the NSERC Chair in Aerospace Design Engineering (NCADE) at Concordia University, aimed at addressing challenges in the aerospace industry. The objective is to expose students to the complexity of aircraft design to better align with industry needs. The study evaluates four design methodologies (systems engineering - SE, quality function deployment - QFD, theory of inventive problem solving - TRIZ, and environment-based design - EBD) within the NCADE project, assessing their effectiveness in supporting project activities. The evaluation, conducted subjectively, concludes that the studied design methodologies inadequately support capstone project activities. The paper suggests the need for future research to explore more effective methodologies to better fulfill NCADE's goals in the capstone project. This research contributes to the literature by highlighting challenges in utilizing specific design methodologies within aerospace capstone projects and advocating for improved support mechanisms.

Cartile, et al. [52]investigates the effectiveness of aerospace design engineering education by addressing anecdotal feedback from various stakeholders, including the aerospace industry, the Canadian government, the University, and enrolled engineering students. Despite the implementation of curriculum reform initiatives, the impact of these changes has not been quantitatively studied. To fill this gap, the paper proposes a comprehensive approach that integrates a theoretical model of design creativity, the statistical methodology, and a case study involving an aerospace undergraduate capstone team. The objective is to develop a tool for the quantitative evaluation of the effectiveness of aerospace design engineering education. This research contributes to the literature by providing a systematic and quantitative assessment of the impact of curriculum reforms on design engineering education within the aerospace domain.

4.2.2. Biomedical Engineering

Demaria, et al. [53] investigated the perspectives of senior Biomedical Science students regarding the essential work competencies, both before and after completing a required capstone course that emphasized the acquisition of transferable skills. The findings derived from pre-unit and post-unit surveys indicated the following regarding students: 1) They placed greater importance on communication skills rather than discipline knowledge or technical skills in terms of future employment; 2) They perceived that their transferable skills had improved throughout their degree; 4) They developed these skills through both assessed and non-assessed learning activities; and 5) They were capable of providing specific instances of transferable skills encountered in the workplace. We propose that capstone units of STEM degrees be utilized to explicitly emphasize transferable skills in order to help senior-year students acquire such abilities, thereby enhancing the employability and future career success of

4.2.2.1. Graduates

Ostrowski, et al. [54] investigate the ideation habits of BME students in a capstone design course during a specified team ideation session and make recommendations for structuring idea generation education. During their concept generation sessions, five student teams were recorded. A subset of students was interviewed after the session. Thematic themes connected to design activities and factors influencing idea development were revealed through qualitative analysis of transcripts. During generation, students frequently transitioned into convergent idea evaluation tasks. Course activities and frameworks, design criteria, and sponsor comments all shaped their approaches to ideation.

Suh and Ahrar [55] discusses an educational initiative designed to enhance system integration skills for Biomedical Engineering (BME) students before they begin their open-ended Capstone projects. Recognizing the interdisciplinary nature of BME and the challenges students face in integrating various components into a functional system, the intervention introduced three connected modules within a junior-level course. These modules focused on developing a Do-It-Yourself (DIY) spectrophotometer/colorimeter, encompassing electrical circuit design, mechanical hardware creation, and design impact analysis. The spectrophotometer/colorimeter was chosen as the central theme due to its relevance and complexity, requiring students to integrate multiple subsystems to achieve overall functionality. The intervention provided formative feedback and utilized presentations, reports, and exams to assess student progress. While not formally evaluated, the initiative was well-received by students and improved their readiness for Capstone projects by allowing them to practice system integration in a structured and hands-on environment.

4.2.3. Food Microbiology

Zhang and Ranadheera [56] described the redesign of a food science major capstone subject at The University of Melbourne for bichronous ERT delivery. The original goal of the subject was to equip students with communication, analytical, and problem-solving skills through practical experimentation in the lab or internship projects. We updated the online learning environment in 2020 to best support individualized learning and collaborative partnerships between students, teachers, and subject matter when face-to-face interactions become impractical. Among the four main subjects covered by this are food microbiology, data mining, and literature reviews that are redeveloped from laboratory-based initiatives. Even with the disadvantages of remote delivery of peer-based interactions, design-based research participation is still a feasible way to help students acquire critical transferable skills during ERT.

4.2.4. Civil Engineering

Jagupilla, et al. [57] describe a successful approach to enhancing the senior design course in a civil engineering undergraduate program. The approach integrates technical, educational, and industry elements through collaboration among a technical advisor, course instructor, course facilitator, and industry sponsor. The results show high student satisfaction, particularly among seniors, with significant improvements in industry engagement and professional opportunities. This success is attributed to the department's focus on integrating industry contacts into the undergraduate experience. As students transition to alumni, their continued connection with the institute is expected to support ongoing program development. The approach has streamlined departmental activities, saving time and enhancing student outcomes. However, adapting this model to programs of different sizes may require adjustments in the setup and role distribution.

Hungness, et al. [58] discusses the integration of community partnerships and industry collaboration into the senior design capstone course for Civil and Environmental Engineering (CEE) students at the University of Wisconsin-Madison. It highlights the challenge of continuously sourcing unique public works projects across various CEE sectors for a growing undergraduate program. The paper introduces a novel approach, focusing on a long-standing partnership with the UW-Madison University Year program, which aligns real-world community needs with academic coursework under the guiding philosophy of "The Wisconsin

Idea." This partnership allows students to engage in practical, community-driven projects that enhance their learning experience while contributing to societal needs. Additionally, the involvement of industry professionals, recognized as Professors of Practice, further strengthens the program by bridging the gap between academic learning and professional practice, preparing students for the workforce.

Chan, et al. [59] give evidence-based findings from students regarding a capstone design course in a civil engineering school in Hong Kong. A student-experience questionnaire was created to generate evidence. Internal consistency of the questionnaire instrument was examined on four measures (curriculum and structural adjustments; design and problem- solving; personal and transferable abilities;

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and industrial links and Real-Life Authentic Academic Knowledge). Each scale's interior structure was also analyzed independently. Overall, the results indicate that this internal structure is unidimensional and has good internal consistency. Our quantitative and qualitative data support the student learning experience in the reformed capstone design: how students were able to develop depth and breadth in engineering knowledge and skills that were previously not covered by teachers in conventional taught courses to enhance student learning. The curriculum's rationale and revisions were documented in order to contribute to the development of an authentic capstone-design curriculum.

The capstone course at North Dakota State University, USA, was designed by Padmanabhan, et al. [60] as an innovative approach to address the Accreditation Board of Engineering and Technology's (ABET) request for improved and streamlined design instruction in the curriculum. Since then, it has undergone consistent development to align with the advancements in technology, professional standards, and societal demands. By definition, a capstone design course should provide students in their final year prior to graduation with a design experience that integrates all the main design concepts they have acquired thus far in the program. In this collaborative course, students are tasked with design-oriented real-world projects that span across all subdisciplines of civil engineering. These projects have been meticulously selected. Presentation topics include the design process, project management, leadership within an engineering environment, public policy, global perspectives in engineering, professional careers and licensers, and topics chosen by faculty and practicing professionals. Additionally, professional practitioners evaluate the culminating student presentations. A number of faculty members serve as technical consultants, and a faculty mentor provides non-technical guidance and direction to each team of students. Students are expected to exhibit proficiency in the subject matter and collaborate effectively within a group setting. Evaluation of the final design, presentations, written technical reports, a project design journal, the project design schedule, and reaction papers comprise the course evaluation.

Labossière and Roy [61] describes the testing of an original concept for a culminating project during the Fall 2000 term at the Université de Sherbrooke. All graduating class members were required to create complementary components for a single open-ended project for this assignment. Five consulting firms comprised the consortium that was tasked with coordinating their design efforts in order to provide the client with a unified, comprehensive, and integrated proposal. An essential element of the undertaking was the execution of a novel coordination strategy. In the paper, the conceptual components of this novel capstone endeavor are described. A discussion of the organizational aspects is provided with the academic constraints and requirements in mind. The paper offers a critical evaluation of the results obtained from theendeavor. The paper provides an assessment of the project's educational merit as perceived by the coordinating professor and incorporates the views of the students, who were invited to reexamine this pedagogical experiment subsequent to a decade of professional experience.

Brown and Morris [62] describes the design and execution of a capstone project for senior-year civil engineering students at the University of Auckland, New Zealand. The Capstone project, which is grounded in the operations of a civil engineering design office, provides students with the opportunity to actively participate in an open-ended, real-world under-taking. By collaborating in teams to deliver an engineering design report and presentation that must accomplish tangible, coordinated results for a non-specialist client, students apply their acquired technical knowledge. Annually, the Capstone design project is determined in collaboration with regional engineering professionals, enabling students to engage in a demanding civil engineering endeavor.

Gnanapragasam and Canney [63] focuses on the development of a rubric for assessing year-long civil engineering capstone projects within the context of project-based learning. The challenges in assessing such projects arise from the variability in content, difficulty, and required deliverables across different teams. The paper highlights the difficulty in achieving consistent assessment, especially in diverse engineering disciplines. It addresses issues related to faculty perceptions of Likert scales and the need for a grading system accounting for project complexity. To enhance consistency in grading student proposals and final reports, the paper introduces an in-progress rubric designed to normalize grades across faculty members and consider disciplinary expertise and project difficulty. The preliminary inter-rater reliability evidence is presented and derived from academic and professional reviewers. The paper aims to contribute a useful grading tool for engineering programs employing project-based learning, particularly those requiring final written documents for assessment.

According to this study by Leu and Liu [64] IEET, all civil engineering programs in Taiwan have some kind of capstone course in place. However, IEET also discovered that different programs have different perspectives on the essential components of a capstone course. IEET needs to give the programs extra training and mentorship in order for them to apply the new demand on the Capstone Course. This will ensure that in a few years, all programs will be able to submit documentation proving they meet the IEET requirements.

Lee and Kim [65]suggest utilizing the project-based learning methodology to create a brand-new Senior Capstone course. A Senior Capstone course is currently being developed by the Construction Management (CM) program at Central Connecticut State University (CCSU). The course will employ the ADDIE (Analyze, Design, Develop, Implement, Evalu-ate) approach, which is a tried-and-true method of instructional design. The study's primary goal is to show how a methodical approach can be used to create a Senior Capstone course for degrees in construction engineering and management. This paper showcases the authors' progress toward a Senior Capstone course development while the course is still in its developmental stages. The authors anticipate that once this course is finished, it will help students make the transition from the classroom to the workplace by giving them a chance to develop and demonstrate their critical thinking and problem-solving abilities.

4.2.5. Manufacture Engineering

Viswanathan [66] centers on three distinct capstone projects undertaken within an undergraduate program in manufacturing design engineering. The projects encompass the design of an office chair, the development of an enhanced balloon marker positioning system for catheter manufacture, and the design of a modular motorcycle helmet. This article provides a summary of the design approaches and strategies implemented by the students and faculty members. Furthermore, this scholarly article utilizes the knowledge acquired from engagement in these projects to elucidate the optimal approach for designing a capstone project in the field of manufacturing design engineering, with the aim of achieving the utmost efficacy. Within the given setting, this paper gives a comprehensive range of recommendations and guidelines.

4.2.6. Computer Science and Engineering

Haji Amin Shirazi, et al. [67] reports on an intervention in a senior capstone course for Computer Science students that aimed to enhance their oral communication and public speaking skills, which are crucial for technical and non-technical settings. By integrating targeted training in team management, public speaking, and leadership into the course, the authors observed a significant improvement in students' confidence and communication abilities, particularly among underrepresented minority students. This intervention demonstrated that incorporating communication skills training alongside technical education in capstone courses can effectively prepare students for the diverse communication demands in their professional careers.

Rad and Lynch [68] of this paper propose a new approach to funding capstone design projects within the School of Engineering and Computer Science at Washington State University – Vancouver. Traditionally, students engaged in two semester, team-based projects funded by local industries at no cost. However, beginning in the 2022-2023 academic year, the authors introduced a modest fee for industry-sponsored projects. This paper outlines the strategies employed to attract industry funding and discusses the outcomes of implementing these fees as part of the capstone program.

We provide our students with a specific learning outcome, as outlined byBastarrica, et al. [69] which focuses on the importance of acquiring and cultivating important soft skills in order to achieve success in project-based endeavors. In the previous academic year, there was a concern regarding the extent to which our pupils were effectively in their projects, namely technical challenge, teamwork, planning, and negotiation with the client. In order to assess the statistical significance of the survey results, we conducted a one-tailed dependent paired sample t-test. It has been determined that the significance of soft skills is increasing while the importance of technical challenges is diminishing. Additionally, students have expressed that they encounter greater difficulty than anticipated in areas such as planning and teamwork. Furthermore, our analysis has revealed statistically significant findings indicating that the perceived relative importance of the tested soft skills changes for the duration of the course.

Deepamala and Shobha [70]examines the methodology employed over a span of three consecutive academic years (2014-2017) to evaluate the performance of a cohort consisting of 180 students every year. The assessment of student performance during the Final Year Project course over a three-year period can be effectively measured through various means, including training sessions, evaluation rubrics, utilization of project management tools, alignment of student performance with course and program outcomes, and feedback from stakeholders such as companies and students. These methods collectively provide a comprehensive and accurate understanding of the student's progress and improvement throughout the course.

Domínguez, et al. [71]examine the variables that assessors of engineering capstone projects take into account and how these variables affect the differences in assessors' evaluations of the same project. 162 capstone projects in computer science engineering that were created by a single student under the guidance of a single advisor were quantitatively analyzed in this study. A committee and the project advisor evaluated each project. Each project had an additional questionnaire on product qualities, student competencies, and project supervision that the advisor and committee were required to fill out. When the committee and adviser assessed a capstone project, the competencies displayed by the student were deemed to be the most important factor; product attributes came in second. Moreover, advisors assign a low priority to the advisor-involvement element. Grade disparities appear to be related to areas where one assessor has access while the other does not, including the abilities students displayed when working on a project or how well they performed in the oral defence. In evaluating this intricate undertaking, the viewpoints of the committee and the advisor are complementary and both significant.

Olarte, et al. [72]investigate the differences in staff and student opinions of a number of key components related to finishing this specific project. These components include the qualities of the project, student competencies, advisor involvement, and the student's perceptions of their learning. The primary finding of this study indicates a notable discrepancy in the expectations held by staff and students. In particular, it has been shown that students, as opposed to professionals, typically have a more positive opinion of their projects, their skills, and the advice they receive. However, review committees and advisers often concur that projects have similar attributes. The way in which students view their learning outcomes may not always correspond with their happiness levels or grades. This discussion emphasizes how important it is to improve the efficacy and clarity of communication when it comes to stated expectations for staff and students.

The development of the University of Ljubljana's software engineering capstone course from its inception in the 2008–09 academic year to the present is detailed by, Mahnič [73]. The most popular agile methodology, Scrum, must be closely followed by students who are creating a project that is almost real. Furthermore, the course design makes it possible to carry out research that adds to the body of empirical knowledge about agile processes. The article covers

the course design provides an explanation of the rationale behind integrating Scrum, provides examples of empirical investigations carried out inside the course, and concludes with a course upgrade that incorporates lean approaches to software development. The overwhelming majority of students'

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feedback on the course is favorable, suggesting that it is both engaging and helpful for their professional and employment prospects.

Damaj and Yousafzai [74]present a unified methodology for evaluating student outcomes that are based on undergraduate computer engineering students' senior design experiences. Senior design projects give students exceptional chances to showcase the knowledge, expertise, and experiences they have gained throughout their Bachelor of Engineering degree. Senior design classes and capstone design projects serve as the foundation for the suggested structure. It is possible to carefully craft senior design course learning objectives that correspond to every student outcome. As a result, senior design courses can result in precise program-level evaluations and a straightforward senior course configuration. The suggested approach enables accurate assessments of student performance and project attributes. The resultant framework includes a summative statistical formulation, thorough analytic rubrics, indicators, and criteria. A pilot study's evaluative and comparative analyses of the course and student outcome assessments bolster the framework.

Parker [75]examine affective reaction as a determinant of professional identity building and involvement in the university-to-work transition, as reinforced by a senior capstone project experience. Through qualitative interviewing, we highlight three distinct ways that affective responses provide value to the student experience, with a particular emphasis on students discussing their emotional reactions throughout the capstone project. First, when a project is being pitched and later evaluated, students are open to the emotional responses of the sponsors. Second, affective reactions from students are evident across the whole capstone project experience and fluctuate greatly throughout the project's duration. Third, student affective responses are connected to the practical effects of project outcomes and offer a measure of their involvement and commitment to the projects. This essay provides a theoretical framework for emphasizing affective responses in the classroom as a means of fostering involvement and the development of a professional identity. We wrap up by making recommendations on how these findings might influence the advancement of education in the field of computer science.

Malik, et al. [76] addresses the issue of subjectivity in the evaluation of capstone projects in computer science. Acknowledging the lack of awareness among students regarding the evaluation process, the authors propose a solution by categorizing types of capstone projects and introducing a new evaluation model. The paper includes rubrics for each identified project category, offering a standardized grading scale. To enhance the robustness of their findings, the authors gather input from professors across more than six universities, both national and international. The results of this collaborative effort are reported and critically analyzed, providing valuable insights into factors influencing the evaluation of computer science capstone projects. This research contributes to the literature by offering a systematic approach to mitigate subjectivity in the evaluation process and by providing a comprehensive analysis of the proposed evaluation model based on input from a diverse group of academic professionals.

Jaime, et al. [77]investigate the synergies between internships and computer science engineering capstone projects, examining their combined impact on student competencies, project outcomes, and supervision efforts. The research, based on data from 274 capstone projects, supports the hypothesis that completing internships positively influences various aspects of subsequent projects, enhancing student skills in autonomy, technology, methodology, and project management. The findings reveal increased project complexity and technological novelty, as well as a reduction in advisor involvement in practical issues and a simultaneous rise in engagement in monitoring student work. Notably, these positive effects are observed across both industrial and academic capstone projects, highlighting the universal benefits of integrating internships into computer science engineering curricula. This research adds valuable insights to the existing literature on work-related learning, specifically in the context of the interaction between internships and capstone projects in computer science education.

Ferdiana [78] address challenges in assessing software engineering capstone projects, emphasizing issues of subjectivity and the absence of standardization in assessment models. Proposing a triangulation assessment model developed through a Delphi study in the academic year of winter and spring 2019, the paper evaluates its consistency across ten projects. The Delphi study identifies three main contributions: defining typical software engineering capstone projects, implementing the triangulation assessment model, and identifying characteristics of successful projects. This research provides a systematic solution to assessment challenges in software engineering capstone projects and contributes a framework for consistent evaluation of the existing literature.

Elfaki and Bassfar [79]addresses challenges in managing final-year projects (FYPs) in information technology (IT) programs, particularly those utilizing the traditional software development life cycle approach. Recognizing the distinct nature of educational software development, the paper proposes an alternative model by conducting a benchmarking exercise comparing business and educational software projects across ten project management knowledge areas. The findings high-light significant differences, leading to the modification of the capability maturity model integration (CMMI) to create an educational version (educational CMMI). The proposed model is evaluated using student results and questionnaire feedback, demonstrating its utility and applicability in the context of educational software development. This research contributes to the literature by offering a tailored software development model for educational purposes within IT and IT-related degree programs, providing valuable insights into enhancing the management of final-year projects in these domains.

Gottipati, et al. [80]discussed the implementation of a career track-based capstone course in Information Systems (IS) education at a large university. The authors highlight the importance of capstone projects in applying classroom knowledge to real-world problems and preparing students for various career paths in IS. They describe the design and delivery of a new capstone course aligned with different IS career tracks, involving over 100 students and 20 industry-sponsored projects. The study outlines the challenges faced in designing such a course and shares experiences from its first offering. Feedback from faculty supervisors and students indicates that the course largely met its learning objectives. The authors also discuss common concerns raised by stakeholders and interventions planned for future course offerings.

4.2.7. Architecture Engineering

Jung, et al. [81] a comprehensive curriculum for the CM & BIM studio is presented, encompassing specific teaching objectives and student deliverables. Myongji University tried a new way to teach future architects as a capstone project for the 5-year architecture program. To meet the common requirements for architects, which include "planning capability," "integrated understanding of design and construction," and "IT skills," new ways of teaching architects were tried. The name of this studio was CM&BIM studio, and it was mainly about three things: planning, life-cycle integration, and building information modeling (BIM). The initial identification of educational requirements throughout the era of emerging architecture was undertaken. The CM & BIM studio was introduced in 2012 as a case study to evaluate the adaptation of the planned curriculum. The comments provided by professors and architects have been validated and have provided positive reinforcement for the intended educational outcomes outlined in this study. In conclusion, this study provides an overview of the findings and imparts insights gained from the research.

Tafahomi and Chance [82] examined the challenges and evolution of capstone experiences in architectural education, particularly the shift from final-year design projects to research-based theses. Using a case study at an institution struggling with this transition, the authors identify gaps between the intended and enacted curricula, largely due to a lack of shared understanding among faculty and inadequate support for change. The study presents a new integrated model that aims to reconcile differing approaches to design and research education. The authors propose this model as a tool to foster dialogue and understanding among educators, encouraging a more unified and effective approach to capstone projects in architecture and engineering education. Future research is suggested to further explore the implementation of this model and its impact on students' transition from academic study to professional practice.

4.2.8. Electrical Engineering

The study by Bhuyan [83]examines the implementation and evaluation of lifelong learning as a program outcome (PO) within the Bachelor of Science in Electrical and Electronic Engineering curriculum at Southeast University. Specifically, the authors investigate the delivery, supervision, assessment, and evaluation of lifelong learning through the integration of three capstone design project (CDP) courses (EEE492, EEE494, and EEE496). Moreover, this article examines the process of formulating a suitable evaluation strategy and rubrics to determine the extent to which these three courses meet the requirements of this aspect of accreditation. The submitted data pertains to the evaluation of lifelong learning, as judged by the board of examiners during the final defense. In light of the aforementioned information, the accomplishments of the PO pertaining to lifelong learning are examined.

Pasya, et al. [84] address the existing assessment practices and associated difficulties while providing an overview of the Capstone Project implementation at the Faculty of Electrical Engineering, UniversitiTeknologi MARA (UiTM). The course outcomes demonstrated by the capstone project have a good correlation with the engineering program standards set out by Malaysia's Engineering Accreditation Council (EAC). The study made a number of suggestions for enhancing the evaluation processes for ethical skills and project consequences related to environmental concerns. In subsequent works, self-assessment surveys to assess students' experiences will be used and examined.

4.2.9. Medical Science

To replace a first-come, first-served student sign-up procedure, a methodical process was devised and executed byKennedy and Dickson [85] to match healthcare delivery students with quality improvement (QI) initiatives. The objective was to enhance the match's caliber and the capstone experience as a whole. The journals revealed the following three major themes: (1) According to the student, a "successful" QI capstone match encompasses both technical and affective elements; (2) "If you are not visible, they will forget about you;" and (3) Students desire capstone endeavors that are significant and have the capacity to have a wide-ranging influence. The results of our study indicate that affective elements, including a sense of acceptance and support at the site, have an impact on how students perceive the capstone match. These factors should be taken into account when designing experiential learning for quality improvement. In addition, academic program support, a structured matching procedure that incorporates behavioral interviewing, student input on project preferences, and robust community partnerships all contribute to high-quality work and abundant learning opportunities, which are to the advantage of the capstone site and the students. Those who organize experiential learning for students, including administrators, educators, and practitioners, may find these findings useful.

The global health capstone project is described byChamberlain, et al. [86] as a cutting-edge teaching tool used in a competency-based curriculum. The authors provide a definition and description of the longitudinal global health capstone, along with information on its specific requirements, student deliverables, and potential integrations with broader curricula to teach the competency domains recognized by the Consortium of Universities for Global Health. In order to characterize the features of finished capstone projects, the writers also examined the final capstone projects for 35 graduates. The global health capstone was created as one teaching resource for medical students as part of a larger global health curriculum. Out of the 35 capstone projects, 26 (74%) required conducting original research, and 25 (71%) involved traveling abroad. Five initiatives resulted in a publication (14%), whereas nine led to a conference abstract or presentation (26%). Faculty mentorship focused on topic areas was provided for twenty-one initiatives (60%).

4.2.10. Music

Augustine, et al. [87]examined the undergraduate program in Bachelor of Education (Music), with a specific emphasis on the course titled 'Final Performance Project'. While the primary focus of the program is on the development of high-quality teachers, the capstone project also serves to support students in their transition to employment opportunities beyond the field of education. The study inquiries centered on the assessment of strengths and problems inherent in the project, the manner in which it fosters the development of well-rounded people and potential strategies for enhancing its efficacy. The present study employed a survey methodology to gather data from both former and current final-year students enrolled in the Faculty of Music and Performing Arts. The findings indicate that the music capstone project has been effective in fostering the development of soft skills, including communication, leadership, and teamwork. However, it is worth noting that the students encountered certain hurdles during the course of the project. It is advisable to incorporate capstone projects in several disciplines as a means of equipping students with the necessary skills and knowledge prior to their transition into the professional realm.

4.2.11. Mechanical Engineering

Friess and Goupee [88] redesign the University of Maine's mechanical engineering capstone project, building on the program's current strengths and better meeting new demands related to student enrollment and ABET assessment. Additionally, the study aimed to enhance the overall student experience. After undergoing a successful restructuring, the assessment and evaluation process has been in place for two complete academic years. In the Capstone sequence, a total of 15 ABET performance indicators—corresponding to 7 Student Outcomes—are being examined using this method. The technology satisfies both course objectives and ABET SO standards by enabling the efficient assessment and evaluation of the customarily team-based deliverables on an individual basis.

4.2.12. Chemical Engineering

Hirshfield and Wisniewski [89]discusses an ongoing endeavor to revamp a chemical engineering capstone course by integrating an entrepreneurial approach. Previously, instructors defined project products, limiting student involvement in problem identification and creativity. In response to student feedback seeking more autonomy and creativity, the course was re-designed to allow teams to propose and pitch unique product ideas using entrepreneurial communication techniques. Class activities emphasized entrepreneurial skills, garnering positive feedback and enthusiasm from students. The conclusion indicates ongoing research with anticipated findings

from student evaluations to assess how the entrepreneurial context influences student perceptions and project valuation. This work-in-progress highlights the potential impact of an

entrepreneurial framework on students' approach and value of capstone projects, promising insights into the effectiveness of this innovative course structure.

4.2.13. Psychology

Bitz and Hair [90]examine the impact of a uniquely designed psychology capstone course at a small private Midwestern university, which focuses on developing students' under-standing of vocation, career strengths, and weaknesses, talents, goals, servant leadership, and life purpose. Through a 10-item questionnaire administered at the beginning and end of the course over four consecutive fall semesters, the study found significant perceived student growth in all areas measured. Students reported increased confidence in identifying their talents and goals, understanding their academic and career paths, and grasping the concepts of vocation and servant leadership. The results suggest that the course design effectively contributes to student development in these areas, making it a model potentially worth adopting in similar educational settings.

4.2.14. Animal Science

Brandão, et al. [91] employs a design-based research approach to refine the implementation of Design Thinking for Engaged Learning (DTEL) in an animal science capstone course over five iterations (spring 2021 to spring 2023). DTEL integrates design thinking into a collaborative, project-based learning framework aimed at developing problem-solving and team- work skills. Through the analysis of 276 student reflections, the study identifies challenges and strengths, leading to iterative course improvements that increasingly align student experiences with learning theories such as cognitive constructivism and social constructivism. Five key design principles emerged: prioritizing hands-on lab work, designating a course coordinator, scaffolding for instructors, maintaining consistency in processes, and fostering effective teamwork. These principles, while rooted in animal science, may also benefit other disciplines in agriculture and life sciences. The research highlights the value of iterative refinement and data-driven design for enhancing student learning experiences and suggests future investigations into the application of DTEL across broader curricula.

4.3. Application

In this subsection, we present a few key applications of final-year capstone projects developed by various departments.

4.3.1. Electrical Engineering

O'Neill-Carrillo, et al. [92] and Sykes, et al. [93]highlights the collaborative efforts between the University of Puerto Rico-Mayaguez (UPRM) and a local community to establish Puerto Rico's inaugural solar community in the southern region of the Island. The collaboration, rooted in community self-reliance initiatives and bolstered by strong community leadership, is propelled by the integration of electrical engineering capstone design projects. Initially planned as an expansion of the community center, the project evolved into a comprehensive solar community initiative, blending technology, citizen empowerment, social justice, and environmental sustainability. UPRM students engaged in capstone courses contributed to the design of an expanded community center building and a photovoltaic (PV) system, along with exploring various scenarios for implementing rooftop PV systems in surrounding houses. The interaction between students and community members resulted in documents pivotal for obtaining initial grants and subsequent community activities. Subsequent capstone courses in 2017 further delved into solar community design, enriching the community's knowledge towards energy autonomy. The collaboration not only emphasized technological advancements but also underscored the value of community activism and university partnership in fostering socio-economic initiatives like solar communities for achieving social and environmental equity. Assessment outcomes indicated the educational success of the design experience for students, fostering transformative growth both professionally and as responsible citizens. Additionally, the collaboration served as an interdisciplinary learning exchange, promoting social integration and challenging prevailing paradigms that often marginalize STEM students from excluded communities. Ultimately, the Coquí Solar collaboration exemplified the significance of community organization and locally driven sustainable endeavors while offering invaluable technical contributions through capstone design projects.

Sykes, et al. [93]investigates the integration of wide band-gap devices, specifically silicon carbide (SiC) converters, in an electrical engineering final-year capstone project. It examines how the adverse effects of these devices, such as increased harmonic content and EMI, were utilized as learning tools for students. Through a case study at the University of Newcastle, Australia, this approach aimed to consolidate and expand students' electrical engineering knowledge and research skills. The project served as a template for future electrical engineering endeavors, emphasizing its ability to solidify core degree aspects while offering an invaluable opportunity for the exploration of current power electronics research. Additionally, the conclusion underscores the potential for scalability and expansion of this project, suggesting further prototypes to minimize PCB size and integrate enhanced heat management strategies. This innovative project not only contributed to students' learning experiences but also holds promise for future iterations and enhancements in electrical engineering education.

4.3.2. Aeronautical Engineering

Anderson and Terrill [94] showcases aeronautical engineering design projects focusing on rigid wingsail vehicles, deemed suitable for undergraduate studies due to their alignment with core curriculum subjects. At the University of California San Diego, seniors in Aerospace Engineering have the opportunity to engage with wingsail technologies in their capstone design course, providing a departure from conventional aerospace projects. While some students opt for more traditional aircraft or spacecraft projects, those selecting wingsail projects find the challenge stimulating as it diverges from standard textbook examples. Continuous refinement of these projects, particularly to meet tight schedules within a ten-week quarter system, has led to the strategic integration of commercial sailboat kit parts and pre-assembled electronic components, streamlining assembly and allowing more time for experimental design and data analysis. Overall, these wingsail projects offer a fresh perspective to students, encouraging hands-on exploration while effectively meeting the essential accreditation outcomes for aeronautical engineering programs.

4.3.3. Chemical Engineering

Scholes [95]addresses the challenge of evaluating extensive calculation-based assessments in engineering capstone design projects, which often consist of complex spreadsheets, coding, and calculations spanning hundreds of pages. Educators struggle to assess these thoroughly within grading timeframes, necessitating quantitative tools for rapid evaluation. This study implements forensic auditing tools to analyze chemical engineering capstone design project assessments. These tools scrutinize data presentation, spreadsheet structure, and statistical principles to swiftly flag potential manipulation or calculation errors. Results demonstrate the effectiveness of forensic auditing tools in detecting student errors and misconduct, uncovering anomalies missed during standard grading. This approach offers a rapid and efficient means of verifying engineering student reports, relieving educators from time-consuming assessments, and allowing them to concentrate on ensuring the accuracy of design equations and procedures. Ultimately, the integration of forensic auditing tools presents a promising method to expedite the evaluation of extensive calculation-based assessments in engineering education, enhancing assessment efficiency and accuracy.

4.3.4. Environment Studies

Aoro [96] developed a semi-autonomous robotic system named Lotus as a prototype to gather field sensor data in the Salton Sea region of the Imperial Valley. Constructed using commercial-off-the-shelf components and powered by an 8-bit MCU and a 64-bit CPU, the system incorporates power management techniques like energy harvesting, charge control, and adaptive load control. It features a long-range wireless communication radio with a custom-designed antenna and utilizes TensorFlow's machine-learning algorithm for image recognition to minimize data transmission. This project fulfills a crucial capstone requirement for ABET accreditation while also establishing a framework for continuous improvement, aiming to raise awareness and propose solutions for a local environmental issue. The development of Lotus presents an innovative application of robotics and sensor technology to address environmental challenges, show-casing a significant contribution towards academic accreditation and community-focused problem-solving.

4.3.5. Electronics Engineering

Heymann and Greeff [97] explores the utilization of interactive, serious games as capstone projects for final-year Electrical and Electronic Engineering students, enabling them to showcase their acquired skills while addressing challenges beyond traditional engineering domains. Students developed electronic devices to attach to children, capturing motion data transmitted to a computer game, and transforming movements into game interactions. This innovative approach encourages active participation and potentially aids therapeutic interventions. Beyond meeting academic requirements, these projects exposed students to ethical, usability, and interdisciplinary challenges, fostering diverse problem-solving experiences. The study highlights how these capstone projects enriched students' learning by engaging them in real-world applications, expanding their skill set, and demonstrating engineering proficiency in varied fields beyond conventional boundaries.

4.3.6. Nursing

ThisEl Hussein, et al. [98] scoping review examines the experiences of final-year nursing students (FYNS) transitioning to newly graduated registered nurses (NGRN) during the COVID-19 pandemic. The authors analyzed peer-reviewed articles from 2019 to 2021, focusing on North America, Europe, and Australia. Three main themes emerged: emotional turmoil and coping, clinical competence and readiness for practice, and teaching strategies. The pandemic significantly impacted students' transition, highlighting the need for mental health support and innovative teaching methods. The review emphasizes the importance of integrating nursing students into

healthcare teams, providing adequate support, and implementing mentorship programs. Virtual simulations and online learning were found to be effective alternatives during the pandemic, though their long-term efficacy requires further study. The authors identify several gaps in the literature and suggest areas for future research, including the long-term effects of pandemic-related changes on nursing education and practice.

Table 2.
Summary of Capstone Design Research Studies.

Ref	Year	Author	Title	Source Title
Taheri, et al. [50]	2017	Taheri, S., Gutierrez, R.,Zeng, Y., & Marsden, C.	"Effectiveness Of Student Learning in An Aerospace Engineering Capstone Project: Investigation of Assessment Methods."	"Proceedings of the Canadian Engineering Education Association"
Gutierrez, et al. [51]	2017	Gutierrez, R., Liu, L., Singh, D., Marsden, C., & Zeng, Y.	"Which Design Methodologies Are Effective to Support a Capstone Project in Aerospace Design Engineering?"	"Proceedings of the Canadian Engineering Education Association"
Cartile, et al. [52]	2017	Cartile, A., Marsden, C. C., Zeng, Y., & Caron, B.	"Teaching Aircraft Design: A Case Study on An Alternative Engineering Undergraduate Capstone Final Year Project"	"Proceedings of the Canadian Engineering Education Association"
Demaria, et al. [53]	2018	Demaria, M. C., Hodgson, Y., & Czech, D. P.	"Perceptions of Transferable Skills among Biomedical Science Students in the Final Year of Their Degree: What are the Implications for Graduate Employability?"	"International Journal of Innovation in Science and Mathematics Education"
Suh and Ahrar [55]	2024	Suh, Ga-Young Kelly and Ahrar, Siavash	"Structured Modules to Promote Students' Readiness for Capstone Projects"	"Biomedical Engineering Education"
Ostrowski, et al. [54]	2020	Ostrowski, A. K., Daly, S. R., Huang-Saad, A., & Seifert, C. M.	"Idea Generation Practices in a Biomedical Engineering Capstone Course"	"IEEE Transactions on Education"
Zhang and Ranadheera [56]	2023	Zhang, Y., &Ranadheera, C. S.	"Redevelopment of Undergraduate Food Microbiology Capstone Projects for Unprecedented Emergency Remote Teaching During the COVID-19 Pandemic: Then and Now"	"Microbiology Australia"

Jagupilla, et al. [57]	2024	Jagupilla, S. C. K., O'Connell, E., &Hajj,M. R	"A Holistic Approach to Civil Engineering Capstone Design"	"2024 ASEE Annual Conference & Exposition"
Hungness, et al. [58]	2024	Hungness, Derek and Kucher, Jan and Luter, Gavin and Harrington, Greg	"Civil and Environmental Engineering Senior Capstone Design and UniverCity Year Partnership"	"Capstone Design Conference 2024"
Chan, et al. [59]	2017	Chan, C. K., Wong, G. C., Law, A. K., Zhang, T., & Au, F. T.	"Evidence-based Conclusions Concerning Practice, Curriculum Design and Curriculum Reform in a Civil Engineering Capstone Design Course in Hong Kong"	"Innovations in Education and Teaching International"
Padmanabhan, et al. [60]	2018	Padmanabhan, G., Katti, D., Khan, E., Peloubet, F., & Leelaruban, N.	"A Unique Civil Engineering Capstone Design Course"	"International Journal of Engineering Pedagogy"
Labossière and Roy [61]	2015	Labossière, P., & Roy, N.	"Original Concept for a Civil Engineering Capstone Project"	"Journal of Professional Issues in Engineering Education and Practice"
Brown and Morris [62]	2020	Brown, A. C., & Morris, H. W	"Development and Implementation of a Final Year Civil Engineering Capstone Project – Successes, Lessons Learned, and Path Forward."	"ASEE Virtual Annual Conference Content Access"
Leu and Liu [64]	2015	Leu, L. J., & Liu, M.	"Summary of Developments in the Civil Engineering Capstone Course in Taiwan"	"International Conference on Interactive Collaborative Learning"
Gnanapragasam and Canney [63]	2015	Gnanapragasam, N., &Canney, N. E.	"Work in Progress: Rubric Development for Year-Long Civil Capstone Projects"	"ASEE Annual Conference & Ex- Position"
Lee and Kim [65]	2020	Lee, N., & Kim, S. J.	"A Systematic Course Design Approach to Guide the Development of a Construction Engineering and Management Capstone Course"	"Annual Conference Northeast Section"
Viswanathan [66]	2017	Viswanathan, S.	"Implementation of Effective Capstone Projects in Undergraduate Manufacturing Design Engineering Program"	"American Journal of Engineering Education"
Haji Amin Shirazi, et al. [67]	2024	Haji Amin Shirazi, S., Salloum, M., Speer, A., & Watkinson, N	"An Experience Report: Integrating Oral Communication and Public Speaking Training in a CS Capstone Course"	"Proceedings of the 55th ACM Technical Symposium on Computer Science Education V. 1"
Rad and Lynch [68]	2024	Rad, Hamid and Lynch, John	"Impact of Requesting Funds from Industry Sponsors to Support Capstone Projects"	"Capstone Design Conference 2024"
Bastarrica, et al. [69]	2017	Bastarrica, M. C., Perovich, D., & Samary, M. M.	"What Can Students Get from a Software Engineering Capstone Course?"	"International Conference on Software Engineering: Software Engineering and Education Track"
Deepamala and Shobha [70]	2018	Deepamala, N., & Shobha, G	"Effective Approach in Making Capstone Project a Holistic Learning Experience to Students of Undergraduate Computer	"JOTSE: Journal of Technology and Science Education"

			Science Engineering Program"	
Domínguez, et al. [71]	2020	Domínguez, C., Jaime,A.,García-Izquierdo, F. J.	"Factors Considered in the Assessment of Computer Science Engineering Capstone Projects and Their Influence on Discrepancies Between Assessors"	"ACM Transactions on Computing Education"
Olarte, et al. [72]	2015	Olarte, J. J., Domínguez, C., Jaime, A., & García, F. J.	"Student and Staff Perceptions of Key Aspects of Computer Science Engineering Capstone Projects'	"IEEE Transactions on Education"
Mahnič [73]	2015	Mahniˇc, V.	"The Capstone Course as a Means for Teaching Agile Software Development through Project-Based Learning"	"World Transactions on Engineering and Technology Education"
Damaj and Yousafzai [74]	2016	Damaj, I., & Yousafzai, J.	"Simple and Accurate Student Outcomes Assessment: A Unified Approach Using Senior Computer Engineering Design Experiences"	"IEEE Global Engineering Education Conference"
Parker [75]	2017	Parker, R.	"How Do You Feel: Affective Expressions from Computer Science Senior Capstone Projects"	"International Conference on Learning and Teaching in Computing and Engineering"
Malik, et al. [76]	2018	Malik, Z. H., Butt, S., & Sajid, H.	"Quality Scale for Rubric-based Evaluation in Capstone Project of Computer Science"	"Intelligent Computing: Proceedings"
Jaime, et al. [77]	2020	Jaime, A., Olarte, J. J., García-Izquierdo, F. J., &Domínguez, C	"The Effect of Internships on Computer Science Engineering Capstone Projects"	"IEEE Transactions on Education"
Ferdiana [78]	2020	Ferdiana, R.	"The Triangulation Assessment Model for Capstone Project in Software Engineering"	"International Conference on In-formation Technology and Electrical Engineering"
Elfaki and Bassfar [79]	2020	Elfaki, A., &Bassfar, Z.	"Construction of a Software Development Model for Managing Final Year Projects in Information Technology Programmes"	"International Journal of Emerging Technologies in Learning"
Jung, et al. [81]	2016	Jung, Y., Kim, H., & Kim, N.	"Virtual Plan-Design-Build for Capstone Projects in the School of Architecture: CM & BIM Studios in Five-Year B.Arch. Program"	"Journal of Asian Architecture and Building Engineering"
Tafahomi and Chance [82]	2024	Tafahomi, Rahman and Chance, Shannon	"Comparing the Meaning of 'Thesis' and 'Final Year Project' in Architecture and Engineering Education"	"European Journal of Engineering Education"
Bhuyan [83]	2021	Bhuyan, M. H.	"Assessing 'Lifelong Learning' through the Capstone Design Project of BSc in EEE Program"	"International Journal of Learning and Teaching"

DOI: 10.55214/25768484.v9i6.8146

Pasya, et al. [84]	2015	Pasya, I., Al-Junid, S. A. M., &Buniyamin, N.	"Overview of Capstone Project Implementation in the Faculty of Electrical Engineering, UniversitiTeknologi MARA, Malaysia"	"IEEE 7th International Conference on Engineering Education"
Kennedy and Dickson [85]	2021	Kennedy, D. M., & Dickson, K. R.	"A Process for Matching Science of Health Care Delivery Students to Quality Improvement Capstone Projects and Implications for Experiential Learning"	"Health Professions Education"
Chamberlain , et al. [86]	2020	Chamberlain, S., Gonzalez, N., Dobiesz, V., Edison, M., Lin, J., &Weine, S.	"A Global Health Capstone: An Innovative Educational Approach in a Competency-Based Curriculum for Medical Students"	"BMC Medical Education"
Augustine, et al. [87]	2020	Augustine, C., Yi, W. H., Wong, C., bin Saidon, Z. L., & bin Hashim, Z.	"The Implementation of Capstone Project Among Undergraduate Music Students"	"International Journal of Academic Research in Business and Social Sciences"
Friess and Goupee [88]	2019	Friess, W. A., &Goupee, A. J.	"Transformation of a Mechanical Engineering Capstone Experience"	"IEEE Frontiers in Education Conference"
Hirshfield and Wisniewski [89]	2016	Hirshfield, L., & Wisniewski, E.	"Teaching Entrepreneurial Communication in a Chemical Engineering Product Design Capstone Course"	"International Professional Communication Conference"
Bitz and Hair [90]	2024	Bitz, Kristi L. and Hair, Rodney	"An Innovative Approach to the Psychology Capstone Course"	"Teaching of Psychology"
Brandão, et al. [91]	2024	Brandão, A. P., Donaldson, J. P., Dunlap, K. A., Wiegert, J. G., Kao, S., &Paudyal, S	"Design Thinking for Engaged Learning in Animal Science: Lessons from Five Semesters of a Senior Capstone Course"	"Translational Animal Science"

5. Discussion on the Review Results Based on RQ#

Figure 2 shows a graph comparing the number of papers in conference versus journal. The graph shows that journal papers account for 22 papers, compared to 20 for conference papers. Figure 3 shows a graph showing the number of countries involved in the final year capstone project. The USA published more papers about the final year capstone project. Canada, Australia, Hong Kong, New Zealand, China, New Britain, Chile, India, Bangladesh, Spain, Slovenia, Kuwait, South Korea, Malaysia, Indonesia, Saudi Arabia and Pakistan are participating in it. Researchers are also working on it. Figure 4 shows engineering courses are engaged with final-year capstone courses. Almost all engineering subjects adapted capstone courses for their students. Figure 5 shows the year-wise paper published. The x-axis shows the year, and the y-axis shows the number of papers published. Table 2 shows the publication venue, year, corresponding title and author name of the selected paper.

5.1. Answer to the Research Question

RQ1: How many countries and universities are involved in researching final-year capstone projects?

There are approximately 18 countries involved in researching final-year capstone projects as far as our collected papers. These countries include the USA, Canada, Australia, Hong Kong, New Zealand, New Britain, Chile, India, Spain, Slovenia, Kuwait, South Korea, Malaysia, Bangladesh, Indonesia, Saudi Arabia, and Pakistan.

RQ2: How many engineering subjects include the final-year capstone project?

There are approximately 15 engineering subjects that include final-year capstone projects based on collected papers from different databases. These subjects are Aerospace Engineering, Biomedical, Food

Microbiology, Civil, Construction Engineering, Computer Engineering, Medical, IT Program, Software Engineering, Architecture, Manufacture, Music, Electrical Engineering, Mechanical Engineering.

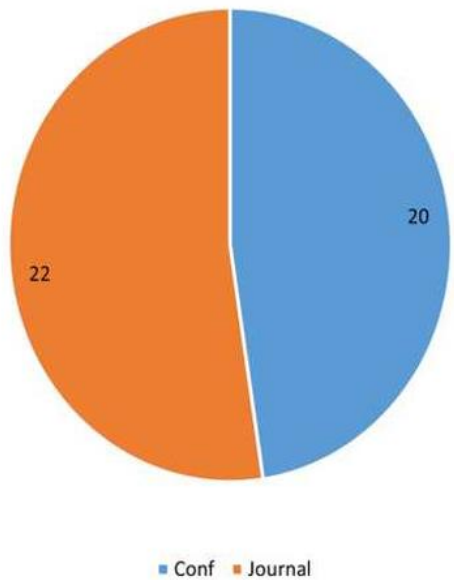

Figure 2.
Journal and Conference paper among collected papers.

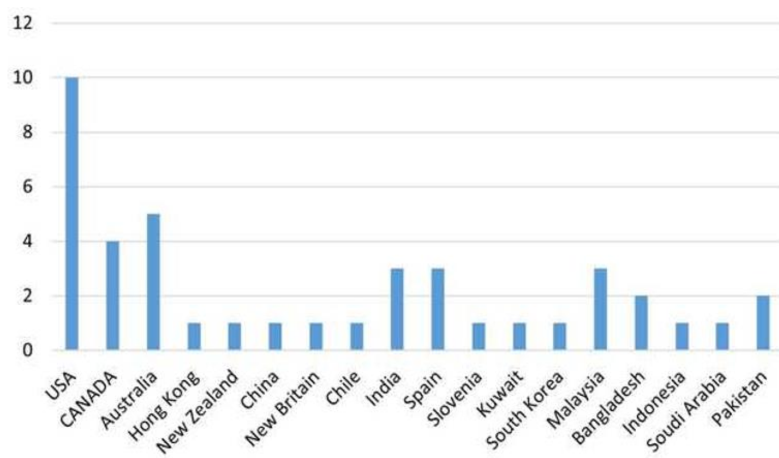

Figure 3.
County involvement in FYP.

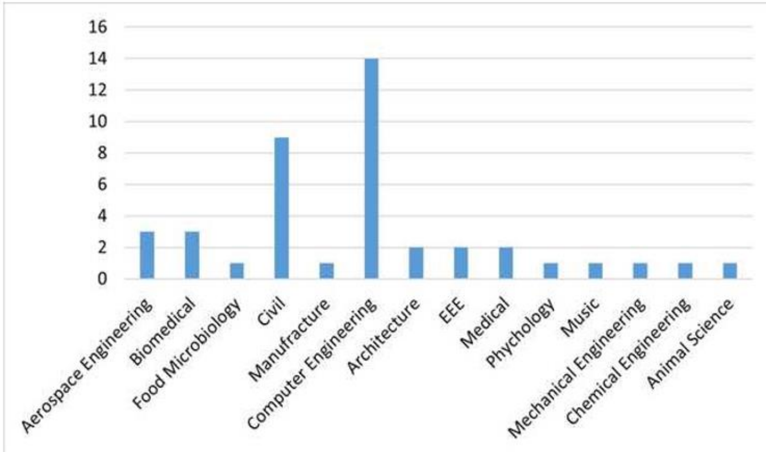

Figure 4.
Faculty involvement in the FYCP.

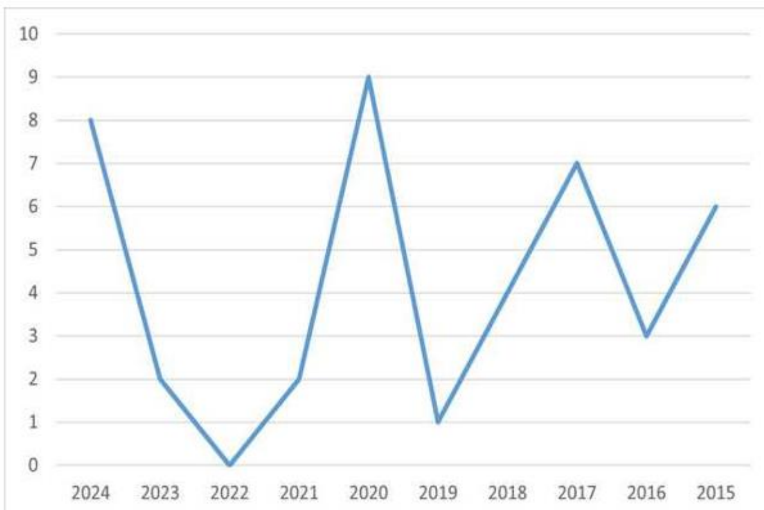

Figure 5.
Year wise paper among collected papers.

RQ3: Which accreditation bodies are involved in the accreditation for the currently available capstone projects, and what standards do they set?

Several accreditation bodies are integral to the accreditation of capstone projects within engineering and technology degree programs, each setting distinct standards to ensure the quality of education. The Accreditation Board for Engineering and Technology (ABET) is a prominent accrediting organization that establishes rigorous criteria for engineering education programs, including capstone projects. ABET emphasizes program outcomes and assessments, ensuring that graduates possess essential skills such as the ability to design systems, solve engineering problems, and communicate effectively. Similarly, the Washington Accord is an international agreement that outlines standards for engineering education across member countries, adopting 12 graduate attributes that describe the competencies expected from engineering graduates, including technical knowledge, skills, and professional behaviors. Additionally, organizations like ACM-IEEE (Association for Computing Machinery - Institute of Electrical and Electronics Engineers) provide guidelines and structures for capstone courses in computing and engineering disciplines, ensuring alignment with industry standards and educational best practices. By establishing these criteria, these accreditation bodies play a crucial role in maintaining the consistency and quality of engineering education globally, preparing students for professional roles through rigorous and relevant capstone projects.

RQ4: How long are capstone courses, and what are the benefits or drawbacks of a specific duration?

Most institutions prefer to structure capstone projects over two semesters, typically during the final year of study. This extended duration allows for a comprehensive learning experience, enabling students to engage deeply with their projects, refine both technical and soft skills, and thoroughly explore real-world problems. A two-semester capstone project provides ample time for iterative design, feedback, and adjustments, leading to a more robust understanding of the subject matter and better-prepared graduates. However, this longer duration can require more resources and may result in reduced focus if progress is slow. In contrast, shorter capstone courses encourage concentrated efforts and rapid learning but may limit the depth of exploration and understanding of complex concepts. Thus, finding the right balance in the duration of capstone projects is essential to provide a meaningful educational experience while efficiently managing institutional resources.

6. Possible Future Research Detection

Based on the findings from this systematic literature review on final-year capstone projects in engineering curricula, several avenues for future research can be pursued to enhance the understanding and effectiveness of these educational experiences.

Firstly, a comparative analysis of capstone project structures across different engineering disciplines and institutions could provide valuable insights. Research could focus on the various configurations of capstone projects, such as project duration, team composition, and levels of industry involvement, and their impact on student learning outcomes and skill development. By identifying best practices and understanding how different approaches influence educational outcomes, educators can design more effective capstone experiences tailored to diverse contexts. Secondly, conducting longitudinal studies on graduate outcomes would be beneficial in evaluating the long-term effects of capstone projects on students' careers. Tracking graduates over time could reveal how participation in capstone projects influences employability, career progression, professional development, and overall success in the engineering field. Such studies would provide concrete evidence of the value of capstone projects in preparing students for the workforce.

Another promising direction is exploring the integration of emerging technologies into capstone projects. With the rapid evolution of technologies such as artificial intelligence, virtual reality, and the Internet of Things, future research could investigate how these tools can be incorporated into capstone projects to enhance learning and better prepare students for contemporary engineering challenges. This could lead to the development of innovative project models that leverage cutting-edge technologies to foster creativity and adaptability among engineering students. Furthermore, research into the impact of capstone projects on soft skills development is critical. While technical competencies are often the primary focus of engineering education, capstone projects also offer an opportunity to develop essential soft skills, such as teamwork, communication, leadership, and ethical decision-making. Future studies could explore how different capstone formats, project types, and team dynamics contribute to the development of these skills, providing insights that could help educators design more holistic educational experiences.

The exploration of multidisciplinary capstone projects represents another valuable research avenue. With engineering problems increasingly requiring interdisciplinary solutions, investigating the benefits and challenges of capstone projects that involve collaboration between students from different engineering disciplines or even non-engineering fields could be highly informative. Research could examine the dynamics of interdisciplinary teamwork, the integration of diverse knowledge areas, and the impact of such projects on innovation and creativity. Additionally, with the rise of digital education, the evaluation of capstone projects in online and hybrid learning environments is becoming increasingly relevant. Future research could compare the effectiveness of capstone projects conducted in traditional in-person settings with those delivered online or in hybrid formats. This could involve assessing differences in student engagement, project quality, and learning outcomes, providing insights that could guide the adaptation of capstone experiences to various learning modalities.

Finally, an assessment of capstone project mentorship models could offer valuable information on optimizing student support and project outcomes. Different mentorship approaches, such as faculty mentorship, industry mentorship, and peer mentorship, can have varying effects on student learning and satisfaction. Future studies could investigate the impact of these models on project success and overall student experience, helping to identify the most effective mentorship strategies for capstone projects.

7. Threats to Validity

When conducting a literature review, there are several factors that can affect the accuracy and reliability of the study. This section discusses potential threats to both internal and external validity and the steps we have taken to minimize these risks.

7.1. Internal Validity

Internal validity refers to how well a study can show a cause-and-effect relationship within the data analyzed. A key threat to internal validity in our review is selection bias, which can happen if the studies we chose are not fully representative of all the research on final-year capstone projects in engineering curricula. This could lead to misleading conclusions. To reduce this risk, we used a thorough search strategy, looking at multiple databases and applying strict criteria for including or excluding studies. We also had multiple reviewers involved in selecting the studies to ensure consistency and minimize bias.

7.2. External Validity

External validity refers to the ability to apply the findings of a study to other contexts outside the specific research setting. In our review, the main threat to external validity is the challenge of generalizing the findings to different educational settings and engineering disciplines. Because capstone projects can vary widely in structure, goals, and cultural context, our results might not apply everywhere. To address this, we included a wide range of studies from different

countries, institutions, and engineering fields to capture a broad view of experiences and practices. We have also clearly defined the scope of our review and noted that while our findings provide useful insights, they may not be applicable to every situation.

8. Conclusion

The capstone project course is designed to develop and enhance students' practical skills, teamwork, communication abilities, project management skills, and social awareness. This paper presents a systematic literature review of final-year capstone projects within the engineering curriculum of undergraduate or bachelor's degree programs. We have reviewed scholarly literature published from 2015 to 2024 to gain a comprehensive understanding of how these projects are integrated into engineering education. Our analysis reveals that many countries have incorporated final-year capstone projects into their educational programs, highlighting their importance in bridging the gap between theoretical learning and practical application. Among the various accreditation standards, ABET and the Washington Accord are the most commonly utilized frameworks by universities worldwide, underscoring their role in ensuring the quality and consistency of engineering education.

Transparency:
The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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