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Outcome-Based Evaluation of Capstone Projects: Methodology, Impact, and Best Practices

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***Abstract*—Capstone projects are a critical component of engineering education, bridging academic theory with practical application and fostering industry readiness. This study examines the implementation and evaluation of capstone projects within an engineering program, emphasizing their role in skill development, innovation, and professional preparedness. The research focuses on a rubric-based assessment framework applied across multiple project phases—problem identification, design, development, evaluation, and presentation—to ensure alignment with Outcome-Based Education (OBE) objectives. A three-year analysis of program-level data reveals measurable improvements in project quality, student competencies, and placement outcomes, alongside increased participation in sponsored projects and national and international competitions. The findings highlight that structured evaluation, coupled with real-world engagement, significantly enhances problem-solving, teamwork, and communication skills. This paper concludes that integrating rubric-driven assessment with OBE principles provides a replicable model for technical institutions aiming to produce industry-ready graduates while promoting excellence in academic project work.**

***Keywords*—Capstone Projects, Outcome-Based Education, Technical Education, Skill Development, Rubric Assessment.**

I. INTRODUCTION

Capstone projects have been widely recognized as a pivotal pedagogical tool in engineering and technical education, serving as a bridge between theoretical instruction and professional practice. It has been shown that graduates are expected by industries to think critically, solve real-world problems, and collaborate effectively—skills that traditional lecture-based learning often fails to fully cultivate. These gaps are bridged through capstone projects, where theoretical knowledge is integrated with practical application, multidisciplinary challenges are addressed, and professional competencies such as project management, teamwork, and communication are developed (Rahman, M., 2025).

The term *capstone* (Nkhoma, R., 2024) has been used metaphorically to denote a culminating academic experience, analogous to the final stone placed atop a structure, which consolidates prior learning. It is so named because these projects typically span long durations, are structured in phased segments, and involve continuous evaluation—thereby symbolizing the unifying "top stone" of a student's academic journey.

Within the framework of Outcome-Based Education (OBE), capstone projects provide a direct mechanism for assessing program outcomes. A structured environment is created in which problem identification, requirements analysis, solution design, implementation, testing, and evaluation are systematically carried out. This multi-phase process fosters technical proficiency while simultaneously promoting creativity, innovation, adaptability, and other professional competencies valued by employers (Abdulmawjood, K., 2024; Shingan & Ugale, 2018).

In the present implementation, capstone projects are conducted over two academic semesters, typically spanning the third-year second semester and the final-year first semester (da Silva-Ovando, 2025). The process is structured into sequential stages, including problem identification, objective formulation, literature review, benchmark model development or simulation of existing systems, proposed module development or simulation of new approaches, performance evaluation, documentation, and presentations before an expert panel. A key feature of this methodology is the adoption of rubric-based evaluation across multiple stages, ensuring objectivity, transparency, and alignment with Outcome-Based Education principles (Sasipraba et al., 2020; Nieto-Chaupis, 2018).

Despite the recognized significance of capstone projects, limited empirical research has examined the effects of multi-phase, rubric-driven evaluation frameworks on both project outcomes and graduate competencies in technical institutions. Observed gaps include insufficient exposure to real-world problem-solving, limited interdisciplinary integration, and underexplored impacts on professional skills such as communication, teamwork, and ethics. This study addresses these gaps by analyzing a three-year dataset from the Department of Computer Science and Engineering (CSE) at RIT, focusing on the execution and assessment of capstone projects. Specifically, it investigates how a multi-phase, rubric-based evaluation framework influences students' technical competencies, professional skills, and alignment with Outcome-Based Education, providing insights that can guide other institutions in refining their OBE-aligned project evaluation systems.

While capstone projects are widely implemented across engineering institutions, this study distinguishes itself by presenting a structured, multi-phase rubric-based evaluation

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model supported by a three-year longitudinal data analysis. Unlike conventional capstone descriptions, this work quantitatively links project evaluation metrics with Course Outcome attainment, innovation indicators (patents, competitions, publications), and placement outcomes. The study provides empirical evidence demonstrating how structured assessment and industry integration systematically improve both technical and professional competencies. This data-driven validation of an Outcome-Based capstone framework constitutes the primary contribution of the present work.

II. Literature Review

Capstone projects serve as a culminating and practice-oriented learning experience that bridges the gap between theoretical coursework and real-world engineering challenges. They are intentionally designed to simulate professional environments where students must apply multidisciplinary knowledge, technical skills, and problem-solving abilities to develop tangible solutions. The incorporation of CDIO (Conceive–Design–Implement–Operate) principles has been shown to significantly enhance the design quality and educational impact of these projects by promoting authenticity, hands-on engagement, and industry collaboration (Zhang, 2019). These principles encourage students to work on projects that not only meet academic requirements but also reflect real market needs, thereby fostering creativity, teamwork, and project management capabilities. Similar improvements in logical reasoning, collaborative problem solving, and critical thinking through visualization-based collaborative learning have also been reported (Ugale & Shingan, 2018).

Within the framework of Outcome-Based Education (OBE), capstone projects act as a critical performance indicator for measuring the extent to which students have achieved program-level learning objectives. By employing structured rubrics and evaluation matrices, institutions can ensure that assessments are transparent, consistent, and directly mapped to defined learning outcomes (Vijayalakshmi et al., 2013; Sasipraba et al., 2020). This approach supports fair and evidence-based grading while providing students with constructive feedback that identifies both strengths and areas for improvement. Furthermore, the strategic integration of capstone project assessments into institutional self-evaluation and accreditation mechanisms enhances program credibility and relevance. For instance, in fields like electrical, networking, and systems engineering, such integration ensures that graduates possess competencies aligned with rapidly evolving industry demands, ultimately contributing to the production of skilled, employable, and future-ready professionals (Nieto-Chaupis, 2018).

A complementary body of research emphasizes the importance of making capstone projects closely aligned with industry practices to maximize both learning outcomes and professional readiness. In software engineering contexts, the deliberate integration of Agile methodologies, version control systems, emphasis on code quality and testing practices, and attention to ethical and security considerations has been shown to enhance students' technical proficiency and workplace preparedness (Mandale et al., 2020). When these practices are reinforced through collaboration with industry partners, students gain exposure to real-world workflows, project constraints, and professional standards, thereby bridging the gap between academic exercises and industrial expectations.

Beyond technical skill development, innovations in assessment strategies have been found to enrich the capstone experience and foster critical soft skills. External peer-to-peer evaluations, when designed with clear criteria and proper training, can encourage active learning, critical thinking, and effective communication among students (Fazelpour, M.,et al., 2024). Similarly, continuous peer evaluation in team-based projects promotes accountability, ensures fair recognition of individual contributions, and provides ongoing formative feedback, thereby improving both team dynamics and overall project quality (Friess & Goupee, 2020). These assessment approaches complement traditional faculty evaluation and allow for a more holistic measurement of student performance.

Capstone projects are also increasingly leveraged as platforms for international collaboration and sustainability education, broadening the scope of learning beyond local or technical contexts. Cross-border student cooperation has been recognized as an enriching experience that cultivates intercultural competence, global research skills, and adaptability in diverse team settings (Zagar et al., 2019). Additionally, initiatives like the European Project Semester (EPS) illustrate how project-based, cross-cultural teams can effectively embed principles of sustainable development into engineering education, equipping students with the knowledge and skills required to address complex environmental and societal challenges (Duarte, 2019). These expanded perspectives not only enhance the educational impact of capstones but also prepare graduates to engage responsibly and innovatively in a globalized workforce.

Operational frameworks have been developed to manage the inherent complexity of capstone projects and improve the fidelity of their execution. For example, the easyCapstone system provides structured support for critical project workflows, including allocation of tasks, progress monitoring, documentation, and assessment, thereby offering a scalable backbone that can be adapted across multiple engineering and technical disciplines (Erradi, 2012). Despite such technological and process-oriented supports, several persistent challenges have been identified. Resource limitations and difficulties in coordinating interdisciplinary teams continue to complicate the implementation of CDIO-style projects, which emphasize authentic, industry-aligned learning experiences (Zhang, 2019). Similarly, while rubric-based assessment frameworks are effective in mapping student outputs to Course Outcomes (CO) and Program Outcomes (PO), their impact on broader professional skill development, including communication, teamwork, and ethical decision-making, remains insufficiently explored (Jagtap et al., 2016). Previous studies have demonstrated the effectiveness of collaborative and student-centered learning environments in enhancing technical competencies; however, limited work has examined their integration within structured, multi-phase capstone evaluation

frameworks (Dharwadkar & Shingan, 2017; Shingan & Ugale, 2018).

Collectively, the literature highlights the need for a comprehensive, multi-phase evaluation approach aligned with Outcome-Based Education (OBE) principles, industry expectations, and structured operational frameworks. The key findings and limitations of the reviewed studies are summarized in Table I, which also highlights the research gaps addressed in this work. Moreover, there is a clear gap in empirical studies examining the longitudinal impact of such structured assessments on both technical competencies and holistic student development. Addressing these gaps requires systematic studies that integrate rubric-driven evaluation across project phases, monitor both technical and soft skill growth, and assess outcomes in a way that informs continuous improvement of capstone programs.

TABLE I
LITERATURE REVIEW

SR NO	PAPER NAME	YEAR	METHODOLOGY USED	RESULT
1	Design of Capstone Project under CDIO	June 2020	CDIO (Conceiving-Designing-Implementing-Operating)	This paper proposes a solution for the design and evaluation of capstone projects based on the author's teaching research and practice,
2	Work-in-Progress: International Student Cooperation in Capstone Research Project	April 2019	Case study-Collaboration with international students on project implementation	By acknowledging and addressing the challenges and implementing best practices, educators and institutions can harness the full potential of international student collaboration and empower students to become effective researchers and global citizens.
3	Outcome-Based Education Performance Evaluation of Capstone Project using Assessment Rubrics and Matrix	2013	Outcome-Based Education Performance Evaluation	improved learning by students and enhanced participation of both faculty members and students right from the beginning of the project phase
4	Self-Evaluation and Accreditation Schemes of Engineering Schools Based on the Capstone Projects Outcomes Assessment in Electrical, Networking and Systems Engineering Programs	2018	Self-evaluation	wide spectrum of possibilities including entrepreneurship
5	Improved Undergraduate Software Capstone Project Development with the Adoption of Industry Practices	April 2021	Outcome-based practices for a project course	IOSEP methodology for academic software project development which helped in improving the overall quality of the project work
6	Assessment Tools and Rubrics for Evaluating the Capstone Projects in Outcome-Based Education	2019	Outcome Based Education	The assessment mechanism used for the evaluation of capstone projects that provide solutions to complex engineering problems and prevailing real-world issues
7	Work in Progress – External Assessment Through Peer-to-Peer Evaluation of Capstone Projects	October 2007	peer-to-peer assessment	Improvements to the assessment process have been identified
8	easyCapstone: A Framework for Managing and Assessing Capstone Design Projects	July 2012	a web-based system, named easyCapstone, was built to automate key workflows	The adoption of easyCapstone resulted in better ways to teach, manage and assess the technical and nontechnical capstone course outcomes
9	Engineering Education for Sustainable Development: The European Project Semester Approach	2019	evidence-based analysis, semi-automatic analysis	results suggest that Iberian EPS programs are oriented towards sustainability
10	Using Continuous Peer Evaluation in Team-Based Engineering Capstone Projects: A Case Study	MAY 2020	continuous peer evaluation	The presented system is capable of assessing individual contributions in a team project, facilitates team formation and operation by requiring continuous team, and internal feedback, and generates a transparent grading system

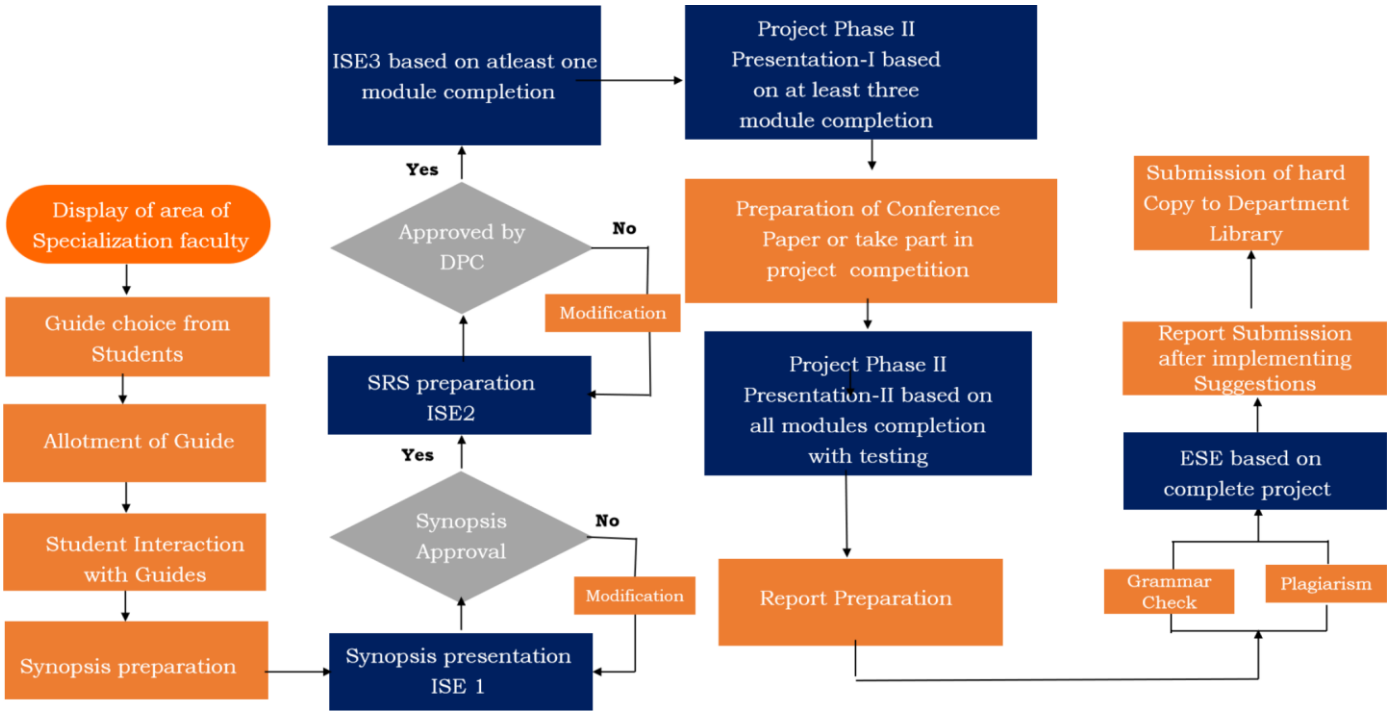


Fig.1. Workflow of Capstone Projects

III. METHODOLOGY

The structured methodology adopted for planning, development, and evaluation of the capstone projects is presented in Fig. 1, which illustrates the workflow of the Capstone Projects.

Group formation and guide selection:

Students are organized into groups to work collaboratively on the capstone project. Group sizes vary based on project complexity, typically consisting of a minimum of four and a maximum of five students per group. Group formation is encouraged at the early stage of the capstone process to allow sufficient time for team dynamics to develop and for members to plan their projects effectively. Students are given the autonomy to form their own groups and may collaborate with peers who share similar interests, expertise, or a common project vision. The group formation strategy also aligns with student quality circle principles that encourage peer learning, shared responsibility, and continuous improvement (Dharwadkar & Shingan, 2017).

Students may select a guide based on the faculty member's expertise, research interests, or familiarity with the project domain. Faculty members provide recommendations to ensure that group composition aligns with project objectives and includes a balanced mix of learners, such as weak, intermediate, and advanced students, to promote collaborative learning and collective contribution. Finally, the project coordinator finalizes the mentor–mentee allocation based on the preferences and data collected from students.

Project Proposal:

Students present three to four innovative problem statements along with proposed solution approaches before the departmental committee. After rigorous evaluation, the topic is finalized with suggested modifications. Students submit the report to their guide and prepare a synopsis of the selected topic. Students meet their guide to discuss the topic and prepare the synopsis containing a complete Literature Review, problem statement and methodology. The project proposal presentation, modifications, action taken report, and final approval collectively constitute Review 1 of the capstone evaluation process.

Project Design:

After getting sanction from the internal expert committee, students have to prepare Software Requirements Specification (SRS) for prototype-based projects and a complete literature review on research-based projects. It describes the requirements and broad design for a software system or application. It serves as a communication bridge between stakeholders, including clients, users, and development teams, ensuring everyone has a clear understanding of what the software is expected to accomplish. Students are evaluated through Presentation Phase-I before an expert panel. The SRS and comprehensive review of research-based projects are completed during the Third Year of the B.Tech program, and implementation begins in the subsequent semester.

Implementation:

The implementation phase is a dynamic and iterative process that involves continuous development, testing, and improvement. It requires effective teamwork, technical skills,

and the ability to adapt to challenges. The successful completion of this phase brings the project closer to its final stages and eventual completion. After receiving approval and positive evaluation in the design phase (Presentations Phase-I), students begin the implementation phase. Students work on coding and developing the software or solution based on the requirements outlined in the Software Requirements Specification (SRS) or the research findings. The team collaborates to write code, create algorithms, design user interfaces, and integrate different components. The project group and the assigned guide hold regular meetings to discuss progress, address challenges, and make decisions. Updates on the project's development are shared, and any adjustments to the plan are discussed. Version control systems (e.g., Git) are commonly used to track changes to the project's source code and ensure collaboration among team members. This helps in maintaining a stable codebase and managing different versions of the software. As development progresses, testing and quality assurance activities are performed to identify and rectify bugs, errors, and issues. Different types of testing (unit, integration, system, etc.) are conducted to ensure the software functions as intended. Throughout the implementation phase, documentation is created and maintained, including code comments, user manuals, and technical documentation. Final adjustments are made, and any remaining issues are addressed. As the project nears completion, preparations for the final presentation and demonstration are made. The project team compiles the results, accomplishments, challenges, and lessons learned during the implementation phase.

Documentation:

Effective documentation is an integral part of any software development process, playing a crucial role in facilitating understanding, collaboration, and maintenance of the code base. Clear and comprehensive documentation not only aids in understanding the existing code but also becomes essential for on boarding new team members or collaborators. This ensures that the knowledge about the software is not confined to a single individual but is accessible and transferable across the team. Plagiarism checking adds an ethical dimension to this process, ensuring the integrity and authenticity of the documentation. At the conclusion of the semester, students are required to submit their final reports along with plagiarism reports generated from tools such as Turnitin or other authentic software. The submitted report is deemed acceptable only when the plagiarism percentage is below 10%.

Final presentation

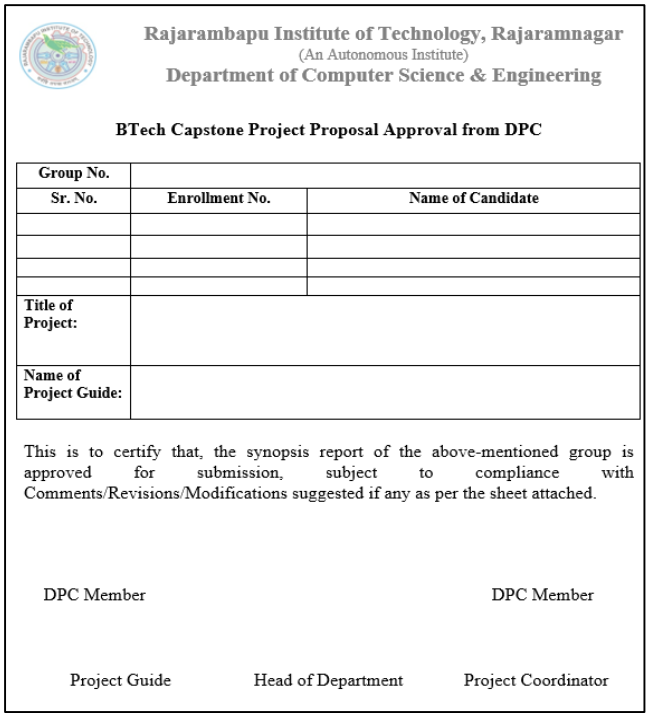
The project is presented to a panel of experts, faculty members, and potentially external stakeholders. The team showcases the implemented solution, explains its features and functionality, and discusses the challenges faced during implementation. The project is evaluated based on its effectiveness, innovation, quality, and adherence to the initial objectives and outcomes achieved, including complete analysis of the project.

IV. Capstone Project Selection Process

The assessment includes critical thinking skills, practical knowledge, learning of cutting-edge technologies, and the development of writing skills using LaTeX. Furthermore, it examines students' proficiency in using various tools such as Jira, Ajax, GitHub, and many more, which are vital for recent software development.

B.TECH Project Approval Form

The B.TECH Project Approval Form is a required document where students propose project topics and objectives to their respective departments for review and approval before proceeding with the project implementation phase. This form outlines the project's scope, objectives, and expected outcomes, serving as a preliminary agreement between students and their academic advisors. The formal approval process is documented through the project proposal approval mechanism shown in Fig. 2.



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Department of Computer Science & Engineering

BTech Capstone Project Proposal Approval from DPC

Group No.		
Sr. No.	**Enrollment No.**	**Name of Candidate**
Title of Project:		
Name of Project Guide:		

This is to certify that, the synopsis report of the above-mentioned group is approved for submission, subject to compliance with Comments/Revisions/Modifications suggested if any as per the sheet attached.

DPC Member DPC Member

Project Guide Head of Department Project Coordinator

Fig. 2. Project Proposal Approval

Modifications required

The "Modifications Required Form" is typically used in the B.TECH project approval process when proposed project topics or objectives need adjustments or improvements. The peer team evaluates the topic in terms of novelty, the scope of the project, the technology used, and other factors, and provides suggestions where necessary. Students have to work on it and complete the necessary modifications or changes to align the project more closely with the desired goals and outcomes. If modifications are required, feedback is provided by the Department Project Committee (DPC), as illustrated in Fig. 3.

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Department of Computer Science & Engineering

Sr. No.	Enrollment No.	Name of Candidate

No	Comments/Revision/Modifications suggested by DPC members
1	
2	
3	
4	

Project Guide Date:

Group No.		
Sr. No.	Enrollment No.	Name of Candidate

Fig. 3. Comments/revision by DPC members

Action Taken report

The "Action Taken Report Form" is used following the Modifications Required Form in the B.TECH project approval process. In this form, students document the specific actions they have taken to address the modifications or improvements suggested by academic advisors or department heads.

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Department of Computer Science & Engineering

No	Action Taken by Candidates on Comments/Revisions/Modifications Suggested by DPC members
1	
2	
3	
4	
5	

Name of Candidate	Signature

Project Guide Name	Signature

Fig. 4. Action taken report

It serves as a record of the steps taken to refine the project proposal and ensures that the project aligns better with the desired objectives and outcomes. The structure and format of the Action Taken Report are illustrated in Fig. 4.

Final Proposal

The "Final Proposal Form" is the concluding step in the B.TECH project approval process. After addressing any required modifications and receiving approval, students submit this form. It contains the comprehensive details of the project, including objectives, methodology, scope, and expected outcomes.

Rajarambapu Institute of Technology, Rajaramnagar
(An Autonomous Institute)
Department of Computer Science & Engineering

B Tech Capstone Project Proposal Final Approval

Group No.		
Sr. No.	Enrollment No.	Name of Candidate
Title of Project:		
Name of Project Guide:		

This is to certify that; the above candidates have satisfactorily submitted an action taken report on the Comments/Revisions/Modifications suggested by the DPC committee and incorporated them in the final synopsis report.

Project Guide Head of Department Project Coordinator

Fig. 5. Final Project Approval

Criteria & Points Assigned	Creativity and Originality	Knowledge of related problems and use of resources and methodology/approach used	Presentation skills & coordination
Unacceptable (1)	Lack of Creativity and originality in project ideas.	The literature review in the project is incomplete. Bare understanding of the problem, with scarce knowledge of relevant material	Lack of confidence and familiarity in some parts of the presentation
Below Expectations (2)	The idea of the project is somewhat creative and original.	A literature review is brief, with insufficient detail. Basic understanding of the problem, but lack appropriate study of relevant material	Basic organization and preparation -Confident in only some parts of the presentation
Meets Expectations (3)	Creativity and originality in project ideas	A literature review is brief but complete. Good understanding of the problem, with study of relevant material.	-Good organization and preparation -Confident in most parts of the presentation
Exceeds Expectations (4)	The project idea is very creative and original.	A literature review is complete; sufficient detail is provided. Very good understanding of the problem and relevant material	-Excellent organization and preparation -Confident and relaxed during the whole presentation

Fig.6. Evaluation sheet for Review 2

The Final Proposal Form serves as an official agreement and guideline for the successful execution of the approved project. The format and approval structure of this stage are illustrated in Fig. 5.

Criteria & Points Assigned	Domain Knowledge (10 Marks)	SRS document (10 Marks)	Technical Contents (10Marks)	Individual Participation with Question & Answer (5 Marks)
Unacceptable (1)	Lack of Domain Knowledge	Very poor SRS document prepared without good design diagrams.	Lack of technical content.	Answer at least one questions correctly
Below Expectations (2)	Poor Domain Knowledge	SRS document prepared with design diagrams.	Very poor technical content.	-Answer most questions correctly -Need clarification sometimes
Meets Expectations (3)	Good Domain Knowledge.	The SRS document prepared is good with good design diagrams.	Good technical content.	-Answer most questions correctly and concisely.
Exceeds Expectations (5)	Excellent Domain Knowledge	Very excellent SRS document prepared.	Very excellent technical content.	-Handle difficult questions with ease and Confidence. -Illustrative explanation

Fig. 7. Evaluation sheet for Review 3

Criteria & Points Assigned	Problem solving abilities (5 Marks)	Coding (at least three modules completed) (5Marks)	Presentation skills, coordination & Question & Answer (5 Marks)
Unacceptable (1)	Basic concepts used correctly Lack self-study, but apply previously taught technique on a satisfactory level	Code is not working properly validations are not used and exception handling is not used properly.	Lack of confidence and familiarity in Some parts of the presentation
Below Expectations (2)	Superficial usage of new concepts Self-study of new technique, with basic understanding	Code is working properly but validations are not used but exception handling is used properly.	Basic organization and preparation Confident in only some parts of the presentation
Meets Expectations (3)	Self-study of new concepts /techniques, with a good understanding Minor innovative work	The code is working properly validations are used at some places only and exception handling is used properly.	Good organization and preparation Confident in most parts of the presentation
Exceeds Expectations (5)	New concepts used frequently Self-study of new techniques and solve technical difficulties; Innovative work with research value.	Code is working properly validations are used everywhere in the project and exception handling is used properly.	Excellent organization and preparation Confident and relaxed during the whole presentation

Fig.8.Evaluation sheet for Presentation-I

Criteria & Points Assigned	Code Development and proper implementation of all modules in the project (10 Marks)	Testing (5 Marks)	Individual Participation with Question and Answer (5 Marks)
Unacceptable (1)	Code is not executed properly and validations are not used and exception handling is not used properly.	-Test cases are not written properly. -Testing tools are not used. -Some test cases are missing.	Answer at least one questions correctly
Below Expectations (2)	Code is executed properly but validations are not used but exception handling is used properly.	-Test cases are not written properly. -Testing tools are used. -Some test cases are missing.	-Answer most questions correctly -Need clarification sometimes
Meets Expectations (3)	Code is executed properly validations are used at some places only and exception handling is used properly.	-Test cases are written properly. -Testing tools are used. -Some test cases are missing.	-Answer most Questions correctly and concisely
Exceeds Expectations (5)	Code is executed properly and validations are used everywhere in the project and exception handling is used properly.	-Test cases are written properly. -Testing tools are used. -All test cases are covered.	-Handle difficult questions with ease and confidence -Illustrative explanation

Fig.9. Evaluation sheet for Presentation II

Structured Multi-Phase Evaluation Framework

Capstone project assessment is conducted through a structured, rubric-based, multi-phase evaluation process to ensure transparency, consistency, and alignment with Outcome-Based Education principles. Each review stage assesses distinct technical and professional competencies using defined performance levels: Unacceptable, Below Expectations, Meets Expectations, and Exceeds Expectations.

During Review 2, the evaluation focuses on domain knowledge, SRS preparation, technical content, and individual participation in discussion and question-answer sessions. The detailed criteria are presented in Fig. 6. At this stage, students are assessed on their understanding of the problem domain, completeness of design diagrams, technical depth, and ability to respond confidently to evaluators. This review primarily measures foundational technical preparation and conceptual clarity. In Review 3, the assessment emphasizes implementation progress and execution quality. The evaluation sheet shown in Fig. 7 assesses problem-solving ability, completion of coding modules, validation mechanisms, exception handling, and presentation effectiveness. Greater importance is given to applied learning, innovation, and the justification of technical decisions. This stage ensures that students move beyond planning and demonstrate functional development.

Presentation-I evaluates creativity, originality, literature review quality, and coordination during presentation. The rubric used at this stage is shown in Fig. 8. Students are assessed on background study, methodological understanding, confidence, and communication skills. This phase strengthens research orientation and analytical thinking. Presentation-II focuses on implementation refinement, documentation quality, and scholarly contribution. The evaluation format presented in Fig. 9 includes assessment of code improvements, paper presentation or competition participation, and the quality of the final report. Emphasis is placed on validation completeness, clarity of written communication, and professional presentation standards. The final stage, Presentation-III, follows the structured criteria provided in Fig. 10. This stage evaluates full code execution, testing rigor, coverage of test cases, and individual participation during the viva. Students are expected to demonstrate technical confidence, comprehensive validation practices, and the ability to handle complex questions with clarity.

This phased evaluation structure enables continuous monitoring of student progress from proposal to final defense. The use of standardized evaluation sheets at each stage supports objective grading and provides measurable evidence for Course Outcome attainment while strengthening both technical and professional competencies.

Each faculty member mentors two project groups, with four students per group. This results in a mentor-to-student ratio of 1:4 at the group level, while each faculty member supervises eight students in total. Students meet their faculty guides twice a week for regular academic and technical support. Intermediate evaluations (ISE) are conducted by a panel comprising one DPC member and three faculty mentors, with teams assigned based on faculty expertise aligned to student project domains. The final evaluation is conducted jointly by the internal guide and an industry expert, assessing technical competence through implementation quality and functional prototype development. Presentations and project defense are used to evaluate communication skills, teamwork, and conceptual clarity. Evaluator feedback highlights strengths and areas for

improvement, supporting the holistic development of both technical and soft skills.

Criteria & Points Assigned	Changes suggested in code development (5 Marks)	Paper Presented /Project presented (5 Marks)	Final Project Report (5 Marks)
Unacceptable (1)	Changes suggested in the code are **not** working properly.	-Paper is not presented in any conference or journal. -Project is not presented in any project competition.	-Frequent errors in spelling and grammar Mostly readable, but a A few points are hard to understand
Below Expectations (2)	Changes suggested in the code are partially working.	-Paper is presented in conference but not selected as best paper. -Project is presented in project competition but not got any prize.	Some errors in spelling and grammar Some errors in spelling and grammar Readable
Meets Expectations (3)	Changes suggested in the code are working properly validations are used at some places only and exception handling is used properly.	The paper is presented at a conference and selected as the best paper or the Project is presented in a project competition and gets a prize.	A few errors in spelling and grammar. Readable and easy to understand
Exceeds Expectations (5)	Changes suggested in the code are working properly validations are used everywhere in the project and exception handling is used properly.	-Paper is presented in conference and selected as best paper and The project was presented in a project competition and got first prize.	Well proofread Clear and easy to understand Graphs and diagrams used appropriately

Fig. 10. Evaluation sheet for Presentation-III

Each criterion in the evaluation sheets is assessed using predefined performance levels that correspond to numerical points. The cumulative points obtained in a particular review are scaled proportionally to the maximum marks allocated for that review stage under the institutional assessment scheme. Marks from Review 1, Review 2, Review 3, and intermediate presentations contribute to the Internal Session Evaluation component, while the final presentation and external evaluation contribute to the end-semester project assessment. The aggregation and scaling mechanism ensures uniformity, transparency, and consistency in grading across all project groups.

V. PROCESS FOR SELECTION OF A BEST PROJECT

The selection of the best projects follows multiple evaluation criteria including project impact, execution quality, innovation, teamwork, and industry relevance, as shown in Fig. 11: Process for Selection of the Best Project. Firstly, we consider the project's impact. How much of a difference will it make? Does it solve a real problem? Next, we look at how well the project was executed. Did the students follow the plan? Did they use their skills effectively? We also consider creativity. Did the project bring something new to the table? Did it show innovation? Collaboration is important too. Did the students work well as a team? Did they get help from mentors? Lastly, we think about how the project can benefit not just the students but also the industry and the school. By looking at these factors, we can pick the best projects that show innovation, skill, teamwork, and real-world impact.

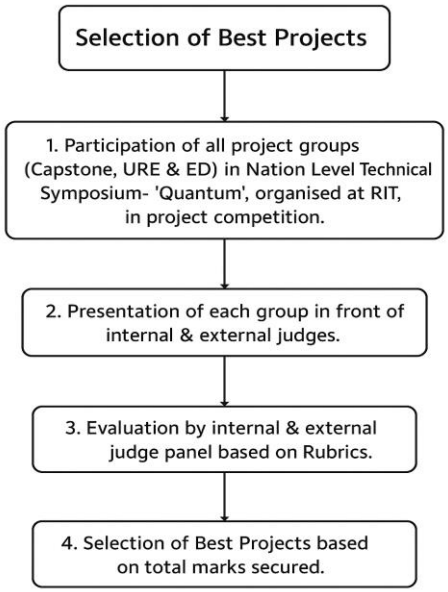

Fig. 11. Process for selection of the best project

The evaluation of capstone projects was carried out using a generalized rubric that ensured fairness across diverse domains such as healthcare, web services, and e-learning. As presented in Table III, the rubric incorporates six core criteria, namely innovation, technical quality, practical relevance, impact, presentation, and scholarly/competitive participation.

The institution has shown consistent growth in the number of projects undertaken, with a significant increase from 19 projects in 2020-21 to 40 projects in 2022-23 and 2023-24 as student intake increased from 60 to 120. The data are described in Table II.

TABLE II
CAPSTONE PROJECT RESULT ANALYSIS

Achievements and Statistics	2020-21	2021-22	2022-23	2023-24
Total Number of Projects	19	20	38	40
Total Number of Students Involved	73	79	166	172
Quality Projects Recognized	3	5	11	21
Project Competition Winner groups	3	5	6	9
Total Sponsored projects	5	5	2	7
Total Paper Published	8	9	8	15
Total Patent Published	-	-	-	7
Student Placement (%)	95%	100%	95%	97%

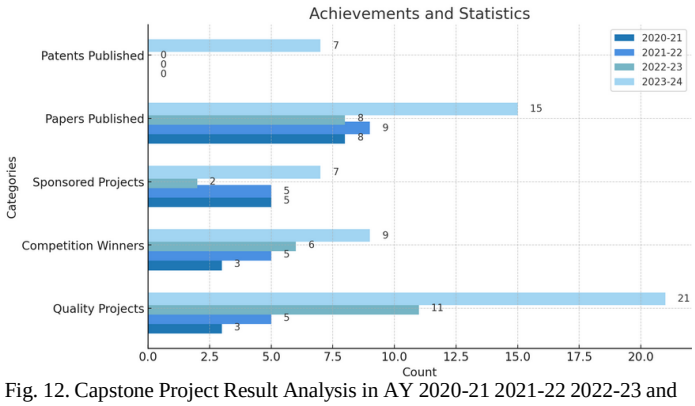

Fig. 12. Capstone Project Result Analysis in AY 2020-21 2021-22 2022-23 and 2023-24

Over the past four years, there has been a significant improvement in various academic and research-related achievements. The number of quality projects recognized has grown remarkably from just 3 in 2020-21 to 21 in 2023-24, showcasing a strong commitment to innovation and excellence. Similarly, the number of competition-winning groups has increased from 3 to 9, reflecting an improvement in students' competitiveness and project quality at national and international levels. While the number of sponsored projects remained stable in the first two years at 5, it saw a decline in 2022-23 with only 2 projects but rebounded significantly in 2023-24 with 7 sponsored projects. This indicates a renewed focus on securing external funding and collaboration opportunities. In terms of research output, the number of published papers has fluctuated but ended on a positive note, increasing from 8 in 2020-21 to 15 in 2023-24. surged to 7 patents in 2023-24, demonstrating The most notable improvement is seen in patent publications, which were non-existent in the first three years but an advancement in intellectual property and innovation.

Over the past four academic years, there has been a consistent improvement in CO Attainment across all Course Outcomes CO1 to CO5 described in table IV. In 2020-21, the attainment levels ranged between 67 and 69, indicating a moderate level of achievement. However, through continuous efforts in curriculum enhancement, teaching methodologies, and student engagement, significant progress has been observed. CO1 improved from 67 in 2020-21 to 86 in 2023-24, demonstrating a strong upward trend. CO2, which showed a slight dip in 2021-22, recovered and improved to 84 in 2023-24. CO3 and CO4 also showed remarkable progress, reaching 84 and 92, respectively, by 2023-24. CO5 saw one of the most significant improvements, rising from 67 to 87 within four years.

TABLE III
RUBRICS FOR SELECTION OF BEST CAPSTONE PROJECTS

Criterion	Weight	General Description	Domain Mapping (Examples)
Innovation and Originality	25%	Novelty of the idea, creative approach, use of modern/emerging technologies	Healthcare: AI or IoT based diagnosis, detection and recommendation Web: Cloud-native microservices E-learning: Gamified/VR modules
Technical Quality and Depth	20%	Complexity, correctness, and robustness of technical implementation	Healthcare: Model accuracy, integration with datasets Web: Performance, security, scalability E-learning: Adaptive engines, interactivity
Practical Relevance and Usability	15%	Alignment with real-world needs, usability for end users	Healthcare: Clinical adoption feasibility Web: Business/service relevance E-learning: Learner accessibility & inclusivity
Impact & Outcomes	15%	Tangible benefits, improvements, or measurable outcomes	Healthcare: Better diagnosis, patient safety Web: Cost/time savings, user engagement E-learning: Learning gains, retention
Presentation and Documentation	10%	Clarity, professionalism, completeness of reports, demos, and artifacts	Applies equally across all domains
Scholarly and Competitive Participation	15%	Involvement in external project competitions, hackathons, paper publications, or patents	Cross-domain: Hackathon awards, IEEE/Elsevier papers, startup pitches, prototype showcases

TABLE IV
COURSE OUTCOMES

Cos No.	Course Outcomes
CO1	Interact with customers and identify real world problem statement / identify problems in engineering and technology in selected field of interest.
CO2	Synthesize and apply prior knowledge of mathematics, computer science and engineering to design and implement solutions to open-ended problems.
CO3	Design and develop the software with Software Engineering practices and standards.
CO4	Use different tools for communication, design, implementation, testing, report writing and oral presentation skills.

CO5	Develop better interpersonal communication skills, teamwork and leadership qualities.

The institution's continuous monitoring and analysis of CO attainment data can serve as a valuable tool for program improvement, ensuring that students not only engage in a greater number of projects but also achieve the intended learning outcomes within those projects. This approach aligns with best practices in educational assessment and further reinforces the institution's dedication to academic excellence and student success.

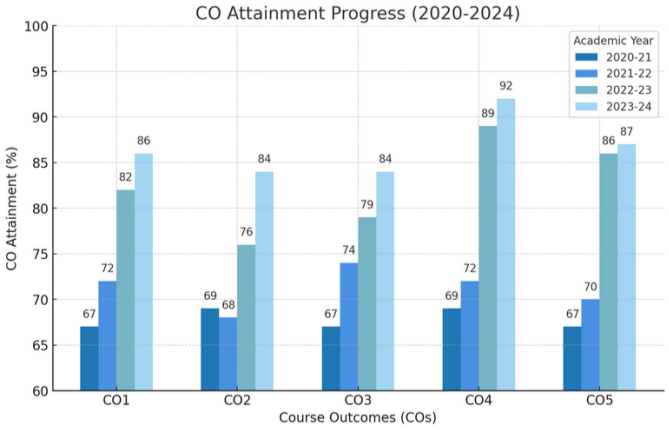

Fig. 13. CO Attainment Progress in AY 2020-21 2021-22 2022-23 and 2023-24

The improvement in CO attainment depicted in Fig. 13 is a positive reflection of the institution's dedication to academic excellence and the continuous enhancement of its educational offerings. It signals that students are not only actively engaged in projects but are also achieving their intended learning outcomes, further solidifying the institution's reputation for quality education.

VI. Results and Discussion

The capstone projects completed over the past three years covered diverse domains such as healthcare systems, web services, and e-learning platforms. Nineteen projects were recognized as high-quality based on structured metrics including technical complexity, innovation, real-world applicability, and alignment with Course Outcomes (CO) and Program Outcomes (PO). A considerable number of these were industry-sponsored projects, which demonstrated higher technical depth, better alignment with professional standards, and stronger practical impact than non-sponsored projects. These results indicate that industry-connected projects enhance curriculum relevance and improve the quality of student outputs.

Participation in capstone projects supported the development of both technical and professional competencies. Students strengthened skills in system design, software development, and data analytics, while also improving teamwork, communication, and problem-solving abilities. Industry mentor feedback highlighted strengths in creativity, adaptability, and collaboration, and suggested improvement in advanced documentation and specialized technical problem-solving. A clear relationship was observed between strong capstone performance and student placement outcomes, indicating that structured project engagement contributes directly to employability and career readiness.

Project evaluation was conducted through structured, rubric-based frameworks aligned with Outcome-Based Education principles. The rubrics assessed innovation, technical quality, documentation, teamwork, and practical relevance. Multidisciplinary projects were evaluated using adapted rubrics to account for integration across domains and technologies. Peer reviews and external expert evaluations enhanced fairness, objectivity, and industry alignment. The phased evaluation model covering proposal, design, implementation, documentation, and presentation enabled continuous monitoring of both technical performance and professional skill development.

The reported improvements were validated through longitudinal comparative analysis across three academic years using institutional records, including project evaluation scores, Course Outcome attainment data, placement statistics, sponsored project records, and research outputs. Consistent rubric-based scoring criteria were applied across all years to ensure uniform assessment standards. Industry expert participation in final evaluations provided additional external validation of technical quality and professional competence. This multi-source validation approach strengthens the reliability and rigor of the findings.

The longitudinal analysis and systematic outcome mapping provide empirical validation of the structured rubric-based capstone framework, distinguishing it from descriptive or implementation-focused studies. The findings demonstrate that a multi-phase evaluation approach strengthens transparency, consistency, and outcome alignment in long-duration engineering projects. Continuous feedback across project stages guided student growth in ethical responsibility, collaboration, and communication. For the Engineering Education community, these findings offer practical guidance for curriculum improvement, accreditation processes, faculty development, and institutional policies aimed at enhancing student learning outcomes and industry readiness.

Conclusion

This study demonstrates that capstone projects play a significant role in fostering holistic student development, improving project quality, and strengthening industry readiness. Over the three-year period analyzed, students worked across diverse domains including healthcare systems, web services, and e-learning platforms, with 19 projects recognized for their quality and innovation. Industry-sponsored projects and structured mentorship enabled students to gain practical exposure, strengthen teamwork, communication, and problem-solving skills, and apply theoretical knowledge in real-world contexts. Participation in competitions and multidisciplinary initiatives further reflected students' adaptability and technical competence.

The structured, multi-phase, rubric-based evaluation framework implemented in these capstone projects ensures objectivity, transparency, and alignment with Outcome-Based

Education (OBE) principles. It not only assesses technical competencies but also addresses broader aspects of student development, including ethics, collaboration, and professional readiness. The longitudinal outcome analysis and structured rubric mapping provide empirical validation of the proposed framework, offering a replicable and evidence-based model for institutions implementing Outcome-Based Education.

FUTURE RESEARCH AND RECOMMENDATIONS

Building upon these insights, future work can focus on the development of standardized and adaptive assessment frameworks that account for diverse project types, student backgrounds, and industry requirements. Technology-driven evaluation methods, including AI and analytics tools, could be integrated to provide real-time feedback, predictive insights, and more objective assessment metrics. Cross-cultural comparisons of capstone outcomes could be explored to understand the influence of diverse educational and industrial contexts on project execution using tools such as Agile methodologies, Jira, and GitHub. Additionally, longitudinal studies tracking graduates' career progression would provide evidence of the long-term impact of capstone projects on employability and professional development. Addressing these areas will help create a more robust, scalable, and universally applicable framework for evaluating capstone projects, ultimately enhancing the quality of engineering education and students' preparedness for the workforce.

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