Enhancing Engineering Education: A Curriculum Framework for Integrating Experiential Learning and Research

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Abstract—**Engineering education is changing to better equip students for dynamic work environments by means of experiential learning and research integration. This study offers a complete framework meant to easily combine research with experiential learning in engineering courses via curriculum redesign. The framework starts with evaluating engineering education's present situation, pointing up gaps in opportunities for experiential learning, and stressing the gap between classroom instruction and practical application. Inspired by present research and teaching methods, it suggests ways to close this disparity by include research elements all through the course. A case study showing how this approach is applied inside a particular engineering program offers actual evidence for its success. It is observed that the components that are essential for preliminary exposure to organized research experiences are, faculty and industry expert mentoring, multidisciplinary teamwork and activities relating to the real-world challenges and process of solving them with knowledge and skills. These components are meant to inspire among students critical thinking, ability to solve problems, and a closer awareness of disciplinary knowledge. Along with improving students' academic experiences, the suggested structure helps them to be creative leaders in their domains. Engineering education can more effectively satisfy the needs of a global environment growing in complexity by encouraging a culture of investigation and application.**

***Keywords*— Case study; Curriculum redesign; Engineering education; Experiential learning; Research integration; Student engagement in research**

ICTIEE* Track*: Curriculum Development
ICTIEE Sub-Track: Incorporating Research Opportunities into the Curriculum to Encourage Student Engagement in Research

I. INTRODUCTION

RESEARCH is important for engineering students as it helps them develop research competencies early in their careers, preparing them for future graduate studies and professional lives. Different approaches, like research-oriented, research-based, research-tutored, and research-led, can be used to implement research-based learning in the classroom. Research benefits engineering students by providing them with opportunities to develop communication, leadership, and technical skills, as well as build self-confidence. Higher education institutions are still putting a lot of money into new engineering programs for first-year students that focus on hands-on learning. While this investment is being made, the community needs to think about the theoretical basis of experiential learning as well as the linked methods used in engineering. This kind of thought can help you find your way through the 21st century's changing school and work environments. (Tembrevilla G., et al., 2024). However, the general observation suggests that engineering students are not inclined towards research-based learning styles during their undergraduate programs. It may be interesting to explore the reasons for this attitude. Factors that influence engineering student research interest include personal interest, family influence, high school teachers, peers, previous success in math and science courses, and interests in the career track. A few recent research have demonstrated that students who persist in engineering programs frequently do so because they associate engineering with their sense of self, an attainment values. Students are more likely to persist in a field if they value the outcomes associated with it and believe they can succeed in that field. This theory also highlights the importance of personal beliefs and attitudes in shaping motivation and behavior. Such research encourages us to further explore the reasons why and how students may be motivated to carry out research activities. Understanding these motivations can help us create more effective learning environments. One of the most significant tools for providing a research-oriented environment to the learners is the program curriculum. One must also consider that Bloom's taxonomy is crucial for engineering education as it provides a structured framework for developing higher-order thinking skills, enabling students to not only understand and apply theoretical concepts but also analyze, evaluate, and create innovative solutions to complex engineering problems

(Lavado-Anguera, S., et al., 2024). There are a lot of students in the classroom who have trouble understanding and applying what they are learning to real life, and they may be supported by modern methods of learning namely experiential learning or project-based learning (Zahraee A., et al., 2024). On the other hand, curriculum structure can influence research interest of students by incorporating topics that spark curiosity and engagement among students, leading to increased motivation and deeper learning (Golecki, H. & Bradely, J., 2024). Research has shown that individual interest plays a significant role in attention, recognition, and recall, especially in young children. By aligning curriculum content with students' interests in Project-based learning, internships, training, and engineering practices they can improve their real operation and innovation skills and thereby educators can enhance the overall learning experience and foster a positive attitude towards research among the learners (Fang, W., 2024; Reddy, P. L., & Singh, D. N., 2024). However, a question arises: what should be the structure, content, overall framework, and key components of a research-oriented curriculum? The answer to this question may vary depending on the specific goals and objectives of the educational program. It is recorded that students can think about the professional knowledge and skills they need and improve their design thinking, engineering application, and creativity through a large training project that combines software and hardware (Jiang, C., & Pang, Y., 2023; Routhe H. W., et al., 2023). Ultimately, it is essential to consider the needs and interests of the students and the desired outcomes of the research curriculum. A research-based curriculum should be based on design-based research (DBR) principles for its structure, content, overall framework, and key parts. DBR involves drawing design principles from theoretical and empirical foundations, using them to create the curriculum, and improving them based on data gathered during implementation cycles (Reilly, C., & Reeves, T. C., 2024). Learners' needs should determine the content structure, focusing on what is most sensible to the learner rather than solely on scientific subject content. Domain-specific design principles, derived from research on teaching and learning in the specific field, guide the development process and are refined based on evaluation results. Curriculum design should not solely rely on disciplinary content structures but should prioritize coherence-seeking by students as the agents of coherence. Curriculum design processes should consider micro to macro levels to ensure the core ideas, subtopics, and sequencing are appropriate for the target audience (Cunningham, K., et al., 2024). Additionally, it is important to incorporate assessment practices that align with the desired outcomes. Furthermore, feedback mechanisms should be in place to monitor the effectiveness of the curriculum and make necessary adjustments.

Overall, promoting research at the undergraduate level of learning among young engineers requires a concerted effort from both educators and industry professionals. Key components of a curriculum that encourages students to do research include integrating multimedia tools for critical thinking skill development, using technology for peer evaluation and feedback, and allowing students to research and obtain information independently. Problem-based learning is also effective in enhancing critical thinking skills and promoting student participation in class activities. However, instead of offering activities, the curriculum should be redefined with a modern concept to promote research skills and hands-on learning opportunities for learners (Ambos, E. L., et al., 2024).

Another aspect is the teaching methodology or pedagogy that can enhance research interest among the students. Different teaching methods impact research engagement by encouraging student participation through various activities such as workshops, brainstorming, presentations, and peer critiquing (Radovan, M., & Radovan, D. M., 2024). Research engagement can improve teachers' professional development by increasing teaching plans, educational objectives, and reflective behavior. However, traditional teaching methods should not be completely abandoned in the process. Therefore, there is a need to propose a systematic model for redesigning the engineering program curriculum.

This research paper focuses on developing a comprehensive framework for integrating experiential learning into the engineering curriculum that eventually connects students to research activities in their domain specific field. The article reviews the current state of engineering curriculum, identifies gaps in experiential learning opportunities, and proposes strategies for implementation. A case study is also presented to support the proposed concept of including research attributes in the conventional engineering curriculum.

II. Current State of Engineering Curriculum

The engineering curriculum is experiencing swiftness in its framework and contents due to several influential parameters. Earlier, the old engineering curriculum in Indian institutes focused on material science, electric machines, measuring instruments, digital and analog electronics, computer programming, control engineering, and similar contents. We may refer to them as traditional curricula. However, in modern times, we observe the promotion of multidisciplinary, the development of research skills, self-management skills, and critical thinking skills. NEP 2020 aims to develop multidisciplinary academic curricula in universities, but it is still a challenge due to inhibiting factors. Structures in Indian universities do not require new ones for NEP 2020 implementation, but there is a need for an inclusive curriculum for holistic education. Additionally, the topics emphasized in Indian engineering programs include knowledge acquisition, knowledge dissemination, leadership, culture, and technology as important dimensions of knowledge management orientation in engineering institutions. However, over and above these attributes, the engineering curriculum lacks concentration on research-related aspects. The lack of emphasis on research in the engineering curriculum can be attributed to various factors, such as traditional teaching methods, limited resources for research, and a focus on theoretical knowledge over practical application. There is a need for a shift towards modern pedagogies, for example, problem-based learning (PBL) and project-based learning, to enhance research skills among engineering students. However, the current curriculum may not adequately prepare students for real-world challenges and industry demands. Research contents in the curriculum of engineering programs can support innovations by creating an informed, interdisciplinary educational environment where students are educated through active participation in cutting-edge engineering research and technology innovation. This integration of research and education can lead to new technology and curriculum innovations. To have a closer look at the content-wise proportions of a typical engineering curriculum with course types, the following chart in Fig.1 may be referred to.

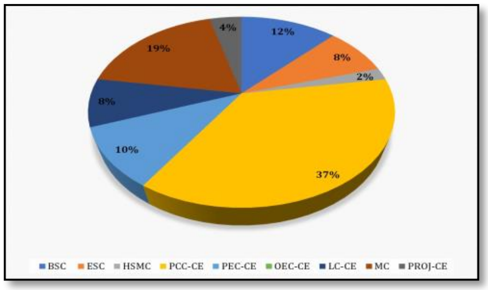


Fig. 1. Content proportions in Engineering Curriculum

From the chart shown in Fig. 1, it may be ascertained that research related components are still missing and create a partial vacuum. It demonstrates that there is a need for a shift towards research integration in the curriculum, supported by research-based activities that can benefit students by spending time working and learning in community contexts where they can apply theory and increase their awareness of social issues as well. Integrated experiential education emphasizes learning in real-life settings and interdisciplinary collaboration among instructors, promoting a more holistic educational experience.

With the spread of National Education Policy 2020 (NEP 2020) within the academic landscape of higher engineering education in Pan India, the scenario is changing (Shukla, B., 2023). Current methods of teaching research skills in engineering include the Optimizing Problem Solving (OPS) pentagon model, which was devised by students for students and piloted in first-year engineering courses (Purush, K., et al.,2017). This model has been associated with improved student problem-solving skills and teachers' capacity to teach problem solving. However, in all these discussions, it is also important to consider the learner's perspectives toward the research attributes. Therefore, it is first interesting to understand what role a curriculum plays in increasing the interest of students in research, particularly in a full-time undergraduate engineering program and may require a redesigning exercise in the present context of the discussion.

III. Proposed Curriculum Redesign

Redesigning a curriculum may be compared with the reformation process of an existing framework. However, the process is complex to pursue at first impression, so there may be a simplified approach required to carry out the exercise. For this purpose, the following model discusses the three major steps for redesigning the conventional curriculum for developing, promoting, and implementing research activities and research environments at the engineering organization. The major aspects are shown in Fig. 2.

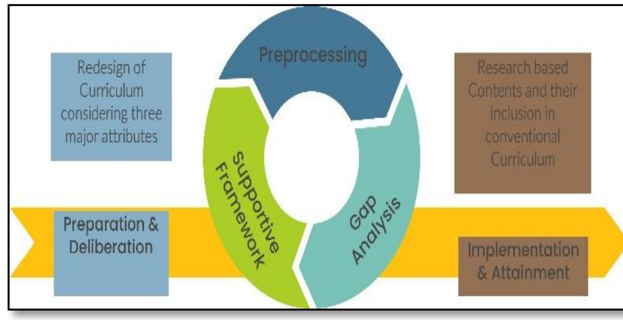


Fig. 2. Stages of Curriculum redesign

A. Preprocessing: Review and analysis of the existing curriculum framework

The authors have identified characteristics for new suggestions and ideas to increase students' interest in research. With the consideration of these attributes, the redesign of a curriculum may become more research centric for the learners. A broader classification is illustrated in Fig. 3. It shows four attributes that may get included in a curriculum to give a kick start to the redesign process of the curriculum.

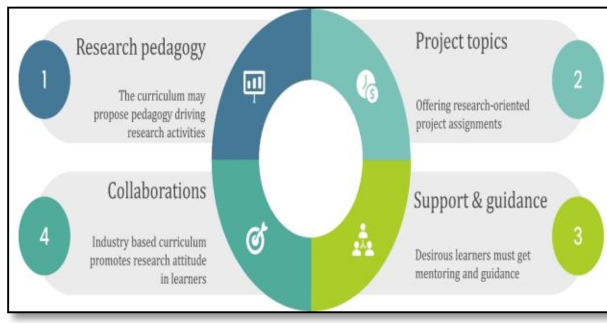


Fig. 3. Review Process for Curriculum redesign

To simplify this work, the authors have followed a simple scientific method. To incorporate research methods courses into the engineering curriculum, departments can offer courses that explicitly teach fundamental research skills, interdisciplinary skills, and professional development to graduate students at the beginning of their coursework. These courses can cover topics such as research objectives, research questions, reading journal articles, work-life balance, scientific writing, and the business of academics. By providing structured training in these areas, students can be better prepared for conducting scientific research and navigating the demands of graduate student life. Additionally, exploring innovative instructional methods that emphasize student involvement and discussion can enhance the effectiveness of teaching research methods in engineering education.

B. Pre-processing for incorporating research interests into curricula.

The process begins with a preview of the existing curriculum structure and its components, namely teaching hours, evaluation pattern, and most importantly, content type.

Fig. 4. Replacement of content to research oriented contents

Fig. 4 indicates pre-processing for starting the curriculum redesign process at the departmental or program level. The illustration also shows some other ways to add research elements to an engineering curriculum. The keywords of content attributing Bloom's Taxonomy may be a supportive framework for the effectiveness of the research attributes in developing and measuring life-long learning graduate outcomes. One more aspect of the pre-processing of curriculum design is the feedback of the faculty, who are deeply involved in daily academic tasks, and students. Feedback from faculties can help in designing a research-oriented curriculum by emphasizing research processes and problems, allowing students to actively engage in research activities, and increasing the proportion of research-based and research-tutored courses in the curriculum. Different courses can have varying emphasis on research outcomes, processes, and problems, with students participating in research activities to enhance their learning experience. Finally, it comes to the implementation part. That means the activities through which the research work may get through the learning environment. Specific activities that may be included in a curriculum to make it more research-oriented could involve curriculum development with teacher learning and school development, the design and evaluation of curriculum materials, and the research methodology of design research in education.

C. Reworking the curriculum contents for transformative changes: Gap Analysis

In a conventional curriculum, research components may be incorporated by performing a gap analysis. In general, a typical curriculum structure consists of information on the course, its evaluation scheme, details of contents, a list of exercises, the weighting of proportions of concepts, and references. However, the modern curriculum also talks about the objective and outcome of the course. However, it does not necessarily indicate how research-related activities are involved in the framework. Therefore, it is necessary to find the gap using the following components of the curriculum for the gap analysis:

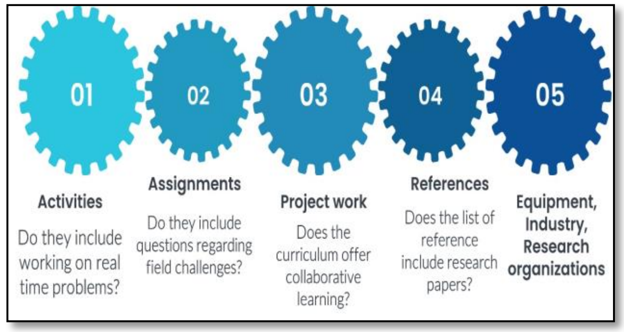


Fig. 5. Gap Analysis for curriculum redesign

Fig. 5 illustrates the aspects to be reworked to transform the conventional curriculum into a research-oriented curriculum. One of the most effective ways to find the gaps is to focus on the above five elements of the framework. If activities are based on real time problems, the students will work innovatively. If the assignments ask for research-based questions like methodologies, process descriptions, interpretations of questions, and many more, the learners get to know about preliminary research aspects. When a curriculum offers project work, the learner starts stepping into the world of research.

Generally, project work represents theory and practice and, therefore, is an important attribute of any technical curriculum in today's time. One more often ignored attribute of a typical curriculum is the list of references. It is rarely observed that the list of references in a syllabus mentions research articles. This is very important. There may be an argument that the learners, especially in their first or second year, may not have exposure to this term at all! But the answer is in the question itself. This is what was expected: the learner should ask at least about the research article. And this is how they may start getting interested in research. Furthermore, to attract students towards research articles, teachers should exhibit behaviors that show care and interest in the subject, as students are more likely to be motivated to learn when they feel supported and engaged. Teachers' behaviors can influence students' interest in learning mathematics, but there may not be a direct link between teachers' behaviors and students' career development. It is important for teachers to be approachable, responsive, and motivating to encourage students to engage with research articles.

D. The inclusion of research projects in the curriculum as a mandatory component

To ensure effective reinforcement of the curriculum for research, the next step is to include research projects. The same can be done in the first-year curricula of the engineering courses, too. However, the intensity of such projects may be carefully selected and drafted in accordance with the learning levels of the students as per their semester levels. It is reported that the inclusion of research projects in the curriculum provides several benefits. To introduce research projects in core engineering courses, universities can incorporate service-learning (S-L) projects into existing core courses. This approach can meet ABET requirements, involve community partners, and allow students to work on multidisciplinary teams. Examples like EPICS show how S-L can be integrated into elective interdisciplinary courses from the first year to the senior year. Some universities, like UMass Lowell, have integrated service-learning into core undergraduate courses by replacing traditional projects with S-L projects. This integration does not add more class or homework time for students and covers a wide range of topics (Barrington, L., & Duffy, J., 2010). However, this process requires a little preparation in the classroom. To include research projects in engineering courses, it is recommended to balance concrete and abstract content in the presentation of all engineering courses. Most courses already contain a reasonable level of abstraction, so the challenge is generally to promote active learning in the classroom by involving students in productive activities without sacrificing important course content or losing control of the class.

E. Supportive framework: Provision of dedicated mentoring and state-of-the art infrastructure

Another important attribute that works as the scaffolding for research support in the curriculum is the dedicated mentoring and infrastructure facility, along with the funding opportunities. The organization needs to cultivate a research attitude amongst the stakeholders and focus on investing more in state-of-the-art facilities. One-on-one mentoring combined with group mentoring may provide distinctive relational support that can meet adolescents' needs more effectively than either approach alone in developing research awareness from the first to the final semester. Youth mentoring has been linked with positive effects on academic achievement, social skills, self-esteem, peer connections, and risky behaviors. As mentioned, the redesign of the curriculum for research requires the availability of relevant infrastructure. Lab facilities play a crucial role in research activities in engineering institutes by providing the necessary equipment and resources for conducting experiments and studies (Feisel, L. D., & Rosa, A. J., 2005). One of the ways to attain this is by having visits by experts from the field or industry to the campus and including their sessions in the regular curriculum as partial delivery of the contents. The curriculum framework must ensure a blended teaching-learning model for the successful implementation of the research activities in the courses.

IV. Benefits of Research in Engineering Education

The inclusion of research and related activities provides several advantages to all the stakeholders, especially students, teachers, and institutions. Some of the major benefits may be discussed as follows:

A. Development of critical thinking and problem-solving skills among students

Research can help in the development of critical thinking in students in engineering education by examining how academics define critical thinking, identifying appropriate pedagogical techniques, and analyzing student work to create a model for teaching and assessing critical thinking skills across disciplines, including engineering. Research often involves integrating knowledge from various disciplines. Moreover, the research attributes of a curriculum can contribute to students' problem-solving capacities by providing a structured framework for developing generic graduate attributes that are essential for problem-solving skills. Different conceptions of graduate attributes among academics can influence the teaching and learning processes that facilitate the development of these outcomes. Qualitative and quantitative research approaches can be used to study problem-solving abilities in the science education curriculum, with a focus on ethical considerations and suggestions for future research. To improve the problem-solving skills of engineering students using research-related activities, implementing problem-based learning (PBL) can be highly effective. PBL involves students working on complex problems that do not have a single correct answer, identifying what they need to learn, engaging in self-directed learning, applying new knowledge to the problem, and reflecting on their learning and strategies used. This approach helps students develop flexible knowledge, effective problem-solving skills, self-directed learning skills, collaboration skills, and intrinsic motivation.

B. Exposure to real-world engineering challenges

Through the years of experience of the academicians, it has been observed that hands-on experience provides significant learning skills and clarity to the students. Engineering students can solve real-world challenges by learning research-oriented content in the curriculum using real-world problems as context, fostering long-term learning and deeper understanding of topics. Partnerships are crucial to boost the authenticity of the problems and prepare students for future success by arming them with the necessary skills (Kirn, A., & Benson, L., 2018). Engineering students develop skills in research-based learning (RBL) through activities such as formulating and answering research questions, making observations, developing hypotheses, conducting research projects, and publishing papers or research results. They also enhance their research skills by participating in small group discussions with teachers, observing real-world research, learning research methods, analyzing research papers, and engaging in peer reviews. Considering an example, research skills benefit students in civil engineering by helping them acquire the competencies required by companies, motivating them to perform well in their jobs. Additionally, research skills allow students to apply theoretical and practical knowledge from specialists in different areas, enabling them to explore various civil engineering specializations. The relationship between research-oriented curriculum and real-world challenges is explored in the context of mathematics education in various jurisdictions. The analysis reveals variation across jurisdictions in how real-world contexts are integrated into the curriculum content and assessments, highlighting a lack of coherence between official orientations towards real-world applications of mathematics and their implementation in educational practices. To promote research attitudes among students in engineering curricula, influential factors such as student interest, practical application skills, and gender/ethnic background should be considered. Engineering integration into school science curricula can help improve technical high school students' interest and confidence in science. In summary, the addition of research-oriented content to the curriculum inspires students to start developing the capacity to face real time conditions and how to seek solutions for such problems.

C. Preparation for post graduate studies and professional careers

Research skills are some of the primary requirements expected from students when they apply for higher studies. For example, the M. Tech. Courses in any engineering stream demand research-oriented work and attention from a candidate. The students who have already been exposed to the research aspects can perform better in their post-graduation studies. A research-oriented engineering curriculum can support students in their postgraduate studies by emphasizing procedural knowledge about the research interests of faculty members or learning about the process by which knowledge is produced. This helps students develop research and inquiry skills and techniques, preparing them for future graduate studies and their professional lives. Post-graduate engineering studies and research are related through the development of creative power and specialization, which are essential for engineers to excel in their field. Collaboration between industry and universities plays a crucial role in postgraduate activities, including post-graduate research. It is suggested that post-graduate research could be conducted mainly in industry to enhance practical knowledge and skills. A student graduating from the institute with sufficient research skills can perform better in their developing professional career owing to the following aspects: Research inclusion in graduate level learning through the curriculum can significantly benefit engineering students in their professional careers. Here are some key attributes:

Enhanced problem-solving skills: Research involves identifying problems, formulating hypotheses, and testing solutions.

Development of Critical Thinking: Engaging in research encourages students to critically analyze data, question assumptions, and draw evidence-based conclusions.

Exposure to Cutting-Edge Technologies: Research often involves working with the latest technologies and methodologies.

Improved communication skills: Presenting research findings, writing papers, and collaborating with peers and mentors improve students' communication skills.

Networking Opportunities: Research projects often involve collaboration with industry professionals, academics, and fellow researchers.

Increased Interest in Graduate Studies: Participation in research can spark an interest in further studies, leading students to pursue advanced degrees. This can enhance their expertise and career prospects in specialized fields.

Recognition and Career Advancement: Successfully conducting and publishing research can earn students' recognition in their field. This recognition can lead to career advancement opportunities, such as promotions or leadership roles.

V. Case Study

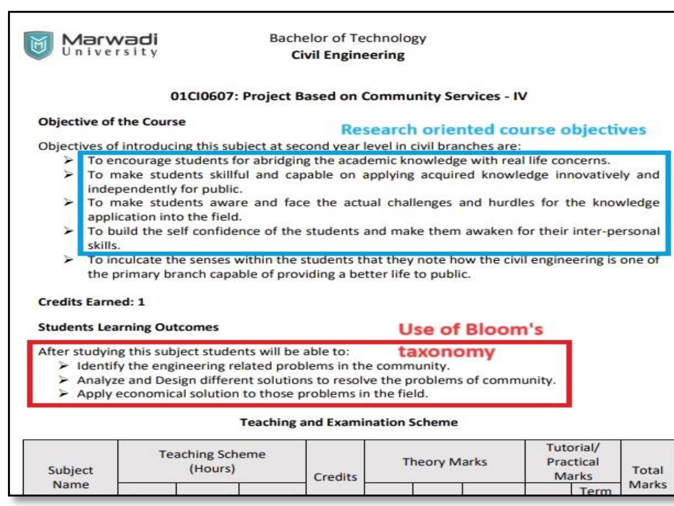
A. Purpose of presenting the case study:

The conventional engineering curriculum lags with the research-oriented contents, actions, activities and inputs by the faculties. Therefore, it was interesting to develop a curriculum that deals with the solution and addressing problems requiring solutions from the engineering students. The present case study shows the impact of inclusion of the research-oriented activities in curriculum on the enhancement of the cognitive capacity of the students, improvement of analytical, critical thinking, and communication skills. The case study represents the benefits of having research-oriented content in the curriculum for the learners.

B. Background:

At a prominent university, the civil engineering department introduced a research-oriented curriculum for the course titled "Problem based on Community Services-IV (PBCS)" for graduate students. This curriculum aims to foster deeper understanding, critical thinking, and practical skills among students eventually developing interest in research related advanced studies or degrees in civil engineering.

It is to mention that the curriculum discussed in the case study has been carefully drafted by examining the existing gap in the old curriculums course than one course. On the completion of the gap analysis stage, the curriculum contents have been reworked as shown on Fig.6 and Fig.7. It is to mention that the curriculum has been enriched with all major aspects of research based or research dependent contents. This includes setting new objectives, use of effective keywords of Bloom's taxonomy, special exercise and directions to carry out project work in real-time conditions, emphasizing creativity attributes in evaluation methods and boosting the application of skill based working techniques for the students.



Marwadi University

Bachelor of Technology
Civil Engineering

01CI0607: Project Based on Community Services - IV

Objective of the Course

Research oriented course objectives

Objectives of introducing this subject at second year level in civil branches are:

- To encourage students for abridging the academic knowledge with real life concerns.
- To make students skillful and capable on applying acquired knowledge innovatively and independently for public.
- To make students aware and face the actual challenges and hurdles for the knowledge application into the field.
- To build the self confidence of the students and make them awaken for their inter-personal skills.
- To inculcate the senses within the students that they note how the civil engineering is one of the primary branch capable of providing a better life to public.

Credits Earned: 1

Students Learning Outcomes

Use of Bloom's taxonomy

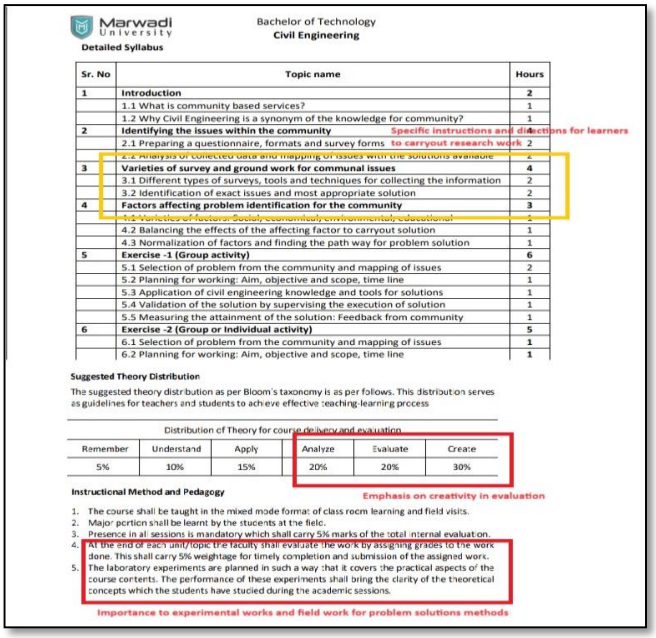
After studying this subject students will be able to:

- Identify the engineering related problems in the community.
- Analyze and Design different solutions to resolve the problems of community.
- Apply economical solution to those problems in the field.

Teaching and Examination Scheme

Subject Name	Teaching Scheme (Hours)	Credits	Theory Marks	Tutorial/ Practical Marks	Total Marks

Fig. 6. Redesigned Curriculum contents


Marwadi University
Bachelor of Technology
Civil Engineering
Detailed Syllabus

Sr. No	Topic name	Hours
1	**Introduction**	2
	1.1 What is community based services?	1
	1.2 Why Civil Engineering is a synonym of the knowledge for community?	1
2	**Identifying the issues within the community**	4
	2.1 Preparing a questionnaire, formats and survey forms	2
	2.2 Analysis of collected data and mapping of issues with the solutions available	2
3	**Varieties of survey and ground work for communal issues**	4
	3.1 Different types of surveys, tools and techniques for collecting the information	2
	3.2 Identification of exact issues and most appropriate solution	2
4	**Factors affecting problem identification for the community**	3
	4.1 Varieties of factors: Social, economical, environmental, educational	1
	4.2 Balancing the effects of the affecting factor to carryout solution	1
	4.3 Normalization of factors and finding the path way for problem solution	1
5	**Exercise -1 (Group activity)**	6
	5.1 Selection of problem from the community and mapping of issues	2
	5.2 Planning for working: Aim, objective and scope, time line	1
	5.3 Application of civil engineering knowledge and tools for solutions	1
	5.4 Validation of the solution by supervising the execution of solution	1
	5.5 Measuring the attainment of the solution: Feedback from community	1
6	**Exercise -2 (Group or Individual activity)**	5
	6.1 Selection of problem from the community and mapping of issues	1
	6.2 Planning for working: Aim, objective and scope, time line	1

Specific instructions and directions for learners to carryout research work

Suggested Theory Distribution

The suggested theory distribution as per Bloom's taxonomy is as per follows. This distribution serves as guidelines for teachers and students to achieve effective teaching-learning process

Distribution of Theory for course delivery and evaluation

Remember	Understand	Apply	Analyze	Evaluate	Create
5%	10%	15%	20%	20%	30%

Emphasis on creativity in evaluation

Instructional Method and Pedagogy

1. The course shall be taught in the mixed mode format of class room learning and field visits.
2. Major portion shall be learnt by the students at the field.
3. Presence in all sessions is mandatory which shall carry 5% marks of the total internal evaluation.
4. At the end of each unit/topic the faculty shall evaluate the work by assigning grades to the work done. This shall carry 5% weightage for timely completion and submission of the assigned work.
5. The laboratory experiments are planned in such a way that it covers the practical aspects of the course contents. The performance of these experiments shall bring the clarity of the theoretical concepts which the students have studied during the academic sessions.

Importance to experimental works and field work for problem solutions methods

Fig. 7. Evaluation scheme showing higher order skills

The redesigned curriculum clearly explains the incorporation of experiential learning attributes along with the research-oriented activities and guidelines for effective outcomes of the course.

C. Participants:

The learning abilities of students via research-oriented methodologies were studied for the enrolled students in the 6th semester program in Civil Engineering at the University where the authors are affiliated. These students came from diverse backgrounds namely from the local region, out states, and from the African continent. Their interests in domain specific courses were also different, namely structural engineering, transportation engineering, environmental engineering, and geotechnical engineering and similar other areas. The curriculum was redesigned during the academic year 2020-2021 approved by the apex academic body of the department and has been in force from the past two years for semester 6 students.

D. Objectives of the study:

To observe the attainment of research-oriented skills among the students by offering the research enriched curriculum contents. The following skill sets shown in Fig.8 were set to be evaluated:

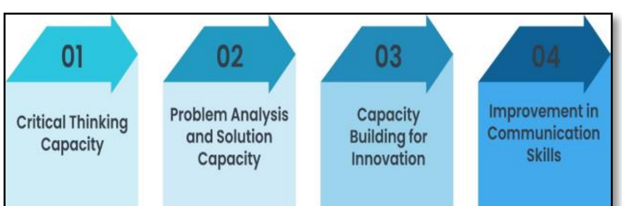


Fig. 8. Skill sets as evaluation criteria of case study

E. Methodology

The methodology includes a stage wise process starting with allocation and identification of topics for project work inspired from the real-world challenges to final evaluation process. The sequence is shown on Fig.9. A sample of supportive framework as per the curriculum delivered to the students is shown in Fig. 10, and the samples of students' work based on the guidelines are shown in Fig. 11 and Fig.12 respectively.

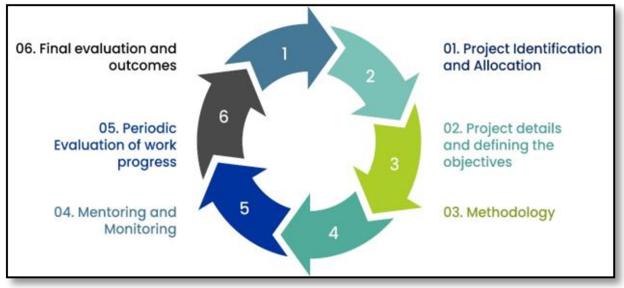


Fig. 9. Methodology adopted in the project work

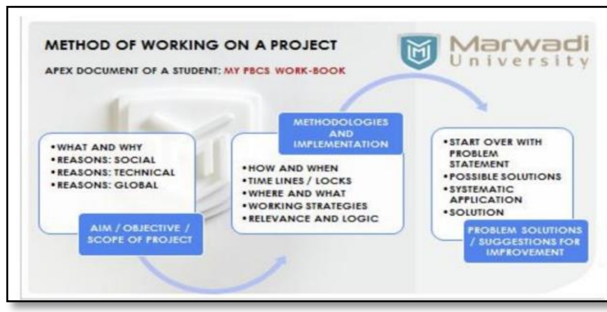


Fig.10. Sample of method of working with projects

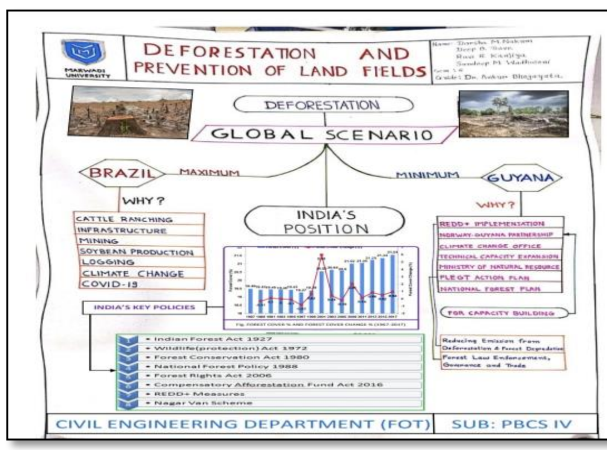


Fig. 11. Sample 1: Student's work on problem identification

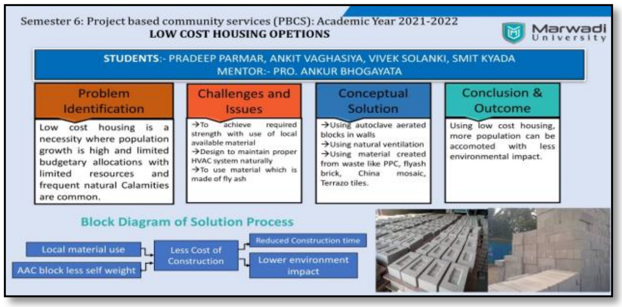


Fig. 12. Sample 2: Student's work on problem identification

F. Evaluation

The progress monitoring, instructions, guidance and evaluation processes were carried out by using Canvas Instructure tool. The following are the samples for the interactions and progress reported by the students on Canvas Instructure. However, keeping the space limitations and formatting of the article, the grading or evaluation has been presented in a graphical format for ease of understanding to the readers. Fig. 13 shows the use of Canvas platform in course management and Fig. 14 shows the project evaluation criteria.

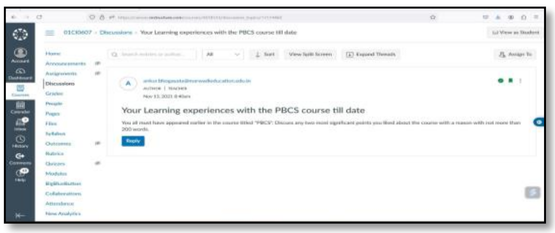


Fig. 13. Sample evaluation using Canvas platform

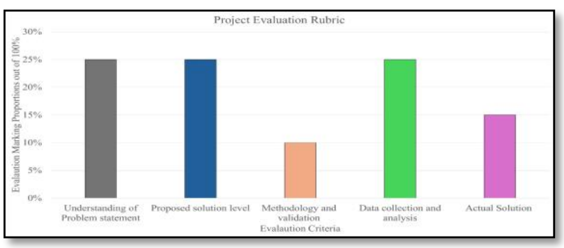


Fig. 14. Project evaluation criteria with proportional distribution

TABLE 1
PROJECT ASSESSMENT CRITERIA WITH PROPORTIONAL DISTRIBUTION

Project: Solution for Unorganized community waste disposal challenges	Maximum Marks	Obtained Marks
Group Leader: Victorien Bidias		
Understanding of problem	25	21
Proposed solution	25	19
Methodology and validation	10	8
Data collection and analysis	25	22
Actual solution	15	10
Outcome	Effective	IUCEE symposium

Fig. 15. Certificate of paper presentation by a student

Table 1 displays the assessment of a student in the course where he selected a topic on providing solutions to the challenges raised due to the unorganized waste management system and solution for keeping the environment clean and green by proposing a systematic methodology for waste management. Fig. 15 shows his participation in a students' symposium where he presented his solutions and received a vote of confidence and appreciation from the IUCEE experts.

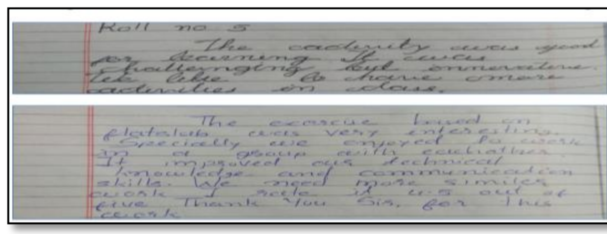


Fig. 16. Actual samples of students' feedback on the course

All students who appeared in the course were requested to share their feedback on the course management, methodologies, mentoring, supportive framework, contents of curriculum and curriculum design along with their learning experiences. Fig. 16 shows a few of the feedback of the students mentioning their level of excitement and satisfaction due to the overall curriculum framework. It will be interesting to explore the detailed analysis of such feedback by all students in a group as a separate study to obtain complete success ratio of the implementation of research enriched curriculum design. The author will be taking this task as futuristic study. With successful implementation of the course using research-oriented contents and titles, the students showed greater enthusiasm in the learning process throughout the course.

G. Work summary

The project work by the students was monitored consistently and grades were allotted for each stage of progress. The team of instructors, mentors and guides observed significant improvement in the students' work attitude, and reflections in the learning outcomes. The following are the preliminary outcomes observed at the end of the course work.

1. Students learned to work in a group though with their diversities
2. The course improved the analytical skills of the students

3. The project work effectively resulted in realistic solutions in many cases
4. A few students were inspired to participate in conferences and presented research papers
5. Students became sensitive to the community-related problems and made efforts to resolve them using their learning, knowledge and skills
6. A few students decided to carry on their academic journey with higher studies after completion of their undergraduate program.

Coursework Integration: Research-oriented courses were integrated into the curriculum, focusing on research methodologies, literature review, data analysis techniques, and presentation skills.

Research Projects: Students were encouraged to undertake research projects aligned with their interests and career goals. These projects often addressed current challenges in civil engineering, such as sustainable infrastructure, urban planning, or disaster resilience.

Faculty Mentorship: Each group of four students was assigned a faculty mentor who provided guidance throughout the research process, from defining research objectives to publishing findings in journals or presenting at conferences.

Outcomes and attainments:

1. Development of Research Skills: Students reported significant improvement in their ability to formulate research questions, design experiments, and analyze data effectively.

2. Enhanced Communication Skills: Through presenting their research findings to peers and faculty, students gained confidence in public speaking and academic writing, essential for disseminating research outcomes.

3. Depth of Knowledge: Students acquired a deeper understanding of specific topics within civil engineering, beyond what was covered in standard coursework, through extensive literature review and practical research.

4. Career Advancement: Several students secured internships, co-op placements, or job offers in prestigious engineering firms or research institutions, attributing their success to the research experience gained during the program.

5. Academic Achievements: Some students published their research in peer-reviewed journals or presented it at national and international conferences, enhancing their academic credentials and reputation in the field.

H. Remarks on the course work:

The research-oriented curriculum in civil engineering under PBCS-IV course title at the graduate level proved instrumental in enhancing learning skills among students. It not only equipped them with advanced technical knowledge but also fostered critical thinking, practical application of knowledge, and professional development essential for successful careers in civil engineering.

I. Lessons Learned: Curriculum implementation with special research emphasis exhibited following important aspects:

1. Prior to developing or executing a curriculum that focuses on research, it is essential to carry out a thorough needs assessment to gain a contextual understanding. This requires comprehending the distinct requirements, difficulties, and objectives of the intended audience or students. It is important to consider contextual elements such as socio-economic background, past knowledge, and cultural influences. This preliminary stage guarantees that the curriculum is pertinent and customized to meet the specific requirements of the learners.

2. Integrating the development of research skills into the curriculum is crucial for promoting critical thinking and academic excellence. It is important to expose students to research methodologies, data analysis tools, and academic communication at an early stage. Offering opportunities for practical research experience and guidance can greatly increase students' research skills and equip them for future academic endeavors.

3. Continuous evaluation and feedback systems are necessary when implementing a curriculum with research emphasis. Periodic evaluations of student learning results, research outputs, and curricular effectiveness aid in identifying strengths, flaws, and areas that require enhancement. By incorporating feedback from students, teachers, and stakeholders, the curriculum can effectively adapt to changing educational requirements and research trends.

4. Interdisciplinary Collaboration and Resource Sharing: Collaborating across several disciplines and departments enhances the implementation of a curriculum that focuses on research. Promoting multidisciplinary collaborations, collaborative seminars, and research symposia fosters the sharing of knowledge and stimulates creativity. In addition, forming alliances with business, government organizations, and research institutes grants students access to valuable resources, specialized knowledge, and practical applications, so enriching their research experience.

5. Adaptability and flexibility are crucial in curriculum design as they enable adjustments to be made in response to evolving educational environments and emerging research patterns. A dynamic curricular framework is designed to incorporate changes in discipline knowledge, technological breakthroughs, and pedagogical innovations. By placing a strong emphasis on developing lifelong learning abilities, such as adaptability, resilience, and curiosity, students are equipped to effectively navigate intricate research contexts and make valuable contributions to their chosen disciplines.

This case study illustrates how a research-oriented approach can significantly benefit graduate students in civil engineering, preparing them to tackle complex challenges and contribute meaningfully to the field through innovative research and practical application.

VI. Recommendations for Future Implementation

The present article discusses the importance of research in the curriculum for undergraduate students in engineering programs at the university level. The authors would like to discuss the strategies for effective implementation of research components in the conventional curriculum with the following observations:

A. Strategies for faculty involvement in research activities for students via curriculum restructuring

Strategies for faculty development in research mentoring can include implementing faculty technology mentoring programs, utilizing reverse mentoring, creating communities of practice, and providing professional development frameworks for online teaching. These strategies can help overcome barriers to technology integration and enhance faculty knowledge and skills in research mentoring.

B. Assessment methods for measuring the impact of curriculum redesign for research attributes

Though it is a bit difficult to directly measure the impact of the inclusion of research components in the curriculum on the students' progress and improvement of knowledge and learning, such outcomes may be qualitatively measurable. The following are the suggested methods for the same:

- Evaluate group work with predefined rubrics.
- Identify specific activities carried out by the students directed towards the research.
- Quantification of outcomes by assigning appropriate grades to the group members
- Declaring awards and recognition to the students by the department and university for their academic co-curricular gestures such as paper writing, participation in conferences, and similar actions.

CONCLUSIONS

The authors would like to propose the following conclusions and remarks on the work presented in the article and the case study discussed:

- The conventional engineering curriculum requires a blend of actions, activities, and frameworks that can redirect students towards research.
- By following three basic exercises, namely review, gap analysis, and reframing of supportive framework, can help in transforming the conventional curriculum into a research-oriented curriculum.
- The inclusion of research attributes in conventional engineering curricula enhances the learning capacities of students, improves interpersonal skills and makes them industry ready to an extent.
- The learner gets training for critical thinking, innovation, and understanding of how the technical theoretical contents may support innovation and the real-time problem-solving process.
- Activity-based content or project-based learning addressing real time challenges should be included in the curriculum to encourage the research inclination of the students.

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