RESEARCH ARTICLE

Algorithm for Planning Flexible Outcome-Based Engineering Curricula to Meet the Employee Needs of a Cluster of Companies

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Abstract

In the last twenty years the graduates of traditional engineering programs could get employment. More than 1000 engineering colleges were closed. One of the reasons is due to an outmoded curriculum without providing any exposure to real-world projects, on-the-job training, flexibility, no challenging problems that demand problem-solving skills, critical thinking skills, no case studies, and no exposure to entrepreneurship. By getting feedback from industry representatives, faculty members, and graduates, this action research has been undertaken to develop a flexible, outcome-based, industry-specific curriculum. Further, the credits earned through on-the-job training, internships, courses completed through mass open, online courses, and knowledge earned by self-directed learning and taken into account. These flexible courses have to be accredited and the institutes should offer the needed industrial exposure, industrial training, and advanced cognitive methods, curriculum evaluation based on the fast growth of industrial advancements. The developed algorithm can be adopted to evaluate many other engineering programs. Three successful case studies have also been presented. It is suggested to create policies to offer needed on-the-job training, internships, and compensation to the companies.

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1. Introduction

When India globalized its economy in 1991, transnational companies established their planning, designing, and manufacturing units in India under foreign direct investment. This gave rise to the demand for engineering graduates. The Government of India permitted private associations to start self-financing colleges. The demand for seats increased rapidly. Later after twenty years, the market was saturated, and sizable numbers of colleges could not fill the sanctioned seats. In the last ten years, more than 1000 engineering colleges were closed for want of applicants. Since most companies demand industry-ready graduates with outstanding competencies in analysis, design, product development, and manufacturing, these colleges could not improve their programs. The traditional curriculum was centrally developed

by the affiliating university which relied on a face-to-face instruction system, with no industry input on the advanced cognitive abilities and industry-specific skills. Most of the institutes could not attract outstanding faculty members. There is no on-the-job training component in the curriculum. Since the rules are very rigid, no college recognizes the skills earned by the students through mass open online, no learner attempted to enroll in them. Further, the colleges could not offer cooperative courses due to the absence of active linkages with the industry. Hence, one has to conduct action research in planning flexible curricula, offering on-the-job training, including credits earned through MOOCs, planning internships in various regional companies, enabling the learners to get credits for internships, undertaking capstone projects from the industries, and offering electives based on the needs of the learners.

A Cluster of Companies that Recruit One Degree holder with Different Skill Clusters with one large Common Cognitive Abilities.

In civil engineering, the students are offered various courses to meet the specific job descriptions. The courses can be classified as basic, applied, core, advanced, and electives:

Basic Courses: Communication, Applied Mathematics, Applied Science, Drawing, Computer Applications, Workshop Practices, and Survey.

Core Courses: Applied Mechanics, Strength of Materials, Theory of Structures, Building Drawing, Building Materials, Building Construction, Structural Engineering, Steel Engineering, Soil Mechanics and Foundation Engineering, Hydraulics, Hydraulic Machines, Soil Mechanics Laboratory, Hydraulics Laboratory, Strength of Materials Laboratory, Project Works, Basic Electrical Engineering, Basic Mechanical Engineering, and Workshop Practices.

Advanced Courses: Needs analyses, state rules, industrial practices, product design, project management, stakeholder management, environmental protection, environment assessment, safety, product development, costing, value analysis, testing, mass production, marketing, maintenance, management, entrepreneurship, and return on investment.

2. Literature Survey

Felder and Brent[1] suggested designing and teaching engineering courses to satisfy the ABET Engineering Criteria. However, the problem of the large number of unemployed engineering graduates was not addressed. Ismail and Khalifa[2] focused on engineering curriculum design and development but the need for on-the-job training, and consideration for blended learning was not included. Ambrose[3] focused on the ultimate design challenge in the undergraduate engineering curriculum but didn't focus on internships as a part of the program. Every industry has its in-house employee development program to improve the analysis, design the prototypes, test them for better performance, and improve them with up-to-date components. Schell[4] suggested introducing flexibility in the undergraduate curriculum through student-designed elective courses. This is an improvement in the curriculum design process that considers students' creativity. Beatty[5] suggested the development of an engineering curriculum through hybrid and flexible course design. This flexible method is very much required to meet ever-growing advancements in industrial practices. Preethy

Ayyappan et al.[6] suggested using outcome-based education (OBE) in developing engineering curricula. All engineering programs have to consider the attributes of graduates that are needed so that they will be industry-ready when they join the profession. Jones[7] suggested designing the curriculum for a future engineer. Most well-performing companies use the advice of chief learning officers to change to advanced manufacturing or introduce cost-effective innovative products. Johns Hopkins Peabody Institute[8] focuses on promoting teaching and learning by focusing on the high-performing graduates' skills. Brink et al.[9] developed curriculum agility principles to design engineering programs. Divine Kpe[10] suggested developing a new curriculum to allow students to choose desired electives. Harvard University[11] built a core engineering program and design methods that involve gaining an understanding of complex challenges, imagining novel solutions, and building and assessing prototypes**.** This approach will enable the learners to choose appropriate analytical methods, and develop needed prototypes of products, test and improve them to suit the trends of the market. Carnegie Mellon University[12] introduced hands-on practice in the undergraduate engineering programs which is essential to improve their attributes. PLTW[13] included the real-world challenges in the curriculum.

Inferences: Universities focus on i). Satisfy ABET criteria, Design and Development, Ultimate design challenges, Flexibility, Outcome-based Education, Transformative Innovation, Building and Assessing prototypes, Student-designed program, hands-on practice, and Real-World Challenges. These papers provide clues to developing outcome-based, flexible, student-designed, real-world applications and choosing a path of innovation. These indirectly list algorithms for building industry-specific programs so that all the students end up in well-paying jobs. All these suggestions have to be diligently included in the flexible curriculum of engineering programs so that the attributes of the graduates will be improved.

3. Statement of the Problem

> *"The traditional courses in engineering that don't offer flexibility in implementation, don't transfer credits from previous learning, don't recognize the learning through internships, or on-the-job training will not be successful and the graduates may not get appropriate jobs. Hence, it is urgently required to develop a flexible graduate program that includes credits for internship, previous learning, and on-the-job training. This type of flexible program will create outstanding graduates who can get jobs in different companies without any bottleneck."*

This statement will be considered as a central core of this this research paper.

3.1. Objectives

- Review the significant feedback obtained from the industry representatives, faculty members, and graduates.
- Developing flexible professional programs by combining mass open online courses (MOOCs), on-the-job training, employers' in-house training, and self-directed learning
- Designing a flexible outcome-based curriculum in civil engineering, as an example, to meet the needs of a cluster of companies that demand expertise in core courses in advanced cognitive abilities and skills to plan, design, and

implement projects

- Develop strategies to overcome resistance from traditional universities, accreditation agencies, and learners.
- Evaluate what might resonate most with traditional universities, faculty members, employers, accrediting agencies, learners, and mass media regarding flexible learning processes to meet the industry's fast-changing needs.
- Utilize Artificial Intelligence tools to find solutions in implementing industry-specific and flexible engineering programs and implement them.

Research Methodology

Case study approach.

Population

1. Executives of various companies situated in the Chennai- Bangalore Industrial Corridor, Coimbatore Industrial Hub, and Tiruchirappalli Industrial Hub
2. Unemployed engineering graduates in Chennai, Coimbatore, and Tiruchirappalli
3. Faculty members from various self-financed engineering colleges from Chennai, Coimbatore, and Tiruchirapalli

Table 1. Sample

Sample	Chennai- Bangalore Industrial Corridor	Coimbatore Industrial Hub	Tiruchirapalli Industrial Hub
Executives	32	31	34
Faculty Members	53	43	29
Unemployed /Underemployed graduates	87	68	53

Industry: Automobile Ancillary Components Manufacturing, Civil Engineering, Body Building, Electrical motors manufacturing, Furniture manufacturing, Pharmacy, Transport, TV manufacturing, Chemical, Leather goods manufacturing, Granites, Cement Production, and Cooperative Sugar Mills.

Faculty Members: Civil, Electrical, Mechanical, Automobile, Computer Science, Electronics, Instrumentation, Chemical, and Textile.

Graduates: Civil, Electrical, Mechanical, Electronics, Automobile, Agricultural Engineering, Textile, and Chemical.

Feedback Collection

Three one-day meetings were held in Chennai, Coimbatore, and Tiruchirappalli and major issues were discussed. Each group created quality circles and each circle had a maximum of ten participants. The summaries of feedback are presented in Table 2.

Table 2. *Significant Feedback of the Samples*

Industry Representatives	*Faculty Members*	*Graduates*
76% of them are willing to offer on-the-job training for two weeks.	They need industrial exposure during summer.	They demanded three months of industrial training for the second year to the fourth year.
56% of them are willing to offer 3 months internship	They are interested in undergoing training courses on curriculum revision and development.	They desired industrial exposure in the winter and part-time jobs in the summer. Workshops are to be updated so that they undertake sponsored job work.
21% of them are willing to send their senior engineers to offer industry-specific lectures	They suggested incorporating compulsory on-the-job for their students.	They need credits for industrial training.
36% of them are willing to recruit graduates through campus recruitment.	They also wished to jointly supervise the project works.	They need improved workshop facilities in the college.
5% showed a willingness to participate in the curriculum development meetings.	They suggested the government establish dormitories in the industrial estate for students.	They need more video programs on industrial production methods.
All of them specified that the students should follow the rules of their enterprises.	They expressed a certain amount of additional pay for travel in connection with supervising the industrial training.	They wanted a paid internship for three months in the final year.
They expected that their companies would need financial incentives from the government.	They desired the need for adjunct faculty from the industries.	They need less theory and more industry-specific training.
The students should have health insurance.	They desired seminars on industrial development and the desired attributes of the graduates.	They desired to undertake sponsored production instead of routine workshop exercises.
Time management will be followed.	They wanted learning modules on current industrial practices.	They wanted modern tools and equipment instead of obsolete equipment.
They don't have funds to pay incentives to the trainees	They wanted to undergo development courses for two weeks per year.	They desired counseling and coaching for choosing appropriate on-the-job training.

Inference: The significant points are welcomed and the Directorate of Technical Education has to develop a policy for long-term collaboration with industries and sanction compensation to the companies for devoting their resources and assistant managers to training the students. The state engineering universities could develop industry-specific video programs to supplement classroom lectures. AICTE has to develop a flexible, outcome-based curriculum with inbuilt on-the-job training. This significant feedback will be incorporated into the curriculum.

3.2. Algorithm for Planning a Flexible Outcome-based Program

The following are algorithms for planning, and developing a flexible outcome-based program.

- Dual Program
- Co-operative Program
- Built-in internship followed by Optional Courses/ Electives
- Supplementing Online Courses
- Credits for Industry-Offered Courses
- Credits for Self-Directed Courses

- Credits for Project Works Completed in Industries
- Transfer of Credits from Institutions

3.3. Integration of Mass Open Online Courses (MOOCs), employers' in-house training programs, and self-directed learning with universities traditional curriculum method

3.3.1. *Mass Open Online Courses (MOOCs)*

- Accessibility: MOOCs provide access to high-quality courses from top universities and institutions worldwide. This allows students to learn at their own pace from anywhere.
- Specialized Content: Students can choose from a wide range of specialized topics that may not be available in their local institution.
- Certification: Many universities offer certificates upon completion, which can be added to a student's professional portfolio

3.3.2. *In-House Training:*

- Customization: Tailor-made training programs to meet the specific needs of the institution or industry. This ensures that the training is directly relevant to the student's future careers.
- Hands-on-Experience: Provide practical training with real-world equipment and projects. This helps students through their learning journey.
- Mentorship: In-house training can include mentorship from experienced professionals who can guide students through their learning journey.

3.3.3. *Self-Directed Learning*

- Autonomy: Encourage students to take control of their liability by setting their own goals and seeking out resources.
- Flexible Learning Pathways: Allow students to choose learning pathways combining different courses and resources to fit their individual needs.
- Reflective Practice: Encourage students to reflect on their learning experience and outcomes, which can help them develop critical thinking and problem-solving

3.3.4. Implementation Process

1. Curriculum Design: Develop a flexible curriculum that integrates MOOCs for theoretical knowledge, in-house training for practical skills, and self-directed learning for personal growth and exploration.
2. Blended Learning: Use a blended learning approach that combines online courses with face-to-face training sessions and workshops.
3. Assessment and Feedback: Implement continuous assessment and feedback mechanisms to track student progress

and provide support where needed.

4. Support Systems: Provide resources and support systems such as libraries, online databases, and academic advisors to assist students in their self-directed learning.

By combining these elements, we can create a dynamic and flexible engineering education model that meets the diverse needs of students and prepares them for successful careers.

3.3.5. Step-by-step guide for combining flexible components to award a professional degree that can also accredited

i) Curriculum Design: Example: [Example: Civil Engineering]

The flexible curriculum has to be tailored to meet the specific needs of companies while providing students with a strong foundation in civil engineering and advanced skills for their chosen specialization**.**

- ***Basic Courses***: Identify the basic courses like Applied Mathematics, Applied Science (Applied Physics, Applied Chemistry), Materials of Construction, Building Construction, Communication skills, Engineering Drawing, Building Drawing, Surveying, Geology, and Workshop Practices.
- ***Core Courses:*** Engineering Mechanics, Strength of Materials, Theory of Structures, Hydraulics and Hydraulic Machines, Structural Engineering, Soil Mechanics and Foundation Engineering, and Environmental Engineering,
- ***Advanced Courses:*** Check the job specifications of the employers and develop advanced courses. This list is an example: Bridge Engineering, Steel Structures, Irrigation Engineering, Design and Drawing of Irrigation Structures, Water Management, Design of Water Treatment Units, Design of Waste Water Treatment Units, Earth Quake Engineering, Transportation Engineering, Ports and Harbor, Airport Engineering, Railways, Building Technology, Construction Management, Estimating and Costing, and Design of Multistory Structures.
- ***Specialized Tracks:*** Construction Technology: Advanced courses in modern construction methods, project management, and safety. Develop specialized courses for different jobs like smart cities, and multimodal transport systems by conducting needs analysis.
- Railways and Transportation: Design and Planning of Railways, Highways, and Multimodal Transportation Systems.
- Harbor and Port Engineering: Specialization in port design, dredging, and marine structures
- Airport Design: Focus on airport layout, runway design, aviation safety
- Earth and Rockfill Dams: Advanced courses in dam design, hydrology, and geotechnical engineering
- Smart Cities: Integration of Technology in urban planning, sustainable infrastructures, and smart grids.
- Water Treatment Plants: Advanced Water Treatment process, wastewater management, and environmental regulations
- Bridges and Highrise Buildings: Design, analysis of large structures, load calculations, and material selection
- Multimodal Transport Systems: Integration of different transport modes for efficient logistics and connectivity
- Flexible Components: Integrate MOOCs, On-the-job training, and self-directed learning into the curriculum.
- Hands-on Experiences:
    - Internships, Co-ops: Real-world experiences in industry settings
    - Capstone Projects: Collaborative projects addressing real-world problems

- Laboratory and Fieldwork: Practical experience with modern equipment and techniques

ii) Blended Learning Approach

- Face-to-Face Learning: Schedule regular face-to-face classes for core courses and specialized tracks.
- MOOCs: Incorporate MOOCs for theoretical knowledge and advanced topics that can be accessed online.
- In-House Training: Identify needed industry-based in-house training through Apprenticeship training/ Co-op training
- On-the-job Training: Partner with industry to offer practical experience through internships and co-op placements
- Self-Directed Learning: Encourage students to pursue self-directed learning projects and research

iii) Accreditation Preparation

- Accreditation Standards: Ensure that the flexible curriculum meets the standards set by relevant accrediting bodies.
- Documentation: Prepare detailed documentation of vision, mission, details of the curriculum, Board members, Program Educational Objectives, courses, learning outcomes, faculty members and their qualifications, and other details prescribed.
- Self-evaluation Document: Prepare a self-evaluation report and check the accuracy against the prescribed standards.

iv) Continuous Improvement

- Feedback Mechanisms: Implement feedback mechanisms from students, faculty, and industry partners to continuously improve the curriculum.
- Professional Development: Offer professional development opportunities for faculty to stay updated with the latest industry trends and teaching methods
- Adaptation: Regularly update the curriculum to reflect changes in industry requirements and technology advancements.

iv) Advanced Cognitive and Skills Development

a. Critical Thinking and Problem-Solving: Structured methods to enhance problem-solving capabilities
b. Project Management: Advanced techniques in scheduling, resource management, and cost control
c. Innovation and creativity: Encouraging innovative approaches to engineering challenges
d. Data Analysis and Modeling: Using large data sets, conceptual tools, and probability models.

3.3.6. Addressing Resistance to Changing Traditional Degree Programs

Changing the traditional concept of face-to-face institution-based degree programs will be resisted by traditional universities, accreditation agencies, and learners. This requires a strategic approach, focusing on benefits and addressing concerns:

i. Highlight Benefits: Emphasize how flexible programs can attract a more diverse student body, increase enrollment, and align with more educational trends.
ii. Pilot Programs: Introduce pilot programs to demonstrate success and gather data on student performance and

satisfaction

iii. Faculty Involvement: Involve faculty in the design to ensure their concerns are addressed and they feel ownership of the new programs.

iv. Accreditation Agencies: Evidence-based Approach: Present data and case studies showing the effectiveness of flexible learning models in other institutions.

v. Quality Assurance: Ensure that all components of the flexible program meet or exceed existing accreditation standards.

vi. Regular Reviews: Propose regular reviews and assessments to continuously improve the program and maintain quality standards.

vii. Learners: Flexibility and Access: Emphasize the convenience and accessibility of flexible learning, allowing students to balance their studies with work and personal commitments.

viii. Personalization: Highlight how these programs can be tailored to individual advising, tutoring, and career services to help students succeed.

3.3.7. Overall Strategy

- Transparent Communication: Maintain open and transparent communication with all stakeholders, addressing consensus and providing updates.
- Success Stories: Share success stories and testimonials from students and institutions that have adopted flexible learning models.
- Gradual Implementation: Implement changes gradually to allow time for adjustment and acceptance.

By focusing on these strategies, we can build a compelling case for transitioning to a more flexible and modern education model.

3.3.8. Possible resonate most with traditional universities, learners, faculty, employers, accrediting agencies, and mass media for a flexible learning process to meet the changing needs of the industry

i) Traditional Universities:

- Increased Enrollment and Revenue: Highlight the potential to attract a broader range of students, including working professionals and international students, leading to increased enrollment and revenue.
- Enriched Reputation: Emphasize how being at the forefront of flexible learning can enhance the institution's reputation as an innovator in education.

ii) Learners:

- Convenience and Accessibility: Stress the flexibility to learn at their pace and from anywhere, making education more accessible for those with work or family commitments.
- Personalization: Emphasize the ability to tailor their education to their interests and career goals, providing a more

relevant and engaging learning experience.

iii) Faculty:

- Professional Development: Highest opportunities for faculty to learn new teaching methods and technologies, enhancing their professional growth.
- Innovating teaching methods: Emphasize the freedom to experiment with innovative teaching methods and materials, making their work more dynamic and impactful.

iv) Employees:

- Skilled workforce: Focus on how flexible learning produces graduates with up-to-date skills, practical experience, and better learning needs.
- Ongoing Education: Highlight the potential for their current employees to continue their education while working, leading to a more skilled and adaptable workforce.

v) Accrediting Agencies:

- Quality Assurance: Stress the commitment to maintaining high standards and continuous improvement, ensuring that flexible programs meet or exceed traditional benchmarks.

vi) Alignment with Industrial Trends:

- Emphasize how flexible learning aligns with global educational trends and the evolving needs of the workforce.

vii) Mass Media:

- Innovative Story: Frame the adoption of flexible learning as an innovative story that addresses the challenges of modern education and workforce development.

viii) Success Stories of students and faculty who have thrived in a flexible learning environment:

A strong case for the adoption of flexible learning processes that meet the changing needs of the industry:

- **M. Tech. (HRD):** The program offered by the National Institute of Technical Teachers Training and Research, Chennai
- An interdisciplinary postgraduate program
- All the graduates undertook sponsored dissertations from MSMEs and completed them.
- Entry for engineering graduates from all branches
- Met the needs of industries in training and development
- Graduates were employed in the software industry, manufacturing companies, banks, government departments, the 1public sector, and mining companies.
- 15% of them completed their Ph.D. either in HRD or management
- 20% of them are employed in various overseas companies in Australia, Singapore, Africa, the Middle East, the UK, the USA, and Canada.

- **B. Arch:** The curriculum was approved by the Council of Architecture
- Six months internship at leading Architects
- Students competed under the National Association of Students of Architecture (NASA)
- **Harvard Professional Development Program (PDP)**
- A flexible program offered to professionals from many branches
- **M.S. (Instructional System Technology**) offered by the School of Education, Indiana University, Bloomington, Indiana State, USA
- This program considered the 6 credits earned in other graduate programs and transferred to M.S. (IST)
- The learner can design 6 credit course based on his/her needs
- Provided seven years to complete the program
- Offered many electives to join various companies in training and development or teaching profession

4. Discussion

The problem of unemployment or underemployment of engineering graduates is due to not focusing on the changing needs of the fast-growing technologies, poor assessment of the attributes of the graduates, and not developing appropriate models of planning curricula like industry-specific or industry-relevant curricula and implementing them. The Technical Education Council should continuously focus on the technology disruption and appropriate faculty development programs. The State Governments have to create needed resources and offer incentives to companies that offer on-the-job training and internships to the graduates. Engineering Colleges should continuously upgrade their facilities and incorporate faculty development. State Technical Universities should produce industry-relevant video programs, textbooks, manuals, and multimedia learning packages to supplement class lectures. The State's open universities could also put their expertise into developing needed mass open online courses based on the advancement of industrial practices. The industries could offer their services to engineering colleges through advising, participating in curriculum evaluation, and designing industry-specific curricula. This is a win-win proposal. Ultimately every graduate will be employed and GDP will be increased. Industrial training of faculty members and students will impact the economy of the nation.

5. Conclusion

The cluster companies may subscribe to existing industry-relevant curricula with additional industry-specific advanced courses followed by on-the-job training and internships. Co-op programs will be very much required to create needed attributes. It is essential to plan flexible outcomes-based programs and incorporate the learning through mass online open courses, and planned on-the-job training. The programs should incorporate self-directed learning so that the graduates continue lifelong learning. Further, the companies have to establish in-house training so that no employee becomes burnout. Blended learning is very advantageous for institutes. The resistance to change has to be strategically considered.

Additional grants-in-aid have to be offered to colleges to modernize the existing obsolete resources. No single stakeholder is responsible for the current state of affairs. If all stakeholder contributes to planning and implementing a flexible, outcome-based which includes industrial training will lead to synergy.

5.1. Limitations of this Paper

This paper focused on the possible changes that are available for developing flexible and outcome-based industry-specific curricula. However, there are many advancements due to artificial intelligence-based approaches. The whole research centers around one state only.

5.2. Suggestions for Further Research

Future research work can consider an all-India approach and consider the companies in various industrial corridors and hubs, various types of educational organizations, and the status of faculty members

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