



Effective Assessment of Teaching in Interdisciplinary Engineering Postgraduate Programs

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Abstract

Interdisciplinary postgraduate programs have to be very effective in the engineering profession due to the explosion of knowledge in various branches. These enable engineers to effectively solve many professional problems in analyses, design, prototype development, testing, improving, mass production, marketing, and maintenance. The whole curriculum development will be based on current projects. The development of curriculum has to be from the inputs from alumni, different partner companies which are actively involved in product development, the inputs from the experts from research and development departments of the engineering universities, national research and development labs. The curricula have to be evaluated using the formative evaluation process. Then the instructional resources have to be developed based on the approved curricula and the faculty members have to be exposed to the advances in the industry, use of digital technologies, quality assurance, value engineering, manufacturing, testing, marketing, and maintenance. Then they have to prepare course plans, assignments, internships, and industry-specific dissertations. After completion of the program, the academic audit has to be undertaken for verifying the effectiveness of teaching. If there are many deficiencies, the curriculum and the instructional method have to be improved before implementation for the next batch to ensure significant benefits to the graduates. The whole process assures the development of competent graduates with adequate skills and abilities.

Keywords: Interdisciplinary Postgraduate Programs, Industry-Specific Curriculum Planning, Formative Evaluation, Course Material Development, Instructional Planning, and Dissertation.

Introduction

In the last 5 years, more than 1000 engineering colleges were closed in India due to a shortage of resources, and faculty members. Around one million engineering students could not get appropriate engineering jobs whereas the employers state that more than 50% of the engineering students don't have the required skills and competencies to perform the tasks. Performance audits and improvement of engineering institutions for a sustainability of human capital development reveal that there is a greater need for interdisciplinary programs (Thanikachalam, 2022). Engineering institutions have to be designed to support an engineering transformation in professional colleges in India (Thanikachalam, 2021). A collaborative dissertation based on the human resource needs of MSMEs will improve their competitiveness and overcome the disruption (Thanikachalam, 2020). The desired educational ecosystem will bring the curriculum to meet the needs of industry (Thanikachalam, 2019) Faculty performance can be improved through effective human resource development and management process (Thanikachalam, 2020). Critical reviews of many postgraduate programs in transportation engineering revealed the gaps between the industry and institutions (Thanikachalam, 2018). Hence, it is concluded that the

administrators have to create a desired educational ecosystem to meet the demands of a fast-growing industry (Thanikachalam, 2019). From the above research works, it is found that the curriculum, faculty members, industry, and the students are to be integrated through an interdisciplinary framework. The engineering companies are facing severe competition due to explosive growth of various branches, raw material shortages, fast changes in the consumer markets, globalized economy, growth of multinational corporations (MNCs), and various environmental problems. MNCs have established corporate universities in their headquarters to train their employees who are hired throughout the world. They prefer industry-ready outstanding graduates from various developing countries. Due to the globalized Indian economy, the country attracts thousands of MNCs to start their manufacturing centers in India both for local markets and exports. Considering the availability of creative engineering graduates, they prefer to start design centers also. Many global companies have benefitted much from the design centers. They value the innovative products designed by the local centers. Hence, the engineering institutions have to modernize the laboratories, workshops, curriculum design processes, and instructional planning and delivery methods. Ultimately, both the companies and the engineering institutions can benefit from collaboration and planning interdisciplinary postgraduate engineering programs that will ensure required industry-ready graduates with desired attributes. Each university can plan one or two interdisciplinary postgraduate programs in selected branches. They may plan Private-Public-Partnership (PPP) model.

Research Objectives

To review the needed industry-specific postgraduate curricula in engineering and technologies

- To suggest an effective planning process of curriculum, instructional design, and evaluation methods
- To assess the teaching in interdisciplinary engineering postgraduate programs through an academic audit process
- To suggest appropriate quality assurance processes from curriculum planning to the placement of the graduates

Research Methodology

Naturalistic evaluation of opportunities and possible developments by comparison of well-established programs have been adapted. A snap study has been conducted with a purposely selected 80 senior faculty members (Associate Professors; experience more than 20 years; specialization in various engineering branches; 66 men and 14 women) of autonomous engineering colleges and deemed universities to get their feedback on the concepts, models, feasibility, and critical success factors for introducing interdisciplinary postgraduate engineering programs. They represented 8 branches of engineering. Their institutions were located in leading industrial cities in Tamil Nadu, Kerala, Andhra Pradesh, and Puducherry. Most of them offer postgraduate programs as per AICTE regulations. Their institutes are well equipped and with sufficient qualified faculty members. All these institutes are offering consultancy services to the companies based on the requests. Further, their alumni are well placed in software companies and MNCs throughout India.

Literature Survey

Interdisciplinary Programs

These are joint programs for postgraduate studies between two or more departments or two or more universities/ colleges/schools as per the rules established by the University Council/Senate/Academic Council on the recommendation of the deanship of graduate studies. Interdisciplinary engineering education aims to train engineering students to bring together expertise from different disciplines in a single context (Antoine Van den Beemt, et al. (2020). Challenges exist for identifying clear learning goals and assessments for interdisciplinary education in engineering (vision). Most engragogy (the process of preparing instruction, delivering, motivating, mentoring the engineering students, etc.), for interdisciplinary learning, is designed to promote collaborative teamwork requiring organization and team management. According to Antoine Van den, Beemt et al. suggest that developing interdisciplinary skills, knowledge, and values needs sound engrogogy and teaming experiences that provide students with authentic ways of engaging in interdisciplinary practice. The designers have to identify the understanding of what resources hinder the development of engineering programs designed to support interdisciplinarity.

Industry Needs

The industry needs more interdisciplinary graduates who can tackle the problems of design, prototype development, testing, improving, mass production, marketing, maintenance, and innovation. The program is based on project-based learning. The course outcomes are very essential to solve the problems faced by the industry. If a person gets a degree in one branch of specialization, then the industry may need more employees with various fields of specialization. The creativity of the interdisciplinary graduates is much more than the graduates who have been trained through a single branch of specialization. All the well-developed universities have introduced the interdisciplinary programs. In the case of training and development, engineering graduates need exposure to organizational development, training needs analysis, instructional design, and materials development, multimedia learning package development, evaluation of the performance of the employees, motivation, research, etc. No engineering program focus on these aspects. Non-engineering graduates can't evaluate the deficiencies of engineers. Hence, the need for interdisciplinary human resource developers with engineering degrees arises. In all types of companies, the need for engineering degree holders with various engineering degree holders

A sample survey has been conducted and a few interdisciplinary programs have been selected that are offered in various universities. The following is the sample list of interdisciplinary postgraduate programs in engineering in Table 1.

Table 1: Interdisciplinary Postgraduate Programs

Program	University/College	Remarks
Any Undergraduate Student can take up an interdisciplinary postgraduate program	Indian Institute of Technology, Kharagpur, India	M. Tech. in Financial Engineering M. Tech. in Entrepreneurship M. Tech. in Transdisciplinary Program in Petroleum Engineering (TPPE)
Nine interdisciplinary areas	Indian Institute of Technology, Madras, India	Energy systems, Robotics quantum science and technology, Computational engineering, Advanced materials and Physical Systems, Nanotechnology, Data Science, Cyber Systems and Dynamics, Biomedical Engineering.
M. Tech. (HRD), Ph.D. (Engineering Education)	National Institute of Technical Teachers Training and Research, Chennai	M. Tech. is open to any engineering graduate; 4 semester duration. Ph.D. is open to any postgraduate student
Aerospace Engineering	The University of Houston, Cullen College of Engineering, Houston, Texas State, USA	Includes aerodynamics, and heat transfer. Structural mechanics and materials.
M. Tech. (Construction Management)	IIT Madras, NIT Tiruchirappalli, Tamil Nadu, NIT Suratkal, Karnataka.	Engineering Construction Company provides a stipend to the students. Both Civil Engineers and Architects can join.
Interdisciplinary doctoral program	Berkeley Graduate Division, University of California, Berkeley, USA	Selects only outstanding students, exceptional merit, and uniqueness.
Interdisciplinary graduate programs	M.I.T Boston, USA	Collaborative programs that extend beyond departments or school boundaries.
Chemical Engineering	M.I.T Boston, USA	The Leaders for Global Operations (LGO)
Interdisciplinary Master of Science in Engineering (M.S./ M.S.E.)	Purdue University, Indiana State, USA	Rated as one of the best programs combines both Master in Engineering and MBA at Sloan School of Management.
Interdisciplinary Program, Special Program, Multidisciplinary Program, Individualized	Concordia University, Canada	An interdisciplinary Master's program between Science and Engineering
Interdisciplinary program in Environment Science and Management	The Hongkong University of Science and Technology, Hongkong	MSc and PGD in Environmental Science and Management

Synthesis: Most of the well-established institutions have implemented interdisciplinary graduate, postgraduate, and doctoral programs. They are very successful.

Feedback of the Senior Faculty Members

Feasibility of Introducing Interdisciplinary Postgraduate Programs: 81.25% of the Members welcomed the introduction of interdisciplinary postgraduate programs based on the active cooperation of the Confederation of Indian Industries (CII), Federation of Indian Industries, and Chambers of Commerce (FIICI), AICTE, Educational Administrators. They also expressed the need for developing the junior faculty members. Industries may face problems due to severe market competition, shortage of ancillary components, obsolescence of the products due to rapid technology disruptions, shortage of qualified executives, loss due to low production, cost escalation, etc. The collaboration between the institutions and the companies is to be reviewed periodically.

Methodology of Planning

All of them wished to develop programs that have long-term potential for employment. Further, they wanted active collaboration with the MNCs which could recruit the graduates.

Desired Cooperation from the Industries: Active participation from planning and employment of the graduates; sparing the product design experts for offering expert lectures every month; providing exposure to the faculty and the students in all units of the industry from Design, Manufacturing, and Maintenance.

Critical Success Factors: Recognition by the AICTE, foreign universities, and employers for interdisciplinary postgraduate programs. According to Koutsikouri, et al. (2006), the critical success factors are better control of timescales, budgets, and resource planning. Further, they concluded that project success is related to individuals, teams, processes, projects, and products. If AICTE fails to recognize, the graduates will not get selected by colleges. This will lead to the collapse of the system and the loss of human capital.

Planning Interdisciplinary Postgraduate Programs

For effective planning, the following are essential requirements: Autonomous institutions with adequate high-performing faculty teams, capacity to retain them, adequate modern resources, lab and workshop facilities, proper linkage with the industry, the government approval through AICTE/UGC, expertise in offering consultancy programs through Industry-Institute-Government-Community-Partnership, capacity to attract and enroll excellent students, and well-established academic council. The government could fund the starting of interdisciplinary postgraduate programs to meet the disruptive technologies. The institutions have to develop active linkages with the partner companies. The collaborative process is based on mutual trust, ethics, and focus on the win-win model. Companies may introduce innovative products frequently to survive in the fierce market. They can collaborate with the institutions for getting human capital.

Institutional Requirements

The institutions benefit more if they have sufficient highly qualified faculty members, resources, academic, financial, and administrative autonomy. They need to delegate authority to the departments for developing outstanding industry-relevant and interdisciplinary programs. Further, the Institutes should offer graduate, postgraduate, and doctoral degree programs. They should plan active linkages with the companies in the state and region. Industry-Institute- Industry-Government-Partnership is essential. The faculty members must have completed a sufficient number of consultancy projects. All these indicate the readiness of the institutes. The academic ecosystem will welcome interdisciplinary postgraduate programs.

Supporting Government Policies

The following policies of the government of India support the interdisciplinary engineering education: Globalized Indian Economy, Make in India, Digital India, Special Economic Zones, Collaboration with the International Universities, and National Education Policy 2020. Further, the government should support the starting interdisciplinary postgraduate programs to take advantage of creative engineering students.

Institutional Networking with Research Universities and MNCs

The Engineering Universities/Institutions can establish active linkages with global universities for faculty development, exchange of students, joint programs, and joint research projects. It is essential to create close cooperation and collaboration with the

companies in the state and region. Many new schemes of the Ministry of Education support this development. The faculty should be aware of the technology used by MNCs, products manufactured, current global trends, and the need for industry-specific interdisciplinary graduates.

Curriculum Planning

The first step is to plan cooperation/collaboration with a set of well-performing companies in the region. Assess the human resource requirements for the next five years in a chosen branch of specialization. Conduct a needs analysis survey. Prepare a detailed questionnaire and validate it through a set of alumni and employers' representatives. Distribute the questionnaire to them and try to get the completed questionnaires within two weeks. Analyze the feedback and open suggestions. Based on the high potential areas, new programs could be planned under the Public-Private-Partnership model. Review the existing basic and core courses and improve them. Plan advanced courses and electives to suit the industry.

Key Questions for Curriculum Planning

Whether the interdisciplinary postgraduate program is feasible in the institute? Will there be sufficient job potential for the next five years? Whether you can co-opt adjunct faculty members from the industry or research universities if required? Can you expose the faculty members in all stages from product analysis, design, prototype development, testing, improving the product, mass manufacturing, marketing, maintenance, scrapping, and improving the whole process to meet the changed condition? Can you modernize the lab and workshop facilities to meet the courses planned? Can you get projects for the dissertation from the partner companies? Can you get an internship for the students? Can you collaborate with other similar institutes from planning to placement? All the answers are to be carefully analyzed and appropriate decisions can be taken. Next, identify the Program Educational Objectives and desired course outcomes and validate with the industry partners. Develop the curriculum. Identify the advanced courses and elective courses. Get approval from AICTE/University Grants Commission (UGC) for the curriculum. The net result will be based on the positive outcome of the answers to these questions.

Formative Evaluation

Conduct a formative evaluation of the draft curriculum and involve the faculty members who will be responsible for implementation. If they express difficulties in implementing the curriculum, try to resolve the problem. Equip the library, labs, and workshops. Place the curriculum before the academic council and get feedback. Rectify the deviations, shortfalls. Mass-print the final curriculum and distribute it to various department and faculty members.

Faculty Development

Identify the training needs of the faculty and plan needed training programs based on the implementation schedule. Equip the departments with needed software and hardware. Conduct a trial run and train the technical support staff also. Provide funds to undergo needed Massive Open Online Courses (MOOCs) that are offered by the global universities. Provide project-based additional grants for undertaking research. Encourage the faculty to bid for consultancy projects under multinational companies (MNCs), International Development Agencies, and ongoing state development projects. Coach and mentor, the faculty members to undertake development projects.

Preparation for Implementation

Advertise and send the program brochure to all the colleges in the state and upload it on the web. Give wide publicity to the students on the advantages in the interdisciplinary postgraduate programs. Select the students as per the rules, counsel, and orient them to the proposed program. Provide a copy of the course schedule, test dates, projects to be completed, industrial visits, on-the-job training, and internships. Provide learning packages as per the curriculum on day one.

Instructional Planning

It should be done in cooperation with the partner companies. The students should get a total picture of work, assignments, case studies, tests, On-the-Job Training (OJT), term papers based on research articles specific to the program, and electives. The students also need sufficient journals, advanced materials, video programs, case studies, and online journals.

Instructional Aids Requirement

The faculty desired to have virtual labs, design studios, data for planning and analysis. They desired nondestructive technique-based tools for dissertation works. They further desired to have access to MOOCs in the program-specific topics.

Instructional Delivery System

The executives and the faculty members can offer online programs, OJT, video conferences, besides FTF lectures. If more than one institute joins the program, an online program can be profitably used. The recording can be used for subsequent use. Self-instructional can also be supplemented. The students can use the www for assessing needed research papers, videos, case studies, etc.

Dissertation

It is essential to undertake a dissertation based on the company's problems. Both the faculty members and the faculty can jointly guide the students. The outcome should be useful for the collaborating company. If patents are to be filed, they can be jointly filed so that no individual is left behind.

Internships

The students can be offered assistantships as it is done in the case of GATE passed students. Industry can share 50% if the students opt for sandwich program mode. This is essential to attract deserving students.

Placement of Graduates

The graduates need counseling to choose an appropriate job. Successful graduates can be absorbed by the company. Those who wanted to pursue a Ph.D. program, they can be permitted. A few others may prefer to become faculty members. There can't be any restriction. The graduates need mentors to complete the program successfully.

Advantages to the Graduates

Exposure to the state-of-the-art in planning, design, development of a product, testing, improving, mass production, manufacturing, marketing, and maintenance; full involvement

in professional management, first experience in working with the employees, gaining competencies and abilities for transfer of skills to other companies, identification of needed further research, possible areas for entrepreneurship development, good exposure to interpersonal relationships, product planning and key result areas, product costing, and gaining market share. All these are additional advantages that can be gained through conventional classroom interaction.

Academic Audit

This is an essential component of the quality management of the program for replication and continuation. At the end of the program, the students, faculty, and the expert faculty from the industry should provide total feedback from planning to graduation. The difficulties have to be analyzed and solved. The feedback from the alumni who joined the jobs or pursuing Ph.D. has to be contacted for giving feedback on the program. All the strengths are to be maintained. The quality of instruction, assignment, action research, resources available, OJT, dissertation, paper publication, facilities, etc. is to be evaluated. The strength of the courses is to be evaluated and modified if required.

Return of Investments (ROI)

The companies can be given tax concession for their financial input as the Singapore Government does. If SMEs are also involved, they may be paid an “innovation” fund as the German Government does. ROI is not restricted to financial return but included nontangible output. The creation of human capital, knowledge capital, the contribution to GDP, exports, etc. is to be assessed. In the long-term more interdisciplinary programs could be planned. A successful model can be synthesized.

Future Research Topics

There are more problems in planning interdisciplinary postgraduate engineering programs in India. The authorities have to formulate policies, the industry has to invest its resources, the universities have to develop new programs based on viability, and long-term utility. Considering the rapid changes in technology, the interdisciplinary team has to invest more efforts to plan appropriate interdisciplinary/ multidisciplinary programs. Any investment in the interdisciplinary programs will enrich both the knowledge and human capital to meet the challenges of disruptive technologies. Future research has to center around *meeting disruptive technologies*.

Summary

Interdisciplinary postgraduate engineering programs are successfully planned and implemented by the research universities in various countries. This approach will assist the students, industries, and government in developing human capital and resulting knowledge capital. Even though there are many obstacles, it is better to resolve them early and launch needed interdisciplinary postgraduate engineering programs to support the government to make in India using digital technologies. There is a need for a vision for planning and implementing such innovative programs.

Conclusions

By considering the problems faced by the faculty members and the postgraduate engineering students, it is concluded that the industries are looking for industry-ready graduates. This is possible to achieve by planning interdisciplinary postgraduate programs in collaboration with the industries in the state and region. Most of the well-known universities have established interdisciplinary postgraduate programs. Hence, this model could be replicated in India which will solve many problems. 80 senior faculty members from autonomous colleges have expressed the need for developing interdisciplinary postgraduate programs by conducting a learning needs analysis with the partner companies, developing draft curricula, evaluating through a formative method, preparing final curriculum after approval of the Academic Council. The curriculum has to be approved by the AICTE. The instruction planning has to be done in total for each semester indicating lecture schedule, tests, assignments, OJT, term papers, and case studies. The partner companies need to spare their experts based on the needs of the institutions. The faculty and the students are to be trained in the current product design, testing, improving, manufacturing, marketing, maintenance, and safe scrapping. The dissertation problems are to be sourced from the partner companies. The students are to be counseled, coached, and mentored. Courses can be offered through online methods or face-to-face (FTF). The outcome has to be evaluated by academic audit and the problems have to be resolved. There is a need for further research in developing interdisciplinary postgraduate engineering programs. The partner companies have to be compensated for their expenditure on the whole project. The students have to be provided with a stipend.

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