Research Article

Dynamism and Total Integration in Engineering Curriculum Planning to Meet Industry Needs and Implementation based on Theory into Practice (TIP)

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In this knowledge-based economy, the role of engineering colleges and technical universities has an important effect on developing needed knowledge capital and human capital. The industry-specific programs are focused on the desired outcomes. Most of the well-established universities started improving their curricula to meet the demands of transnational organizations. This paper aimed at developing a dynamic curriculum design model from the assessment of needed attributes of the graduates, preparing a draft curriculum, conducting formative evaluation, improving them, continuously improving resources, and faculty members, offering needed instructional materials, and incorporating on-the-job training, introducing industry-specific projects/dissertations, and placing the graduates in the industry or guide them to become entrepreneurs. The research methodology is the action research method. SWOT Analysis has to be done and the vision of the institute has to be focused on creating human and knowledge capital. The draft curriculum has to be evaluated by groups of experts, improved, piloted, and implemented systematically with well-designed resource learning packages, periodically evaluated through tracer study. The stakeholders are to be involved at every stage and the program has to be accredited.

1. Introduction

Most engineering institutions offered fixed curricula without dynamic improvements to incorporate the dynamic changes in industrial design, prototype development, testing, improving the prototype,

manufacturing, marketing, maintenance, scrapping, and developing innovative products. The old model is called the 2-4-6 model (curriculum within the end of two pages of the document, classroom within four walls, and 6 hours of teaching per day). When there were no dynamic changes, this model served, and the graduates got the job. In the 21st century, innovations in engineering technology have started impacting the industrial process. When most of the countries globalized their economies, transnational companies started moving their factories to other countries and used the local resources, employing local skilled workers, technicians, and engineers for their plants. When innovations are introduced, companies have to upgrade their manufacturing technology. Otherwise, they can't sell their obsolete products. This demands continuous improvements in the curricula, industry-specific instructional design and delivery, incorporating on-the-job training, and taking industry-specific projects/ dissertations. The institutions have to establish linkages with the companies in the region and involve adjunct faculty from the industry. This also demands continuous improvement in the curriculum, and preparing new methods of planning and implementing the programs so that the graduates can get jobs and be ready to serve various units of manufacturing. It also demands continuous improvements in the resources, upgrading the cognitive abilities of the faculty members. Hence, any engineering curriculum has to focus on vulnerability, uncertainty, complexity, and ambiguity (VUCA). This research paper focuses on VUCA so that the graduates are developed as innovators.

2. Literature Survey

In this 21st Century, a globalized economy demands more industry-specific attributes in the graduates. Many companies started establishing their new design, production, and maintenance units in viable centers throughout the globe. This demands up-to-date and industry-specific curricula in all countries. One of the success factors for the globalization of manufacturing demands accredited curricula, and well-trained and industry-ready graduates. Most of the researchers focused on updating the curriculum design process by incorporating educational technology, strategies, innovations, and entrepreneurship[1][2][3][4][5][6][7][8][9][10][11][12][13][14][15][16][17][18][19][20][21][22][23][24][25][26][27][28]. Hence, almost all global universities continuously improve their curricula and develop their faculty, resources, instructional design, and delivery process. Carnegie Mellon University, Case Western Reserve University, Grand Canyon University, MIT, Nanyang Technology University, The University of Chicago, the University of Michigan, the University of Applied Science

Upper Austria, and Texas University have started revising their curriculum vigorously to meet the advances in technology[29][30][31][32][33][34][35][36]. Suzanne Cecilia Brink et al. (2004)[27] brought the concept of curriculum agility. This is defined as a responsively organized education, with dynamic learning contents and flexible pedagogics, in which all involved staff are continuously developing and competing to deal with the necessary transitions. Further, they brought the following 10 principles of curriculum agility: 1). Education vision, 2). Stakeholder involvement, 3). Pedagogy and didactics, 4). Learning objectives, 5). Program and Course Design, 6). Learning Spaces, 7). Management Approach, 8). Logistics and Policy, 9). Organization and Governance, and 10). Decision Making. Hain Baruh (2012) explored the need for a change in engineering education. Fawwaz Habbal, et al. (2024)[37] have advocated reshaping engineering education to address complex human challenges. Karlson James Hargroves and Cheryl Julia (2015)[38] suggested a deliberative and dynamic model for engineering education curriculum renewal. Sheila et al. (2001)[39] created a linear model for curriculum change. This consists of planning, prototype development, assessing, modifying, and adapting. Sameh et al. (2020)[40] explored the main challenges in human capital formation. Innovative curriculum model development has been suggested in Robotic education[41]. Considering the challenges, it is explored to bring a dynamic curriculum design model by assessing the needs of the fast-changing growth of technology, educational technology, faculty development, stakeholder management, and placement of the graduates.

3. Statement of the Problem

> *"Develop a dynamic curriculum design model from the assessment of the needed attributes of the graduates, preparing draft curricula, conducting formative evaluation, improving them, piloting, continuously developing the resources and faculty members, offering needed instructional materials, and incorporating on-the-job training, introducing industry-specific projects/dissertation, and placing the graduates in the industry or guide them to become entrepreneurs*".

3.1. Objectives

The following are the objectives of this research:

- Design an integrated curriculum model by assessing the needed attributes

- Planning and updating the needed modern resources
- Continuously developing the faculty members to offer the curriculum effectively and efficiently
- Incorporate on-the-job training, undertaking industry-specific projects, and internships,
- Continuously assess the industrial needs through tracer study
- Introducing desired flexibilities to suit the learners
- Introducing counseling, coaching, and mentoring of the learners

3.2. Research Methodology

Primarily use action research principles. Strength, weakness, opportunity, and threat analysis was undertaken. Then the institute's vision was considered. Next, the needs of the industry were assessed. Training needs analysis was undertaken. It is followed by curriculum planning. The draft curriculum was evaluated through a formative evaluation. The curriculum implementation process was considered. Further Chief Learning Officer (CLO) and Chief Knowledge Officer (CKO) were proposed for continuous assessment of the fast-changing technology and updating the curricula. Further steps to continuously improve the curriculum, and instructional system, and offer needed industrial exposure are provided. This paper gives needed attention to developing graduates with desired attributes and ensuring they are industry-ready. The whole program integrates various proven components from Industry-Specific Curriculum Design/Outcome-based curriculum, Instructional System Technology, Instructional Media, Design, Educational Measurement, Educational Research, Tracer Study, Industrial Linkages, Entrepreneurship Development, Learning and Cognition, and Impact studies.

3.3. SWOT Analysis of Existing Methodology of Planning and Implementing Engineering

Curricula

Strengths	Weaknesses
Uses the existing textbooks on basic and core courses The faculty uses their expertise and satisfied The existing resources are fully utilized Students are satisfied during learning No big challenges Traditional dissertations	Does not focus on the fast changes in the industry Need case studies for understanding the complexes Teachers need exposure to the advances Demand for additional resources Institutions have to link with the industry Needs adjunct faculty from the industry Graduates don't get jobs Criticism of the education process increases Impacts on industrial growth
Opportunities	**Threats**
For the expansion of educational programs Consultancy works based on the industry needs Development of interdisciplinary programs Assisting learners in acquiring current technology Will become industry-ready from graduation Can offer continuing education programs to the executives and employees The fast growth of industries due to the availability of well-trained graduates Higher return on investments (ROI) Sustainability of cost-effective production Development of human and knowledge capital	Social unrest due to unemployment Traditional programs will be discarded Poverty increases Transnational companies may not prefer the country for establishing new plants due to a shortage of technical personnel. GDP will be reduced Shortage of foreign currency The country has to continuously depend on ex-pats Shortage of foreign currency that affects the existence

Table 1.

3.4. Focused on the Institute's Vision

The institute should have a focused vision on excellent engineering programs so that the graduates can become human capital. There is a need for smart faculty who can effectively plan and implement courses.

- Industry-Specific/Industry-Relevant Curriculum
- Part-time Cooperative Programs
- Dual Programs
- Nonformal Programs
- Continuing Education Programs
- Part-time Courses
- MOOCs
- Finishing School Courses
- Minimizing the gap between industrial Practices and Academic Programs
- Introducing Entrepreneurship
- Approving Workshops to undertake Job works
- Every workshop Practice Should Yield a Salable Product

3.5. Focusing on the Industrial Needs

The focus on the industrial needs will guide the institute in planning appropriate programs.

- Problem-solving skills in the analysis of desired industrial products, design, prototype development, testing, improvement, planning for mass production, global marketing, maintenance, scrapping, and selecting new innovative product development.
- Selection of new raw materials.
- Use of new tools and equipment.
- Protecting the environment.
- Improving the production process, and quality, reducing cost, and eliminating accidents.
- Use of industry-4.0 methodology.

3.6. Training Needs Analysis

Training needs are to be analyzed for every cadre like design engineer, manufacturing engineer, and maintenance engineer. They should be linked to basic courses, core courses, and advanced courses.

- Identifying needed attributes of graduates.
- Strategic planning.
- Project planning and management.
- Value analysis.
- Financial planning and management.
- Interdisciplinary approach.
- Problem-solving.
- Quality improvement through in-house training.
- Kaizen approach.
- Communication skills.
- Teamwork.
- Continuous improvement in manufacturing technology.
- Internship in a desired department of a company.

3.7. Curriculum Planning

Curriculum planning requires a more careful assessment of the needs and the contents have to be assessed based on the procedural analysis.

- Feedback from alumni and alumnae.
- Feedback from recruiting agencies.
- Preparing program educational objectives (PEOs).
- Preparing course outcomes.
- Planning basic courses in communication, applied sciences, applied mathematics, engineering drawing, use of Auto Cad, Experimentation, product testing, computer applications, and project management.
- Planning core courses based on industrial needs.
- Planning advanced courses based on industrial needs.
- Planning electives based on the students' needs.

- Selecting cooperative courses/dual programs.
- Planning on-the-job training.
- Undertaking project works based on industrial advancements.
- Selecting internships.

3.8. Formative Evaluation of the Draft Curriculum

Once the draft curriculum has been developed, this should be evaluated by a team of specialists drawn from institutions and industry.

- Getting feedback from industry representatives, faculty, administrators, and expert faculty members.
- Revising the draft curriculum.
- Deliberations at the Board of Studies.
- Follow-up improvement.
- Deliberations at the University's Academic Council.
- Implementation Process.
- Faculty Orientation.
- Orientation to Students.

3.9. Developing Instructional Packages

Instructional packages are based on the improved curriculum and the learning needs of the students. The faculty members have to be developed in preparing instructional materials.

- Develop textbooks, case studies, laboratory manuals, workshop manuals, and design and drawing manuals based on the current curricula.
- Develop multimedia learning packages, video programs, and working models wherever needed.
- Establish a publication center.
- Edit and publish through reputed publishers for publishing at a national level.
- Periodically update the learning packages.

3.10. Providing Semester Plans, Assignments, Tests, Term papers, and Classroom Meetings

It is essential to have a total planning of the instruction so that the learners can plan and follow the transformation.

- Providing copies of instructional packages.
- Indicating industry standards.
- Research journals.
- Conference reports.
- Case studies.
- Design, drawing, and estimation assignments.
- Seminars.
- Student and faculty feedback.
- Counselors, Coaches and Mentors.
- Special Classes.

3.11. Prescribing Assignments

The assignments should be based on the learning outcome.

- Problem, Data, desired outcome: Analysis, Design, Drawing, Estimation, and Report
- Check against industry standards.

3.12. Conducting Quiz Programs

It is advisable to conduct quizzes before starting the class meeting.

- 30 minutes before the start of discussions.
- Discussion on the previous quiz.

3.13. Conducting Periodical Tests

Tests and assignments are essential to evaluate the learning and improvements in the skills.

- Two-hour test.
- Application-focused and outcome-oriented.

- Case study based.
- Group Problem-solving.
- Incorporates Self-directed Learning.
- Linked Industrial Application.
- Action research-oriented.

3.14. Term Paper

Term paper alone gives proof of problem-solving ability, creativity, and innovation.

- Maximum 10 pages.
- Focused on solving a new problem for a company.
- Could be published in a journal.
- Room for creativity.

3.15. Mission Based on the Institute's vision

Mission is required to plan various courses so that the vision can be achieved.

- Offering interdisciplinary programs.
- Offering credits for completing MOOCs that are needed as per the curriculum.
- Offering dual degree programs.
- Offering needed on-the-job training.
- Undertaking projects, and dissertations based on the identified problems of MSMEs.
- Offering needed in-house faculty development programs.
- Bidding for consultancy projects through outstanding faculty teams.

3.16. Focusing on the Global Innovations

In a globalized economy, graduates should be able to join any transnational company and render services.

- Offering flexible programs through the cooperation of global faculty members.
- Undertaking joint research projects through international universities.
- Undertaking consultancy projects through International Development Agencies.
- Creating a Consortium of Institutions to Offer More Electives and Joint Degrees.

3.17. Creating a Chief Learning Officer (CLO)

The CLO's post focuses on the rapid changes in technology and industrial applications. The department can nominate a senior professor to act as a CLO.

- A senior professor will focus on the technology fast-growing companies develop.
- Will assess the utility and needs of companies.
- Assess the possibilities of creating new courses, electives, finishing courses, and seminars in new technology.
- Estimate the additional capital expenditure needed to develop resources.
- Prepare a detailed report for implementing advanced courses.

3.18. Creating a Chief Knowledge Officer (CKO)

The CKO will analyze the possible development of appropriate courses to meet the new industrial demands. A group of senior faculty members can be formed to work in this unit.

- Conduct an Academic Council meeting to prepare new innovative and interdisciplinary programs.
- Estimate the additional capital needed to start new interdisciplinary programs.
- Assess the possibility of training the needed faculty members and implement.
- Explore the possible donors who can support the establishment of new courses.

3.19. Involving Adjunct Faculty/ Part-Time Industry Executives

Whenever new courses are planned, it is needed to hire a set of experts to deliver advanced industry-specific courses until in-house faculty members acquire the needed cognitive abilities.

- Invite adjunct faculty for short-term consultancy works.
- Involve part-time industry executives to assess the policies, planning, and development.
- Collaborate with industry research units to finalize innovative programs.
- Involve them in evaluating the projects and dissertations.
- Get case studies from the companies.

3.20. Focusing on the Attributes of the Graduates

Human capital needs desired outstanding performance skills in a complex situation.

- *Assess the additional attributes desired by* the employers.
- Revise and update periodically.
- Counsel the learners in choosing electives, projects, and dissertations.
- Coach them and scaffold them.
- Evaluate the performance through the industry expert.

3.21. Checking the Suggestions of the Latest Research Reports and Papers

Since the disruptions due to fast development always impinge on the curriculum, the faculty members can the needed new knowledge.

- Form a committee of faculty members from all branches.
- Create an in-house evaluation team.
- Assess the potential of new advancements.
- Conduct in-house workshops to develop follow-up actions.
- Verify the possibility of short-term courses.
- Plan advanced certificate courses.
- Undertake action research projects.
- Improve the cognitive abilities of the faculty team.
- Plan postgraduate programs in collaboration with the companies.

3.22. Flexible Design

Flexible design is essential so that changes can be implemented easily.

- Plan flexible programs.
- Include on-the-job training.
- Incorporate internship.
- Incorporate self-directed learning.
- Encourage action research projects.

3.23. Multiple Dependent Degree Program (MDDP)

Multiple dependent degree programs will give room for choosing needed courses based on career planning.

- Collaborate with similar universities to offer needed advanced courses.
- Expose the advances to the faculty members.
- Encourage joint research projects.
- Conduct joint faculty development programs.
- Conduct peripatetic seminars.

3.24. Formal Dual Degree Programs

Dual programs: i) Graduate and postgraduate courses are integrated into a single program (American Model), ii) The cooperative program provides adequate industrial exposure (German model).

- Incorporate an integrated postgraduate program with the undergraduate program.
- Offer desired advanced courses and electives.
- Offer needed industry-sponsored projects and dissertations.
- Cooperate with professional associations.

3.25. Continuous Training the Faculty Members

The success of the program depends on the high-performing faculty teams. They have to be continuously trained through different modes.

- Train them through MOOCs and offer credits.
- Offer medium-term industry-specific training programs.
- Encourage self-directed learning and appoint a faculty to supervise and mentor the learner.
- Encourage short-term collaboration with industry leaders.
- Encourage to undertaking of industry-specific research projects.
- Scaffold them to plan multi-disciplinary research and development projects.
- Encourage them to undergo internships.
- Develop in-house faculty development programs focused on research and development projects.

3.26. Transfer of Credits from Other Programs Undergone

It is better to have a policy to give credits for the courses completed in other programs offered by other Institutions.

3.27. Pilot Study

In some innovative and industry-specific graduate programs, a pilot study will be of great use to resolve the bottlenecks. An improved program can be accredited easily.

3.28. Encouraging the Learners to Attend the Meetings of Professional Associations

This will provide information on the advancements of professionals, organizations, and companies. The learners can also get an opportunity to undertake on-the-job training.

3.29. Sufficient Resources

Whenever a new curriculum was introduced, many institutions faced insufficient resources. They need advanced laptops, program-specific software, and advanced equipment. Hence, the needs of the students and faculty should be met without any delay.

3.30. Unity in the Vision

The institutional development depends on unity in the vision. Hence, the authorities need to update the faculty in realizing the vision.

3.31. Real-life Problems for Projects

Every step has to be taken to improve the goal of the industry-relevant programs. A merely advanced curriculum is only a paper tiger. Every industrial development has to be understood by the faculty teams and the learners. The projects, assignments, and research work should be centered around real-life problems so that the graduates become industry-ready.

3.32. Summative Evaluation

Once the first batch graduated, efforts are to be taken to get feedback from employers, alumni, and faculty members. Their feedback will assist the project team in updating the curriculum and instructional delivery.

3.33. Feedback from the Academic Audit

It is suggested to audit the completed courses and get 360-degree feedback from all stakeholders. An in-depth analysis of the feedback will assist in improving the implementation. Such audits are to be

conducted every year.

3.34. Sufficient Linkages with Recruiters

It is essential to maintain an active linkage with companies, and recruiting agencies through the placement department. The website should project the curriculum, innovations, and achievements of the department and graduates.

3.35. Recruiting required Number of Outstanding Faculty Members

It is not uncommon for many faculty members may leave the institute from time to time. Hence, efforts have to be undertaken to recruit outstanding faculty members. They need to be exposed to the planning and implementation of the innovative program. If needed, they have to be offered orientation to industries.

3.36. Continuous Evaluation of Achievements

There is a need for continuous evaluation of achievements and improvement. Tracer study and impact study will provide the needed data. The establishment of an alumni association will be very advantageous.

3.37. Support from the Ministry of Education, Governing Council, and Professional Associations

Every innovation needs continuous support from the stakeholders. The funds, resources, and infrastructure have to be periodically updated. There is a need to create needed information in the social media. Many donors will come forward to donate and offer funds to improve the resources. The Ministry of Education could offer scholarships and grants in aid.

3.38. Assistantships to learners during Projects

Students need assistantships to actively engage in company-sponsored projects or National Council-sanctioned projects. Every effort has to be taken to offer assistantships to the students.

3.39. Part-time Works

Necessary opportunities could be offered to involve graduate students through part-time work. This will attract qualified learners to the projects.

3.40. Support from Publishers

Various instructional materials, learning aids, case studies, and design and drawing manuals are to be published at the national level. The royalty can be added to the corpus fund. Around 50% of the royalty can be shared with the faculty members who developed the materials.

3.41. Support from Industrial Training Centers of the Companies

Further, we need continuous support from the Industrial Training Centers for collaboration in planning executive and employee courses. In addition, they can offer needed resources for conducting joint programs both for the students and faculty members. State Industries Department/State Industrial Development Corporations can assist the institute in utilizing the resources.

3.42. Support from the Board of Apprenticeship Training

The existing Boards of Apprenticeship Training can offer training programs through various companies and award assistantships to the trainees. They can be involved in offering cooperative programs to the learners.

3.43. Support from National Laboratories

Many National Laboratories can be invited to share their expertise and develop interdisciplinary research and development programs.

3.44. Support from International Development Agencies (IDAs)

Many International Development Agencies like UNESCO, UNDP, Asian Development Bank, USAID, etc may be looking for similar initiatives in establishing such graduate programs in the ongoing projects. It is better to look for consultancy programs under these IDAs.

3.45. Support from the Council for Technical Education/ University Grant Commissions

In many countries, these councils/ commissions have to approve the program before implementation. Only approved programs can attract funding from the government. The students can get assistantships only when they enroll in the approved programs.

4. Discussion

In this 21st century, the growth of the economy of any nation is based on the growth of human and knowledge capital. Most of the global universities started improving the outcome-based programs and created linkages with transnational companies. Hence, in this paper, the design of an integrated curriculum development model has been based on industrial needs. This demands updating modern resources, continuously developing the faculty members, and incorporating training as an important component of instructional delivery. Further, the needs are to be validated through tracer studies. The research methodology is based on action research. It is suggested to conduct a SWOT analysis to know the current status of the institute. The institute should have a committed vision to create needed human and knowledge capital. It is suggested to conduct a training needs assessment for various entry-level jobs that a graduate can be employed. Based on this analysis, a draft curriculum has to be prepared and assessed through an expert group. It is better to pilot the curriculum and get feedback from the learners, faculty members, and employers. The institute should expand the resources, develop needed learning packages, and continuously train the faculty. To effectively implement the curriculum, the needed program-specific instructional package has to be developed and instructional delivery has to be planned. To check the acquisition of knowledge, the learners have to be assessed continuously. To implement as per the planning, there is a need for linkage with the companies. Ultimately to accept the innovation, a tracer study has to be implemented and the suggestions are to be incorporated into the curriculum and its implementation. Further, it is suggested to conduct an impact study to confirm the desired outcome.

5. Conclusion

Since 1976, this model has been adopted in engineering institutes in four southern states of India. For effective implementation, the faculty needs to be updated continuously. The resources are to be modernized. The needed instructional packages are to be developed as per the needs of the curriculum.

The institute should have a vision to meet the needed human and knowledge capital. Appropriate steps are to be taken to create linkages with the companies for cooperation and placing the learners for skill development, and employment. The stakeholders are to be included at every stage so that the project becomes a win-win model. This model incorporates human resource development, outcome-based curriculum development, industry-institute interactions, institutional development, Instructional System Technology, tracer studies, impact studies, continuous faculty development, continuing education, and formative and summative evaluation. The success of this model depends on stakeholder management and a focused vision of developing human capital. The mission of the institutes, the resources, and the collaboration between the companies and the institutes play an important role.

5.1. Limitation

The autonomy may vary from country to country. The authority to develop the outcome-based curriculum, funding, grants in-aid, Industrial linkages, and government policies in providing compensation to the industry may also vary. This model has been successfully implemented since 1975 in the southern states of India.

5.2. Suggestions for Further Research

This model can be refined for global applications and updated based on the local administrative process, and the willingness of the companies to cooperate with the development process.

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