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Roadmap to inclusive curriculum: a step towards Multidisciplinary Engineering Education for holistic development

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Abstract : One of the key aspects to measure the prosperity of any nation in this global economy can be its leadership in technology & innovation. Engineering is applied everywhere; from the design and development of novel products and processes to providing solutions to complex challenges. Engineering education is therefore of key significance to a growing economy. With a prime focus on improving quality and providing holistic development of learners, developments are taking place worldwide in Engineering education & research. The term 'learners' indicate students and has been used interchangeably in the entire script.

Purpose: National Education Policy 2020 of the Government of India proposed reforms to the existing education framework of the country and emphasized on introducing multidisciplinary undergraduate programmes with multiple exit options. This study proposes an inclusive curriculum with different course types from multiple disciplines for an undergraduate engineering programme and articulates the relevance of the framework to foster holistic development.

Research Methodology: The study incorporates a structured design approach where inputs from senior leaders of 60 Universities offering undergraduate programmes formed the basis of the preliminary work. The academic framework was designed under the regulations and guidelines of the statutory body for technical programmes. On successful implementation, a research instrument was administered to a cohort of learners of an undergraduate engineering programme, and the data collected was then analysed.

Findings: From the findings, we infer that a multidisciplinary engineering programme would enhance research skills and enable the learners to self-manage to a great extent along with developing their critical thinking skills. The results are statistically significant with $p<0.05$.

Implications of the Study: This study would help Universities and Higher Education Institutions to explore the possibilities of provisioning courses from diversified disciplines in an Engineering curriculum to promote multi-disciplinarity. The findings from the study would be beneficial to the learners to realize the potential of multidisciplinary education and accordingly pursue their career aspirations. The study

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provides an insight into competencies to be developed through the framework of a four-year undergraduate engineering programme thereby enabling Industry practitioners to reorient the job roles that thrive in the future.

Keywords: Multidisciplinary Education; academic curriculum; holistic education; Engineering Framework; Learners.

1. Introduction

Higher Education is instrumental in bringing about change in society and accelerating the development of a nation. Apart from bringing in economic benefits, higher education results in the personal development of an individual by providing career opportunities. The significance of quality higher education is manifold for any Nation that strives to compete in a globalized economy. Indian Higher Education System has undergone huge expansion in the last decade and is today one of the largest in the World (Nigam, et al., 2020). This system though colossal faces challenges in terms of a huge dearth of skilled resources, redundancy, inadequate funds, and less focus on learning outcomes. The current scenario of Education is that non-professional education has taken a back seat (Choudhury, 2021). In contemporary times the focus of multidisciplinary education was in place in India and the concept was deeply embedded. Takshashila, Nalanda, Vikramshila, and Vallabhi were World-class institutions of ancient India which had set the highest standards of multidisciplinary teaching and research and hosted scholars and students from diverse backgrounds and nationalities (Shukla, 2020). These Institutions aimed to prepare students for life (Shukla, 2020). These Institutions set the highest standards of multidisciplinary teaching and research and have produced great scholars who have significantly contributed to the World in diverse fields such as mathematics, astronomy, medical science, engineering, architecture, and fine arts. However, the challenge started with the evolution of certain specialized Institutions such as the Indian Institute of Technology (IITs) & Indian Institute of Management (IIMs). In India, a lot of preference is given to professional education. One of the dominant factors causing this scenario of the popularity of professional programmes is Employability. Engineering is one such profession that is highly popular among students with a large number of Engineering Institutions in the Nation (AISHE, 2020). Employability certainly is one of the objectives of higher education but it is not the soul of holistic education (Suleman, F. 2018, Pardo-Garcia 2020.)

Engineering skills and knowledge are foundational to technological innovation and development that drive long-term economic growth and help solve societal challenges (National Academy of Engineering, 2018). Engineers are required to become more specialized and more committed in their world views because the world needs better science, better politics, and greater belief (Yaman et al., 2005). Engineers are rewarded for their work with relatively higher salaries as compared to other graduates (Engineering Salary Statistics). The educational pathway of engineers is therefore required to be continuously improved because of the National competitiveness and quality.

The Government of India has taken a tremendous step in bringing out a National Education Policy 2020 (NEP 2020) that outlines the vision of India's new education system. The aim of the NEP 2020 is to make higher education institutions multidisciplinary and focus on holistic education. The objective is to move towards learning how to think critically and solve problems, how to be creative, and how to innovate and hone skills from multiple disciplines. NEP 2020 has created a new set of opportunities for Institutions in India. The policy emphasizes introducing multidisciplinary undergraduate programmes with multiple exit options. With this policy in place, many aspects of Higher Education are being reimagined to promote holistic education. The policy emphasizes integration and having a student-centric flexible curriculum. This study proposes an inclusive curriculum with different course types from multiple disciplines for an undergraduate engineering programme and articulates the relevance of the framework to foster holistic development. The proposed Engineering curriculum has been designed with mutually supporting disciplinary courses from multiple disciplines, with a focus on integrating value-added courses for personal and interpersonal skill development. The paper has been sectionalized into 6 sections. The rationale behind the study has been elaborated in section 2. Extant literature has been reviewed for related studies and the findings are presented in section 3. This section is presented in two parts. 3.1 is about multidisciplinary education and 3.2 presents multidisciplinary engineering frameworks. Section 4 outlines the inhibiting factors that prohibit

multidisciplinary education in India considering the current education system. The proposed framework for multidisciplinary engineering education has been presented in section 5. Section 6 provides recommendations and scope for further extension of the work.

2. Rationale behind the Study

To create a progressive world, knowledge alone is not sufficient; we require holistic education, where education is integrated with vital universal human values and has a focus on learning multiple disciplines. NEP 2020 is a great initiative of the Government to promote learning in multiple disciplines and the correct implementation of this policy is very essential (Muralidharan 2022; UGC, 2020). This section presents the key features of this policy for higher education as outlined in the excerpt by the University Grants Commission, which is a statutory body of the Government of India responsible for maintaining the standard of higher education. The features are highlighted in figure 1.

There are sufficient structures in the Indian Universities and the implementation of NEP 2020 essentially does not require creating new structures. Structures refer to units/cells/boards/committees that have been mostly set up in higher education institutions such as the Board of studies, Industry interaction & Placement cell, Innovation incubators, etc. The existence of these structures enables the attainment of desired aspirations and meeting the set targets. However, learners are right now only acquiring knowledge in Universities. There is a need to encourage assimilation. dissemination and generation of new knowledge for holistic education. To promote multidisciplinary education, an inclusive curriculum that prepares learners for life is essentially required.

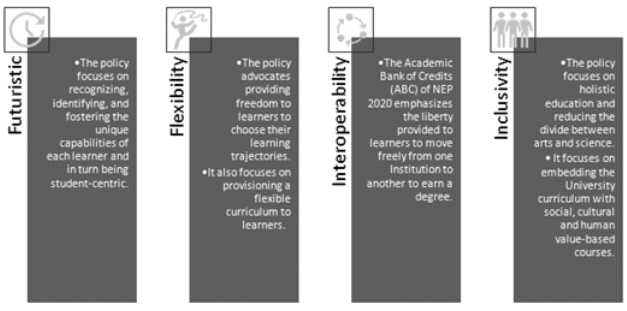

Fig.1:Salient features of National Education Policy 2020

3. Review of Literature

3.1 Multidisciplinary Education

A review of existing literature in the area shows that many studies have been conducted to explore the advantages and challenges of multidisciplinary education in general. Experimental studies have been conducted to examine learning experiences in a group consisting of learners from multiple disciplines. Many authors have discussed and analyzed the advantages and challenges of multidisciplinary education (Ferlin et al., 2005; Pirrie et al., 1999; Shen & Zhu, 2019). Studies have been conducted by combining multicultural and multidisciplinary teams to analyze their learning trajectories and behavioural patterns. Authors have proposed a novel sandwich programme design for multidisciplinary education in the field of engineering. The study advocates that a sandwich programme increases the chances of hiring fresh engineering graduates (Yaman et al., 2005). Sandwich programs help students to learn according to the industry's needs and requirements. Different organizations are invited to make these courses or programs work. These organizations provide equipment and training to students. It is beneficial for students because having experience with industry equipment will increase their chances of placement. It is also valuable for organizations because the recruited students will not be required to undergo extensive training as they have gained practical knowledge during their course of study. In this study (Yaman et al., 2005) a framework was proposed which explains how a sandwich program can be created by universities. As of now, it is a new concept in the experimental stage so many institutes might hesitate to conduct such programs until they see some promising results.

Karin Wolff & Kathy Luckett conducted a study to analyze the knowledge gained by students of a University in a mechatronics engineering program in South Africa. The study revealed that the curriculum focuses on theory (conceptual) knowledge rather than practical (contextual) knowledge (Wolff & Luckett, 2013). S. Benedetto selected a multidisciplinary program named Alta Scuola Politecnica (ASP). This program offered an M.Sc degree with an integrated multidisciplinary education in it. Students opting for this program were awarded a double degree. Students benefited from this special program as they were able to attain knowledge in multiple domains (Benedetto et al., 2010). Johannes M. N. Van Kasteren worked on

the development of a course named 'Sustainable Development'. This multidisciplinary course was implemented in engineering education at the University of Technology. The results showed that multidisciplinary projects worked to be an excellent teaching method and that the course stimulates interdisciplinary work within engineering education. (Johannes & Kasteren, 1996). Fátima Monteiro et. al conducted a study of the official mission of Portuguese higher education institutions that offers engineering courses. The researchers aimed to identify the current engineering education conceptions and the importance attached to them to the service of humanity. The findings revealed that there is a need to create a new perspective to strengthen the role of engineering as a service to humanity, social justice, and the common good (Monteiro et al., 2019).

3.2 Multidisciplinary Engineering Frameworks

Researchers at European Organization for Nuclear Research (CERN) conducted a study on difficulties faced by students during the multidisciplinary, remote collaborating engineering design course Challenge-based Innovation (CBI) (Jensen et al., 2018). Since multidisciplinary teamwork is essential in the field of engineering design, the groups participating in the CBI course came from backgrounds in technology, business, and design. Teams from seven different Universities from multiple countries were part of this course. All teams were given a challenge, which had to be solved with technological inspiration from research at CERN while working through remote collaboration except for 3 co-located collaborations. It was found that analyzing and convergent phases were correlated. Remote and co-located collaborations were also compared where learners found remote collaboration more difficult. They also found that different education backgrounds affected which phase the learners found difficult. Researchers suggested a few ways to further improve future courses on engineering design. Another group of researchers has worked on the ATLANTIS initiative funded by The European Commission and the US Department of Education Fund of Improvement of Post-Secondary Education (FIPSE) programme to create a new collaborative multinational model for interdisciplinary education in real-time software engineering (Grega et al., 2009). Researchers worked in 3 phases (Preparatory Phase, Research Phase, and Pilot Implementation Phase) to create a framework for introducing new components to engineering programmes and also proposed a methodology for the development of a multinational, multidisciplinary engineering programme, which was fully implemented in Oct 2009. This project helped to establish joint programmes between universities and government institutions of the EU and the US. Which helped the EU to encourage cross-border collaboration in higher education and gave the US a chance to engage in a global educational experience which is more integrated with the European educational system. It also played a role in common curriculum development and the recognition and portability of credits across educational institutions in Europe and the US.

Researchers at the University of Huddersfield, UK conducted a study in UK's Higher Education Teaching and Learning (T&L) context to develop a best-practice model for integrating interdisciplinarity into the UK higher education undergraduate experience (Power & Handley, 2019). The study focused on two main questions, first being the barriers to embedding interdisciplinarity within the student learning experience and secondly, key facilitators and potential solutions that maximize the successful integration of interdisciplinary collaboration into the student learning experience. The study utilized an expert panel and semi-structured interviews. The data collected were analyzed and categorized into barriers, and facilitators/solutions. Based on the results of this study, researchers proposed a Higher Education Interdisciplinarity Model (HIM) of best practice. This model brought together the six enablers of interdisciplinarity (positioning, people, environment, reward, factors for conduct, and communication). The HIM provides a potential solution to the effective implementation of interdisciplinarity into the higher education student experience. Researchers at Universidad Catolica de Santa Maria worked on the design, implementation, and evaluation of training courses under the e-learning modality of a technological higher education institution (Duche Perez et al., 2019). The experience of training courses took place in the Institute of Higher Technological Private Education Arequipa in 2018 on the e-learning platform “Plataforma Educativa” across various streams such as Computing and Informatics, International Business Administration, etc. A total of 612 students and 9 teachers were part of the experience. For the evaluation, constant feedback was taken so that periodic updates could be made to the system. The researchers concluded that e-learning is very suitable for higher institutions where many

students are also working while studying and are not able to attend many classes. The data collected from students showed that e-learning has many advantages such as time-flexibility, accessibility, and others. They recommended that the e-learning modality be kept more to theory subjects and can be enhanced using virtual tutoring and learning content.

Inclusivity in curriculum design is an area of interest to many researchers across the globe, as is inclusive curriculum delivery in the teaching-learning process. The curriculum must be designed proactively to promote heterogeneity (Lawrie G. et al.). It is found in multiple studies that more heterogeneous teams perform more effectively than the other teams. There can be multiple reasons for high productivity in these teams. Colleagues are more motivated to work with each other because they can learn different skills while working together. Higher heterogeneity also means there will be people with different backgrounds, their opinions can be beneficial for better decision-making in the team. Approaches to curriculum design engage learners as partners by offering them flexibility and opportunities through the academic framework to customize their learnings (Lawrie G. et al.). The literature findings reveal that though across the globe research is being done to study propositions of multi-disciplinarity. From the Indian context and given the regulations of the Indian statutory bodies, it is of prime importance to establish a framework of curriculum for Engineering education that promotes multi-disciplinarity. This work presents a framework for one degree with multiple subject areas.

4. Multidisciplinary Higher Education in India: Fad or Challenge

Holistic and multidisciplinary education aims to develop all capacities of human beings and should be the approach of all undergraduate engineering programmes. To analyze the Indian pretext concerning multidisciplinary higher education, the expert opinion of 60 senior leaders of Universities and Higher Education Institutions assembled for a National Conference was considered. Imparting multidisciplinary education appears to be a challenge rather than a common trend in Universities. Though, because of NEP 2020, the Universities are keen to develop multidisciplinary academic curriculums. The barriers stated in this section have been drawn from the proceedings of a National Conference on the New Education Policy organized by a University in India during November 2020.

4.1 Inhibiting Factors

This section presents the factors that inhibit the offering of multidisciplinary education. The factors have been considered from the inputs of experts at senior management positions from 60 higher education institutions in India.

1. The challenge in providing a holistic and multidisciplinary education environment is to create an eco-system where students who enter into the portals of the higher education system develop a well-rounded holistic engagement in several disciplines. To create an open and highly flexible environment for students to pick multiple disciplines, it is a challenge to conform to the requirements of unlimited flexibility in the course curriculum (Jensen 2018; Sahoo, 2021; Maniar, 2022).

2. The evolution of certain specialized institutions particularly in the field of technology and management has limited the imagination of an Institution/University concerning multidisciplinary education. Institutions of excellence in core disciplines limit education in multiple disciplines. The idea of contemporary Universities with specializations has been a challenge to multidisciplinary education in India.

3. The existing available infrastructure in Indian Universities has affected the promotion of multidisciplinary education.

4. Allocation of courses, scheduling of Timetable, and mindset of academicians impact the promotion of multidisciplinary education.

5. There is an operational challenge in offering multiple courses in diverse streams maintaining a decent faculty-student ratio. Private Institutions are barely able to meet the faculty-student ratio as per the requirement of the statutory bodies. The lack of faculty members and other resources hinders the promotion of multi-disciplinarity.

6. Another challenge is the resistance to accepting teachers having education in multiple disciplines.

From the valuable inputs of the experts, it is evident that there is a need for a clear definition of processes for effective implementation of the NEP 2020 policy and also there is a need to build and

provide a good framework to deliver education in multiple disciplines.

The challenging issues for the academic institutions can be seen in the light of the challenges faced by all three stakeholders be it students, teachers, or Institution administration. One of the biggest challenges faced by students is in terms of the realization of self-directed learning. Most of the students do not inculcate the concepts of self-learning and peer learning for cross-disciplines (Ma L., Lee CS.,2019). As technology is a catalyst for the successful implementation of this approach, access to IT infrastructure and technology interface is yet another challenge being faced by students. The teachers in the Engineering Institutions are specialization focused and there is tremendous resistance to change due to a fixed mindset or being over-occupied with existing assignments. This often leads to a lack of collaboration which is an essential element for imparting multidisciplinary education. From the administration's point of view, resistance from top management is a challenge as education in India is still widely considered to be teacher-centric rather than student-centric. Successful implementation would require acceptance of technology, strategic planning for manpower, and skill enhancement.

5. Multidisciplinary Engineering Education Framework

A good quality higher education aims to develop thoughtful, well-rounded, and creative individuals. A multidisciplinary education would aim to develop intellectual, aesthetic, social, physical, emotional, and moral values in an integrated manner (UGC, 2020). A multidisciplinary Engineering programme must enable an individual to study one or more specialized areas of interest at a deep level. The curriculum should have courses that help an individual to develop character, learn ethical and constitutional values, develop intellectual curiosity, attain a scientific temper, develop creativity and inculcate a spirit of service. The curriculum must incorporate courses that provide 21st-century capabilities across a range of disciplines including arts, humanities, social sciences, and sciences, as well as technical, professional, and vocational courses. To ensure a student-centric contextual curriculum and achievement of desired student learning outcomes, a flexible 'Choice Based Credit System (CBCS) is the need of the hour. CBCS enables the students to satisfy their scholastic needs and aspirations, as the system provides enhanced learning opportunities through an interdisciplinary curriculum. The framework must be inclusive to provide equal opportunities to learners to attain the outcomes of the programme.

Outcome-based education is student-centric that emphasises the attainment of Programme Learning Outcomes (PLOs). The Programme Education Objectives (PEOs) are aligned with the University's mission and the graduate attributes. Considering the changes in the global environment, skill requirements for industry 4.0, and NEP 2020 agendas, graduate attributes for the programmes have been accordingly stated. The University ensures that the learning outcomes of the engineering programmes are aligned with these graduate attributes. Therefore, the programme structure of engineering programmes has diverse courses from various disciplines such as social sciences, sports, performing arts, etc. A multidisciplinary approach thereby helps in fostering outcome-based education.

The curriculum and pedagogy of an Engineering programme must develop a deep sense of respect towards the fundamental duties and Constitutional values, bonding with one's country, and conscious awareness of one's roles and responsibilities in a changing world. The proposed framework includes diversified course types which have been detailed in this section as follows:

(1) Human Social Sciences & Management Courses: Courses that fall under these course types help learners acquire knowledge of how history, literature, politics, economics, and culture have shaped the modern world. These courses aim to produce technocrats, who can contribute productively to the world of economics and commerce. They help foster creative thinking besides technical expertise for engineers and scientists in the making.

(2) Basic Sciences Courses: The basic sciences course are based on the scientific disciplines of Mathematics, Physics, and Chemistry, and they provide a fundamental understanding of natural phenomena and their processes which is highly important for Engineers to strengthen their fundamentals.

(3) Engineering Sciences Courses: Engineering Sciences courses on different engineering

disciplines are essential to develop strong rudiments and to build further specializations on them. These specializations include unique fields of study like basic Electronics, Electrical Engineering, Material Science, and Environmental Sciences.

(4) Core Courses: Core courses are courses in the main discipline of Engineering that all learners are required to complete before they can be promoted to the next level in the educational hierarchy. Core courses are a must for a learner to meet the requirements of their programme.

(5) Programme Electives: Learners can select elective courses to study the topics and areas that interest them. Across an Engineering discipline, many programme electives are offered in various baskets from which learners can pick the courses of their choice.

(6) Domain Elective Courses: Domain elective courses are courses from a related discipline/domain, intending to seek exposure in that discipline/domain. Domain Electives for learners are the courses offered by disciplines of Engineering other than the learner's discipline.

(7) Open Elective Courses: Open elective courses are from an unrelated discipline intending to seek exposure in that discipline. For example, Open Electives for Engineering learners are the courses such as photography, painting, personal grooming, and branding, etc. offered by institutions outside the Engineering domain.

(8) Non-Teaching Credit Courses: Non-teaching Credit Course (NTCC) is a self-exploratory course for the professional and academic development of learners as well as to enable the learners to pursue research in the area of their interest. It includes courses such as Internships, Projects, Independent Study & Research, etc.

(9) Value Addition Courses:

(i) Foreign Business Language: This course comprises offering Foreign Business Languages for learners to enhance their foreign language skills while pursuing Engineering. It could be any foreign language of their choice German, French, Chinese, Sanskrit, Russian, Arabic, Japanese and Spanish.

(ii) Behavioral Science: This course type emphasizes both on theoretical foundations and real-world application in core and advanced areas of behavioural science and the cognitive science of judgment and decision-making. These courses enable learners to prepare for the corporate world.

(iii) Professional Ethics: This course intends to develop a set of beliefs, attitudes, and habits that learners should display concerning morality. The prime objective is to teach integrity, respect for others, tolerance of diversity, and adapting to their professional areer.

(10) Outdoor Activity-Based Courses: Outdoor Activity-Based course refers to the course which requires recreation engaged out of doors, most commonly in natural settings pursued purposes of physical exercise, general wellbeing, spiritual renewal, and an opportunity to partake in nature whilst doing so. These are outdoor sports courses such as Basics skill of Badminton, Basic skill of football and some others are Kathak, Bharatanatyam, or even a week-long Military Training Camp which is essential for holistic development.

(11) Employability & Skill Enhancement Courses: Employability enhancement courses are crafted to bridge the gap between skills possessed by the learners and the abilities that are sought by the organization with a greater emphasis on the improvement of employment opportunities and research activities.

(12) MOOCs: Massive Open Online Courses (MOOCs) are online courses available for anyone to enroll from any corner of the globe. MOOCs provide an affordable and flexible way to learn new knowledge and skills. The University Grants Commission of the Government of India has recommended that learners in Higher Educational Institutions may be allowed to earn up to 20% of the Semester credits through MOOCs.

Table 1 depicts the credits range for the above-detailed course types as recommended by the All India Council for Technical Education (AICTE) which is a

National-level apex body for technical programmes in India and the range of credits as per the proposed model framework for an undergraduate Engineering Programme. Figure 2 illustrates the span of these course types across Four Years of undergraduate Engineering Programme. The importance of value-added courses throughout the Programme is indicated in the figure as it spans all four levels. AICTE has circulated guidelines to Higher Education Institutions to offer Minor Degree/Hons. in emerging areas along with the major discipline of study to promote multi-disciplinarity. The Minor Degree/Hons. will cumulatively require additional 18-20 credits in the specified specialization in addition to the credits essential for obtaining an undergraduate Engineering degree in the area of major discipline, as per the guidelines. The proposed framework is well in sync with the guidelines and offers additional 22 credits for obtaining Minor Degree/Hons to promote multi-disciplinarity.

As a case study, the authors have considered the Engineering framework of their University where courses of multidisciplinary nature are offered to learners. By undergoing courses from diverse disciplines such as performing arts, sports, mass communication, social sciences, etc, engineering graduates would be able to hone their skills and pursue a passion in the area of their interest for holistic development, which is the prime aim of NEP 2020. For instance, the proposed framework provides the flexibility to learners to opt for courses as per their career aspirations and pursue their passion to a great extent. Learners aspiring to get placed get an opportunity to avail courses that will add value to building their technical and functional competency and capabilities. A learner who aspires to start up a venture gets the opportunity to pursue courses related to entrepreneurship and design thinking. They also get a platform to transform their engineering projects into knowledge resources and get the opportunity for incubation. Through such processes, the vision of the NEP to provide holistic education to engineering students is achieved.

Table1: Range of Credit Units for each Course Type

Sl. No.	Course Type	AICTE Range (CU)	Proposed Range (CU)
1	Human Social Sciences & Management Courses	12	14
2	Basic Sciences Courses	25	Min :26 Max :32
3	Engineering Sciences Courses	24	Min :19 Max :33
4	Core Courses	48	Min :44 Max :53
5	Programme Electives	18	Min :13 Max :29
6	Domain Elective Courses	18	Min :0 Max :14
7	Open Elective Courses		Min :0 Max :10
8	Non-Teaching Credit Courses	15	15
9	Value Addition Courses		
	➡Foreign Business Language	------	14
	➡Behavioural Science	-------	8
	➡Professional Ethics	-------	2
10	Mandatory Courses Outdoor Activity Based Courses	-----	Min:0 Max:12
11	Employability & Skill Enhancement Courses	-----	Min :4 Max :8
12	Massive Open Online Courses (MOOCs)	-----	Min :0 Max :30
		160 Credits	**185 Credits**

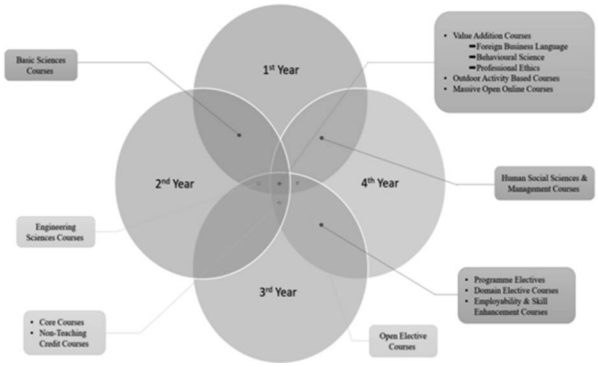

Fig. 2: Span of Various Course types across Undergraduate Programme

The focus of the study is engineering & technology programmes. To create a multidisciplinary framework, the programme structure provides the opportunity for learners to opt for open and domain electives by following the Learning Outcome-based Curriculum Framework (LOCF) of the UGC mandate. For instance, a course on professional ethics has been included in all programmes in engineering & technology. The multidisciplinary approach has been ensured by including up to 20 % of the courses of diverse nature in the programme structure.

To encourage learners to opt for multidisciplinary courses, they are given enough opportunities to explore and examine the skill requirements of the industry through engaging in Professional Skill Development Activities (PSDA) as part of the internal assessment of a course, major and minor design

projects, etc. This exposure allows the learners to get acquainted with the latest industry trends and make an informed decision for choosing a particular course.

The strategic annual academic planning before the commencement of each academic year is done for the planning of manpower and other resources. This planning considers infrastructure, software and hardware requirements, manpower requirement, industry expert sessions, and other material resources. A gap analysis of the existing and required resources is undertaken and projections are accordingly made. Based on the projections, recruitment of human resources is done and Professional Development Programmes (PDPs) are conducted for upskilling faculty and staff members. For optimum utilization of resources, planning of the multidisciplinary courses to be offered as Massive Open Online Courses (MOOCs) is also undertaken. The manpower planning as per the UGC mandate of LOCF is followed.

To motivate the students, a course advisory committee is formed at the programme level which includes faculty subject experts from various disciplines. The course advisory committee encourages and guides the learners to opt for multidisciplinary courses in alignment with their career aspirations.

To measure the effectiveness of the framework, a research instrument was designed and administered to a cohort of learners of an undergraduate Information Technology engineering programme, and the data collected was analyzed. The skills that are developed by pursuing a multidisciplinary Engineering programme were identified from literature and learners were asked to rate the identified skills on a scale of 0-3 where zero indicated that skill is not at all likely to develop after undergoing courses in multiple disciplines and 3 indicated a possibility to a great extent. The skills and the question corresponding to the skill that was included in the online survey form is presented below:

- ·Critical Thinking – Multidisciplinary education helps you acquire the ability to compare and contrast across disciplinary boundaries?
- ·Analytical & Problem-Solving Skills – By undergoing a wider range of disciplines, you acquire deeper skills to analyze and solve the problems?
- ·Synthesis of Ideas – Study of multiple disciplines helps you to consolidate learnings by combining ideas from multiple courses?
- ·Communication Skills – Undergoing different courses and their varied assessment methodologies would help you develop written and verbal communication skills?
- ·Research Skills – Knowledge of multiple disciplines will enhance your research and inquiry skills?
- ·Self-Management - Choosing multiple disciplines to allow you to identify and organize your priorities?
- ·Collaboration Skills – Multidisciplinary education helps you to get broader and deeper skills to collaborate?

Figure 3 above illustrates the perception of the respondents which indicates a multidisciplinary Engineering programme would enhance research skills and enable the learners to self-manage to a great extent along with developing their critical thinking skills. The results are statistically significant with $p<0.05$.

6. Recommendations & Discussion

NEP 2020 has provided a strong impetus to promote holistic and multidisciplinary education. Problem-solving in the real world requires knowledge of multiple disciplines and hence the proposed framework that truly implements Education 4.0 is the right answer to offer multi-disciplinarity in Engineering education. To prevent our leading Institutions of the Nation to become isolated in terms

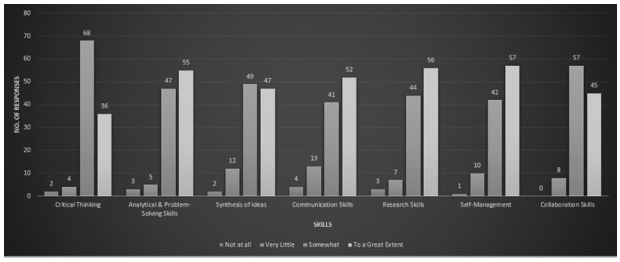

Fig. 3: Perception towards Skills developed through Multidisciplinary Programme

of knowledge exchanges and imparting education in a specific discipline, the curriculum requires a strong focus on liberal arts, humanities, and social science studies along with Science, Technology, Engineering, and Mathematics (STEM) disciplines. Along with the curriculum, it is also important that collaborations are encouraged to promote multi-disciplinarity. Collaboration between Institutions is required to enable the academic bank of credits to work effectively and mapping is required between the National skill qualification framework with the National higher education qualification framework to ensure effective implementation of NEP 2020. There is further a need for correct manpower projections and work towards manpower planning as per the specified goal. Learners should be allowed to migrate to different dimensions and then employability would be enhanced. Rather than having discipline-specific degrees, Higher Education Institutions need to offer interdisciplinary degrees. There is a need for control to be given to the beneficiary (learner) rather than the Institution. It is also important to build systems to allow the migration of learners to different programmes after the First Year at the graduation level to further promote multidisciplinary education.

Another important pillar to ensure effective implementation and offer multiple disciplines is competent and skilled faculty members. A flexible system requires a large number of members to be made available. Faculty members have to responsibly act to create interest among the learners in the discipline chosen from the abundant offered opportunities and also have to ensure to deliver engaging sessions. Adequate faculty training is the key to ensuring competencies and promoting multi-disciplinarity. The government is also expected to facilitate the environment and provide sufficient funds to promote multidisciplinary education. Multi-disciplinarity will come with a provision to have a joint appointment of faculty members with Industry and Institutions, across different Institutions, and also within multiple departments.

A flexible Engineering curriculum would encourage learners to have T-shaped (depth & breadth) in place of I-shaped (in-depth) specialization. Learners are required to be counseled to have a broader base in place of having straight specializations. Educating learners to be good human beings, good citizens, and then good professionals is very essential. Giving academic credits for community work in the curriculum would give learners motivation to undertake such courses and gain an experience of a kind. Learning beyond the classroom is the answer to making learners responsible and changing their mindset. Multidisciplinary education is possible by inculcating learning by doing in the curriculum.

Integrating multiple disciplines in the curriculum is an evolutionary process. Universities and Higher Education Institutions alone would not be able to deliver this task. We have to take society on board, and industry on board and need to be very open to putting the academic curriculum. Minor areas of specialization along with major areas are to be promoted. Multidisciplinary education is cultivated when we have learning by doing. There are immense opportunities for integrating a new paradigm of education to offer to learners to nurture multidisciplinary culture. Knowledge alone is not a sufficient resource. We require holistic education that integrates universal human values to create an environment where persons of integrity practice the morals that have been imparted to create a progressive world.

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