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Transformation of engineering education through student-centric learning

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Abstract

Modernisation in higher education is one of the major objectives to meet the universal challenges and provide higher knowledge-based and sustainable development levels. It is decisive to encourage the quality of teaching and innovative pedagogy. Technological advancement has led to the development of many efficient methods for innovative pedagogies in the field of education. Engineering education is built on a new-fangled standard in which engineering is to be practiced with technical expertise as well as social responsibility. The teaching fraternity has incorporated a lot of teaching strategies for changing teacher-centric education to learner-centric education. This paper aims to present the aspects of the teaching–learning process, teaching pedagogy and curricular approaches of engineering pedagogy and study the teaching strategies followed by engineering teachers. To study the different teaching strategies followed by teachers in engineering education, an online survey on teaching strategies was conducted for the engineering teaching fraternity all over India. The survey depicts that there is a change in the teaching and learning process from teacher-centric education to learner-centric education. Almost 80%–90% of the teachers follow student-centric teaching by using different tools and strategies, which in turn results in outcome-based education.

Keywords: Engineering education, learning, learner-centric, outcome-based education, pedagogy, teaching, teaching strategies.

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1. Introduction

Education is a vibrant energy, which induces the physical, emotional, mental, ethical and social development of an individual. Education is defined as a means to transform the behaviour of an individual. It is defined as a process in which an individual progresses his intelligence and skills of reasoning, obtains knowledge, and fosters good practices, necessary skills and human values. Education can be categorised into two types: formal education and informal education. Formal education is determinedly designed and planned with definite objectives, instructional policies and assessment processes. Informal education is supplementary and occurs without any curriculum and formal setting. Education must aim at a complete programme for the student's intellectual, physical, moral, aesthetic, social, cultural, domestic, vocational and recreational requirements for their overall growth.

1.1. Teaching–learning process

Teaching is a fundamental fragment in education. It consists of a structure of actions envisioned to make learning happen. The main function of education is imparting knowledge, developing skills and understanding. There exists an interaction between teachers and students through which students are guided towards the objective of learning. Teaching may be considered as a skill of assisting others to learn. Teaching is usually oriented towards achieving a goal and can be considered as a multidimensional activity.

Learning is an act of attaining knowledge, values, skills and experience by understanding and synthesising the information perceived by an individual and bringing change in an individual's behaviour. Learning can be defined as a process which inhabits a vital part in shaping behaviour and personality. Learning encompasses different techniques of doing things, adopting diverse methods to achieve the objective. Learning is a comprehensive and continuous process that covers the cognitive, conative and affective domains of human behaviour. Teaching includes setting suitable learning experiences for learners, which comprise an assortment and arrangement of activities or interactions that lead to anticipated learning. Teaching is anticipated to learning and deprived of learning; always teaching will be incomplete.

A teaching–learning strategy is a set of scheduled activities that enable the teacher to teach and the learner to learn content that successfully achieves the instructional objectives. The teaching process is usually acknowledged to form the centre of the education process. Innovative alternate strategies need to be developed and explored to attain a higher level of teaching.

The teaching techniques are categorised into:

- **Teacher-Centric Approach:** In this approach, instructional interactions initiate from the teacher and students are the receivers. Students are directed by the teacher throughout the process in the means planned by the teacher. Both the teacher and the students are enthusiastically involved in this process, but the emphasis is on demonstrating learning practices by the teacher.
- **Learner-Centric Approach:** In this approach, students are enthusiastically involved with the learning experiences, and the teacher is circuitously involved in the instructional process. Both students and teachers share the focus and equally interact with each other. This approach is usually beneficial in increasing the cognitive capabilities of students.

Different models are developed in order to apprehend the diverse ways through which learning happens to be the best. One standard model, the VARK model, ascertains four main kinds of learners: visual, auditory, reading/writing and kinaesthetic. Figure 1 shows a description of the types of learners and learning styles.

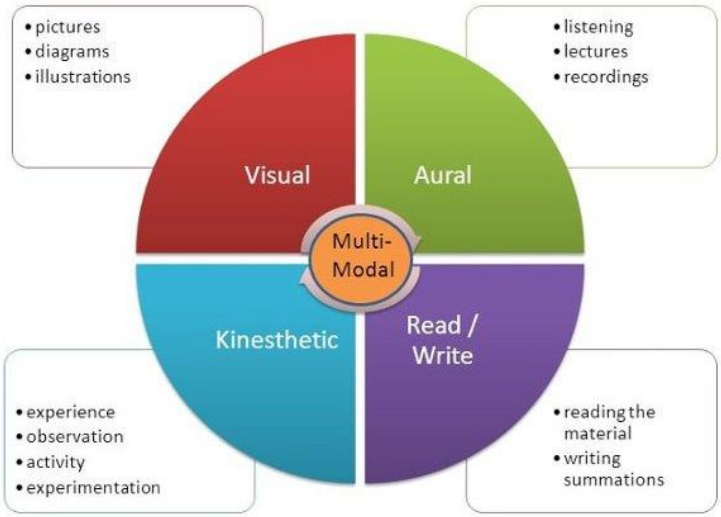

Figure 1. Types of learners and learning styles

V: Visual – Visual learners will learn pre-eminently by what they see as they think in pictures or videos or images. These learners will learn at their best when pictorial or graphical means are used to epitomise what they are learning. Visual learners usually prefer graphs, mind maps, images and other visual representations in the form of instruction.

A: Auditory – Auditory or aural learners learn best through enthusiastically listening. This type of learner depends predominantly on speaking and listening as an important learning mode, and they are good listeners.

R: Read/Write – Read/Write learners are traditional students. They are suitable for the orthodox school-taught routine of study, such as writing notes and reading books. Common features found in this type of learners are that they recollect information which they write down or read.

K: Kinaesthetic – Kinaesthetic learners learn best by involving in physical activities or learning activities, including active participation. They learn moving around engaging in small or large groups. In order to understand something, they need to feel it, touch it and move around. They are hands-on learners and learn effectively by figuring out things through experiences.

Teaching and learning always go hand in hand. Learning happens through education, and the teaching process is the planning of an environment where the students can study how to learn and interact. The teaching–learning process targets the effective transfer of knowledge, conveying skills and developing values, attitudes and behaviour. Teaching policies are administered by the student's contextual knowledge, situation and environment and also the learning objectives set by the teacher and student.

2. Teaching pedagogy

Pedagogy refers to the principle and practice of learning and how the process impacts the learner. It is prejudiced by the political, social and emotional development of learners. Pedagogy is habitually defined as an act of teaching. The pedagogy implemented by a teacher forms their judgments, actions and additional teaching schemes by considering concepts of learning, understanding of learners and their necessities, and individual learners' interests and backgrounds. Accustoming the resources of teaching must suit suitable environments for teaching and learning, local and natural norms of culture

and make it reachable to diverse learners. The main adaptations in teaching resources consist of classroom constraints, cultural familiarity, local relevance and diverse learners' inclusivity.

Pedagogy encompasses activities that induce changes in the learner. Modern curriculum developments have stimulated 'teacher-centric' pedagogy methods to 'learner-centric' or 'student-centric' or 'active' learning methods. The word 'effective' is connected with the term 'pedagogy'. The 'effective' pedagogy includes teaching and learning activities that make a discernible change in learners, leading to better commitment and understanding and a determinate impression on the learner's learning. Swift development in technology, economic globalisation necessitates education to be designed towards an outcome-based education (OBE) module. The preparation and presentation without proper organisation will miscue the anticipated objective of motivating and educating the students to endure as educators, students or practitioners. The process of teaching is subject to specific regularities and estimated by a cascade of mechanisms throughout its progression – goals of teaching, materials used in teaching, psychological and social structure, mode of teaching and methods; everything has a complex mutually dependent relationship (Ruutmann & Kipper, 2011). Imparting quality education at a sophisticated level can be accomplished by enhancing and reforming teaching methods and improving the delivery of content in terms of quality (Fawad & Manarvi, 2014). The current education trend focuses on measuring student performance through outcomes, and this learner-centric instruction model is called OBE (Spady, 1994). OBE is a procedure of designing the curriculum, teaching, learning, and assessing the students based on what they can do (termed as 'learning outcomes') after the teacher teaches them.

An OBE prospectus starts with a definite idea of what is to be done by the student concerning what is important to him/her and then organising the system, including assessment and instructions, ensuring the learning happen ultimately. The OBE model is widely being used all over the world at the moment. This is because it helps the students improve their technical education and helps them compete with their global counterparts.

OBE is a necessity of the hour and should be implemented in every field wherever skills and knowledge are concerned. The advantages of OBE are:

2.1. Clarity

The emphasis on outcomes makes vibrant the anticipation of what desires to be accomplished at the end of the course. Students will get to know what is expected of them and teachers will also understand what they are supposed to teach during the course. Clarity is crucial besides years of engineering, and when teaching is accomplished as a team.

Clarity helps every teacher to have a strong considerate of what should be accomplished in each class, making students' progress. The people who are planning and designing the curriculum are expected to work after the outcomes decided. They need to determine what skills and knowledge are essential to arrive at the outcome.

2.2. Flexibility

Any method can be chosen for teaching a student. OBE does not confine the teachers to teach using an explicit method. OBE is a student-centred learning model. Teachers are preordained to help, guide, mentor and monitor the students to master the material using either approach.

2.3. Comparison

Different institutions are compared on the basis of OBE. At an individual level, students' achievement can be used to decide what outcome they have reached. At an institutional level, institutions can be compared by checking their expected outcomes and finding improvement (if

required) at any place, based on the outcomes achieved at competitive institutions. The students can also be given credits according to their performance.

2.4. Involvement

The involvement of students in the class is a vital fragment of OBE. Students in the classroom are anticipated to self-learn to attain a complete understanding of the course content. More participation of students allows students to feel liable for their learning. Other aspects which help students in involvement are parents and society.

3. Curricular approaches of engineering pedagogy

An exceptional education system endows the students to be lifelong learners and solvers of problem-impacting values and to be good citizens. Nevertheless, most of the engineering universities in India design pedagogy around examination that tests memory than students' ability to apply, analyse, evaluate and create knowledge. Scientific conclusions for teaching in engineering education are to be implemented to support a high level of thinking among the students.

Skilled engineering accomplishments are the basis of any enduring profitable growth. Hence, the primary mission of universities is to deliver academically skilled and professionally abled graduates to the society. With its allied growth of competent activities in research, manufacturing and services, economic development gradually needs well-trained engineers, which meets the necessities of society and economy (Kersten, 2018). The curricular methods of engineering pedagogy will contribute to the enhancement of the quality of engineering education. An engineering graduate should demonstrate the depth of knowledge in a specific domain or discipline and competence in analysing, synthesising and integrating knowledge and methods from several fields of study (Navarro, Foutz, Thompson & Singer, 2016). The intricacy inherent in modern technologies, as well as the intricacy inherent in the diversity and multiplicity of societal needs and perceptions relative to these technologies, leads to a new approach in engineering education. A method to engineering education built on a new standard in which engineering is practiced with technical expertise along with social responsibility should be introduced (Kastenberg, Hauser-Kastenberg & Norris, 2006).

Information on engineering education is extremely pertinent for improvising communication among students, professors and researchers in engineering institutions, as well as industry (Davim, 2014). The technological revolution is essential to the advancement of education systems. Engineering education emphasises curriculum development, pedagogy and didactic traits of engineering education, covering appropriate traits from more classical engineering courses to added contemporary courses and information on sustainable development in the context of engineering education.

4. Pedagogical issues and OBE

Yesterday's education system used to be teacher-centric with the highest focus on lecturing and note-taking. The educational resources were limited and costly. The scenario was of gradually shifting frontiers of knowledge and archetypally no technological tool was used and no one well-thought-out competition in the corporate world.

Today's and tomorrow's education system focuses on outcome-based learning. At the end of the study of a 4-year programme, the engineering graduates should demonstrate the expertise of domain-related learning objectives and domain-independent learning outcomes. Graduates should be equipped for their careers in different parts of the world and work in various contexts. Products and services of tomorrow have global implications and effects which almost solely depend on the developers and researchers.

Currently, OBE or the OBE system is being most extensively used by almost all prominent institutions throughout the world. The OBE system can also be stated as standard-based education. It has demonstrated to be a success in facilitating educational institutions to measure their learning outcomes and simultaneously empower students to cultivate new skills that make them stand out from their global counterparts.

These factors contribute to raising the standard of education and help educational institutions to obtain accreditation from acclaimed bodies of accreditation such as the National Board of Accreditation (NBA), and NBA helps in improving unceasingly in the long run. On the other hand, the traditional education system is greatly reliant on the theoretical aspects of learning. It reprises the monotonous means of the teaching–learning process, which mainly emphasises remembering skills of students rather than developing skills.

It scarcely affords students any chance to develop new skills that will help build or create their careers in diverse fields. In a traditional teaching method, usually, teachers are more focused on completing the curriculum with the given time frame rather than innovating. Figure 2 shows how actually the OBE system and traditional education system work. The figure shows the positives and negatives associated with OBE system and traditional education system, respectively. The traditional education system's rudimentary purpose is to pass on the knowledge of the prior generation to the forthcoming generation students.

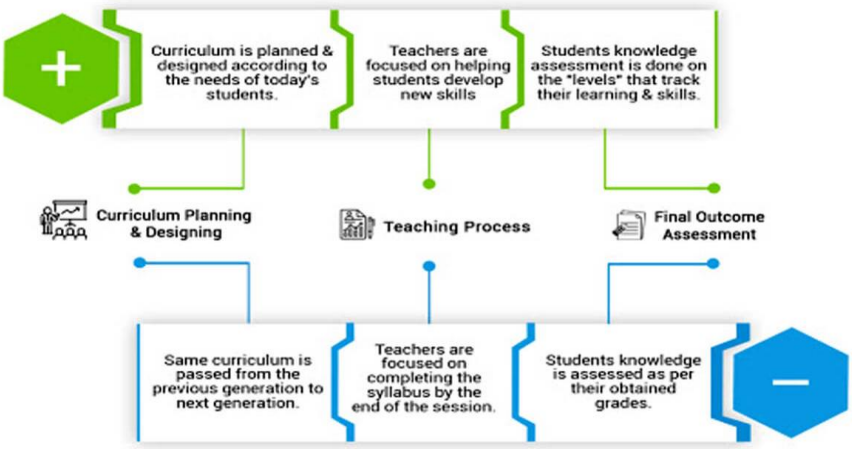

Figure 2. OBE system versus traditional educational system

'Restructuring' and 'Remodelling' the curriculum's standards is not an important goal in the traditional educational environment. The curriculum plays a critical role in providing greater intuitions concerning every course to the students or learners. The more the practicality is involved in learning, the more the students will develop necessary skills that enable them a career worth pursuing and make them industry-ready.

Knowledge is growing at a faster rate today, and learning is not a one-time issue. There is a huge variety of excellent learning resources accessible on the internet and Information Communication Technology (ICT) tools that make access to high-quality learning resources within less time. The new-fangled challenges in education are how we teach a diverse set of students and how we prepare our students with the 21st-century attitude, knowledge and skills. The ICT tools are the modern devices or technology and concepts used in ICT among students to teachers and students to students' interactions (e.g., mobile apps, clicker devices and flipped classroom). In the current situation, the innovation in teaching is essential to occupy the students for the course throughout the teaching hours of the course. At the end of the age, the course's strengths will outclass in performance and attain the course outcomes with profound knowledge about the course and its contents. In order to

overcome the problems of inactive and slow learners to attain the course outcomes, it is essential to refurbish the teaching methodologies. Some inventive learning approaches like think flipped classroom, pair-share activity, virtual classroom techniques, activity-based learning and project-based learning aggravate the slow or inactive learners to become more active in the process of learning the course. It is indicative from studies that the present-day students are very smart, and they tend to feel traditional methods of teaching are uninteresting and monotonous. The impact and significance of the usage of ICT tools over conventional traditional teaching methods promote the learning level of students. To create a revolution in education, learners or students must be well equipped and ready to face learning methods' challenges. The students are currently exposed to renewed teaching methods like project-based learning, simulation-based learning, smart lab-based learning, demonstration-based learning, gamifying-based learning, flipping and inverse flipping classroom. By these teaching methods, the students can learn more than the regular syllabus and think beyond the understanding level to apply level as per OBE's concept. Consequently, students will pay more attention and feel self-motivated to apply the concepts from real-life activities to enhance their skills from the knowledge taught (Fusic, Anandh & Thangavel, 2020).

The knowledge and skills for 21st-century students consist of:

- **Academic Education:** Completing an accredited programme of 4 years.
- **Knowledge of Engineering Sciences:** Applying the knowledge of science, mathematics, fundamentals of engineering and specialisation in engineering to the conceptualisation of the models of engineering.
- **Design/development of solutions:** Designing solutions for complex problems pertaining to engineering and designing systems, processes or components that meet definite needs with apposite contemplation for public safety and health, societal, environmental and cultural considerations.
- **Investigation:** Conducting investigations on multifaceted engineering problems containing the design of experiments, analysis, interpretation of data and synthesis of data to provide effective conclusions.
- **Modern Tool Usage:** Creating, selecting and applying the right techniques, resources and recent engineering tools that include modelling and prediction to engineering activities, with an considerate of the restrictions.
- **Individual and Teamwork:** Functioning effectually as an individual and as a leader or as a team member and in a multidisciplinary environment.
- **Communication:** Communicating efficiently on engineering domain-specific activities with the engineering community and with society, and be able to understand and write reports effectively and design documents to make effective presentations and receive and give right instructions.
- **The Engineer and Society:** Demonstrating the understanding of health, safety, societal, cultural, and legal issues and the consequential responsibilities pertinent to engineering practices.
- **Ethics:** Understanding and commitment to responsibilities, norms of engineering practices and professional ethics.
- **Environment and Sustainability:** Understanding the impact of engineering solutions in society's context and demonstrating the knowledge of and the necessity for justifiable development.
- **Project Management and Finance:** Demonstrating knowledge and understanding business practices and management, such as change and risk management, and understanding their restrictions.
- **Lifelong Learning:** Recognising the necessity and have the ability to engage in independent and lifelong learning.

ICT tools contribute to excellent education since they have the potential to upsurge motivation for students, associate students to various information sources, support active in-class and outclass learning environments and let teachers assign extra time for facilitation. Hence, the use of ICT tools in the process of teaching and learning becomes a prodigious arena of research for numerous educators. The ICT tools and technologies increase motivation in students, self-esteem and self-confidence to learn. Furthermore, new technologies typically reassure active and independent learning, and thus the students themselves feel more responsible for their own learning. Significant research on the contribution of ICT tools in renovating learning and teaching prompts attempts to integrate these technologies to benefit in terms of quality of education, access, flexibility and cost.

The modern approach to curriculum design includes:

- Selecting course objectives that stimulate higher-order thinking skills such as analysis, synthesis, evaluation and creativity.
- Expressing the goals as knowledge, skills and attitudes that the students should validate on successful completion of the course, using measurable action verbs.
- Taking benefit of ICT tools to make these available to everyone concerned well in advance.

5. Methodology for analysis: survey on teaching pedagogy and strategies

A survey on teaching pedagogy and strategies was conducted for engineering faculties all over the country through a questionnaire to study and analyse the teaching strategies, followed by the engineering fraternity all over the country. The survey is based on teaching methodology employed by the teachers, their flexibility in dealing with the students, strategies and efficient techniques used by teachers, project-based learning, modularisation of topics, beyond syllabus or curriculum teaching, usage of ICT tools for better teaching, feedback mechanism from students and many more.

The methodology used for the analysis of teaching strategies is through an online survey with 21 structured questions on teaching pedagogy and strategy was prepared so that the respondent completes over the internet, generally through filling out a form (Google Form). Online mode of feedback mechanism was preferred because it is a more accepted way to reach respondents easily, and it takes less time than the traditional old-fashioned way of collecting information through one-to-one interaction. The questionnaire on teaching pedagogy and strategy consisting of 21 questions with five scales as shown in Table 1, where 1: never; 2: rarely; 3: about half of the time; 4: usually; and 5: always.

The survey was conducted for the engineering teaching fraternity, and 876 teachers from all over India had participated in the survey. The questions and results of the survey in terms of percentage are as depicted in Table 1.

Table 1. Survey questionnaire and feedback

	Questions	Percentage of teachers opted				
		1	2	3	4	5
1.	Discussion is used as teaching strategy when you teach a subject	35.6	45.7	9.1	9.6	0
2.	Creativity and independence are encouraged from your students	57.5	31.1	6.4	4.6	0.4
3.	Appropriate interaction is monitored and facilitated among the students you teach	49.8	37	7.3	5.9	0
4.	Being a teacher, you support student-centric learning	68	22.8	6.4	2.7	0
5.	You are flexible with students in dealing with their needs related to academic issues	68	25.6	3.2	2.3	0.9
6.	Problem solving and Critical thinking are essential skills for your students	68	22.8	5.9	3.3	0

7.	Strategies like active learning, collaboration and participation among your students are encouraged	72.1	22.4	3.2	2.3	0
8.	You use efficient techniques and strategies that make students to engage enthusiastically in the process of learning	55.7	36.5	5.5	2.3	0
9.	Group interaction is encouraged by you to enhance learning	43.8	35.6	10	10	0.6
10,	Constructive and timely feedback is given to students about the given questions and assignments	52.5	37	6.8	3.2	0.3
11.	Appropriate strategies are considered to accommodate the diverse skills and talents of your students	39.7	46.1	10	3.6	0.6
12.	You use student-centric activities and lessons which are based on the ideas of active learning and which are related to real-world applications.	43.5	41.1	10	5.1	0.3
13.	You use different teaching methods to address a variety of learning styles of your students	42	40.2	10.5	7.3	0
14.	You modularise each concept while explaining for better understanding	47.5	42.9	5.8	3.2	0.6
15.	You contact the students immediately to correct their issues and keep them on task	53.4	34.1	8.2	3.7	0.6
16.	You encourage project based learning in the subjects you teach	45.7	33.8	14.2	5	1.3
17.	You encourage open ended experiments for practical/lab courses	43.4	36.1	9.6	8.2	2.7
18.	You teach beyond syllabus topics to students to improve their knowledge	37.4	37.9	12.4	11.4	0.9
19.	You invite people from industry to connect industry and academics	29.7	33.3	13.7	21.9	1.4
20.	As a teacher, you view yourself as a facilitator	73.1	20.1	4.6	1.3	0.9
21.	You use technological and ICT tools to make students understand the concepts better.	72.1	22.4	3.2	2.3	0

The responses are neatly and automatically collected through Google Form with real-time information and charts. From the survey, it is clear that on average, almost the majority of the engineering teaching fraternity has adopted many teaching strategies and focussing on student-centric learning rather than traditional teaching-centric learning. Around 80%–90% of the education teachers have shifted their focus of teaching from the traditional teacher-centric method to the contemporary student or learner-centric method. Definitely, this transformation of teaching from teacher-centric approach to learner-centric approach will yield better students with a higher quality of learning. More significant attributes are required for the students to prominently grow in academics as well as in survival in the industry or to develop skills needed for employability, which eventually leads to OBE.

6. Conclusion and discussion

Several engineering institutions in India impart undergraduate and postgraduate courses in technology, science and engineering. Engineering education is facing substantial challenges since it has to meet the emerging job market and technical profession's demands and requirements. Innovative teaching and learning approaches require efficient, professional development for both experienced and fresh teachers/instructors. It is necessary to redesign pedagogy and teaching strategy

in technical education for making engineering students better engineers for serving the profession and society. OBE system offers extended opportunities for the students by ensuring a student-centric teaching and learning approach. OBE has a clear goal to positively impact teachers' and students' lives to innovation and excellence.

From the survey carried out for engineering teachers all over India, it is clear that education is moving from teacher-centric to student-centric education. Nearly 80**%**–90% of the teachers in engineering education have moved their focus of teaching from the traditional teacher-centric method to the contemporary student or learner-centric method. It is clear that learning is happening in a better way in a student-centric approach, and a technically sound engineering graduate can serve better to profession and society.

7. Recommendations

As a future directive and recommendation of this work, it is suggested to implement more tools and strategies for student-centric learning. This survey questionnaire could be improved, which is more oriented towards enhancing student-learning policies and OBE.

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