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Enhancement of Engineering Education by Incorporating Active Learning Methodologies

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Abstract: In recent years, there has been a decline in the number of students opting for engineering education worldwide. Especially, the declining enrolment in engineering programs was observed sharp for the last two years in India. The widening unfulfilled gap between the educational institutional purposes and the engineering aspirations are exponentially increasing in recent years. Strong knowledge of international trends in engineering education is vital to introduce the state-of-art infrastructure active and project-based learning facilities in the institutions to impart the required competent skills. A case study on active learning methods is implemented on one of the undergraduate courses and academic performance are compared with the feedback. The top-two learning methodologies are found effective to be project-based learning and conference publication. ALM is observed to be one of the motivating factors to enhance the project-based learning among science and engineering students towards capability development. The student's involvement in learning certainly improves their competency and it could be enhanced by the activity-based learning methodologies (ALM) rather than the classroom teaching.

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1. Introduction

Engineering education enjoyed its technical supremacy for several decades, coming up with a lot of noteworthy innovations, lucrative employment opportunities, surety of a stable career and assurance of a comfortable life. Recently, engineering education has lost its allure somewhat as a preferred profession and young students of India are fast losing interest in engineering and technical education mainly due to the fear of inability to successfully complete the challenging course, affordability factor and greater risk of unemployment due to a stagnant job market. Except the premier institutions, the poor enrolment of young aspirants in engineering institutions is a clear alarm to the unemployable engineering educations in India.

A strong uncertainty on employment after four-year degree course is one of the major reasons for the students being getaway from the engineering admissions. Also, female students were not interested in engineering courses. Lack of research and development related activities have been clearly discussed by Naik (2019) and the areas need to be focused by the Indian engineering institutions are research and innovations like the western countries. Emotional learning is also one of the areas to link the

educators, learners, parents and industry (Brackett et al., 2019).

The reforming the higher education systems is the need of the hour to compete our graduated at the international job market and to develop entrepreneurial activities in India. As an individual responsibility and government policies are required to promote the engineering education and technical careers. Hence, the present article is focussing on the positive steps to be taken by engineering institutions in India to reach a fruitful destination for the young students and engineers through active learning methodologies. Inculcation of the importance of our daily needs and the required techno-economical skills to utilize the knowledge gained on engineering for almost all the requirements of a country.

2. Objectives of the study

The objectives of the present study are aimed to provide the required knowledge and skills during the engineering in the selected discipline of engineering to the young students towards their better learning and career prospects. The selective topics of interest in effective learning to reduce the gap between the theoretical study and real-world problems are addressed in this article.

- Nonuniformity in engineering curricula
- Attrition rate in engineering education
- Sustainability careers in engineering education
- Outreach activities of the engineering education
- Case study on active learning methodologies in engineering education

3. Literature Review

Research Methodology of recent literature in the context of improving the science, technology, engineering and mathematics (STEM) education, especially engineering education was carried out using Scopus database. The articles have been searched with the keywords like engineering education, curricula design, attrition rate, sustainability in education, outreach activities to increase the engineering aspirations. Few recent articles were selected based on the publication years of 2018 and 2020 to discuss the recent issues and remedies in the engineering enrolments and technical careers and active learning methodologies to produce engineers with capability of providing sustainable solutions to the society.

A comprehensive literature review has been carried out to understand the real issues of attitudes to science and engineering education. There was enhanced learning outcome of the freshman course using the instructional materials of Massive open online courses and flipped classroom concept (Alario-Hoyos et al., 2019). The blended instructional strategy and learning method, outside classroom study sessions and activity-based learning in the classroom promoted active learning, effectively met the diverse learning needs of students and significantly improved understanding. The enrolment of students in engineering graduate programs in the U.S was on a declining trend since the year 2018 due to lack of self-efficacy or drop in academic self-confidence, their study included student characteristics such as race, ethnicity and gender (Borrego et al., 2018). Multinomial logistic regression models were used to predict student intention to pursue a master's or PhD degree using factors such as outcome, expectations, support, barriers and choice actions, all of which were found to have an influence over the steady decline in the enrolment of students for higher education programs.

The core engineering gateway subjects in the second year of engineering curricula, namely Statics, Strength of materials, Engineering Mechanics, Applied Thermodynamics, Electric Circuits, Multivariate Calculus and Differential Equations were identified in Greece (Yoon et al., 2018). The reasons of the poor grades and academic failures were analyzed with a holistic approach to determine the main cause of the alarming attrition rates in the sophomore year. Student attrition is a matter of deep concern and is a complex problem, involving as it does substantial losses to the institution, to the individual students and concerned/involved stakeholders like the government and academic program planners. The attrition rates in the freshman first year were noted to be lesser than the second year. The sophomore slump was attempted to be reduced by way of analyzing the factors, issues and root causes of attrition and deploying retention strategies (learner support services, student involvement, counselling, mentoring) thereby assisting junior students make a smooth transition to higher classes. The Latina first-generation women college students, an underrepresented group in education, were

investigated to determine if they had equal access to engineering education compared to their male counterparts (Verdin and Godwin, 2018). The engineering education experience, self-efficacy, academic and institutional integration of the students were considered to evaluate their interests and achievements in the field of engineering. Researchers have found that there are many benefits and positive attributes in integrating informal social media tools with the formal education framework and teaching programs, as they can increase educational opportunities and improve educational quality.

An integrated model was used to study the effective use of social networking sites implemented at institution, from the student's point of view (Marjanovi et al., 2018). Female students with self-funding expended more time on social networking sites than male students. The self-efficacy of engineering students is one of the critical factors for their academic success (Paul et al., 2018). This study took into consideration the gender of students, class level and transfer status based on generic as well as domain-specific instruments. Flipped and traditional classroom learning were compared (Yan et al., 2018). Active flipped learning (AFL) methodology, is a student-centric approach that helps the weak students as well as female students to excel with personalized, inquiry-based collaborative learning. The significant contributions by AFL are, improved and active learning, peer management, self-efficacy and critical thinking. AFL is an organizational strategy, whereas the traditional lecture-based conventional classroom approach has a highly structured instructional style with organized classes that involve elaboration strategies.

A study on cosmopolitan engineering students and measures that could be adopted to foster a lifelong love for learning in them (Kingdon, 2018). The education system needs to be gender-sensitive and gender-friendly to ensure effective learning. The study found that gender sensitivity was not much at the undergraduate level, whereas gender-based exclusion and discrimination was significant at the Master level. Systematic patterns in problem exploration in the early design phases of mechanical engineers were investigated by assigning design tasks to both students at various levels of undergraduate mechanical engineering studies and working mechanical engineers (Murray et al., 2019). The participants approached the real-world design problems presented to them in different ways generating multiple solutions as the creative outcome of varying perspectives. The engineering designers, working individually, were observed to apply both problem-specific and more general strategies to explore the design problems.

A theoretical framework was developed for ascertaining all aspects of students' attitudes, ideas and perceptions towards technology in order to improve confidence and foster a more positive attitude (Ankiewicz 2019, Ankiewicz 2019). Unidimensional and multidimensional studies helped to determine the effect of all characteristics of learners' attitudes to develop new knowledge in STEM education. The cognitive component and affective component of attitudes can be easily ascertained. Researching the behavioural component of attitudes needs to be done in a holistic manner and requires statistical techniques and a lot more studies by educational researchers to have a clear understanding of the three components of attitude and their interrelationships. A new light was shed on horizontal stratification in higher education. Their study involved the scrutiny of the sons and daughters of non-academic economically established and academic non-wealthy parents (Ayalon and Mcdossi, 2019). Lucrative fields of study were the popular choice of both categories. However, the daughters of non-academic wealthy parents were noted to prefer remunerative/high-paying professions like business and law rather than STEM.

The STEM Talent Expansion Program (STEP) which was successfully established by Louisiana State University to increase students' persistence in STEM courses in light of the high rates of attrition (Ikuma et al., 2019). Participants in STEP courses and mentoring programs had significantly higher persistence in engineering and STEM majors. Chien et al. (2018) made a scientific teaching module to the high school students to fabricate their own a dye-sensitized solar cell (DSSC) using the daily life appliances to drive a small fan motor. More than 80% of the students were constructed a successful DSSC in 2.5 h. The process also made a better understanding of the solar energy utilization and importance of alternative source towards the sustainable green energy. Thus, the understanding and lifelong learning are vital to improve the engineering education and research.

4. Discussion

Based on the comprehensive literature review, some of the challenging aspects, opportunities of engineering education towards a better learning and understanding the real time societal problems and needs are discussed in this section.

A. Nonuniformity in engineering curricula

There is lack of uniformity in the curricula of specific engineering disciplines among various universities in a country. In the event of transfers, students face a lot of difficulty in coping with the academic studies in the new institutions as a uniform syllabus is not followed. This situation is compounded further when it comes to international universities with the structure and content varying substantially. Hence, the attrition rates of transfer students are rather high as a good number of them struggle to manage the situation. Steps must be taken by a regulatory authority to design, develop and implement a modern engineering curriculum that can offer a professional education based on sound principles equipping students to meet the technological challenges of tomorrow. With the world moving towards globalisation, engineering curriculum must respond to the challenge by tailoring content to meet high international standards, it must offer qualifications that are internationally recognised and result in graduates with global potential. Work-based learning as integrated activities in the curricula may serve effective by matching industry requirements by improving student competency (Rouvrais et al., 2020). An engineer must be capable of applying his professional expertise and skills at any part of the world. Suitable modifications must be made in the standardised syllabus by considering region-specific factors such as the level of available technology, financial resources, political system, religion, language, history, tradition, culture, customs, Governmental policies etc. unique to the country. Through the integration of project-based curricula, an authentic learning of postgraduate students was observed to be a transformative practice and capability development (Karim et al., 2020; Brand, 2020).

B. Attrition rate in engineering education

The attrition rate is high in undergraduate engineering students, especially in the first two years of the four-year programs. This issue of students dropping out from the program impacts the institution's enrolment ratio and the perceptions of the public towards the engineering discipline and the university/institutions. It was observed that students faced academic difficulties, with Mechanics of materials, Mechanics, Thermodynamics, Electric Circuits, Multivariate Calculus and Differential Equations being the most challenging courses that students had difficulty in coping with and the main cause behind most of the attrition cases (Yoon et al., 2018). The courses require many hours of diligent study of difficult course material and are deemed 'tough' or 'too hard' by students who simply give up and are not willing to work harder at it, particularly when the teaching is of a poor standard. It is unfair to expect the students to swim or sink. If assistance is not provided to these floundering students, the large number of failures in the junior classes of undergraduate engineering can bestow a negative image of engineering education, result in the loss of potentially good engineers not to mention the financial and societal cost of student attrition. Several methodologies have been suggested in literature to ensure student success and reduce the attrition rate. The following measures can be considered, particularly to reduce the attrition rate and accord priority to increasing the student retention rate.

- Welcoming institutional climate that is conducive to learning
- Flipped classroom teaching methodology (Yan et al., 2018; Öncel and Kara, 2019; Baughman et al., 2019)
- Problem-based and project-based teaching and learning (Chien et al., 2018)
- Experienced professors and senior faculty members are required to handle challenging courses
- Technical presentations by industry experts for better learning outcomes
- Close monitoring of the intended student learning outcomes during the teaching of the courses with suitable evaluation, assessment and appropriate remedial measures to be undertaken during the course, not the end of the course or semester to ensure students are not overwhelmed by course content.

- Resolving the problems and issues faced by the previous batch students and sharing their inspiring success stories

- The importance and insights of courses to be specified and new teaching and learning methodologies to be evolved based on the region-specific examples and case studies (Brand, 2020)

- Mentorship programmes with faculty or senior students to offer a support system

- Team activities and collaborative projects for better understanding (Barlow and Brown, 2020)

- Flexible examination schedules with offer of supplementary examinations for the courses that have more failures and poor grades (Paul et al., 2018).

- Motivating students to achieve desired learning outcomes for subjects involving greater complexity

Building up critical thinking and real-world problem-solving abilities by discussing engineering problems in everyday life in the classroom for better visualization and understanding.

C. Sustainability careers in engineering education

Engineering education in India inherently lacks the integration of humanitarian and environmental concerns in the curriculum and has the limitation of largely being merely academic-centric. Any engineering discipline must mandatorily include courses on humanitarian and societal concerns that will equip future engineers to work closely with the people of the respective country, satisfactorily resolve region-specific challenges and issues, and contribute to society for the sustainable growth of the nation. If the agricultural economy is the major role player in a country, then it is necessary that engineering students of multiple disciplines have the necessary skills, abilities, attitudes and know-how to devise innovative, immediate feasible solutions to the pressing problems of the agricultural community by working in tandem with industry experts and the public. Such acts of engaging engineering with society helps raise the profile of engineering, gains public perception and elevates the reputation of engineering graduates. More importantly, it attracts the brightest and the best minds to pursue an engineering education. Renewable energy education certainly brings the sustainability (Ruiz-Rivas et al., 2020).

Society being beset with a plethora of problems, an enterprising engineering student can apply his newly acquired technical knowledge to good use to resolves as many issues and problems as he can, reaping the rich harvest of witnessing first-hand the successful outcome of his efforts and the happiness it brings (Ashraf and Alanezi, 2020). Start-up job and career opportunities are a good way for young professionals to learn as they grow, to get the most out of limited resources, and implement creative technological ideas in an interesting and challenging environment (Tasdemir and Gazo, 2020). The added perks are that entrepreneurship brings in its wake laurels to such engineering aspirants as personal satisfaction and recognition. To ensure sustainability in engineering education and affiliated sciences, the focus must be on energy and environment related courses. Quality Circle were required in an institution to identify the desired academic ecosystem (Dharwadkar and Shingan, 2017; Thanikachalam, 2019). All engineering institutions could follow appropriate educational ecosystem for creating human and knowledge capital. Real-life examples to be dealt in the mechanical engineering courses to make the understand the outcomes on the societal concerns (Raghu, 2019).

D. Outreach activities of the engineering education

The engineering faculty and students of universities should jointly work or collaborate with the local high schools to create greater awareness of engineering education and the number of career opportunities. In lieu of this, joint projects, activities and challenges that involve applied and problem-solving skills may be organized by high school and engineering students to rouse curiosity and interest in young children and open their minds to the wonders of science.

By connecting engineers of today with probable engineers of tomorrow, the impact of Engineering as a career path can be driven home. Providing an experience for young learners to think and act like engineers offers them early exposure to STEM and may serve to attract more students to STEM-related courses and fields (Cunningham et al., 2020). Few outreach activities for achieving improvement in the enrolment of students in engineering are given below.

- National and international accreditation of the engineering programs and or institution/university
- Active industrial collaborations and live projects, both nationally and internationally
- National and international students' competition
- MoU with top industries and institutions on an international level to facilitate the regular active collaborative learning of faculty for professional development programmes, research cooperation, and exchange of students
- Exhibition of students' talents to the peer academia and industry groups through live project teams and events

E. Case study on active learning methodologies in engineering education

A learning methodology is important to enhance the learning environment for the teaching community (Cunningham et al., 2020). The objective of the present study is to discuss the effectiveness of active learning methods (ALM) in an engineering undergraduate course. Enhancement of the students' understanding of the selected course with six learning methodologies. Methodologies are lectures, assignments, seminars, case study, conference presentation and minor projects. Students surveys were employed and validated through the attainment of top-grade results. The teaching methodologies are to be adopted by the faculty to impart the scientific knowledge to the young students. Few learning methodologies have been introduced in a course of third year undergraduate studies in a premier institution in Southern India as a sampling to study the outcome of implementation of those learning technologies and the results are analysed based on the accreditation tools and final academic performances. The feedback form circulated to the students contains against each method, the choice is good, fair and average. A feedback space is given to them to write their comments in the paper-pen mode query form.

The effects of few learning methodologies were investigated among the prefinal year mechanical engineering students on a course on Solar Energy Systems with a class strength of 60. The period of study was July 2018 to December 2018. Students were allotted equally into six teams as per their interests. The students were assigned to any one of the following six categories and guided meticulously throughout the semester in the selected tasks.

- Lectures
- Assignments and tutorials
- Seminar presentation
- Case studies and reports
- Conference presentations
- Project-based learning

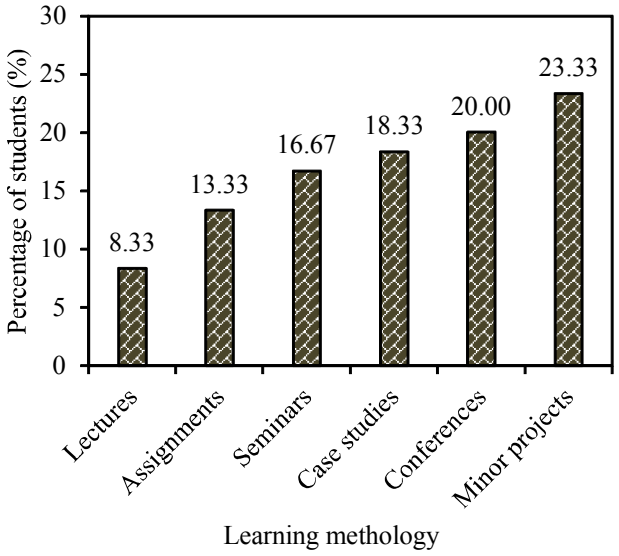

Fig. 1: Students' survey at the completion of the course

All the additional tasks are closely monitored and the grades were not allotted for the additional activities. Classroom lecture and reading method was the basic mode of learning methods. Assignment and tutorials were given as additional works to the respective team. Seminar presentation was given by the students on the selected subject of the course. Case study and reports were submitted by the respective team. Conference presentation team undergone a literature study on solar thermal collectors and presented a review article at an international conference. The project team was constructed a cost-effective flat plate solar air heater of 300 mm by 600 mm size with mild steel plate and steel fins with black board paint coating and tested successfully at outdoor by producing an increase of minimum air temperature by 10 C from the ambient temperature.

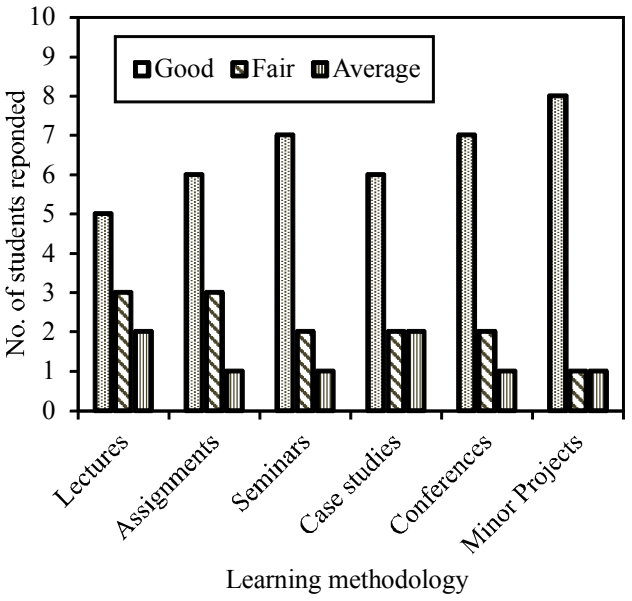

Fig. 2: Students' survey after the end semester examination

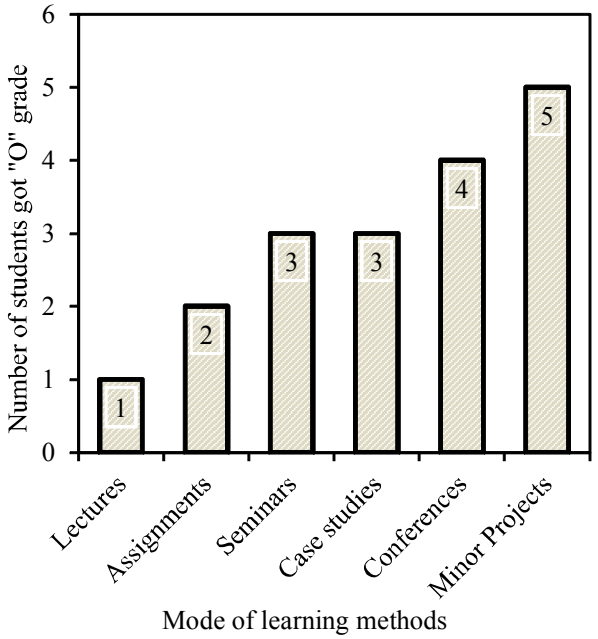

Fig. 3: End-semester results of the students in the selected course

The research methodology was involved student surveys (end-semester and after-examination) with the validation with the results published by the Institution. The academic performance is considered sa the evaluation tool for the selected course (Patil et al. 2016). Two surveys were taken at the end-semester opinions on the learning methodologies and the second one, after-examination surveys on how was the performance in the examination. Both the surveys are shown graphically in the Fig. 1 and 2. The classroom teaching, examination patterns and evaluation methods were maintained same for all the students irrespective of the teams. Figure 3 shows the results (top grade) of the selected class. The trend of the feedback from the students and the final top grades were almost matching.

The top-two learning methodologies are project-based learning and conference publication. The major feedback of students is dealt about the study of more literature to fabricate their project by enriching their overall multidisciplinary knowledge from the material selection, design, fabrication, outdoor testing, instrumentation, measurements and involved economics. Further, students are expressed about their better way of understanding related studied and interlinking knowledge of other courses to complete the activity. The project-based learning influenced the students' confidence level and interest to choose a career path in renewable energy. Strong knowledge of international trends in engineering education and careers of the professors is vital to introduce the state-of-art infrastructure facilities in the institutions and to impart the required competent skills to younger students. The recent trend of waning interest in pursuing STEM is alarming as it is a loss of our country's science talent. Young students must be actively encouraged to consider and pursue STEM courses and due support must be provided all through school by providing needed resources and opportunities to succeed.

5. Conclusions

A case study on active learning methods is implemented on one of the undergraduate courses and academic performance are compared with the feedback. As per the reported case study, the student's involvement has been enhanced by the activity-based learning methodologies rather than the conventional classroom teaching methodologies. The selective methods to improve the learning and sustainable growth of engineering enrolment in addition to other conventional methodologies are concluded here.

- Several awareness programs and the most successful engineers to come forward to motivate the young students.
- Making good use of multidisciplinary activities to familiarize the fundamentals strongly towards sustainable development of a country.

- ALM is determined to be one of the effective learning platforms to be practiced to enhance the understanding of the real-world problems and provide sustainable solutions to the society by implementing ALM in among science and engineering curricula.

Hence, a blend of slightly more activity and project-based learning with the conventional classroom teaching methodology could pave a way forward to retain the glamour and vigour of engineering education and careers in national and international levels by conducting further studies across the different race and ethnicity to fix the exact proportions of theoretical and activity-based learning methodologies. Emotional learning methodologies could be considered along the project-based technologies to predict the trends of engineering education precisely.

Conflict of Interest

No potential conflict of interest was reported by the author.

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