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Project-based Learning-A Novel Approach to Teach Biosensors and Transducers Course for Engineering Students

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Abstract: Bio Sensors and Transducers (BST) is a fundamental subject that provides principles of operations of sensors used in biomedical applications, and transducers are the devices that transmit the signals from the biosensors to the diagnosing equipment. BST is the introductory course in Bachelors of Biomedical Engineering (BME). BST interconnects biosensors and transducers in such a way that the signals are transmitted to the receiving equipment. Given the above, this paper describes the teaching and in-depth learning of BST in the classroom sessions which makes the students challenge and solve real-time problems practically, more effectively and efficiently. At the end of each unit, a practical assignment is given and executed by the students in the BST laboratories. These improve critical thinking, analyzing, interpreting, and solving techniques for students. The primary objective of this paper is to enhance the in-depth learning of the BST course by critical analysis, utilizing creative ideas, novel thinking of extension of existing technologies, and practicing laboratory experiments. The outcomes of this course are analyzed by internal assessment tests, periodical assignments, results of the laboratory experiments, seminars, and quiz programs. With the help of Bloom's taxonomy, the assessment test questions were ranked and the results are investigated for the improvement of intellectual thinking of students on the contents of the course.

The academic transformation of students is measured by using both course outcomes and student feedback. This approach helped the students to improve their understanding of the subject.

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1. Introduction

It is the need of the hour that the education professionals must have sufficient knowledge, talents, and skills for meeting the challenges as required by the engineering students [13]. The integration of emerging trends, technologies, and needs of the students necessitate looking into a new pathway for a suitable solution towards the course curriculum and outcomes. Therefore, there should be a radical change in the conventional teaching methodology to achieve education renovation. [9] [14] This education renovation will be helpful to the students to increase their creativity to find out innovative methods and to find out new problem-solving techniques by real-time hands-on experiments and experiences. To bridge the gap between the actual problems and classroom teaching-learning process, this renovation is essential. For achieving solutions to the real-time problems by students, this sort of education renovation methodologies is helpful.

The BST course is the foundational cores in BME which is application-oriented. For example, critical care equipment used in the Intensive Care Unit (ICU) and biomedical equipment, etc. The biosensors are the primary elements from which we can get data such as temperature, pressure, Electroencephalogram, and Electromyogram. The transducers are the secondary elements which interconnect biosensors and receiving equipment such as indicating and recording instruments. Hence the students must be given proper training assignments and hands-on experience in laboratories. The clear understanding of BST will lead to the successful design of many instruments as well as the latest technologies like body wearable devices used for body channel communication.

By understanding biosensors and transducers, the students can easily acquire knowledge in the subjects such as Biomedical Instrumentation, Diagnostic and Therapeutic equipment, Radiological equipment, Biofluids and dynamics, Drug delivery systems, Wearable systems and various other subjects related to BME. A clear understanding of this BST will be helpful to make a prototype for any new design by conducting temperature testing, load wearing capacity analysis, chemical testing and durability testing in prosthesis design for the amputees and other equipment design. Since BST involves electrical, electronics and communication engineering principles combined, the students need to get familiar with the formulas, derivations, and problems associated with them [6]. Therefore, the deep learning of BST is essential to enhance the subject knowledge as well as the effective utilization of principles and techniques emerging out from the BST subject.

2. Literature Review

D. Anitha (2018) conducted a rubric-based assessment test for web technologies laboratory courses to measure creativity among the 68 number of computer applications postgraduate students. [1] This course was used to develop web development skills to students for 50-60 hours. The students were grouped into controlled and experimental groups. [4] The project-based learning approach was used to measure creativity quality and quantity-wise. The data collection was executed by getting students' feedback, through the performance score and from the teacher's review. [5] [17] It is observed that project-based learning increased creativity. The rubric-based assessment was well accepted by both students and teachers in the first attempt itself. Assessment evaluation has shown that the clarity of outcomes is increased. The author suggested having group discussions in place of oral communication like an interview. At the end of the rubric-based assessment, it is found that the ethics, communication, and teamwork are increased among the students and teachers. For the future scope of work, the author suggested that different studies can be conducted by rubric-based assessment. Also, the comparison of different studies can be conducted to analyse the impact on creativity among them. Finally, the author suggested automating the assessment system for quicker results.

Aruna.S.Nayak (2017) conducted a study on the improvement of student's capability on designing embedded product design-based projects. This study was conducted for fourth-semester computer science and engineering UG students. [2] These students were already familiar with hardware courses like digital electronics in their III semesters. Outcome-based learning was conducted by using 8051 microcontrollers. The 8051 compatible Atmel 89C51ED2 was used to conduct simple exercises through assembly language. Then the interfacing of exercises was done in C programming. The fourth-semester students were motivated to do a project design by using 8051 or any alternative microcontroller of student's choice. This type of exercise is increased self-learning skills, knowledge and problem-solving techniques for the students. The author executed this study to analyse students enhanced motivation involvement and self-learning capacity. The theoretical knowledge of the subjects' embedded product design and its associated laboratory experiments helped the students to conduct a project design [3] of their own choice in an embedded system to solve a real-time problem. The author suggested conducting various reviews to analyse the design capability, conduction of experiments and continuous improvement of students knowledge.

VRSV Bharath Pulavarthi (2017) conducted a study to assess the skill set of students in solving a real-time global problem. [16] The author used a rubric design assessment tool to attain graduate attributes. The author chose B.Tech electrical engineering students (Final year) and automation control lab (EE458) to study this assessment of the skill set of students. The students were encouraged to do course mini projects (CMPs) by implementing different methodologies. [11] The correlation between course outcomes (Cos) and Programme outcomes (POs) was studied. After calculating COs through direct and indirect methods the POs were attained. It was noticed that the students were highly interested and motivated in doing real-time projects. After conducting this study, the CO increased from 77% to 83% and the PO increased from 77% to 83%. The author found that the student's skill set improved by conducting community-based and real-time mini-projects. The author suggested considering the CO and PO scores as benchmarking targets for the future scope of work.

Chandra R. Sekhar (2008) studied the continuous improvement program (CIP) through outcome-based education (OBE) in the department of electrical and computer engineering technology (ECET) for accreditation. An assessment tool was developed to achieve CIP in the students learning process four years ago. It indicated a positive trend in students learning. The data collection was done through inception at the conference. This became an on-going process from 1975. [18] The first accreditation for ECET is achieved from ECTD. To assess internal evaluation at the university level for resource allocation the CIP conducted from 1985 to 1996. In the year 2003, an outcome-based education method was emphasized by faculty members. The author observed that these paper outcomes were helpful for rational and justification for outcome-based applications. Also, it is useful for applying for Accreditation from ABET. The author recommended that outcome-based education is the one that continuously improved after clear understanding and practicing of OBE's concepts and principles.

3. Proposed Work

In this research study, Biosensor and Transducers (BST) course is considered which is being taught to 3rd-semester (2018-19 academic year) BME students in Kalasalingam Academy of Research and Education (KARE). The total numbers of students are 29 boys and 34 girls undertook this course. In Table 1a, the course outcomes of BST are listed which are originally in practice. The newly proposed course outcomes are shown in Table 1b which are re-designed to impart practical skills to the students. In Table 2, the program outcomes are listed. The CO-PO mapping is conducted and shown in Table 3.

According to the syllabus content, the assessment tests are conducted periodically and model exams are conducted at the end of the semester before university semester examinations. The marks are allocated based on the performance of the students in all the above examinations. But, the conventional method of conducting the assessment doesn't ensure student learning the actual engineering aspects of the course. As the course consists of several derivations and formulas in all units, the students felt difficult. Moreover, the attainment of the expected POs in the real sense is not possible with the conventional assessment methods. Hence, it was decided to change the COs to reflect the practical aspects expected from the students and accordingly assessment methods are designed.

So, it is necessary to do a mini project in this course. Previously, the students were given assignments only to increase their knowledge level. But currently, the students were given only assignments in addition to their laboratory experiments for analysing typical problems related to the subject. An assignment on the course includes both on theory as well as practical portions. Assignments on theory include diagrams, working principles, applications, and equations. The students were given practical assignments to solve problems out of the syllabus. The students were grouped into different teams for assessment of the deep learning of this course. The students were grouped into three students per team to do the project based on their expertise in the area. [8]

The team members were involved in the data collection and studied the parameters such as temperature, pressure, pH, Electroencephalogram, Electromyogram, the factor of safety, stress and load-bearing capacity through their mini-projects [15]. In addition to the above mini-project, the students were taken to nearby industries as field visits. Also, Quiz programs were conducted to increase the knowledge level of the students. [10] The field visits, Quiz programs, and mini-projects were very much essential in addition to the classroom learning for the students to clearly understand and solve the emerging real-time problems. The rubric assessment system was executed to study the performance outcomes of the students.

The various parameters used under rubric assessment tests were 1) The ability to conduct investigations of technical issues with their level of knowledge and understanding, 2) Ability to develop an appropriate experimental design/algorithm, 3)

Ability to use tool for the conduct of experiments, 4) Ability to analyse and interpret data and 5) Ability to draw appropriate conclusions.

These are listed under the rubric assessment in Table 4. Based on the students performance, Marks were awarded as excellent, good, fair, and satisfactory and the marks were given as 4, 3, 2, and 1 respectively. The student's attainment details are shown in Table 5. Table 5 consists of Benchmark scores for attainment and Target for Student Outcome (SO) attainment. The targets are also mentioned in Table 5. In order to improve the Deep learning and skill sets of the students, it is desired to derive proposed Cos as fine tuning.

Table 1 : Course Outcome(s) for Biosensors and Transducers

Symbol	Description	
	1a. Conventional	1b. Proposed
CO1	Describe the different types of transducers and its purposes	Identify and design the different sensors circuit using experimental based learning.
CO2	Explain variety of photoelectric transducers	Check the internal components of the different types of transducers.
CO3	Describe the principle and operation of inductive and capacitive transducers.	Design and fabricate the sensors for the different applications of biomedical.
CO4	Discuss about various chemical biosensors and smart sensors.	Deliberate about various meters and analysers
CO5	Discuss about signal conditioning, display and recording devices	Discuss about various types of bridges and recorders

Table 2 : Program Outcome(s) for the Department of BME [12] [19

Symbol	Description
PO1	Apply knowledge of Mathematics, Sciences and Biomedical Engineering fundamentals to solve complex engineering problems
PO2	Identify, formulate, analyse and solve problems associated with human health monitoring
PO3	Design medical equipments, assist devices, implants, etc., to meet the specified needs within real istic constraints of economic, health and safety, cultural, societal, ethical and environmental considerations.
PO4	Conduct investigations using relevant research methodology including literature review, design of experiments, analysis and interpretation of data to provide valid conclusions
PO5	Utilize the techniques, skills, and modern engineering tools necessary to meet the requirements of the hospital industry
PO6	Evaluate societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the biomedical solutions
PO7	Demonstrate the impact of Biomedic al Engineering solutions on environment and the need for sustainable development
PO8	Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice
PO9	Communicate effectively on engineering activities with Engineers, Medical Professionals and the community through discussions, reports and presentations
PO10	Work as an individual or as a team member for the productive execution of responsibilities
PO11	An ability to demonstrate knowledge and understanding Biomedical engineering and hospital management principles and apply these as an Entrepreneur, to manage projects and to work in multidisciplinary environments
PO12	Empathize the impact of Biomedical Engineering on society and demonstrate awa reness of contemporary issues through independent and life-long learning

Table 3 : Mapping of Cos and Pos for BST

Symbol	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	M	H	H							H		
CO2		M										
CO3		M								H		
CO4			M	H	H	L					H	
CO5	L				H							L
H-High, M-Medium and L-Low												

Table 4 : Rubrics for the assessment of BST

Parameters	Excellent (4)	Good (3)	Fair (2)	Satisfactory (1)
Ability to conduct investigations of technical issues with their level of knowledge and understanding	Able to conduct investigations and demonstrates thorough and insightful knowledge of technical issues.	Able to conduct investigations and demonstrates considerable technical knowledge.	Able to conduct investigations and demonstrates some technical knowledge.	Not able to conduct investigations.
Ability to develop an appropriate experimental design/algorithm	Able to formulate and develop an appropriate experimental design/algorithm based on the study objectives.	Able to formulate and provide experimental designs/Algorithm with minimum understanding of study objectives.	Able to formulate and provide experimental designs/Algorithm with minimum understanding of study objectives.	Not able to formulate and provide experimental designs/Algorithm
Ability to use tool for the conduct of experiments.	Computer – aided tools are used effectively to develop and analyse designs.	Computer–aided tools used with moderate effectiveness to develop designs.	Minimal application and use of appropriate tools.	Serious deficiencies in understanding the correct selection and/or use of tools.
Ability to analyse and interpret data.	Accurate selection and application of engineering principles ensuring reasonable interpretation of data.	Effective application of engineering principles resulting in reasonable interpretation of data.	Application of engineering principles and limited interpretation of data.	Inappropriate application of engineering principles yielding unreasonable interpretation of data.

Ability to draw appropriate conclusions.	Able to draw appropriate conclusion with necessary substantiation of the results obtained.	Able to draw conclusion with the results obtained.	Erroneous conclusions based on achieved results.	Not able to draw conclusions.

Table 5 : Attainment Details of BME18R272

Symbol	Description
Benchmark score for attainment	Greater than or equal to 3 out of 4-point scale
Target for SO attainment	75% of students score above benchmark score

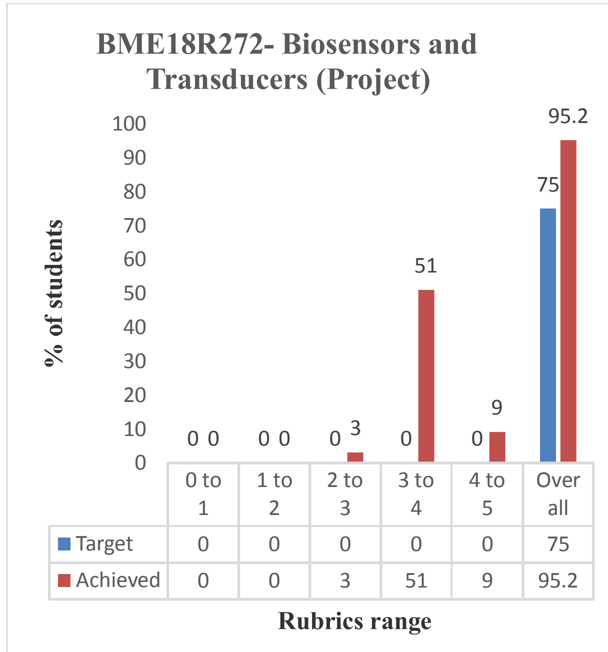
4. Results and Discussions

The analysis was conducted by a rubrics assessment system based on the mini-projects done by students. In addition to the classroom teaching methodologies, field visits, and quiz programs, mini-projects have helped the student's skill sets to improve. This type of encouraging and motivating works conducted increased the capability of the students to face challenges they normally meet in the real-time work environment. While executing mini-projects, students get experienced in collecting data for their total project, analysing the quality of the components, checking the functions of components, setting the required parameters, calibration, and testing, etc., Regarding the exercises, carried out by students, the rubric assessment method practiced and marks are allocated are listed in Table 6 and Fig. 1.

The parameters taken for evaluation purposes were experiment evaluation, field visit analysis report, Mini projects, Research articles, and Quizzes. The marks are allocated according to the results. Deep learning methods like the mini-project execution stimulate the sharing of knowledge and understanding among the team members. It also helps to solve the problems then and there easily as the team members join together to solve a particular problem by various brainstorming techniques.

This type of group activity increases the knowledge levels of the students in the subject, and they clearly understand the concepts and principles of operation of biosensors and transducers. This can be accessed through classroom exams based on Bloom's taxonomy and related ranking [7]. In Table 7 the student's feedback is given by indicating various parameters and marks allocated appropriately.

The various parameters were based on the student's understanding of the subject, the teaching in the classroom with real-time problems, the advancement of the student's career through this course, analysis of problems and design solutions, teamwork and learning efficiency occurred through the field visit, etc,



	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	Over all
Target	0	0	0	0	0	75
Achieved	0	0	3	51	9	95.2

Fig. 1 : Target achievement analysis of the students based on the rubrics framed

This implemented the theoretical knowledge by the experiment-based evaluation, promoted the peer learning and analytical skills by mini-project evaluation and the real-time survey, experimentation, and investigation by research-based evaluation. Fig. 2 gives a clear presentation on these student feedbacks by exhibiting various parameters versus student numbers and related marks. The course outcomes of the BST verses marks are tabulated in Table 8 and shown in Fig. 3. The numbers of students coming under different marks categories are entered for easier understanding. It is seen that a greater number of students secured mark from 40 to 60. This indicates that a greater number of students acquired more knowledge in this course and prepared well for the assessment test.

Table 6 :Assessment and Student Marks for BST

Parameters	Marks	PO	0-20	20-40	40-60	60-80	80-100
Experimental based evaluation (for CO1)	10	4	8	1	7	48	7
Field Visit based analysis report (for CO2)	8	11	0	10	46	7	0
Mini project-based evaluation (for CO3)	15	2,4 & 10	0	0	0	19	44
Research article-based evaluation (for CO4)	7	4	0	0	1	18	44
Quiz (for CO5)	10	1	6	27	28	1	1

Table 7: Students Feedback for Biosensors and Transducers after the completion of assessment procedures

Marks	5	4	3	2	1
Understand the subject clearly?	41	11	5	0	1
Could you relate the teaching in the classroom with the real time problems?	36	15	5	1	1
This course was beneficial in advancing my career	43	9	4	1	1
The course taught me to analyse problems and design solutions	37	15	4	0	2
Team work and learning efficiency has been well established by the field visit	44	10	3	0	1
Implemented the theoretical knowledge by the experiment-based evaluation	36	16	3	2	1
Promoted the peer learning and analytical skills by mini project evaluation	39	14	4	0	1
Have learned the real time survey, experimentation and investigation by research-based evaluation?	36	16	4	1	1

Table 8 : Biosensors and Transducers-CO assessment based on marks secured/scored by the students

Symbol	No. of students secured <40	No. of students secured 40-60	No. of students secured >60
CO1	4	44	15
CO2	3	42	18
CO3	8	43	12
CO4	10	46	7
CO5	42	20	1

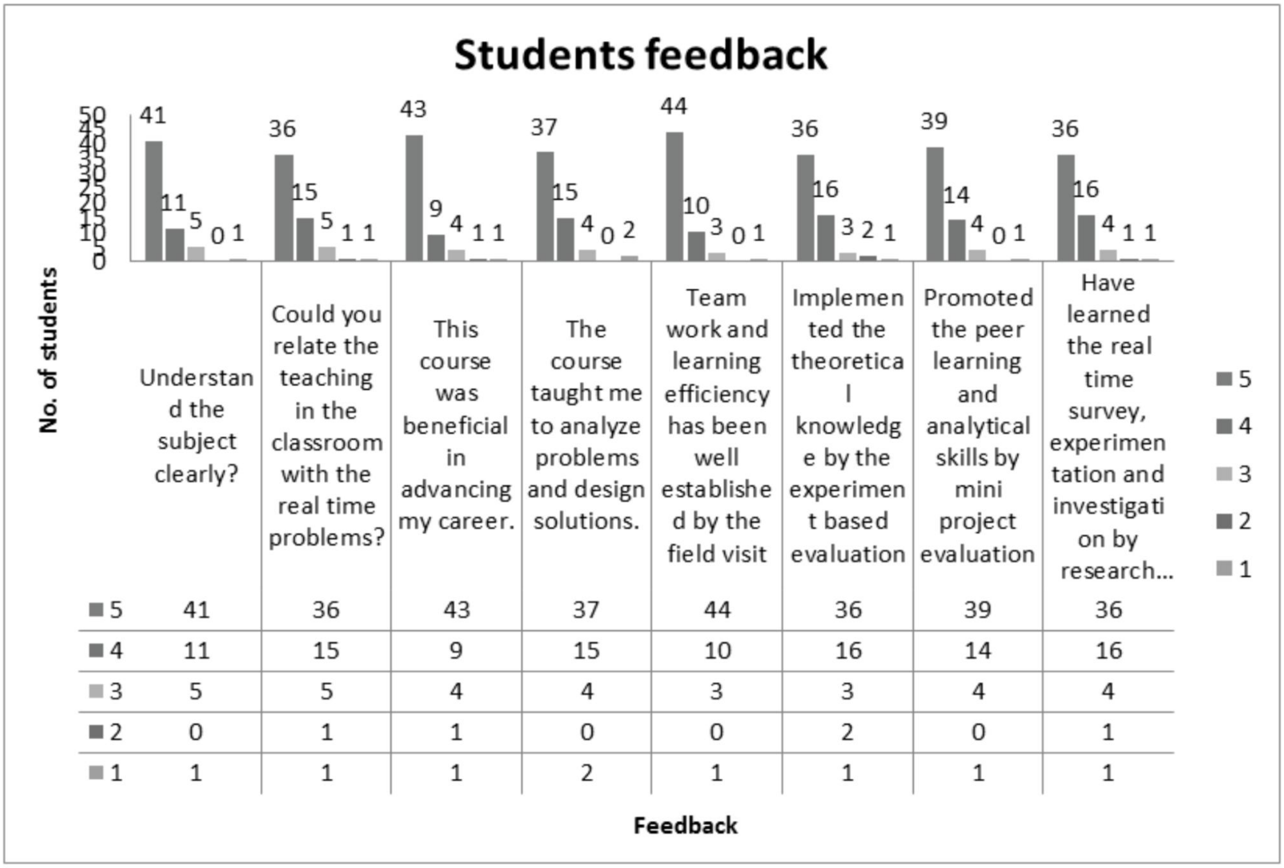
Table 9 : Outcome attainment details for BME18R272

Details	No. of students and their percentage
No. of students registered	63
No. of students appeared	63
No. of students attained	60
No. of students not attained	03
Percentage target for attainment	75
Percentage of students attained	95.2
Percentage gap in attainment	NIL

Table 9 shows the outcome attainment details and number of students under different categories. In this Table 9, the parameters such as No. of students registered, No. of students appeared, No. of students attained, No. of students not attained, Percentage target for attainment, Percentage of students attained and Percentage gap in attainment. In Fig. 4, the attainment results are indicated after the assessment test. The number of students is shown under a different range of marks. It is seen that 63 numbers of students attained more than rubrics scale ranking above 4. This is due to the mini-project conducted by the students with their interest and willingness.

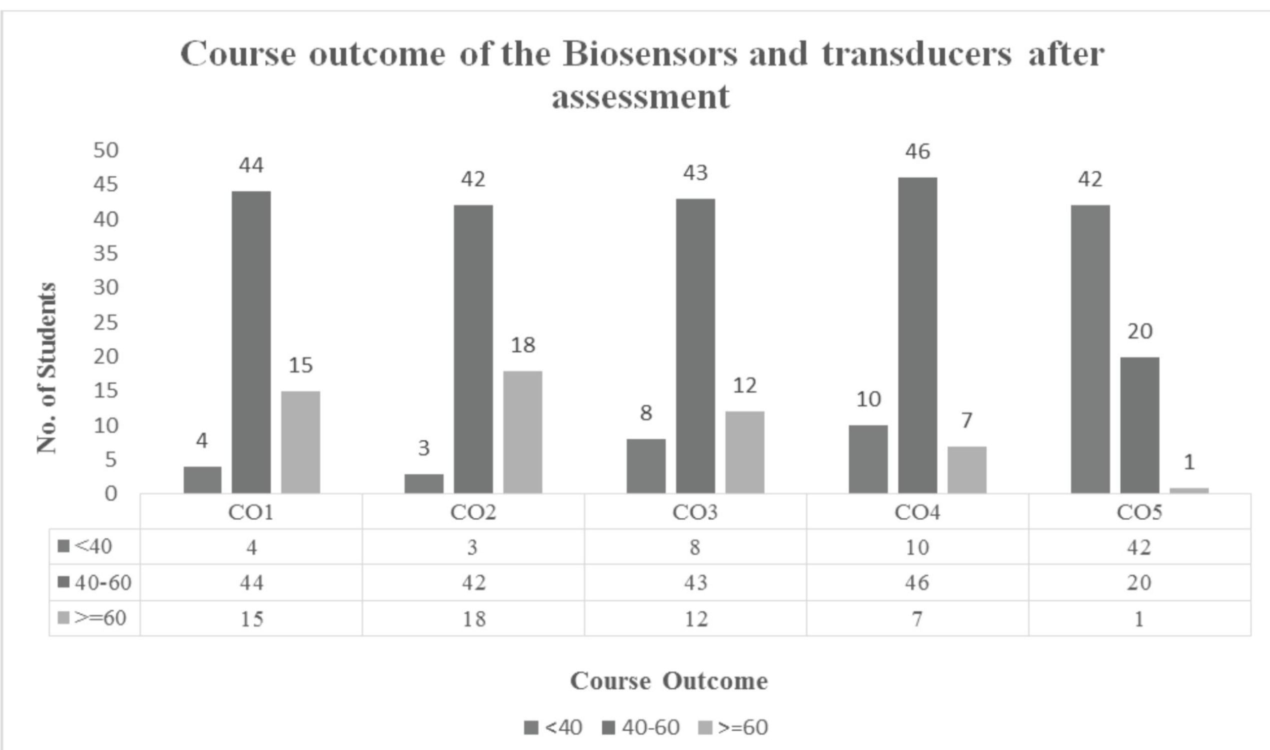
The team spirit and teamwork executed by the group members resulted in higher attainment of results. Fig. 1 indicates the relationship between the percentage of students and the rubrics range. In this Fig. 1, the BST projects are considered and the target rubric range and actual rubric range is marked and shown. The overall targeted percentage of students is 75 whereas the actual percentage of students is 95.2 which shows that there is a significant improvement in the student's strength after conducting a rubric assessment test.

The team spirit and teamwork executed by the



	Understand the subject clearly?	Could you relate the teaching in the classroom with the real time problems?	This course was beneficial in advancing my career.	The course taught me to analyze problems and design solutions.	Team work and learning efficiency has been well established by the field visit	Implemented the theoretical knowledge by the experiment based evaluation	Promoted the peer learning and analytical skills by mini project evaluation	Have learned the real time survey, experimentation and investigation on by research...
5	41	36	43	37	44	36	39	36
4	11	15	9	15	10	16	14	16
3	5	5	4	4	3	3	4	4
2	0	1	1	0	0	2	0	1
1	1	1	1	2	1	1	1	1

Fig. 2 : Deep indirect analysis of course outcomes based on the feedback from the students



	CO1	CO2	CO3	CO4	CO5
<40	4	3	8	10	42
40-60	44	42	43	46	20
>=60	15	18	12	7	1

Fig. 3 : Course outcome analysis of the students based on various modes of assessment.

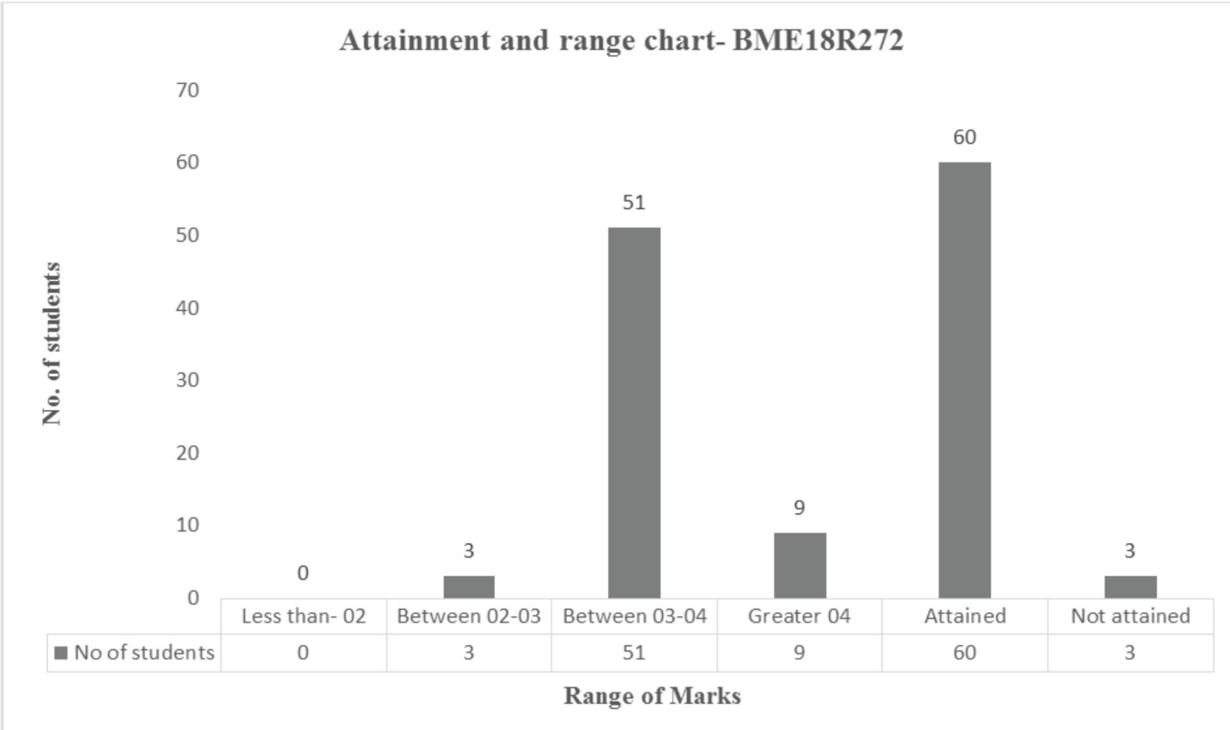


Fig. 4 : Categorical distribution of the students based on the assessment of level of attainment

group members resulted in higher attainment of results. Fig. 1 indicates the relationship between the percentage of students and the rubrics range. In this Fig. 1, the BST projects are considered and the target rubric range and actual rubric range is marked and shown. The overall targeted percentage of students is 75 whereas the actual percentage of students is 95.2 which shows that there is a significant improvement in the student's strength after conducting a rubric assessment test.

5. Conclusion

This paper reveals the key-tasks of providing in-depth learning of the course BME18R272 by the students and enabling them to have fundamental acquisition skills, intellectuality and critical analysis of real-time problems, thus transmuting them to be successful Biomedical Engineers on the completion of the program, and if the same philosophies are unanimously adopted/extended or slightly tweaked based on the content of the other courses. The students learning and understanding abilities of the course and, the level of modification to be done in future in accordance with their performance and understanding is set-through/defined using the ideologies proposed in this paper. Apart from in-depth learning, there should also be enthusiastic participation of the students towards team-learning, and we authors strongly believe that the pedagogical activities conveyed through this paper would be of sure to benefit the students community, making them evolve synergistically and helping them to understand better regarding the essence of team/group learning and performance.

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