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Project based learning and Proctored online assessment in Lab courses to enhance CDIO Skills – A case study of Microcontroller laboratory course

Dr. Kavitha D[1], Dr. Anitha D[2], Dr. Manoharan P.S[3]
[1,3]Department of Electrical and Electronics Engineering, Thiagarajar College of Engineering, Madurai 625 015, India
[2]Department of Applied Mathematics and Computational Science, Thiagarajar College of Engineering, Madurai 625 015, India
[1] dkavitha@tce.edu, [2]anithad@tce.edu , [2]psmeee@tce.edu

Abstract: CDIO(Conceive/Design/Implement/Operate) is an educational framework for engineering programs that aims to produce graduates possessing all- rounded set of skills and competencies. The laboratory courses plays important role in inculcating CDIO skills. This proposal explains an attempt conducted in a Microcontroller laboratory course which uses proctored online theoretical assessment and project-based learning in lab course. Thus, a blend of group and individual activities are inserted during the conduct of lab. It is proposed to give one project relating the concepts of the course and to conduct at least two online theoretical assessments, one at the end of first cycle of experiments and second at the end of second cycle experiments. A representative list of project titles is provided to the students. Assessment questions include all the aspects such as background theory of the experiments, conduction of experiments, observation, calculations and inferences. Three research questions are formulated and addressed. It is found from the assessment results that these projects and assessments results in the better understanding of the concepts in the experiments. On the other hand, these assessments helps teachers to analyze the difficulty faced by the students in understanding the theory back ground of the laboratory experiment and plan accordingly. The results are strengthened using statistical tests.

Keywords: **CDIO, PBL, online assessment, lab courses, Microcontroller**

***JEET Category*—Research**

I. INTRODUCTION

CDIO stands for Conceive, Design, Implement, and Operate. The CDIO approach emphasizes the integration of engineering fundamentals, hands-on experiences, teamwork, and real-world applications. (Crawley, E. F et al, 2011).Thus it includes core knowledge along with personal and interpersonal skills. They are of great importance for engineering students. These skills are focused on developing engineers who possess not only technical knowledge but also the ability to apply that knowledge effectively in real-world scenarios. CDIO skills are valuable for engineering students since it has insights on holistic Problem Solving and involves understanding the broader context, considering various constraints and trade-offs, and developing innovative solutions. (O'Connor et al, 2023)

CDIO skills emphasize the importance of the design process and hands-on experiential Learning. (Wibawa, A. P et al, 2023). It promotes collaboration and communication. It includes ethical and professional Considerations.
Project-based learning (PBL) plays a crucial role in imparting CDIO skills by providing students with hands-on experiences, promoting collaboration, and enhancing problem-solving abilities. PBL is needed to foster CDIO skills because it includes authentic Context, Integration of Knowledge, Practical Skills Development, Problem-Solving and Critical Thinking. PBL as a team work nurtures their ability to think critically, make decisions, and apply a systematic approach to problem-solving. (Kavitha, D et al, 2016, 202). Motivation, self-construal, and gender in project-based learning(Tanaka, M. ,2023).

Students who desire to learn, passionate in gaining knowledge listens keenly to the teacher and try their best in learning through theory as well as practical classes. But unfortunately, now they have lots of distractions and now it becomes teacher's role to frame strategies to make them learn. It is found that many students are conducting lab experiments without the back ground theoretical knowledge and depends mostly on their peers to complete the experiment. Even the inferences are copied from one batch to other.

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Corresponding author: Kavitha D, Department of Electrical and Electronics Engineering, Thiagarajar College of Engineering, Tamil Nadu, India.
Address: Thiagarajar College of Engineering, Thiruparankundram, Madurai, India. Pin: 625 015 (e-mail: dkavitha@tce.edu).

Few research papers explore the integration of PBL and the CDIO approach in engineering education. (Fusic, S. J et al, 2023). It discusses the benefits and challenges of implementing PBL to develop CDIO skills.(Julius et al, 2023). The effectiveness of PBL in enhancing students' CDIO skills have been investigated. (Berggren, K. F et al, 2003). It examines the relationship between PBL implementation and the development of critical CDIO competencies. Microcontroller Laboratory practices through project-based learning has also been discussed.(Metri et al, 2018)

Also, Theoretical assessments using ICT (Information and Communication Technology) tools in lab courses can have several impacts on students' learning experience and outcomes. A few potential impacts include Enhanced Understanding, Integration of Theory and Practice, Active Learning and Engagement. ICT tools can promote active learning and student engagement in lab courses.

Interactive simulations, virtual experiments, or online quizzes can encourage students to actively participate in the learning process, experiment with different scenarios, and receive immediate feedback on their performance and the teacher's work on providing formative assessment feedback is greatly reduced.

The integration of ICT tools in laboratory science education is explored in literature and their impact on student learning outcomes and engagement has been discussed.(Budai, T., & Kuczmann, M,2018).
Richard Joiner et al. investigates the impact of ICT tools on the development of practical skills in science education. It examines how virtual simulations and other ICT-based resources enhance learning outcomes in practical laboratory contexts.

The impact of ICT tools on the development of laboratory skills is studied.(Anitha, D et al, 2020, 2021). It explores the benefits and challenges of integrating ICT in the teaching and assessment of laboratory skills. The benefits of both PBL and individual assessment are well established in the literature. Thus project based learning deals with the enhancement of practical skills and online proctored assessment take care of underlying knowledge. This research work focusses on harvesting the benefits of the combination of both of these strategies.

II. RESEARCH QUESTIONS

With the above literature study, the following research questions have been formulated for the research.

1. What will be the improvement in learning outcome attainment if online proctored assessment is integrated with PBL in lab courses?

2. Will this blended strategy improve the CDIO skills of the student?

3. Will student feel burden of doing these activities?

III. MATERIALS AND METHODS

This research is proposed as a quantitative analysis with performance assessment scores of the students and qualitative analysis with course end survey. The research is conducted with third year Electrical and Electronics Engineering (EEE) students of Thiagarajar College of Engineering, Madurai, India. This research study has been implemented in an undergraduate engineering course "18EE570-Microcontrollers Lab " with 66 students as experimental group during the year (Batch 1:2022-23). The outcome of this research is compared with other 64 students in the previous academic year (Batch 2:2021-22).

Most of the EEE students struggle with writing programs and try to memorize the program to score marks. Microcontroller lab requires the knowledge of hardware working and interfacing, software code developing and testing. The objective is to ensure the students learning in the laboratory. The conventional lab model consists of the following steps:

Step 1. Instruction for conduction of experiments
Step 2. Conduction of lab experiments using available lab equipment.
Step 3. During the conduct, viva will be asked.
Step 4. After the conduct of the experiments, students make observations and inferences based on calculations etc.
Step 5. Getting correction from the faculty concerned.

The above conventional model is followed for a single cycle or two cycles of experiments. In this work, the proposed model practiced for conduction of microcontroller lab is given in figure 1.

The conventional lab model is creamed with ICT tools and two active strategies are introduced during the conduct of the lab. The strategies are Project based learning and online theoretical assessment. Each steps in figure 1 of the proposed model is updated using few innovations as follows.

Initiative in Step 1(S1) : Instructions are recorded and provided as video materials

Initiative in Step 2 (S2): Project based learning
Sample questions for projects:

1. Control a string of LED and generate dancing light patterns/system (Level: simple)
2. Simulate the operation of Coffee/ Tea vending machine / ATM Machine (Level: Intermediate)
3. Simulate the operation of washing machine/ Oven. (Level: Intermediate)
4. Automatic Traffic control system /Elevator control (Level: Intermediate)
5. Develop the microcontroller based system which receives grades of five courses through key pad and compute the CGPA and display in suitable device (Level: Hard)
6. Develop a digital calculator that performs basic arithmetic operations.

Initiative in Step 3 (S3): Proctored online assessment
Proctored online assessment is conducted in class room and the results are analysed. Accordingly, the learning of students in each experiment is measured.

Initiative in Step 4 (S4) : Mentored by Peer / Peer assisted experimentation. Based on the results of step 3, additional engagement is made to weaker students to improve their learning through their peers. Thus, Below average performers are identified and assigned a mentor. Mentor is selected in their own team and if whole team is below average, then peer mentors from another team are identified. The role of these peer mentors is to ensure the learning of the assigned mentee and is responsible for mentee's learning.

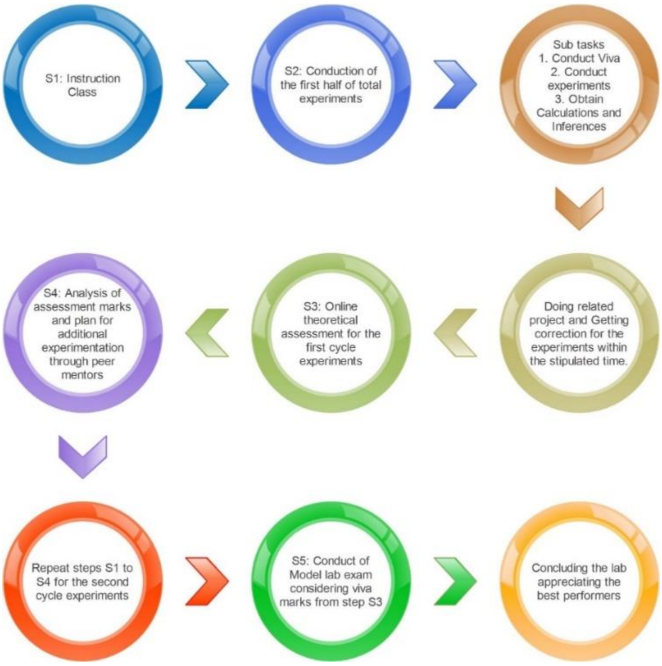

Fig 1: Model practiced for conduction of Microcontroller Lab

When designing a Likert scale feedback form for the conduct of a microcontroller lab course, the major categorization of design of experiments, projects, model& theory based exams, peers support and faculty support are considered and detailed feedback analysis is given in table 1.

TABLE-1
LIKERT SCALE FOR CONDUCT OF LAB COURSE

S. No	Parameters
1	Experiments:
1.1	Clarity of instructions for conducting experiments
1.2	Relevance of experiments to course objectives
1.3	Functionality of lab equipment
1.4	Resource materials provided for experiments
1.5	Opportunities for hands-on learning and practical application of concepts
2	Projects:
2.1	Clarity of project objectives
2.2	Opportunities for creativity and innovation in project work
2.3	Support provided during project implementation
2.4	Relevance of the project to real-world applications of microcontrollers
3	Model Exam and Theory-based Exam:
3.1	Quality of exam questions
3.2	Relevance of questions to experiments conducted
3.3	Balance between theoretical knowledge and practical application in exam questions
3.4	Time provided for completing the exam
3.5	Grading and evaluation of exam responses
4	Peers Support:
4.1	Effectiveness of collaboration and teamwork among peers during lab sessions
4.2	Willingness of peers to assist and share knowledge
4.3	Level of engagement and participation of peers in group activities
4.4	Contribution of peers in problem-solving and troubleshooting during experiments and projects
4.5	Overall supportiveness of the peer learning environment
5	Faculty Support and learning:
5.1	Clarity and effectiveness of faculty instructions and explanations during lab sessions
5.2	Availability and approachability of the faculty for addressing questions and concerns
5.3	Timeliness and helpfulness of faculty feedback on experiments, projects, and assessments
5.4	Confident in working on future microcontroller based projects
5.5	Overall improvement in learning with the faculty's support and guidance in the microcontroller lab course

Participants of the survey are asked to rate each feature on a **scale of 1 to 5**, where 1 represents "not good/effective" and **5 represents "very good/effective."** The Likert scale can provide valuable insights into the perceived strengths and weaknesses of the project and can help identify areas for improvement.

Projects are planned with direct implication on students CDIO skills and the parameters relating to CDIO component is listed in table II.

TABLE-II
IMPLICATION OF PROJECT ON CDIO SKILLS

Parameter Id	**Parameter**	**CDIO Component**
C1	Finding practical application that utilizes Microcontroller	Conceive
D2	Interface plan, Programming and ratings of components	Design
I3	Hardware implementation	Implement
O4	Testing the functionalities of the implementation under various conditions	Operate

Proctored online assessment includes multiple choice questions which tests the basic understanding of the microcontroller, hardware interface and software programming for a particular task. Sample questions are as follows:

1. 8051 can be used to control .... of DC motor (U)

Options: Direction and speed, Only direction, Only speed, direction, speed and position

2. The anodes of 4 LEDs designated from LED1 to LED4 are connected to the P2.4 to P2.7 respectively. All the cathode terminals are connected to the ground. The code MOV A, #8FH; MOV P2,A will light up(A)

Options: LED4 only, LED1 only, All except LED4, All except LED1

3. Assume that a Stepper motor is running in full step mode with step angle =3.6 deg. How many steps are required to make 2 full rotations? (A)

Options: 200,100,720,360

4. The embedded C code used for an application is IE=0X98 . If all the interrupts occurs simultaneously, Which will be serviced? (A)

Options: External 0 interrupt, Timer 0 interrupt, Serial interrupt, Timer 1 interrupt.

The questions formulated tests the understanding (U) and applying (A) level of Bloom's taxonomy.

The individual analysis of students response for the assessment reveals the muddiest topic for the students.

IV. RESULTS AND DISCUSSIONS

In this experiment, 65 students participated in all the aspects of the conduction of lab, PBL and assessment. Figure 2 shows the sample output of electronic score board project of one group of students developed in the microcontroller trainer kit.

Fig 2: Sample output of Electronic score board project

Online assessment proctored exam is scheduled during the theory hours and conducted via google platform. Sample analysis of assessment 1 question is given in figure 3.

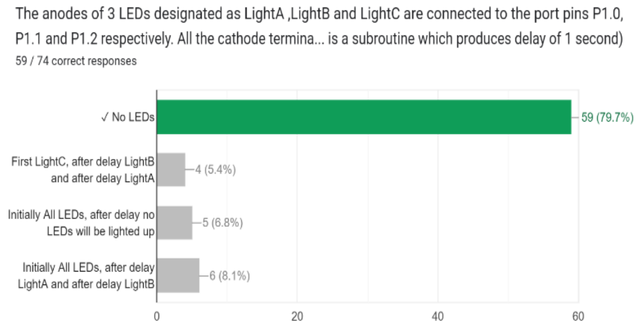

Fig 3:Assessment 1 sample analysis

The average score of assessment 1 is found and it is provided in figure 4. The range of the marks span between 12 and 24 out of 25 marks. Similar analysis for a question during assessment 2 is provided in figure 5.

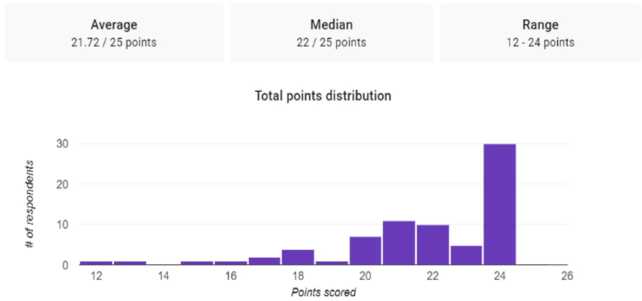

Fig 4:Assessssment 1 average score

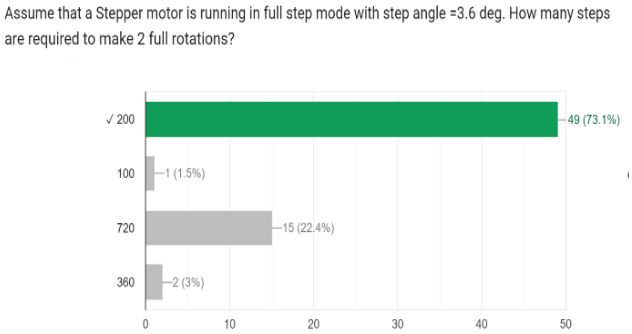

Fig 5: Assessment 2 sample analysis:

A. *Research Question 1- Results and Discussions*

What will be the improvement in learning outcome attainment if online proctored assessment is integrated with PBL in lab courses?

To address this research question, the lab marks for the two consecutive set of students have been taken and independent T- test is conducted on the samples.

Thus, T- test is used to determine whether there is a significant difference between the means of two independent groups

Null Hypothesis (Hyp0): There is no significant difference between the means of the two batches.

To perform T-test, the data sample should be independent and normal. Also, The variances of the marks in both groups should be equal (Homogeneity of variances).

The data is taken from two different batches and hence it is independent. To check for normality, Shapiro- Wilk test is used [Hanusz, Zofia, 2016] . The following steps are done and results are recorded.

Performing the Shapiro-Wilk test on Batch 1 data:

Null hypothesis (H0): The data in Batch 1 is normally distributed. Alternative hypothesis (Ha): The data in Batch 1 is not normally distributed.

Shapiro-Wilk test statistic: 0.983 with p-value= 0.316. Since the p-value (0.316) is greater than the typical significance level of 0.05, we fail to reject the null hypothesis. This suggests that the data in Batch 1 can be assumed to be normally distributed.

Similarly performing the Shapiro-Wilk test on Batch 2 data:

Shapiro-Wilk test statistic: 0.970 with p-value: 0.066. Since the p-value (0.066) is greater than the typical significance level of 0.05, we fail to reject the null hypothesis. This suggests that the data in Batch 2 can be assumed to be normally distributed. In summary, based on the Shapiro-Wilk tests, both Batch 1 and Batch 2 data can be assumed to be normally distributed.

To check for homogeneity of variances, Levene's test (Gastwirth, 2009) is performed. Levene's test statistic on the data is 0.572 with p-value: 0.451. Since the p-value (0.451) is greater than the typical significance level of 0.05, we fail to reject the null hypothesis. This suggests that there is no significant difference in variances between Batch 1 and Batch 2. Hence, variances are equal in both the data.

The T-test results are provided in table III. It is noted that standard deviation is high for batch 2 group implying the presence of very low mark as well as very high mark. For batch 2, the deviation is low indicating the learning of all students is good.

TABLE III
T- TEST RESULTS

S.No	Parameter	Batch 1	Batch 2
1	Student's strength	66	64
2	Mean of lab marks out of 100	76.32	69.64
3	Standard deviation	10.31	12.1

Also, P-value fort he T-test is found to be 0.006.

Since the p-value (0.006) is less than the typical significance level of 0.05, we reject the null hypothesis. This suggests that there is a significant difference between the means of the two batches. This significant difference explains the improvement in the learning outcome due to the introduction of online proctored assessment is integrated with PBL in lab courses.

B. Research Question 2- Results and Discussions

Will this blended strategy improve the CDIO skills of the student?

Form the available data of 21-22 and 22-23 batches, the direct comparison of CDIO components shall not be made. This is due to the unavailability of CDIO based rubrics for 21-22 batch. The average marks scored in the project is compared and provided in the table. Also, it is noted that the theory assessment helped in testing the functionalities of the project implemented under various conditions.

For the overall mark obtained by each student, standard deviation is computed. For group A, it is 2.65 and for group B, it is 4.5. Hence, the dispersion of scores in the group A is lower than group B. This can indicate that the performance or outcomes of the individuals in group A whose rubrics are fixed based on CDIO components are more consistent or homogeneous as compared to the individuals in group B.

TABLE-4
AVERAGE MARKS FOR CDIO COMPONENT

Parameter ID	CDIO Component	Average Mark	
		Group A 22-23	Group B 21-22
C1	Conceive	9.5/10	Rubrics are not formulated as per CDIO Components
D2	Design	35/40	
I3	Implement	22.5/30	
O4	Operate	20/20	
	Average (%)	87	83

The feedback of the students is also considered to answer this research question. Few students reported that the confidence of approaching the problem has increased and the methodology helped them to implement their ideas as prototype comparatively in simpler way.

Further, Controller based projects presented in various inter college competitions:

21-22 Odd semester Students: At the end of their third year, - 8

22-23 Odd semester Students: At the end of their third year, - 14. This data shows the increase in the skills of the students to showcase their project ideas in various platforms.

C. Research Question 3- Results and Discussions

Will student feel burden of doing these activities?

Some feedback in the voice of students are as follows:

1. Interfacing many devices with microcontroller makes the project interesting to do.
2. No burden of spending money on lab project. But learning happened.
3. The assessments helped to recall all the experiments before model exam
4. The assessments are overloading us.
5. The model shall be used in different labs

It is seen from the open feedback, , it seems that students enjoy the experience and wished for the same in near future also. At the same time, some felt that these activities are overloading them. Table – 4 provides the likert scale response submitted by the students. Sample bar chart for peer support is given in figure 5. It is seen that Peer support component needs to be improved compared to other components.

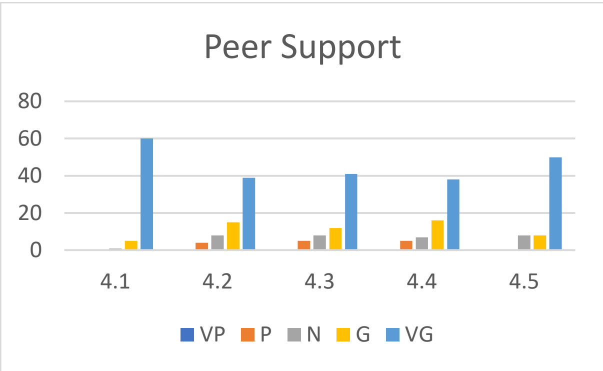

Fig 5: Feedback for Peer support component.

From the Likert scale responses, students satisfaction index is calculated(Kavitha et al, 2018)

TABLE-V
LIKERT SCALE FOR CONDUCT OF LAB COURSE

S.No	1	2	3	4	5
1.1	0	4	8	15	39
1.2	0	0	1	12	53
1.3	0	2	5	7	52
1.4	0	1	2	5	58
1.5	0	0	1	4	61
2.1	0	0	0	6	60
2.2	0	0	5	2	59
2.3	0	0	3	10	53
2.4	0	0	0	3	63
3.1	0	1	2	9	54
3.2	0	3	5	8	50
3.3	0	0	4	15	47
3.4	0	0	8	8	50
3.5	0	2	0	5	59
4.1	0	0	1	5	60
4.2	0	4	8	15	39
4.3	0	5	8	12	41
4.4	0	5	7	16	38
4.5	0	0	8	8	50
5.1	0	0	2	10	54
5.2	0	0	3	15	48
5.3	0	5	6	13	42
5.4	0	0	7	8	51
5.5	0	0	8	10	48

The students satisfaction index is calculated as

$$SI = \sum_{k=1}^{NQ} \sum_{m=1}^{NS} \frac{Number\ of\ students\ with\ kth\ response\ for\ ith\ question\ X\ W_m}{Total\ students\ X\ Number\ of\ questions\ X\ Maximum\ weightage}$$

Satisfaction index (SI) calculated is found to be 0.93 (Ideal value=1) which shows that students are happy with the conduct of lab. Sample bar chart for peer support is given in figure

V. FUTURE IMPLEMENTATION

A. Observations And Future Directions

Providing the Sample questions and circulating to students for doing projects invoke many different ideas among the students. As it is informed that similar questions are asked in the exam, students take projects seriously and work on them. Assessment methods followed to find the effectiveness of the project based learning:

- Through facial expressions and body language of the students.
- Inference on their involvement.
- Oral feedback from the students visiting me during office hours.

B. Difficulties faced

Some batches attempt to copy the coding of projects from peers.
Students resist much to take proctored online assessment
They need sample questions for preparing for online assessment
Finding the best time to conduct assessment
The comparison of students with other classes and they think that they are overloaded.

There is a visible change in the motivation of students after doing project. Hence in future, similar model will be executed and if possible, the model will be followed in different labs

VI. CONCLUSION

This research formulated three research questions based on a innovative attempt conducted in a Microcontroller laboratory course which uses proctored online theoretical assessment and project-based learning in lab course. A blend of group and individual activities are inserted during the conduct of lab. It is found from the assessment outcomes that these projects and assessments results in the better understanding of the concepts in the experiments. Also, it is seen that these assessments helps teachers to analyse the difficulty faced by the students in understanding the theory back ground of the laboratory experiment and it is helpful for them to plan accordingly. The statistical test results confirmed the increase in learning outcomes. The three research questions are answered based on the assessment results and the feedback analysis. The approach is found to be very effective that the model shall be used for most of the laboratory courses.

References

Anitha, D., & Kavitha, D. (2021). Is long-serving teaching experience a barrier of transformation in online teaching?–An exploration. J. Eng. Educ. Transform, 34, 201-205.

Anitha, D., Kavitha, D., Prakash, R. R., & Raja, S. C. (2020). Identification of Opinion Difference in Teaching Learning Methods and Recommendation to Faculty. Journal of Engineering Education Transformations, 33, 421-424.

Awidi, I. T., & Paynter, M. (2019). The impact of a flipped classroom approach on student learning experience. Computers & Education, 128, 269-283.

Berggren, K. F., Brodeur, D., Crawley, E. F., Ingemarsson, I., Litant, W. T., Malmqvist, J., & Östlund, S. (2003). CDIO: An international initiative for reforming engineering education. World Transactions on Engineering and Technology Education, 2(1), 49-52.

Budai, T., & Kuczmann, M. (2018). Towards a modern, integrated virtual laboratory system. Acta Polytechnica Hungarica, 15(3), 191-204.

Crawley, E. F., Malmqvist, J., Lucas, W. A., & Brodeur, D. R. (2011). The CDIO syllabus v2. 0. An updated statement of goals for engineering education. In Proceedings of 7th international CDIO conference, Copenhagen, Denmark.

Fusic, J., Rajalakshmi, R., & Sugumari, T. (2023). Digital transformation of Industrial Automation Course in virtual learning environment during COVID-19 Pandemic. Journal of Engineering Education Transformations, 36(Special Issue 2).

Fusic, S. J., Kavitha, D., & Anandh, N. (2018). A case study of implementing active learning techniques in electrical machine course. Journal of Engineering Education Transformations, 32(1), 49-55.

Gastwirth, Joseph L., Yulia R. Gel, and Weiwen Miao(2009). The impact of Levene’s test of equality of variances on statistical theory and practice. 343-360.

Gratton, L., & Erickson, T. J. (2007). Eight ways to build collaborative teams. Harvard business review, 85(11), 100.

Hanusz, Zofia, Joanna Tarasinska, and Wojciech Zielinski. (2016): Shapiro–Wilk test with known mean. REVSTAT-Statistical Journal 14.1 89-100.

Kavitha, D., & Anitha, D. (2016, December). Project Based Learning Using ICT Tools to Achieve Outcomes for the Course' Microcontrollers Based System Design': A Case Study. In 2016 IEEE 4th International Conference on MOOCs, Innovation and Technology in Education (MITE) (pp. 223-228). IEEE.

Kavitha, D., & Anitha, D. (2018). Flipped Classroom Using ICT Tools to Improve Outcome for the Course'Soft Computing'-A Case Study. Journal of Engineering Education Transformations, 32(2), 39-45.

Kavitha, D., & Anitha, D. (2021). Measuring the effectiveness of Individual assessment methods in Collaborative/Cooperative activity in online teaching. Journal of Engineering Education Transformations, 34, 637-641.

Metri, R. A., Pulavarthi, V. B., Srikanth, I., & Bhattar, C. L. (2018). Microcontroller Laboratory practices through project-based learning. Journal of Engineering Education Transformations, 31(3), 169-178.

O’Connor, S., Power, J., & Blom, N. (2023). A systematic review of CDIO knowledge library publications (2010–2020): An Overview of trends and recommendations for future research. Australasian Journal of Engineering Education, 1-15.

Tanaka, M. (2023). Motivation, self-construal, and gender in project-based learning. Innovation in Language Learning and Teaching, 17(2), 306-320.

Wibawa, A. P., Nabila, K., Utama, A. B. P., Purnomo, P., & Dwiyanto, F. A. (2023). Social informatics and CDIO: revolutionizing technological education. International Journal of Education and Learning, 5(2), 89-99.