Innovative Assessment Strategies for Enhancing Skill Development in ARM Microcontroller and Embedded Systems Laboratory

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***Abstract*— In this paper, the redesign and evaluation of ARM Microcontroller and Embedded Systems Laboratory will be presented to overcome the weaknesses in the conventional assessment practices, which is based on memorization and writing of the record. A five-part format authentic assessment model was introduced using the CDIO (Conceive–Design–Implement-Operate) framework and the tasks included single-peripheral, multi-peripheral integration, hex-file reverse engineering, collaborative open-ended experimentation, and the university-required summative test. The results of 67 students who were working with the LPC1768 Cortex-M3 platform were compared using threshold-based and average-based attainment approaches. The findings show poor performance on foundational and multi-peripheral tasks (CO1, CO2), moderate on analytical reverse-engineering tasks (CO3) and high on collaborative and resource-rich tasks (CO4, CO5). The results indicate that the scaffolding of early conceptual and integrative abilities requires more strength, and that real and authentic, design-based assessments induce more learning than memory-driven assessments. The paper provides a replicable framework of improving embedded systems pedagogy by providing outcome-based, practical assessment techniques.**

***Keywords*—Embedded Systems, ARM Microcontroller, LPC1768, Authentic Assessment, Skill Development, Collaborative Learning, Engineering Pedagogy.**

I. INTRODUCTION

LABORATORY education is one of the pillars of engineering education, offering the much-needed practical skills that connect the school of thought with practice. Nevertheless, the traditional laboratory tests (which are usually typified by rote learning, strict program implementation, and marks given to keeping physical records) do not portray the dynamic problem-solving needs in the contemporary engineering practice (Sadler, 2005a). More specifically, microcontroller and embedded systems laboratories are more inclined to focus on code and procedural repetition correctness, rather than on creativity, analytical thinking, and teamwork (Haladyna, 1997a).

The ARM Microcontroller and Embedded Systems Laboratory (Course Code: BECAEO2) is a critical 4-credit course for 6th-semester B.E. students in Electronics and Communication Engineering at VVCE Mysuru. Conducted during the 2024-25 even semester, it served 67 students across three batches (B1: 23, B2: 22, B3: 22). The course utilized the LPC1768 Cortex-M3-based microcontroller development board, equipped with peripherals such as LEDs, a 16x2 LCD, a 4x4 keypad, stepper and DC motors, and UART interfaces.

Conventional laboratory tests tend to be based on memorizing of material and set exercises that do not allow the development of practical skills and do not mirror the task complexity in the real world (Black & Wiliam, 1998). The practiced programs in Internal Assessments (IA) were usually reproduced by students who obtained marks because they could write records but did not develop practical skills. This disassociation has caused educators to support genuine evaluation that replicates actual practice and entails active knowledge creation (Merrett, 2020). The relevance of real-life scenarios is especially essential in embedded systems, where it is important that hardware and software be co-design and crime-solve (Nethravathi & Geetha, 2016a).

The laboratory was redesigned based on the CDIO (Conceive Design Implement Operate) educational framework in order to match engineering education with industry expectations where students are supposed to have to participate in the entire lifecycle of engineering systems (Crawley et al., 2007). CDIO-based learning develops system thinking, innovation and design implementation, which is essential in the development of embedded systems.

The changing trend of traditional practices to genuine, competency-based evaluations is a literature-based practice. It has been demonstrated that project-based learning and reverse engineering result in increased engagement and concept retention in embedded systems learning (Prasad & Reddy, 2015a). Moreover, allowing students to work together and apply technological solutions, including AI platforms, is an indicator of the changing engineering workplace environments (Deshmukh & Shinde, 2022a).

In order to frame this research on the redone ARM Microcontroller and Embedded Systems Laboratory, the following research questions were developed:

RQ1: What is the effect of the redesigned authentic-assessment framework (A1–A5) on the performance and skill development of students in an ARM cortex-M3 laboratory?

RQ2: What types of assessment best develop analytical, integrative, and creative abilities in undergraduate engineering students?

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RQ3: In what ways can collaborative and open-ended activities be compared to the conventional memory-based assessment in the context of proving the depth of learning?

RQ4: What are the challenges that students encounter during the transition to conventional record-based assessment to authentic skill-based assessments?

This study uses five assessment data sets to show how CDIO-aligned authentic labs move learning from memorization to competency.

II. RELATED WORK

A. Authentic Assessment in Engineering Education

Authentic assessment, emphasizing tasks aligned with learning outcomes and real-world applications, fosters deep learning (Biggs, 1996a). (Sangle et al., 2020)S demonstrated that e-assessment platforms like Poll Everywhere and Edpuzzle provided immediate formative feedback, enhancing higher-order thinking in a production-engineering cohort. (Kandhan et al., 2021)refined analytic rubrics through surveys of 168 students, alumni, and industry partners, reporting higher inter-rater reliability and student acceptance. These studies establish the empirical value of authentic assessment frameworks, extended here to an ARM-based laboratory context.

B. Project-Based and Active-Learning Laboratories

Project-based learning (PBL) and active-learning models promote autonomy and problem-solving competence (Prasad & Reddy, 2015b) (Sangle et al., 2020) outlined a PBL methodology around an ARM9 Telecom project that increased student publication output. (Nethravathi & Geetha, 2016b) reported gains in logical-reasoning scores after "learning-by-doing" microcontroller projects, while (Senthil, 2020) noted that active-learning strategies lowered course attrition and improved competency mapping. These findings justify the scaffolded, hands-on structure adopted in this study.

C. Reverse-Engineering and Debugging as Learning Vehicles

Reverse-engineering tasks promote experiential learning. (Choi, 2014) showed that microcontroller-driven feedback-control experiments strengthened the translation of theory into working code. (Hurtado et al., 2023) linked authentic assessments to gains on the Signals & Systems Concept Inventory, while (Hafiz & others, 2025) embedded reverse-engineering challenges in a microprocessor lab to meet ABET outcomes, validating the A3 hex-file task in this study.

D. Microcontroller-Focused PBL Implementations

(Metri & others, 2018) implemented mini-projects on 8051/Arduino platforms, with 92% of 60 participants meeting "proficient" design-skill criteria. (Nazarov & Jumayev, 2022)used Arduino labs to align Turkmenistan's automation curriculum with digital-economy goals, confirming that low-cost hardware and authentic tasks cultivate technical and soft skills, directly transferable to the LPC1768 Cortex-M3 platform.

E. Technology-Enhanced, Resource-Rich Assessment

Technology-mediated feedback enriches engagement (Deshmukh & Shinde, 2022b). (Shinde et al., 2025a) used Mentimeter and word-clouds for real-time analytics, reporting a 22% rise in sustained learning-outcome scores. (Kim & Lee, 2019) integrated AI in embedded systems labs, similar to the A4 assessment in this study, which allowed Internet and AI resource access, reflecting modern engineering assessment realities.

F. Synthesis and Research Gap

The literature highlights three key gaps addressed by this study:

1. Authentic assessment improves reliability and higher-order learning but is under-represented in Indian microcontroller labs (Jadhav & Patil, 2020a).
2. PBL and active-learning formats boost motivation and competencies, yet few studies integrate reverse-engineering diagnostics (Deshmukh & Shinde, 2022b).
3. Technology-mediated feedback enriches engagement but is rarely coupled with tiered, resource-modulated assessments(Shinde et al., 2025a).

G. Assessment Methods in Engineering Laboratories

According to recent research, there is a need to have improved and equitable assessment procedure in engineering labs. According to Desai and Kulkarni, new methods of assessments assist educators in evaluating students according to authentic learning as opposed to drilling (Desai & Kulkarni, 2024). Similarly, Bhat and Kumar demonstrate that with the help of clear criteria and rubrics, evaluation becomes more predictable and less subjective when taking lab courses (Bhat & Kumar, 2021). Combined, these works point to the fact that carefully designed, outcomes-based assessments might help enhance the quality of learning and provide students with a more realistic assessment of their competencies.

H. Collaborative and Technology-Supported Lab Learning

Technology and project-based approaches are now becoming a common trend in the engineering labs. According to Patil and Kulkarni, students feel more confident when they collaborate on realistic projects and express more ideas and can solve the actual problems of engineering (Patil & Kulkarni, 2019a). To this end, Shinde and Deshmukh reveal that real-time feedback tools in the form of digital devices make lab sessions more interesting and teach students to realize errors faster (Shinde et al., 2025b). These researches indicate that teamwork and technology may be used together to make the laboratory learning effective and friendly to students.

III. COURSE AND CONTEXT

A. Student Cohort and Lab Structure

The laboratory served 67 sixth-semester ECE students, divided into three batches: B1 (23), B2 (22), and B3 (22). Each student was provided with an independent LPC1768 Cortex M3 Development Kit. The first half of the semester involved guided sessions on peripheral interfacing, followed by exercises with minor modifications. The second half focused on continuous assessments.

B. Hardware platform

The LPC1768 ARM Cortex-M3-based development board included:

1. 3.3V/5V power supply
2. Eight SMD LEDs (P0.19-P0.26)
3. Two common anode seven-segment displays
4. 16x2 LCD
5. 4x4 keypad
6. 12-bit SPI external ADC
7. Stepper and DC motor interfaces
8. Two interrupt switches (P2.11, P2.12)
9. Buzzer, UART, and relay

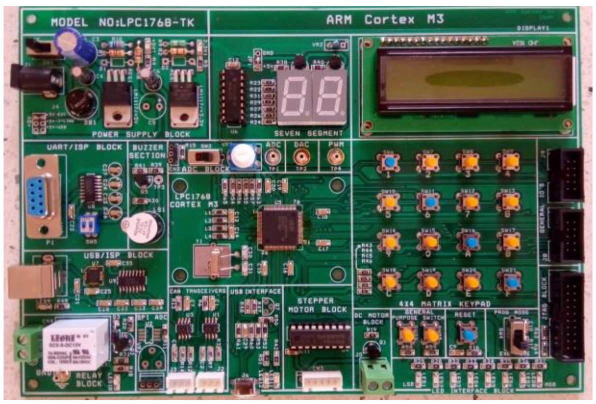

Fig.1. LPC1768 ARM Cortex-M3 Development Kit

IV. ASSESSMENT FRAMEWORK

A. Traditional test-based assessment problems

The previous methodology was based on test-based assessment, where marks were given to record writing, open studies, and summative lab experiment that was to be undertaken at the end of the semester. Even though not part of the syllabus, the out-of-syllabus assignments that were provided after the end of every lab session to facilitate the development of the skills were not actively used by many of the students. Faculty members did not have time to offer individual evaluation and feedback, which helped to develop individual competencies.

In addition, there was low engagement among the students since many of them were mainly driven by the marks related to observation and writing records. Although the assessment structure encouraged documentation, students never felt interested in making observations or keeping records, in many cases, they did it just to get grades. Due to this finding, the conventional assessment method portrayed a number of pedagogical constraints, such as surface learning, no individualized teaching, and low focus on practical learning of skills.

B. Redesigned Assessment Structure

To be effective in terms of the skill development, the semester was planned to be divided into two phases. Faculty in the first phase concentrated on the instruction of fundamental building block capabilities like how to interface with simple peripherals, embedded C programming, the usage of integrated development environments (IDEs) and simple debugging methods. In every lab session, the standard problems were purposely altered and students were asked to solve them on their own with the faculty facilitating and assisting them to ensure an effective implementation of the programs.

Notably, no marks were given to record writing which was totally abolished. This gave the students and instructors the opportunity to concentrate on the real-world learning and acquisition of skills as opposed to the paperwork.

The second semester was marked by a sequence of continuous assessments that were well-planned to demand previous planning among the students. Although the assessment questions were grounded on the same group of peripherals that were introduced in the first phase, they were completely different to the examples practiced in the previous stage, thus testing the students with their skills to practice their knowledge in new conditions. A total of five assessments were conducted, with details presented in Table I.

TABLE I
ASSESSMENT TYPES

Assessment ID	Focus	Description	Max Marks
A1	Single Peripheral	Guided: schematic only (e.g., LED patterns, UART communication)	10
A2	Multi-Peripheral	Guided: closed book (e.g., keypad with LCD)	10
A3	HEX Analysis	Reverse-engineering hex file outputs	10
A4	Open-Ended Project	Collaborative: AI/Internet allowed	10
A5	Traditional Lab IA	Memory-based: fixed questions (university-mandated)	10

V. PROGRESSIVE ASSESSMENTS FOR EMBEDDED SYSTEMS SKILLS

A. Assessment (A1) - Single Peripheral Task-Based Assessment

Objective To evaluate students' proficiency in basic peripheral interfacing and programming skills.

Description This assessment was aimed at individual peripheral interfacing activities like LED blinking patterns, UART communication or basic LCD output. The questions were formulated to assess the knowledge of the students in the field of the basic I/O operations, the configuration of the GPIOs they can translate logical instructions into the functioning embedded C programs. The learners had to utilize the skills gained during Phase 1 and show functionality on the development board.

Implementation Each student was given a different variation of the problem involving the same peripheral to prevent repetition and grow understanding as opposed to memorization. The lecturer made sure that learners were able to use concepts taught in guided classes. The code was written by students, combined through the Keil IDE and uploaded to LPC1768 board. Hardware output needed to be completed successfully.

Alignment with Educational Frameworks This test is concerned with the application level provided by Bloom, since students apply such notions as GPIO configuration and UART protocols in the real life. It reinforces the CDIO operation aspect, which allows students to do a specific set of tasks involving engineering, which form the basis of more complicated skills (Crawley et al., 2007).

Inference This test is successful in bringing about embedded systems, though it is important to note that preparatory sessions on basic programming and hardware interfacing are necessary. This performance gap can be narrowed through targeted feedback and pre-lab tutorials which will make sure that more students can attain proficiency (Nicol & Macfarlane-Dick, 2006). This indicates that before exposure to microcontroller programming was done, it was procedural, memory based and little was understood about it.

B. Assessment (A2) - Multi-Peripheral Task-Based Assessment

Objective To enhance integrative skills by requiring students to interface multiple peripherals simultaneously on the LPC1768, fostering system-level understanding and coordination.

Description The tasks demand simultaneous use of several peripherals, e.g. the integration of a 4x4 keypad with a 16x2 LCD to indicate the input. This test has the capacity to handle inter-peripheral interdependency and sophisticated firmware architecture.

Implementation This was done in the laboratory where students were able to write firmware to interface with other peripherals, such as the keypad and LCD, to ensure that they worked in tandem. Evaluation of integrity of code, functionality and error handling were assessed at the scoring. The scarcity of resources guaranteed that the emphasis was made on problem-solving and system design.

Alignment with Educational Frameworks Aligns with the levels of Bloom of the levels of analyse and create by the fact that students synthesize numerous peripheral operations. Conforms to project-based approach, with a focus on task integration in the real world. Enables peer to peer learning (Biggs, 1996b) during debugging..

Inference The mean score (1.72) is low, which indicates the challenge in the management of multi-peripheral complexity, which may be related to the lack of practice or scaffolding. This is in line with the conclusions made by (Jadhav and Patil, 2020) on the necessity of advanced multi-peripheral training. This brings out the importance of gradual structured exercises and conceptual tutorials on pre-labs.

C. *Assessment (A3) – Hex Analysis (Reverse Engineering)*

Objective To develop the skills to flash hex file, analyse the output and recreate the functionality on the LPC1768 microcontroller.

Description Students download pre-assembled hex files on the LPC1768, view results (e.g., LED patterns, LCD displays, UART data) and infer the configuration of the peripherals and logic, and compile firmware to reproduce the same results, likening outcomes functionally.

Implementation As part of a laboratory work, the students can flash hex files onto the LPC1768 board using Keil uVision or Flash Magic. They use debugging tools, oscilloscopes, or terminal emulators to analyse the outputs and consult datasheets in order to deduce settings. Students then write in C, assemble and flash their firmware to check that output is similar. Evaluation examines the accuracy of the output analysis, correctness of the code and documentation. Access to the internet is limited so as to focus on analytical ability.

Alignment with Educational Frameworks Congruency with Educational Structures: Congruence with the Bloom Taxonomy (1956) at the level of Analyze and Evaluate when it comes to the deconstruction of outputs. Favors practical learning through practical analysis and emphasis on experiments. Enforces feedback-based learning (Shinde & Raje, 2023) by comparing outputs of new iterations.

Inference The average score is 4.16, which indicates moderate success in the development of analytical skills (in accordance with (Deshmukh & Shinde, 2022a). The complexity of the task indicates that some extra scaffold, like guided analysis, is necessary to enhance the proficiency in the replication of codes. The findings indicate that reverse engineering can be used effectively with deep learning, although it needs to be organized using guides or diagnostic templates.

D. Assessment (A4) – Collaborative Open-Ended Experimentation

Objective To promote creativity and collaboration through innovation and team building by allowing students to plan and implement open-ended experiments and have access to resources to stimulate use of creative problem-solving and teamwork ability.

Description This exercise has students create experiments consisting of a combination of several LPC1768 peripherals, including ADC and UART with motors into a new application. Independent research and innovation is encouraged through resource access (e.g. datasheets, online references).

Implementation Work is performed in group laboratories, where teams suggest and implement experiments, and report on them in form of functional prototypes. The scoring is done based on creativity, technical precision, and collaboration. Guided and exploratory learning is moderated by resource access balances.

Alignment with Educational Frameworks Conformity to the Bloom Create level which focuses on original design. Promotes (Patil & Kulkarni, 2019a) team learning framework and (Desai & Kulkarni, 2024) creative assessment methods. Supports criterion-based assessment (Bhat & Kumar, 2021) by well-defined evaluation rubrics..

Inference A 6.18 average engagement and innovation are favorable, and the outcomes agree with the (Patil & Kulkarni, 2019b) results of collaborative learning influence. The increase in scores implies that the availability of resources and collaboration with the team improve the amounts of creative output, but formal instructions are essential.

TABLE IV
COURSE OUTCOMES FOR EACH ASSESSMENT TYPE

Assessment Type	*Course Outcome Statement*	*Revised Bloom's Taxonomy Level*
A1 - Single Peripheral Task-Based	*CO1: Apply embedded systems concepts to configure and program single peripherals (e.g., LED, UART, LCD) on LPC1768, demonstrating GPIO and I/O proficiency.*	*Apply*
A2 - Multi-Peripheral Task-Based	*CO2: Analyze and integrate multiple peripherals (e.g., keypad, LCD) on LPC1768, developing synchronized firmware for inter-peripheral coordination.*	*Analyze / Create*
A3 - Hex Analysis (Reverse Engineering)	*CO3: Evaluate hex file outputs on LPC1768, deducing configurations to replicate functionality via accurate C firmware.*	*Analyze / Evaluate*
A4 - Collaborative Open-Ended Experimentation	*CO4: Create innovative LPC1768 experiments integrating peripherals (e.g., ADC, UART, motors), demonstrating collaborative design and problem-solving.*	*Create*
A5 - Memory-Based, University-Mandated	*CO5: Synthesize embedded systems knowledge to implement firmware for complex LPC1768 tasks, ensuring logical and execution accuracy.*	*Apply / Create*

TABLE V
CO – PO MAPPING MATRIX:

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	-	2	-	2	-	-	-	-	-	-	-	3	2
CO2	3	2	2	-	2	-	-	-	-	-	-	-	3	1
CO3	3	2	-	2	2	-	-	-	-	-	-	-	3	1
CO4	3	-	3	-	2	-	-	-	2	-	2	2	3	2
CO5	3	2	2	-	2	-	-	-	-	2	-	-	3	2

TABLE VI
ASSESSMENT, INFERENCE, AND SKILL IMPROVEMENT

Assessment & Description	Mean Score	Key Inference	Suggestions for Skill Improvement
A1 - Single Peripheral Task-Based	3.32	Low scores (64.18% < 4 marks); weak foundational skills.	Provide structured pre-lab tutorials, interactive demos, and real-time debugging exercises to strengthen basics.
A2 - Multi-Peripheral Task-Based	1.6	Poorest performance; difficulty with inter-peripheral logic.	Use simulation tools(Anees et al., 2025), scaffold multi-peripheral exercises, and implement pair programming for firsthand learning.
A3 - Hex Analysis (Reverse Engineering)	4.25	Moderate success: students show analytical potential.	Offer guided examples, provide visual flowcharts for logic tracing, and conduct reverse engineering workshops.
A4 - Collaborative Open-Ended Experimentation	6.33	High engagement and creativity. No low scores observed.	Encourage idea documentation, mid-project mentoring, and peer evaluations to refine teamwork and innovation.
A5 - Memory-Based, University-Mandated	8.19	Highest performance but inflated due to memorization.	Introduce randomized/scenario-based questions, use live evaluations or oral defences to ensure true understanding.

E. Assessment (A5) – Memory-Based, University-Mandated

Objective To assess comprehensive proficiency in embedded systems programming through standardized, university-mandated tasks on the LPC1768 microcontroller.

Description Students create and implement firmware to perform university-specified tasks, which usually entails complicated peripheral interactions (e.g. stepper motor control with UART feedback). The test is an evaluation of synthesis capacity of course content, in which predetermined questions might allow memorization or excessive practice, which might inhibit true skill measurement.

Implementation In a summative lab assessment, students write logically correct code in C on answer sheets, responding to the requirements spelled out by the university. Once the written code has been verified by evaluators, students are allowed to put together and run their code on the LPC1768 development board. Scoring is done to assess the logic accuracy of the written code, specification accuracy, and system accuracy of the execution. There are no points assigned in the writing of records which is given more importance to practical work. Pre-given questions are fixed and could allow memorizing or practicing.

Alignment with Educational Frameworks Correspondent to the levels of Bloom in the Taxonomy (1956) both on the level of Apply and Create where students are expected to design and implement the firmware. Supports (Sadler, 2005b) criterion-based evaluation by means of standardized testing and (Biggs, 1996b) constructive alignment to the curriculum goals. The necessity of writing code by hand satisfies (Gibbs, 1995) student-centered assessment but falls short of (Haladyna, 1997b) criticism of memorization-based testing because of fixed question.

Inference The mean score of 8.22 is a satisfactory result, which is in line with the findings (Patel & Desai, 2023) regarding practical assessments. Nevertheless, the fixed questions helped memorize or train the same questions, as (Jadhav & Patil, 2020b), and exaggerate their scores without necessarily representing their practical skills. The need to handwrite code and then run tests is a challenge to logical comprehension but could still permit memorized answers and imply that randomized or open-ended tasks are needed in order to guarantee genuine skill assessment. Such a difference indicates that A5 evaluates procedural competence more than actual knowledge or flexibility.

VI. Course Outcome and Attainment

A. Course outcomes for each assessment type

Course outcomes for each assessment type is defined in Table IV.

B. CO-PO and CO-PSO Matrix

CO-PO & PSO matrix is defined in Table V.

C. Target Levels – Direct Attainment

TABLE II

DIRECT ATTAINMENT / TARGET LEVELS:

Attainment Level	Attainment Level Value	Target
Zero	0	0% of students scoring >= 50% marks out of relevant maximum marks.
Low	1	50% students scoring >= 50% marks out of relevant maximum marks.
Medium	2	60% students scoring >= 50% marks out of relevant maximum marks.
High	3	70% students scoring >= 50% marks out of relevant maximum marks.

D. Course Attainment Levels – Direct Attainment

Threshold based Attainment

This method calculates course attainment based on a threshold set by the instructor, which for this course was 50%.

For Threshold based Attainment % = $(x/y) \times 100$

x = Count of Students >= to Threshold %

y = Total number of Students Attempted

Average based Attainment

This method calculates course attainment based on the average score obtained by the class.

For Average based Attainment % = $(x/y) \times 100$

x = Average Secured marks of Attempted Students

y = Maximum Marks.

TABLE III

COURSE ATTAINMENT:

Course Outcome	Threshold-based Attainment %	Attainment Level	Average-based Attainment %
CO1	36.36%	0 (Zero)	33.33%
CO2	22.73%	0 (Zero)	15.45%
CO3	50.00%	1 (Low)	43.18%
CO4	84.85%	3 (High)	62.88%
CO5	93.94%	3 (High)	83.18%

Inference from course attainment

1. CO1 and CO2 show low performance:
   a) Only 36.36% (CO1) and 22.73% (CO2) of students scored ≥50%, resulting in an Attainment Level of 0 (Zero).
   b) Their average scores are also low: 33.33% (CO1) and 15.45% (CO2), indicating a lack of understanding or difficulty in these areas.

2. CO3 shows moderate attainment:
   a) Exactly 50.00% of students scored above the threshold, meeting the minimum requirement for Attainment Level 1 (Low).
   b) However, the average score is only 43.18%, suggesting room for improvement in reverse-engineering and analysis skills.
3. CO4 and CO5 reflect good attainment:

a) With 84.85% (CO4) and 93.94% (CO5) of students above the threshold, both outcomes reach the highest Attainment Level of 3 (High).
b) Their average-based scores (62.88% and 83.18% respectively) reinforce the good grasp students have in collaborative experimentation and complex firmware implementation.

CONCLUSION

The re-architecting of ARM Microcontroller and Embedded Systems Lab in VVCE Mysuru is an important move towards closing the gap between the old engineering education and new industry requirements. The course overcame the rote memorization and record-keeping exercises and incorporated realistic, practical evaluation that instilled critical, creative, and collaborative thinking in students. The five types of assessment including the single peripheral tasks to the collaborative open-ended projects offered a framework of assessment that was structured but flexible enough to allow the students to learn the practical skills with the LPC1768 CortexM3 microcontroller. The high achievement in team and complex tasks (CO4 and CO5) based on the results of this research highlights the importance of the alignment of assessment and real-world engineering activities and the CDIO model.

Nevertheless, the problematic performance in the foundational (CO1) and multi-peripheral (CO2) activities indicates that enhanced scaffolding and preparatory assistance should be provided to all students so that the latter could develop a stable foundation upon which they could solve the more complex tasks. This strategy was not only able to boost student interest but create a greater appreciation of embedded systems to prepare students to the realities of professional engineering settings. This research contributes through the use of reverse-engineering, collaborative project, and resource-rich assignment to provide a scalable model that other institutions may also based on to transform embedded systems education.

FUTURE SCOPE

The success of this redesigned laboratory will be followed up by further initiatives to improve and broaden the assessment framework to cover areas of gaps found. First, we intend to roll out specific pre-laboratory modules, i.e. interactive simulations and tutorials, to enhance the basic knowledge of peripheral interfacing and embedded C programming. These materials will be intended at improving performance in CO1 and CO2, and all students will be ready to deal with complicated assignments. Second, in A3, we plan to add more complex reverse-engineering problems, which might include the use of AI-based diagnostic tools to approximate a real-world debugging experience. This will also improve the analytical and problem solving skills. Third, we intend to embark on the collaborative open-ended projects (A4) through collaboration with industry to present real-world problem statements in the effort to further nurture industry-academia relationships.

Also, as a way of reducing the memorization bias in A5, we will consider randomized and scenario-based tests as a way of assessing genuine skills application. Lastly, longitudinal research will be used to monitor the performance of alumni in the industry with the view to determine the overall effect of this pedagogy on career readiness. Through the process of continuous improvement, we aim to develop a powerful, future-proof curriculum that will equip students with the ability to perform well in the dynamic discipline of embedded systems.

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