Journal of Engineering Education Transformations,
Volume No. 37, January 2024 Special Issue, eISSN 2394-170

Leveraging Agile Framework for a Project Based Learning Environment in Embedded Systems Design Course

Deepa M[1], Susithra N[2], Santhanamari G[3], and Reba P[4]
Department of Electronics and Communication Engineering, PSG Institute of Technology and Applied Research, Coimbatore, Tamil Nadu
[1]deepa@psgitech.ac.in
[2]nsusithra90@gmail.com
[3]gsm@psgitech.ac.in
[4]rebasatheesh@gmail.com

***Abstract*—Fast paced technological advancements lays more emphasis on embedded system design to real world applications. This mandates the inclusion of hardware-based courses like Digital Electronics and Microprocessors & Microcontrollers. These pre-requisite courses introduced in the early semesters pave the way for students to develop keen interest, skill and proficiency in the area of embedded systems and System-on-Chip design. The challenges that lay before the course instructors are to kindle the students' interest in these courses and also to make them industry-ready engineers. In order to bridge the gap between the industry expectations and skills imparted in the undergraduate education, additional courses are offered to the students as value added courses. The students are offered 'Embedded System Design using PIC Microcontrollers' in the sixth semester exposing them to the real time challenges faced during the embedded system development. Further to handle real-time challenges, a modified Project Based Learning (PBL) – Agile based approach is adopted in this course. This paper presents the formation of curriculum for the course addressing the gaps and deployment of Agile methodology during the Project phase of the proposed value-added course. It preludes a habitat similar to the industry so that the students will be able to fit in and fluently blend the transformation from academia to industry. This paper also points out the importance of a well-defined rubric based assessment system, to ensure consistent and unbiased grading of project work by multiple instructors. Also, a quantitative metric 'Attainment Index (AI)' - weighted mean of the class quantizes the cohort's performance in a simpler and more reliable form. A course end student feedback survey is conducted to measure the effectiveness of the employed method.**

As long-term benefits, it was observed that the students undergoing such courses have a competitive edge over the other students when facing interviews and help them during the hiring process while exhibiting greater confidence and additional skill sets to the interview panel, ensuring that graduates are well-prepared to thrive in the ever-evolving field of embedded systems.

Deepa M
Department of Electronics and Communication Engineering,
PSG Institute of Technology and Applied Research
deepa@psgitech.ac.in

***Keywords*—Agile Methodology; Embedded System Design; Project based learning; Rubrics Based Assessment; Self Reflection.**

1. INTRODUCTION

DUE to rapid growth of the Internet of Things (IoT) and technological advancements, the demand for embedded system professionals and developers has been steadily increasing across various industries. Embedded systems, which are specialized computing systems integrated into larger devices or products, play a crucial role in the modern world. These systems play pivotal roles in critical areas such as automotive safety, medical devices, and real-time industrial control. Industries like automotive, medical and consumer electronics require experts to design and develop embedded systems that power the devices and applications. The need for skilled professionals arises from the complexity of designing efficient, secure, and innovative embedded solutions. Professionals with cross-disciplinary skills encompassing hardware design, firmware development, programming, and integration are increasingly sought after. As technology continues to evolve, the demand for experts who can navigate this intricate landscape and create effective embedded systems is said to keep growing.

There exists a noticeable gap between the skill set expected by industries from embedded system professionals and the curriculum offered by universities in embedded system courses. Industry expectations encompass skills like real-time programming, debugging, hardware-software codesign, and integration, which are essential for embedded system professionals while solving real-world problems. However, traditional university teaching often leans towards theoretical concepts of embedded systems with limited exposure to practical applications and rarely based on industry demands. This hinders students' ability to effectively apply learned concepts. To solve the above problem, universities can incorporate more innovative projects, industry collaborations, and up-to-date tools in their curricula. Internships, workshops, and guest lectures from industry experts can provide students with insights into real-world challenges.

This paper is about the experience of authors in the design and implementation of a value-added course titled Embedded System Design using PIC Microcontrollers having theory and laboratory sessions augmented with project-based learning for 6th semester undergraduate students. This paper presents the authors' reflection on designing this specialization course with Project Based Learning (PBL) using Agile framework incorporating industry expectations. This also presents the effectiveness of the course both from the faculty and students' perception.

Project-Based Learning is vital for embedded system courses as it bridges theory with practice. It offers hands-on experience in designing, developing, and troubleshooting embedded systems. PBL fosters skills like application development, problem-solving, teamwork, and exposure to real-world tools and challenges. Students gain confidence, industry-aligned competencies, and a portfolio of practical projects, preparing them to excel in the embedded systems field. As the embedded development involves codesign, the deliverables of the PBL methodology might not be available at different timelines in the project implementation.

Agile-based Project-Based Learning (PBL) differs from traditional PBL by focusing on iterative planning, adaptability, and continuous evaluation. In Agile PBL, projects are divided into short cycles (sprints), allowing evolution of scopes, frequent evaluations, and iterative improvements. This approach mirrors the industry dynamics, fostering adaptability, teamwork, and real-world problem-solving skills. Traditional PBL tends to follow a linear path with predetermined outcomes. By embracing Agile principles, students develop practical expertise, time management, and effective communication within dynamic project environments, ensuring their readiness for the fast-paced, collaborative nature of engineering careers.

The success of the Agile based PBL further depends on the assessment practices to ensure that all types of learners are supported in the learning process. With good assessment practices like rubrics-based assessment, Agile based PBL can create a culture of excellence for all students and ensure industry relevance and holistic learning for all. Also, rubrics-based assessment was chosen due to two reasons: The one is where the students knew the expectations of the course instructors and they could prepare accordingly. The second one is for the situation where the multiple instructors were handling the course and to make the project assessment unbiased.

2. Related Literature

Recent literature highlighted the need for blended learning (Deepa, M et al.,2020) that includes emulator based teaching-learning process, collaborative Jigsaw learning method (Reba, P et al., 2022) Mind map (Susithra, N et al., 2023), motivating them to take online courses (Malik I. Alamayrah et al., 2022) through e-learning to enhance interaction between students and instructors, to help them develop their skills, adapting hybrid education systems and getting insight into industry environments. In (A.Sheik Abdullah et al., 2021), the Active Learning Strategies (ALS) like Quiz by Kahoot! (Daily Assessment), Flipped classroom (Weekly Assessment) and MOOCs online courses (Monthly Assessment) were introduced for a theory course to improve CO attainment level. Fernando Martinez-Rodrigo.et.al., (Martinez-Rodrigo, F et al., 2017) presented active learning, collaborative learning and PBL to teach DC/DC and AC/DC converters, in which they have ensured two qualitative advantages of generic skills like teamwork, project development and greater knowledge gaining in that particular topic.

In (Ravindra Mandale et al., 2021), gaps between industry and academia are identified via feedback obtained from previous years project report analysis, alumni and industry experts' feedback on usage of tools and technologies. Also, authors suggested that using the Agile model encourages continuous rehearsal of development and testing throughout the software development phases of the project. Rajeshwari K.et.al, (Rajeshwari K et al., 2016) insisted on introducing concepts of Agile methodologies like Pair Programming and Rapid Development at an earlier stage to prepare the students for the industry. In (Manoj Joseph D'Souza and Paul Rodrigues 2015), the authors elaborated an extreme pedagogy - a novel framework for teaching and learning in engineering education which focuses on three important characteristics namely 1. Learning by continuous doing. 2. Learning by continuous collaboration and 3. Learning by continuous testing. In (Singh, P.et.al, 2021), it is elaborated that the agile concept of adapting to changing requirement is very much needed characteristic for development of safety critical system, so that all the System Development Life Cycle (SDLC) documents are to be revised according to the requirement changes from the customer side. James Larson.et.al., (Larson, J et al., 2020) has elaborated that, having a mindset of being able to quickly and effectively respond to new challenges, information, and circumstances while maintaining a positive and proactive attitude known as fluid and agile mindset, which is much needed in a fast-paced and dynamic world, where constant change is the norm. They have experimented with self-directed learning in a space where project-based learning is supported for a course Embedded System Design course.

Incorporating Agile practices into engineering projects provide students with valuable skills beyond technical knowledge, including dynamism, adaptability, and effective project management. It also trains them into well trained professionals capable of successfully managing the complexities of real-world engineering endeavors. Studies have shown that a well-designed rubric based technology-enhanced assessment approach could improve students' metacognitive awareness and learning achievement (Chen, B., & Zhang, Y., 2017). Assessment methodologies play a vital role in promoting Higher Order Thinking Skills (HOTS) and provide an opportunity for the facilitators for progressive reflection upon the individual students and the student groups. (Goteti, L. P., & Madhuri, G. V., 2013)

TABLE I
REGULAR SYLLABUS VS INDUSTRY REQUIREMENTS FOR EMBEDDED SYSTEMS

Major topics in regular Embedded System Design Courseware (Theory Course)	Industry requirements of a typical Embedded Systems Engineer
• Embedded system design flow models and design methodologies • Computing and Validation platforms for hardware software design • Program and Performance optimization • Operating system design principles • Multicore and Multiprocessing environments • Introduction to Real time operating system concepts	• Systems Thinking and System Modelling • IoT Product Analysis • Hardware Software Codesign • Real Time Operating System (RTOS) Concepts • Communication Protocols like UART, SPI, Modbus, CAN, RS232 • Middleware and communication layers • Embedded System Development Life Cycle • Working knowledge of Embedded C and Assembly Language • Integration and Usability Testing • Familiar with Agile development methodologies and test-driven development

3. METHODOLOGY: PEDAGOGICAL APPROACHES AND PBL IMPLEMENTATION

A. Course Overview

Embedded System Design using PIC microcontroller involving the Programming and interfacing of various peripherals is usually not offered in the curriculum for the under-graduate (Authors refer to the Anna University Curriculum) and it is suggested as a value-added course, that can be conducted in addition to the regular courses in the curriculum. This course is suited for undergraduate students pursuing Electronics and Communication Engineering or Electrical Engineering or Instrumentation streams, in the sixth semester, having completed the pre-requisites such as C programming, digital electronics, microprocessors and microcontrollers. The course is organized in 30 hours constituting 10 theory and 20 laboratory sessions. The course may be offered alongside the curriculum with 4 hours per week. The student strength of the class under study is 65 and 3 faculty members are in-charge of the value-added course.

B. Course Preparation

Before the preparation of the syllabus and course plan for the Value-added course, the conventional topics covered in a regular embedded systems course and the skills an industry expects in the same domain were brainstormed referring to the descriptions of various job openings in recent times and discussed in the department's Program Assessment Committee meeting and advisory committee meeting. The observations are listed in Table I.

Considering the gap in the regular system and the company expectations, a new syllabus for the value-added course was curated by the faculty members handling the course, in accordance with the prerequisites and advice from the committee members.

TABLE II
NEWLY FRAMED COURSE PLAN FOR THE 'EMBEDDED SYSTEM DESIGN USING PIC MICROCONTROLLER' COURSE

Nature of session	Topics Covered	Hourly Split Up
Theory Session	• Architecture of PIC16F877A with pin configuration • Built in peripherals like ADC, Memory and Timers • Basic I/O devices and interfacing them with controllers.	3 hrs
Software Programming	• Introduction to Embedded C programming using MPLAB • Introduction to Proteus simulation • Introduction to Programmer like PIC kit to program and debug microcontrollers. • Introduction to Agile Methodology	4 hrs
Laboratory Session	• Interfacing input devices like LEDs, Switches and sensors • Interfacing output devices like Seven segment display, LCD and actuators	5 hrs
Team Project – Phase I	Projects related to Interfacing I/O devices, sensors and actuators	3 hrs + Beyond session
Theory session	• Introducing communication protocols like UART, I2C, SPI and RS232 • Embedded Software Development Life cycle and RTOS concepts	2 hrs
Laboratory Session	• Visualize communication between controller and PC via UART by transmitting and receiving text. • Interfacing RTC or read/write EPROM via I2C in the controller. • Interfacing display like Dotmatrix via SPI in the controller. • Interfacing WiFi module like ESP8266 with PIC16F877A to establish connectivity.	8 hrs
Team Project – Phase II	Projects utilizing the various communication protocols: ***Wearable Health Monitoring Device using SPI communication for Athletes (Sample project carried out by one team)***	5 hrs + Beyond session

After proper approval from the head of the department/Academic Dean/Course coordinator, various application-oriented programming tasks were formulated. The course structure encompasses enriched theoretical knowledge with extensive hands-on practical sessions, aligning with industry demands. The newly curated course plan is shown in Table II, the overview of which is shown in Fig.1.

The proposed structure ensures that the students engage in real-world simulations, hardware interfacing, and coding challenges while mastering vital skills. However, what truly sets this course apart is the agile based project development that facilitates students to gain proficiency in sensor integration, debugging, optimization, and system integration. Furthermore, the tasks cover soft skills like teamwork, communication, problem-solving and critical thinking. By fusing academia and industry, we ensure graduates possess not only theoretical prowess but also the practical expertise crucial for successful embedded system careers learnt and practiced in an industry like ambience.

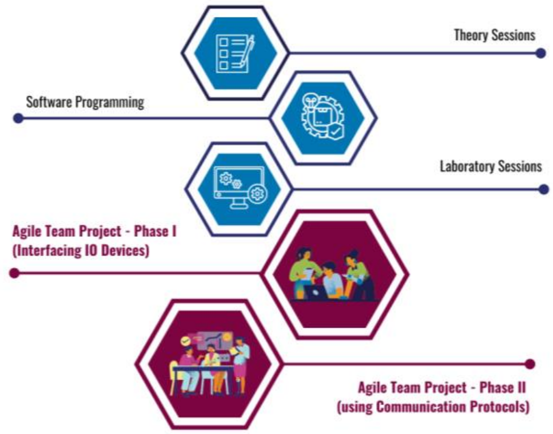

Fig. 1 Curated Course plan for the Value-Added Course - 'Embedded system design using PIC microcontroller'

C. Course Outcomes

At the end of the course, students should be able to:

1. Elaborate the architecture and built-in peripherals of PIC Microcontroller
2. Write assembly level and embedded-C program for PIC16F877 microcontroller architecture.
3. Demonstrate working knowledge of interfacing peripherals like memory, I/O devices, timers, interrupts, digital-to-analogue and analog-to-digital converters to PIC16Fxx and manipulating their signal outputs to monitor or control external environments.
4. Interface sensors and actuators with PIC microcontroller for solving real-time problems and for working cooperatively in a team environment and developing communication skills.

D. Conduct of Theory Sessions

The theory sessions involve the briefing about the architecture of the PIC Microcontroller, built-in peripherals and interfacing them for different applications. The faculty also introduce the students to controller-specific assembly language constructs. Scaffolding materials are provided to students to collaborate and build algorithms for real-world problem statements. The theory sessions were embedded with live coding experiences using Proteus simulation in order to facilitate the students to connect the theoretical knowledge with the internal architectural visualization. Besides, a blended learning approach for active and cooperative learning including the JigSaw method, mind mapping, face-to-face discussions, clarifications, and flipped classes are used, fostering peer-to-peer knowledge exchange and effective dissemination of theoretical topics.

TABLE III
INSTRUCTOR LED APPLICATION ORIENTED TASK

S. No	Objective	Application Oriented Task	Explanation
1	Interfacing I/O devices	Person/Object Counter	Implement a system that counts the number of persons entering and leaving the room and alarms when the number of persons exceeds the seating capacity of the room already stored as a threshold value.
2	Sensor and Actuator interfacing	Implement an automatic temperature control unit	Interface a temperature sensor and if temperature exceeds 30 deg, then the servo/DC motor is to be run with increased rpm to increase the cooling fan speed.
3	I2C Communication	Real-time temperature monitoring	Reading certain memory ICs/reading sensor values
4	SPI Communication	Displaying current temperature and number of persons in a room.	Connect digital potentiometer with PIC using SPI
5	RS232 Connectivity	Sending and receiving a text message	To verify serial communication between host (CPU) and target development board via USART
6	ESP8266 interfacing	To turn on the motor/LED remotely.	Establish WiFi connectivity and control I/O devices remotely

TABLE IV
ROLES OF PROJECT TEAM MEMBERS IN AGILE ENVIRONMENT

Project Based Learning	Role based on Agile Methodology
Faculty Members as Mentors	Product Owners
Student Team Member	Scrum Master
Real world problem statement given by the Mentor	Product Backlog split into specific User Stories
Weekly Reviews with the faculty members	Retrospection and Sprint Planning for the next Sprint
Tasks in the Timeline	User Stories in the Sprint
Monthly Deliverables	Sprint Deliverables
Daily Team Meeting (only Student Teams)	Daily Scrum

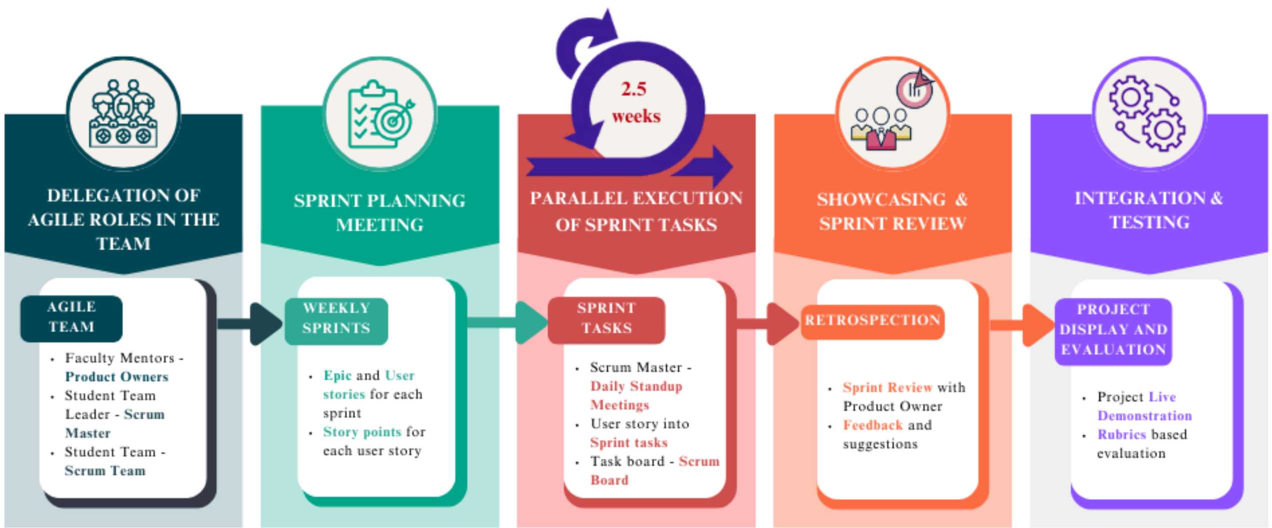

Fig. 2 Agile based PBL Strategy for Value Added Course

This approach equips learners to transition seamlessly into lab sessions, translating their theoretical grasp into practical proficiency in embedded systems design, development, and troubleshooting.

E. Conduct of Laboratory Sessions

In the laboratory session, students were provided with a PIC16F877 development board, to carry out the given tasks. This provides an opportunity for the students to learn programming and aids the experiential learning capabilities and lays a basic foundation for adopting PBL.

As a part of lab sessions, the students are provided a set of application-oriented programming tasks as shown in Table III, in order to understand the architecture of the controller and to appreciate the importance and the need for peripherals interfacing. This phase equipped the students with the necessary knowledge required to implement a real time application in the next phase.

F. Agile Framework for PBL

Alongside the practical lab sessions, students are given real world problem statements to work in a team to develop a firmware prototype. Students are introduced to the Agile methodology for firmware development. Agile framework is analogous to the embedded software development cycle. The various roles and responsibilities of the project team are analogous to that of Agile framework and tasks were assigned as shown in the Table IV.

The Agile framework offers a structured yet flexible approach to project management that is particularly well-suited for the dynamic and iterative nature of embedded system development. Implementing Agile methodologies in a team project for an embedded system course enhances collaboration, adaptability, and the overall learning experience.

- Initially, the **faculty member (Product Owner) outlines** the project scope, goals, and requirements emphasizing the development of a functional embedded system solution within the given time frame.
- The students **form teams (scrum team) and select a project topic** such as building a sensor-based device or developing a real-time control system. Each project is divided into a series of short development cycles called sprints.
- During **sprint planning**, the team collaborates to determine the specific tasks, features, and functionalities **(User stories)** they will work on in the upcoming sprint, ensuring alignment with the overall project objectives.
- Teams hold **daily standup meetings** to discuss progress, challenges, and plans for the day under the leadership of a student team leader **(scrum master)**. These brief meetings encourage transparency, allow for quick issue resolution, and keep everyone on the same page.
- Within each sprint, teams focus on developing a subset of the project's features or components called the **story points**. They develop algorithms, apply embedded system design principles, write code, and test them under the guidance of the faculty mentor. Agile encourages continuous integration of code and frequent testing to identify defects in the early stages.
- At the end of each sprint, teams **showcase their progress** to the class and receive feedback from peers and the faculty mentors. This review process helps refine project goals, identify areas for improvement, and ensure alignment with the embedded system course's learning objectives.
- Teams conduct **retrospectives to reflect on their sprint experience**. They discuss what went well, what could be improved, and strategies for enhancing collaboration and efficiency in the next sprint. Agile's adaptive nature allows teams to adjust their project direction based on feedback and changing requirements. This flexibility is crucial in

"Design and Develop a Wearable Health Monitoring Device for Athletes using SPI Communication"

Problem Statement: In the realm of modern sports and athletics, real-time health monitoring is crucial for optimizing performance and ensuring athlete well-being. The project aims to create a wearable health monitoring device tailored for athletes that employs SPI communication for seamless data exchange and accurate measurements.

Sprint 1: Planning, Sensor Integration, and Data Acquisition	**Sprint Duration: 1 Week**
Epic: Sensor Integration and Data Acquisition	
User Stories	**Estimated Effort**
1. Understand the project scope and objectives.	2 hours
2. Research and select suitable sensors for heart rate, oxygen saturation, and body temperature monitoring.	6 hours
3. Interface the selected sensors with the microcontroller using SPI communication protocols.	10 hours
4. Implement real-time data acquisition from the sensors.	8 hours
Total Effort	**26 hours**

Sprint 2: Data Visualization, Alert Mechanisms, and Wireless Integration	**Sprint Duration: 1 Week**
Epic: Data Visualization and Alert Mechanisms	
User Stories	**Estimated Effort**
5. Design a user interface for displaying real-time health parameters.	6 hours
6. Implement alerts and notifications for deviations in the health parameter.	6 hours
7. Explore and integrate wireless communication for remote monitoring.	8 hours
Total Effort	**20 hours**

Sprint 3: Integration Testing and Documentation	**Sprint Duration: 0.5 Week**
Epic: Validation and Documentation	
User Stories	**Estimated Effort**
8. Estimate power consumption for extended device usage.	2 hours
9. Validate health parameters against benchmark medical devices.	6 hours
10. Perform regression testing to evaluate the functional correctness.	4 hours
11. Create comprehensive documentation covering device architecture, sensor integration, software flow, and user instructions.	8 hours
Total Effort	**20 hours**

Fig. 3 Curated sprint stories for a sample project work

embedded system development, where unforeseen challenges often arise.

- As the sprints progress, teams **integrate their code** into a cohesive embedded system solution ensuring compatibility and reducing integration issues. The final project is presented to the class, showcasing the system's functionality, design decisions, challenges overcome, and lessons learnt.

By applying Agile methodologies, students not only gain technical skills in embedded system development but also learn about project management, teamwork, communication, and adaptability. They are provided with firsthand experience on how the Agile principles improve project outcomes and how it can be applied to n their future careers. Incorporating Agile methodologies into a team project for an embedded system course provides students with practical exposure to industry-standard project management practices while allowing them to navigate the complexities of embedded system design and development effectively. Fig. 1 shows sprint split-up and how the project's epics are divided into user stories and distributed across sprints of a sample project completed by students in Embedded systems course.

4. Project Evaluation - Rubrics Based Assessment

Evaluation of the project work is done in order to track the learning experience of the students. After the completion of the project, the knowledge and skills gained by the students are assessed by the course handling faculty during the final project presentation and demonstration phases. This assessment is not only limited to the final project demonstration, but also includes the formative examination of students' performance and involvement throughout the sprint planning sections of the project phase. Rubrics based assessment is followed to ensure consistent and unbiased assessment. The rubrics provide a structured framework for assessing different aspects of the student's project with clear criteria and descriptions for each level of performance. The rubrics for project examination are shared with the students well ahead in order to make them aware of the examination process as shown in Table V.

5. Results and Discussion

The students get to transform theoretical knowledge obtained as a part of their theory courses into practical exposure through the programming assignments in the first phase. The Agile based PBL approach ensures that the practical exposure is not only limited to the implementation of application-oriented tasks, but also enhances their ability to face real world challenges and provides a holistic approach to end-to-end system development. At the end of the project phase, the students demonstrated the completed project and assessment was done to evaluate and analyze the performance of the students. The projects done as a part of the value-added course are displayed as in Fig. 3.

Fig. 4 Demonstration of project work by the students as a part of the value-added course

TABLE VI
ATTAINMENT INDEX LEVELS

AI	Student Category	Range of Attainment Index (AI)
3	High Achievers	> 80% of students scoring above the set attainment level
2	On Track	70% - 80% of students scoring above the set attainment level
1	Developing	< 70% students scoring above the set attainment level

	Quiz	Lab	Project	Combined Marks (CM)
Maximum Marks	100	100	100	
	$\bar{Q}$	$\bar{L}$	$\bar{P}$	
Class Average	75	94	87	
	Q	L	P	
Student 1	78	86	95	86.71
Student 2	94	92	83	89.53
Student 3	82	96	78	85.78
	q	l	p	
Weights	0.29	0.37	0.34	

A. Weighted Mean Method for computing Class Average

Attainment Index (AI) is calculated by the weighted mean method by giving due weightages (q, l and p) to various assessment components such as formative quizzes (Q), Lab exercise performance (L) and the Project evaluation (P) respectively. The class average marks of the various components are denoted by $\bar{Q}, \bar{L}\ and\ \bar{P}$ respectively. This method is simple, reliable and follows a normal distribution pattern. Upon analysis of the Combined Marks (CM) of each student, Attainment Index (AI) of the class is found out based on the number of students scoring above the set attainment levels as shown in Table VI. It was observed that the class was "On Track".

$$CM = qQ + lL + pP$$

$$Weightage\ for\ Quiz\ component, q = \frac{\bar{Q}}{\bar{Q} + \bar{L} + \bar{P}}$$

$$Weightage\ for\ Lab\ component, l = \frac{\bar{L}}{\bar{Q} + \bar{L} + \bar{P}}$$

$$Weightage\ for\ Project\ component, p = \frac{\bar{P}}{\bar{Q} + \bar{L} + \bar{P}}$$

B. Survey Result Analysis

Two different feedback was obtained from students: One at the end of the course and the other after their placements.

1) Course End Survey Feedback

Student feedback is obtained to analyze the students' satisfaction upon completing the course. The feedback questionnaire and its average responses are as shown in the Table VII. In order to have unbiased feedback, the feedback was collected before publishing the grades scored by the students.

The feedback results show that the students were highly motivated to take up the team Project. They were excited to face the challenges during the course of the project. They were able to imbibe the theoretical concepts to a higher level upon completing the project work. The students felt that the time frame given to them was limited and it could be extended in order to build a full-fledged model of the problem statement.

TABLE VII
COURSE END SURVEY QUESTIONNAIRE

Sl. No	Survey Questions	Average Score (5)
1	How do you rate the new curriculum framed for the Embedded systems value-added course?	4.3
2	Do the lab experiments completely augment the theory taught?	4.5
3	How do you rate the format of lab experiments conducted in this course compared to the conventional laboratory experiments?	4.4
4	What was the level of complexity throughout the course?	3.8
5	How do you rate your involvement level within the team while performing the project?	4.4
6	How do you rate your learning process due to this PBL?	4.2
7	Was the timeframe sufficient for each sprint?	3.6
8	How do you rate your satisfaction level upon the completion of the project?	4.1
9	How appropriate were the rubrics framed for project evaluation?	4.0
10	Would you recommend this course to your junior students?	4.4

TABLE VIII
FEEDBACK OBTAINED AFTER PLACEMENT DRIVES

Sl. No	Survey Questionnaire	Average Score (5)
1	How has the Agile based project learning experience influenced your understanding of real-world project management and development?	4.4
2	Did the use of agile practices like daily standup meetings, sprint planning and retrospectives enhance your learning experience?	4.4
3	How well did the project-based learning approach enhance your problem solving and critical thinking skills?	4.2
4	How well did you confidently answer the interviewer about the Agile process?	4.3
5	How confidently did you explain the project to the interviewer?	4.4
6	How will you rate the level of agreement on inclusion of such a type of course as Value Added Course?	4.5

2) Self-Reflection by the Faculty

The design of the Embedded system course is such that it demands a complete involvement of students throughout the course instead of attending classes from the exam point of view. The students voluntarily spent their leisure hours in the laboratory trying to enhance their technical skills by practical exploration. In addition to technical skill development, they had a practical exposure to implementing the Agile practices in the project workflow, which would act as an edge over the other students during their placements. However, a stringent timeline for the team project posed a challenge to the students to implement the given modules within the deadline.

From the teacher's stand point, they faced a lot of difficulty in planning and implementing the well-structured curriculum, amidst their usual workload.

TABLE V
RUBRICS DEVELOPED FOR EVALUATING THE DIFFERENT STAGES OF PROJECT WORK

Criteria	Excellent	Good	Satisfactory	Needs Improvement
Understanding problem statement (10 Marks)	Demonstrates a deep understanding of the project's objectives, scope, and technical requirements.	Understands the project's objectives and scope, with some gaps in technical details.	Grasps the basic project concepts, but lacks clarity in certain aspects.	Demonstrates limited understanding of the project's goals and technical aspects.
Hardware Integration (40 Marks)	Successfully selects and integrates sensors, ensuring proper interfacing with the microcontroller using SPI communication.	Integrates sensors with adequate interfacing using SPI communication, with minor issues.	Manages to integrate sensors but faces challenges in proper SPI communication setup.	Struggles to integrate sensors and establish SPI communication, leading to functionality gaps.
Design of User Interface (20 Marks)	Designs a precise user interface for real-time health measurement visualization.	Designs a user interface that adequately displays health measurements in a clear manner.	Designs a basic user interface with limited interactivity and clarity.	Presents a user interface that lacks clarity, interactivity, or effective health data visualization.
Validation and Testing (10 Marks)	Successfully validates health measurements against medical devices with high accuracy.	Validates health measurements with reasonable accuracy against medical devices.	Attempts validation but faces challenges in achieving accurate comparisons.	Struggles to validate health measurements accurately against medical devices.
Documentation (10 Marks)	Creates comprehensive documentation covering device architecture, sensor integration, software flow, and user instructions.	Provides well-structured documentation with clear details on most aspects of the project.	Offers basic documentation covering essential aspects, with some gaps or lack of clarity.	Provides incomplete or unclear documentation, lacking essential details or organization.
Presentation (10 Marks)	Delivers an engaging final presentation showcasing the project's features, design, and outcomes.	Delivers a well-structured presentation with clear explanations of most project aspects.	Delivers a basic presentation covering essential points but with some inconsistencies or gaps.	Delivers a presentation that lacks organization, clarity, or engagement with project details.

The faculty got to spend quality time with the students in clarifying their doubts and resolving dependencies in the project development cycle. In order to fulfil these challenges on both sides, faculty had to stride the extra mile with higher levels of dedication and hard work. This course also offered a solid and consistent learning and exposure towards industrial practices.

3) Students feedback about this course after attending placement drive

Besides the survey conducted at the end of the course, overwhelming positive responses were obtained from the students after attending placement drive. They highlighted that

Fig. 5 Feedback Questionnaire Survey responses obtained from students on a Likert scale of 5

the project work enabled them to detail the intricate working details of the sensors and the interfacing challenges to the interviewer. The working knowledge of Agile methodologies seemed to be an icing over the cake in the interviews.

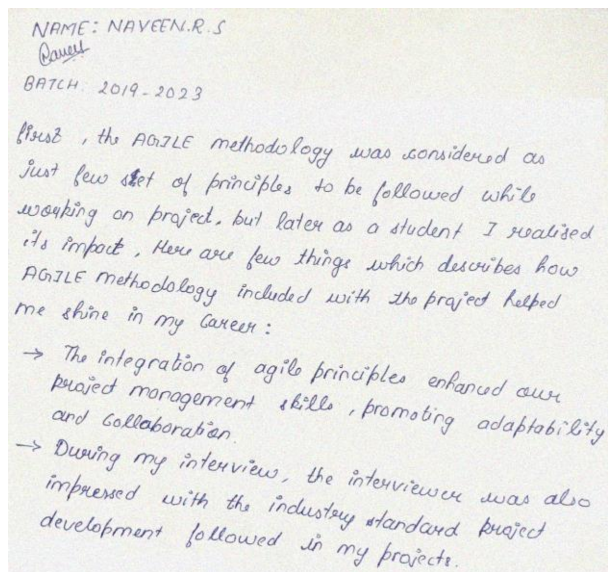
NAME: NAVEEN.R.S
BATCH: 2019-2023
First, the AGILE methodology was considered as just few set of principles to be followed while working on project, but later as a student I realised it's impact. Here are few things which describes how AGILE methodology included with the project helped me shine in my career:
→ The integration of agile principles enhanced our project management skills, promoting adaptability and collaboration.
→ During my interview, the interviewer was also impressed with the industry standard project development followed in my projects.

Fig. 6 Sample student feedback about the conduct of Agile based PBL

6. CONCLUSION

PBL methodology engages students more effectively when compared to conventional teaching methodologies, necessitating the introduction of a PBL environment for the undergraduate students. PBL approach not only stimulates in depth enquiry and experiential approaches, but also promotes interpersonal and intrapersonal competencies. There is also a critical need for the students to work in interdisciplinary teams to develop embedded systems, IoT based products and to take part in project design contests conducted by leading industries. Embedded system development involves using both hardware and software components to interface with the physical world and to perform useful tasks. To strengthen the knowledge of hardware software codesign, it is important to focus on its related laboratory courses even if they are beyond the scope of the syllabus prescribed.

Besides the regular microprocessor and controller lab course, a value-added course on embedded system design using PIC microcontroller is offered to engineering students in the sixth semester. The authors have thus extolled the benefits of using Agile model based modified PBL methodology and the reason for choosing the same. One reason is facilitating students to provide the project deliverables at the end of every sprint thereby ensuring that there is progress and the second important reason is to familiarize the students with industrial practices and to provide a seamless transition to the corporate world. Moreover, the rubric based assessment and weighted mean method of attainment evaluation are also described. Further, this methodology can be applied to any PBL based Engineering course in any stream.

REFERENCES

Abdullah, A. S., Karthikeyan, P., Selvakumar, S., & Parkavi, R. (2020). A Strategic Approach in Handling Information Retrieval Course for Attaining Course Outcomes–A Case Study. *J. Eng. Educ. Transform*, 34, 148.

Alamayrah, M. I., Jaber, J. O., Bashir, A., Othman, A. M., Mansour, I. M., Dalabieh, A., & Al-Aboshi, A. (2022). E-Learning in faculties of engineering during COVID-19 pandemic in Jordan. *Journal of Engineering Education Transformations*, 36(2).

Ammons, B., & Bansal, S. K. (2017). Scrumify: A software game to introduce agile software development methods. *Journal of Engineering Education Transformations*, 30(Special Issue).

Chen, B., & Zhang, Y. (2017, December). A rubric-based technology-enhanced assessment approach to improve students' meta-cognitive awareness and learning achievement. *In 2017 International Conference of Educational Innovation through Technology (EITT)* (pp. 111-115). IEEE.

De Barros, V. A. M., Paiva, H. M., & Hayashi, V. T. (2023). Using PBL and Agile to Teach Artificial Intelligence to Undergraduate Computing Students. *IEEE Access*.

Deepa, M., Reba, P., Santhanamari, G., & Susithra, N. (2020). Enriched blended learning through virtual experience in microprocessors and microcontrollers course. *Journal of Engineering Education Transformations*, 34(Special Issue).

Goteti, L. P., & Madhuri, G. V. (2013, December). Assessing soft and higher order thinking skills among students using a rubric and progressive reflection. *In 2013 IEEE International Conference in MOOC, Innovation and Technology in Education (MITE)* (pp. 332-334). IEEE.

Larson, J., Jordan, S. S., Lande, M., & Weiner, S. (2020). Supporting self-directed learning in a project-based embedded systems design course. *IEEE Transactions on Education*, 63(2), 88-97.

Mandale, R., Patil, A., & Adamuthe, A. (2021). Improved Undergraduate Software Capstone Project Development with Adoption of Industry Practices. *Journal of Engineering Education Transformations*, 34(4).

Martinez-Rodrigo, F., Herrero-De Lucas, L. C., De Pablo, S., & Rey-Boue, A. B. (2017). Using PBL to improve educational outcomes and student satisfaction in the teaching of DC/DC and DC/AC converters. *IEEE Transactions on Education*, 60(3), 229-237.

Rajeshwari, K., Naarayan, B. K., & Babu, K. M. (2016). Android MOOC, Blended MOOC Intertwined with Curriculum for Outcomes-Based Education. *Journal of Engineering Education Transformations*, 30(1).

Reba, P., Susithra, N., Deepa, M., & Santhanamari, G. (2022). Effective Teaching of Electric Circuit Analysis through Jigsaw Cooperative Learning Method. *Journal of Engineering Education Transformations*, 36(1).

Santhanamari, G., Deepa, M., Susithra, N., & Reba, P. (2022). Establishing a Constructive Mentoring Scheme for Engineering Students-A Case Study. *Journal of Engineering Education Transformations,* 35(Special Issue 1).

Singh, P., & Singh, L. K. (2021). Engineering education for development of safety-critical systems. *IEEE Transactions on Education*, 64(4), 398-405.

Susithra, N., Deepa, M., Reba, P., & Santhanamari, G. (2023). Coalescing Mind Maps as a Learning Aid cum Formative Assessment Tool for Effective Teaching and Learning of Computer Architecture and Organization Course. *Journal of Engineering Education Transformations*, 36(Special Issue 2).

Vijayalakshmi, M., Bhandiwad, A., Mellikeri, K., & Nagesh, P. (2018). Transition from Conventional to Agile Process Model an Experience Report. *Journal of Engineering Education Transformations,* 31(Special Issue).