BOARD # 255: IUSE: Agile Methods Coupled with Project Based Learning to Train Mechanical Engineers in the Era of Industry 4.0

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Abstract

As the Industry 4.0 revolution reshapes manufacturing, design, and engineering processes, the role of mechanical engineers is expanding beyond traditional boundaries. Since mechanical systems are increasingly interconnected with digital technologies, training the next-generation mechanical engineers in Internet-of Things (IoT) programming and software engineering methodology is critical for meeting industry demands. However, these critical skills are often missing in traditional mechanical engineering curriculum. To address this challenge, we have modernized our curriculum by integrating IoT technologies and software engineering concepts in a new course. Specifically, we couple project-based learning and Agile methods, which represent the best practices in the IoT industry, to provide mechanical engineering students with a highly practical, hands-on learning experiences. In this paper, we present details of the Agile method component of the new course.

1 Introduction

In the era of Industry 4.0, integration of physical systems with digital technologies transforms industries and has enabled numerous opportunities for creating smart products. Both the number of IoT applications and the revenue are projected to grow significantly, based on recent market analysis forecasts [1]. Mechanical engineers, traditionally focused on the design and development of physical systems, now play a critical role in the IoT ecosystem where mechanical components are interconnected through sensors, software, and data networks. As Industry 4.0 continues to reshape industries, the next-generation mechanical engineers must be equipped with the knowledge and tools to lead the innovation. These skills empower engineers to design smart systems, adapt to evolving technologies, and collaborate effectively in multidisciplinary environments. However, traditional mechanical engineering curriculum often do not include these critical skills. To bridge the gap, we have created a new course focusing on IoT technologies, which integrates programming and software engineering skills seamlessly through project-based learning.

In this course, students learn IoT programming, which enables them to design, control, and optimize smart devices and systems. In addition, they also learn Agile methods which are essential for managing the complexity and rapid evolution of the IoT projects. Together, these

skills empower our students to design and develop innovative IoT applications, which are demonstrated in their course projects. We have offered this new course in two consecutive years [2, 3], and the results show that integration of Agile methods with course projects is a promising approach leading to effective learning.

2 Overview of Agile Method

Agile software development [4] is a flexible and iterative approach to software and product development, and it has been widely used in software industries. The Agile method emphasizes collaboration, adaptability, and customer feedback, enabling teams to deliver high-quality solutions in smaller, manageable increments rather than as a single, large release. The key principles of agile methods include: 1) iterative development: the development process is organized in small cycles (sprints) to deliver manageable increments; 2) early feedback: solicit early feedback from close collaboration between cross-functional teams, stakeholders, and customers; 3) change management: anticipate and accommodate changes in software requirement, even at the late state of the development; and 4) continuous testing and integration: increments are integrated in the system continuously, with the goal of always having a working system. In software industry, the Agile methods represent a paradigm shift from rigid, plan-driven development to a more flexible and iterative approach.

The dynamic and complex nature of the IoT systems results in frequent changes in the software component, which makes Agile development particularly effective. Specifically, an IoT application often involves hardware, software, networks and cloud infrastructure. Agile supports iterative integration of these diverse components, therefore it can ensure that hardware and software are working together seamlessly at every stage. By accommodating rapidly changing requirements, and supporting continuous improvement, Agile enables teams to deliver reliable, scalable, and user-centric IoT solutions efficiently. Therefore, in our new IoT course, we have designed a course module to integrate Agile development into the curriculum. Additionally, students have ample opportunities to practice these skills in their course projects.

3 Use of Agile Method in Class Project

Details of our new IoT course can be found in [2, 3]. At the end of the semester, student teams are assigned a class project. Each student team can either choose to build a new smart product or use a flowerpot and develop complete control software and remote dashboard for it. Each team submits a final report, gives project presentation and demo.

To implement the Agile method, we used the Trello platform, which is a free resource proven to be effective in supporting Agile learning [5]. Each team is required to (1) Select a team lead (scrum master), (2) Set up the team account and Board in Trello, (3) Add 5 initial buckets to their Board, and (4) Capture a screenshot of the Board each week throughout the project timeline. The instructor is also added to each team's Trello Board so that he can monitor team progress by looking at their Boards online. The team captures the weekly screenshot and saves it into a Word

document. For each week, they add a brief discussion about (a) What progress was made, (b) What the roadblocks were, and (c) What they need to get done in the next sprint. This document is submitted at the end of the project along with the team report and presentation slides.

3.1 Initial Buckets on the Trello Board

During the lectures about the Agile method, students are introduced to the use of these initial 5 buckets as a template to get their Trello Board started (Figure 1).

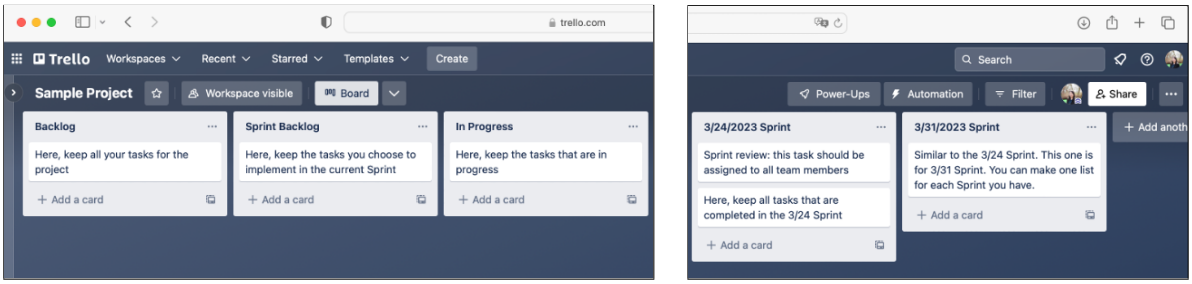


Figure 1: Initial Trello buckets to get the student Boards started.

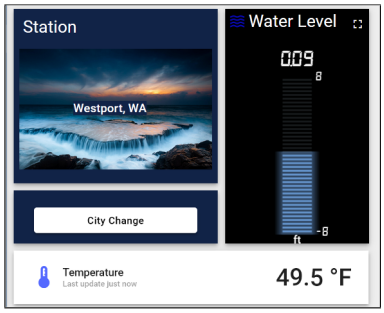
After setting up the initial buckets, students start by populating the "Backlog" bucket with all the project tasks they need to complete. Then, they move one or two tasks out of the Backlog bucket into the "Sprint Backlog" bucket. This is where the tasks to complete in the given week reside. Next, each team member takes on the task assigned to them in the Backlog bucket and moves it into the "In progress" bucket. As the tasks are completed, they get moved into the "Sprint" bucket for that week. In summary, for each sprint week, a few tasks are taken from the complete list of all project tasks (Backlog bucket) and are moved through the Spring Backlog and In-Progress buckets and finally into the Sprint bucket for that week. In Figure 1, we have two sample Sprint buckets (3/24/2023, and 3/31/2023). Each of these corresponds to a 1-week long sprint. At the end of each week, these buckets contain the completed weekly project tasks.

3.2 Sample Trello Board from a Student Team

In the Spring 2024 offering of the course, students formed seven teams [3]. Each team submitted a project proposal, which was reviewed and approved by the instructor. Each team built a different IoT device and all projects were successfully completed. As an example, here we will look at the use of the Agile method in the project of a team that built a tidal clock. The user could select one of the four locations available on the west coast. The clock retrieved real-time tide information from the NOAA servers and displayed it on a phone through its remote dashboard (Figure 2). It also had a moving tide display (blue/white ribbon in Figure 2a) and digital display for weather forecast at the selected location.

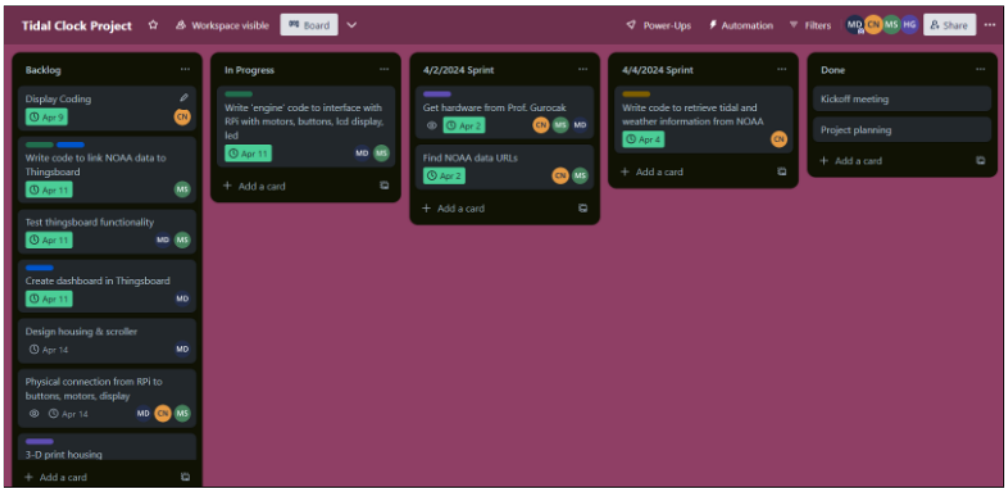
During the project, students used Trello to manage the project tasks. Figure 3a shows the initial Board where lots of tasks appear in the Backlog bucket on the left. As the project progresses, the tasks move from left to right on the Board (Figure 3b), which indicates completion of the tasks and the project.

(a) Tidal clock.

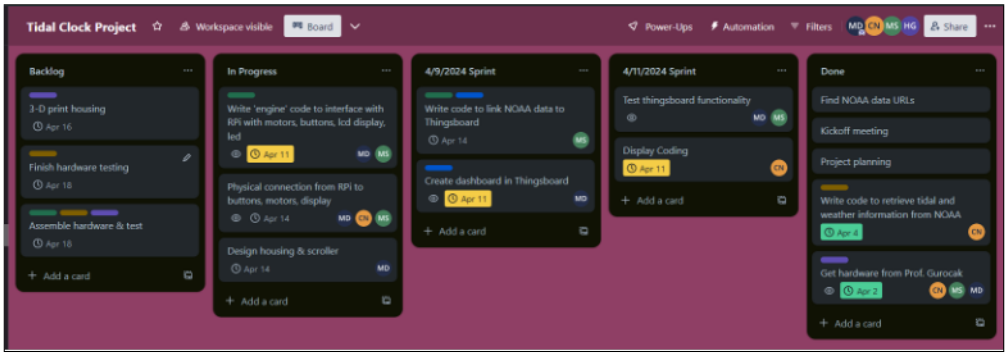


(b) Remote dashboard for tidal clock.

Figure 2: Tidal clock team project (Spring 2024): tidal clock and remote dashboard



(a) Initial Board at week 1. All project tasks are on the left of the Board.



(b) Board at week 2. Tasks are moving right through the Board as they get completed.

Figure 3: Progression of the Trello Board for the tidal clock team project.

4 Conclusions

In this paper, we presented how the Agile method was used in the team project component of a new IoT course we developed. The Agile method is popular in tech companies for software development. Mechanical engineering students learn about it for the first time in this new course. They are quickly able to grasp the concept and put it in use to manage their team projects. With the Agile method and Trello platform, all student teams successfully developed their course projects, and managed their 5-week workload and collaboration effectively. Our work shows that Agile methods can be seamlessly integrated in a mechanical engineering course. Leveraging the Agile method, students can manage complexity, respond quickly to design changes, and enhance efficiency in product development. These are essential skills which better prepare mechanical engineers for the era of Industry 4.0.

Acknowledgments

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