Integrating Agile Methodologies and Gamification for Student Engagement and Success

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Abstract: The article highlights a flexible and adaptable approach for the development of game like activities for higher education students from Politehnica University of Timisoara, Romania. The approach embraces agile methodologies to guide the iterative development process of educational games and consists of several key elements. First, it underlines the importance of defining clear learning objectives and aligning them with the game's design. Second, it encourages multidisciplinary collaboration between teachers and instructional designers to deliver relevant information to students, but also appropriate to their learning styles and needs. Regarding engineering problems and methods, students frequently encounter several difficulties. For this reason, the article attempts to provide an organized and engaging learning environment that encourages active participation and information retention. In industrial engineering, most of the students' exposure is to theoretical materials; nevertheless, there are several ways to give them practical experience with the topics they are studying. Using a comprehensive review of the literature, the article explores the pedagogical benefits, challenges, and practices associated with the use of agile methodologies in education. Agile methods are very based on collaboration, teamwork, flexibility, and participation, and help create a more relaxed learning environment to support students' increasing need for control over their learning path. Throughout regular communication and feedback cycles, students can iterate on content and pedagogical approaches, resulting in activities and games that are more engaging and effective for learning. In the end, the paper presents the conclusions of the authors on the current advantages and limitations of using this approach based on agility and game-based learning in higher education.

Keywords: Agile Education, Scrum, Game-Based Learning, Iterative Development, Sprints, Continuous Feedback

1. Introduction

This article presents an approach used by the authors to incorporate gamification into training exercises for 4th year students studying Economic Engineering within the Electric, Electronic, and Energetic field at the Faculty of Management in Production and Transportation, Politehnica University of Timisoara, specifically for the Computer-Assisted Manufacturing course. The syllabus of the Computer-Assisted Manufacturing course contains a range of topics including Manufacturing Systems, Manufacturing Planning, Models and Modelling in Manufacturing, Artificial Intelligence in Manufacturing, Agile Manufacturing, and Flexible Manufacturing Systems. Typically, when students engage in the study and analysis of manufacturing systems, their exposure is predominantly limited to theoretical aspects, as is commonly observed in many industrial engineering courses (Yiming, 2021). This article focuses on Scrum, an agile methodology widely used today, and explores its potential applications in game-based education. The significance of examining this subject lies in the mutual advantages that it offers both students and professors. When Scrum is implemented, regular feedback can be obtained, allowing for continuous adaptation between students and instructors. The degree of student dedication and the educators' flexibility or agility both have an impact on the continuing learning process (Buciuman, 2020). Furthermore, the article investigates how game-based activities might be used to incorporate concepts related to product development, including Agile and Scrum processes. Agile development concepts encourage students' problem-solving and collaborative abilities in addition to supporting their learning and work methods. The course activities' adaptable format allowed students greater autonomy and the chance to get continuous feedback on their progress.

2. Literature Review

Agile can be viewed as a philosophy that embraces flexibility, adaptability, and innovation that extend beyond its roots in software development. Over the years, agile methodologies have proven their value in various domains. Agile project management techniques, often known as flexible product development methodologies, use strategies that enable affordable modifications in contrast to traditional project management approaches that strictly follow original plans (Buciuman et al., 2012).

Due to the successful application of Agile methodologies in the management of software development teams and projects, researchers recognised the potential to adapt them to the educational context (Dewi & Muniandy, 2014; Salza et al., 2019). Initially, El-Abbasy et al. (2010) proposed a framework for applying agile methods in computer science education. He created an analogy between software development and the educational process. Subsequently, it was discovered that Agile methodologies were equally effective in teaching other subjects, such as mathematics (Duvall et al., 2017). Given that every student has different abilities and learning styles, not all students in a classroom will be able to grasp concepts at the same pace or using identical methods. Considering this diversity, teachers must be aware of these varying learning needs and be prepared to adapt their approach accordingly, rather than following rigidly to a predetermined plan (Buciuman, et.al., 2012). Translating Agile values into the classroom involves aligning the principles of Agile with the dynamics and requirements of an educational environment.

Several studies have demonstrated the effectiveness of implementing Agile methodologies also in online courses, as presented in (Salza et al., 2019). The findings revealed that the integration of Agile strategies within project-based learning facilitated effective team coordination and project management. With this approach, the instructor took on the responsibilities of a supervisor and a facilitator, assisting the students while they worked on the project and guiding them through an iterative learning process that improved their learning outcomes over time.

The directions in which agile can impact the learning process are described below:

1. Iterative and incremental Learning: agile promotes an environment where students learn and progress in small steps. Instead of focusing on long-term plans or a rigid curriculum, an agile education approach encourages continuous improvement and feedback loops.
2. Flexibility and adaptability: teachers can adjust their strategies and content, based on student feedback and emerging trends. This allows the creation of personalised learning experiences that support the needs and interests of the individual student.
3. Collaborative learning: in an agile education setting, students work together on projects, solving problems, and sharing knowledge. Collaborative learning fosters communication, critical thinking, and collaboration between students. Especially in the Romanian educational system, teamwork and collaborative work skills are not adequately supported throughout learning activities, and an agile approach can help minimize this weakness.
4. Student empowerment: agile empowers students by giving them more autonomy and ownership over their learning process. Students contribute by setting goals, planning their learning activities, and monitoring their progress.
5. Continuous feedback and improvement: agile encourages a culture of continuous feedback and improvement in which teachers and students provide regular feedback collaboratively shaping the educational experience.
6. Agile tools and techniques: agile offers a variety of tools and techniques that can be adapted to education. For example, Kanban or Scrum boards can be used to visualize and manage learning tasks, retrospective sessions can be held to reflect on learning experiences and make improvements.
7. Learning from failures: agile education aims to encourage a growth mindset by embracing mistakes as opportunities for learning and improvement. Students are encouraged to experiment and learn from their experiences, fostering resilience and a positive attitude toward challenges.

By adopting agile principles and practices in education, teachers and students can create a more dynamic, adaptive, and student-centered learning environment.

When measuring the impact of Agile practices in education, several Key Performance Indicators (KPIs) can be used to assess the effectiveness and success of the implementation. A list of KPIs used to measure the impact of Agile on education is listed as follows:

1. Student Engagement: measures the level of student engagement by monitoring attendance rates, participation in class discussions and activities, and completion rates of assignments. Higher participation indicates that Agile practices encourage active student participation in the learning process.
2. Learning Outcomes: this KPI assesses the extent to which students achieve the desired learning objectives and acquire the necessary knowledge and skills. It can be measured through tests, exams, projects, and other assessments that evaluate student understanding and application of the taught concepts.
3. Student Satisfaction: conduct surveys or gather feedback from students to assess their satisfaction with Agile teaching methods.

4. Time Management: assess students' ability to manage their time effectively by comparing their ability to meet deadlines and complete tasks within given time frames.
5. Collaboration and Teamwork: evaluates the extent to which agile practices promote collaboration, teamwork, and communication among students. It can be assessed through observations, self-assessments, or feedback from students.
6. Adaptability: monitors students' ability to adapt to changes and adjust their learning approach based on feedback and evolving requirements. The KPI can be calculated as a ratio between the number of task adjustments the student team completed during a predefined period and the total number of adjustments required for that interval.
7. Continuous Improvement: measures the number and impact of improvements made to the curriculum, teaching methodologies, and learning materials due to the adoption of agile practices. This could include the incorporation of student feedback, improvements to learning resources, or changes to instructional techniques.
8. Innovation and Creativity: assesses students' ability to think creatively, generate innovative solutions, and apply critical thinking skills. The KPI measures the ability of students to approach problems from different perspectives and to propose new ideas (Elizondo, et al., 2010).

It is important to note that the KPIs must be tailored to the specific objectives and context of the educational institution or program. The selection of KPIs should align with the course goals, data collection should be carried out consistently, and insights should be used to make informed decisions and improve the implementation of agile practices in education.

2.1 Serious Games to use Agile in Education

Game-like activities have been widely used in Agile Engineering Education to improve learning outcomes and engagement. By incorporating elements of gamification, educators can create a more immersive and interactive learning environment. These activities often simulate real-world scenarios and challenges that students may encounter in professional settings. Through these game-like experiences, students can apply Agile principles, such as collaboration, iteration, or problem-solving, dynamically and enjoyably. Ultimately, game-like activities in Agile Engineering Education offer a practical and engaging approach to prepare students for real-world Agile practices in the field (Buciuman, 2021). There is a growing shortage of specialists in the labour market, and students need new approaches to learning activities that incorporate ways of how the industry approach works and offer an experience closer to what happens in real life. Gamification can vary depending on the perspective, but certain elements commonly exist. These include the presence of rules, goals, players (either individual or team-based), and often the use of physical or virtual artifacts such as cards, dice, or whiteboards. Games are designed to provide entertainment and can involve elements of competition, although they can also promote cooperation through team-based gameplay (Parson, 2014). Figure 1 presents the use of game-like activities in education as a comprehensive system made up of three interrelated pillars: learning and teaching, gaming, and simulation.

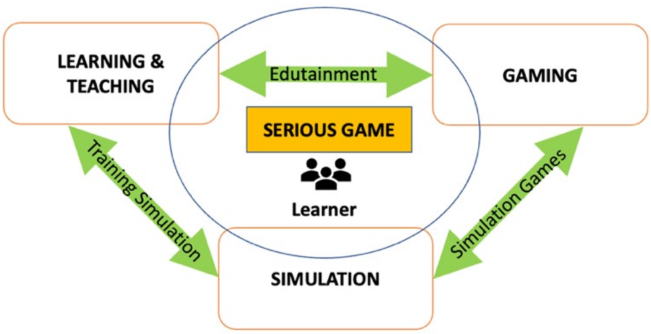

Figure 1: Serious game – a definition model (adapted from Buciuman, 2021)

In Figure 1 the focus is on the learner, highlighting the distinctiveness of training simulation, simulation games, and Edutainment as separate concepts. The Learning & Teaching component encompasses both the learner's perspective and the instructor's viewpoint, considering their respective roles and objectives (Buciuman, 2021).

Game-like activities in education are also known as Serious Games or Edutainment (Yiming, 2021; Laamarti et al., 2014). Edutainment is a term that refers to the combination of education and entertainment. It involves the use of entertaining and engaging content and activities to facilitate learning and educational outcomes. The primary goal of education is to make the learning process enjoyable and engaging, thus increasing motivation and knowledge retention.

The model for defining and categorising serious games in Figure 1, provides a structured framework for defining and categorising serious games. It outlines key components and characteristics that contribute to the experience of serious games:

1. The Serious Purpose: Serious games have a clear educational or training objective beyond pure entertainment. They aim to deliver specific learning outcomes or impart practical skills.
2. The Game Element: Serious games incorporate interactive elements typical of traditional games, such as rules, challenges, and rewards. These elements engage the user and provide a pleasant experience.
3. Contextual Relevance: these games are designed to address real-world problems or simulate specific scenarios relevant to the learning or training context. The content and context are following the intended educational or training goals.
4. Active Participation: Serious games require active participation of the user, who makes decisions and solves problems.
5. Feedback and Assessment: Serious games provide immediate and constructive feedback on the user's actions and performance. Feedback helps learners track their progress, understand their strengths and weaknesses, and make improvements.
6. Progress and Challenge: Serious games offer a sense of progression and challenge by gradually increasing the difficulty level or complexity of the tasks.
7. Integration of Learning Content: Serious games can seamlessly integrate educational or training content into the gameplay. Instructional materials, simulations, and assessments can be included, providing a cohesive learning experience.
8. Learner-Centred Design: Serious games are designed with the learner's needs and preferences in mind. May include different learning styles and the ability to personalize the experience to meet specific learning requirements.

Serious games can be an effective tool to integrate agile principles and practices into education. They promote active learning, teamwork, problem-solving, and critical thinking skills. Additionally, serious games create a safe environment for students to experiment with agile practices and gain a deeper understanding of their benefits and challenges. Generation Z students are digital natives and focused on practical study methods with direct implications for real life (Iftode, 2019). By incorporating serious games into agile education, students can develop a practical understanding of agile methodologies and improve their ability to apply them in real-world scenarios.

3. Methodology

The main purpose of this research was to explore and describe the implementation of an agile approach using game-like activities for 4th year students from the Faculty of Management in Production and Transportation at Politehnica University of Timisoara.

The agile methodology used was Scrum, a project management technique that guided students through the planning, execution, and review stages of a manufacturing project. To comply with the curriculum, students should assimilate concepts related to planning, resource allocation, estimates, assigning tasks, manufacturing models, productivity, and problem-solving. Figure 2 shows the agile principles applied when using agile for engineering courses.

Figure 2: Agile principles embedded in engineering courses

Each of the steps in Figure 2 fosters the iterative and collaborative Scrum mindset, allowing students to develop their engineering projects efficiently and effectively, as follows:

1. Agile Project Planning:
    - Identify the engineering project or problem that students will work on throughout the semester;
    - Break down the project into smaller tasks or milestones that can be completed within shorter iterations (Sprints) and prioritize tasks based on their importance and dependencies;
2. Sprint Planning:
    - At the beginning of each Sprint, collaborate with the students to set goals for the duration of the Sprint (e.g., one week).
    - Assign tasks to students based on their skills and interests, considering the project requirements;
    - Discuss and estimate the effort required for each task using story points or other estimation techniques;
3. Daily Stand-Up:
    - Conduct short daily stand-up meetings in which each student briefly shares his progress, the challenges he faced, and the plans for the day;
    - Encourage students to communicate any obstacles or issues they encounter and collaborate to find solutions;
4. Iterative Design and Development:
    - Encourage students to apply iterative design and development processes, such as Agile Engineering Practices or Rapid Prototyping;
    - Break down larger engineering tasks into smaller subtasks that can be completed within a Sprint;
    - Regular review and evaluation of the progress and quality of the design;
5. Collaborative Teamwork:
    - Assign students to project teams, promoting collaboration, communication, and shared responsibilities;
    - Encourage regular team meetings to discuss progress, exchange ideas, and coordinate efforts;
6. Sprint Review and Feedback:
    - At the end of each sprint, conduct a review in which the students showcase their progress and outcomes;
    - Provide feedback on their work, highlighting strengths and areas for improvement;
7. Retrospectives and Process Improvement:
    - Conduct retrospectives at the end of each Sprint to reflect on engineering processes, teamwork, and project outcomes;
    - Discuss what worked well, and challenges faced, and identify areas for improvement;
8. Documentation and Reporting:
    - Encourage students to maintain documentation and progress reports, capturing their design decisions, challenges, and solutions;
    - Use project management tools or version control systems to track and manage project artifacts;

For the agile manufacturing project, students were asked to develop a solar power bank project, implemented in Autodesk Thinkercad, over a seven weeks period. Agile values and renewable energy scenarios were covered using the "Agile Penny Game" and the "Siemens Energy Island" game. This was an engaging and educational way to learn more about renewable energy and sustainable technologies used in manufacturing. The important aspects of the project were the game-like activities they had to carry out and the fact that the entire activity was developed based on agile principles. In line with agile principles, the project was developed iteratively, in Sprints of one week each. The first week was assigned to activities to learn about agile and renewable energy. Before the beginning of the first Sprint, the teacher explained the learning goals and how agile can help support the achievement of these goals (Buciuman, 2020). For students, it was the first contact with agile methodologies, especially with Scrum. To facilitate understanding of the main concepts of Agile and Scrum, students played the "Agile Penny Game". The "Agile Penny Game" is a very popular agile game and is generally used to teach agile teams, the impact of large workloads on productivity, and the importance of self-organization. To play the game, the students used a Miro virtual board as the one in Figure 3.

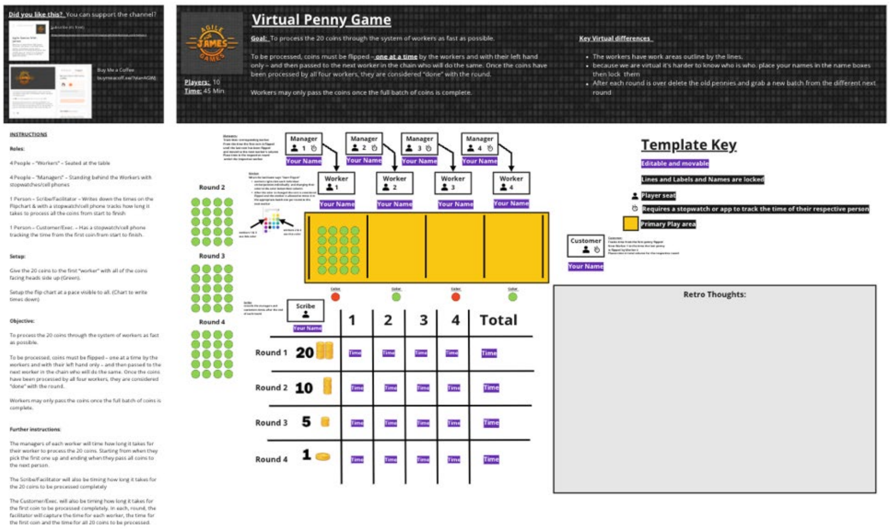

Figure 3: Virtual Agile Penny Game Miro board

Students were organized into teams of four members, with one of the members receiving the role of the Scrum Master. The teacher played the role of the Product Owner. She assumed multiple responsibilities in the agile framework, including defining learning objectives, specifying deliverables, and evaluating educational outcomes. The teacher was responsible for developing the list of tasks in the project. These tasks, also called user stories were used to organize the solar power bank features into a Product Backlog. Due to scheduling restrictions, each Sprint started with a planning meeting and included two daily meetings each week. To facilitate reflection at the end of each Sprint, Miro boards were utilized. Additionally, the teacher provided feedback and offered suggestions to improve the overall learning process.

To have a game-like approach when learning more about the context of the renewable energy sector, the students played the "Siemens Energy Island game". Students found it easy to understand the various ways of producing energy and their advantages and disadvantages. They were reminded that the game was intended to help them generate ideas to develop their solar bank project. It also explained how solar panels capture sunlight and convert it into electrical energy.

All the features of the solar power bank were organized in the Product Backlog, serving as a comprehensive list of requirements, enhancements, and bug fixes for the project. The items in the Product Backlog are typically described as user stories that capture the user's perspective and desired functionality. Each item in the backlog is assigned an estimate, often using story points, to indicate its relative complexity or the effort required. Some examples of tasks from the Product Backlog are shown in Figure 4.

PRODUCT BACKLOG

User Story ID	User Story	Estimate (size)	Priority	Sprint	Task owner	Estimated effort
US001	As a user I need to be able to recharge wireless compatible electronical devices	Medium	5	2	Student 1	7
US002	A a user I need to be able to recharge the power bank with solar energy	Large	4	4	Student 2	21
US003	As a user I want to have a light and portable power bank	Medium	4	2	Student 3	13
US004	As a user I want to have a LED to report battery level	Small			Student 4	3
US005	As a user I want to have a USB port to connect other electronic devices	Small			Student 5	3

Figure 4: Solar power-bank sample Product Backlog

Each of the Sprints began with a Sprint Planning Meeting during which the students determined the amount of work they aimed to complete within the Sprint. The chosen educational tasks were converted into a Sprint

Backlog. Before the first Sprint, the teacher Product Owner instructed students on how to estimate work during a Sprint. Initially, students struggled with accurate task estimation, but this self-regulating process allowed them to gradually improve their ability to complete all learning activities in the Sprint Backlog after one or two Sprints. For task estimation, the students used the Planning Poker Game (Cohn, 2005) with a set of virtual cards.

During each one-week Sprint, students conducted two Daily Meetings. The decision to have only two such meetings and not every day was taken by mutual consent between the students and the teacher Product Owner. Everyone agreed that it was not feasible to have a meeting every day since the students had other subjects to deal with at the same time. Figure 5 shows a board based on a Miro template that the students used to run the retrospective meetings at the end of each Sprint.

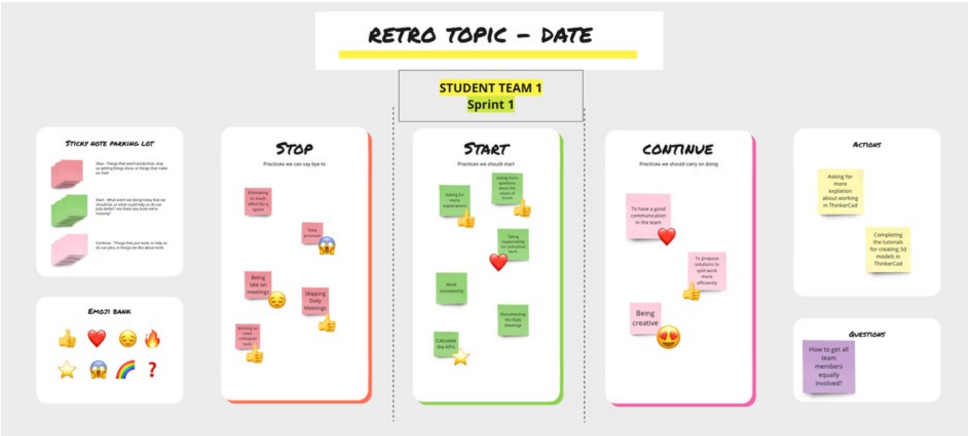

Figure 5: Miro Retrospective Meeting Board for Student Team 1

4. Results and Discussion

The activities described in the paper are intended to provide an overview of the experience of applying agile methods to an engineering course and to offer a perspective of using game-like activities to provide a more engaging learning experience for students. Following teacher observations and feedback received from students, the use of games such as "Planning Poker", "Energy Island" or "Penny Game" allowed them to participate in the activities and embrace concepts more easily. It is important to mention that the balance between fun and education in serious games can be quite subjective and that the teacher is responsible for finding the right approach to fulfil the course learning objectives. There were quite significant differences between the teams' perceptions regarding the work they felt they could complete during a Sprint. Six out of eight teams failed in the first Sprint due to a lack of understanding of the fact that agile is based on an incremental approach and that every Sprint is relevant.

For the students, estimating the amount of work and organizing their approach for each Sprint represented their biggest obstacle. In the first two Sprints, the Scrum Master student struggled to keep the team respecting the principles of the Scrum methodology. They constantly needed to be reminded that the concept of "Done" for a task means that the project they were working on was not just a theoretical exercise to learn agile, but also had the goal of developing a possible viable product in a hands-on project in Autodesk Thinkercad. To provide a brief overview of the agile approach and to summarize the overall performance and engagement of students, the following KPIs were used:

1. The average task completion rate (%): measuring the average percentage of tasks completed by all student teams within each Sprint;
2. The average quality of deliverables (1-5): used to evaluate prototypes for each Sprint and the final product (solar power bank). Rated on a scale from 1 (poor) to 5 (excellent);
3. The average meeting participation rate (%): used to measure the average attendance at Daily Stand-ups, Sprint Planning, and Retrospective meetings by all student teams within each Sprint;
4. The average feedback incorporation rate (%): used to measure the ability to incorporate feedback from Sprint reviews and improve subsequent iterations for all the student teams within each Sprint;
5. The average team collaboration score (1-5**:** used to measure the average level of teamwork and communication within teams, rated on a scale from 1 (poor) to 5 (excellent) for each Sprint;

6. The average learning outcomes (Quiz Scores %): measuring the average percentage of understanding of agile concepts and renewable energy principles, measured through quizzes for the students enrolled in the course within each Sprint.

Table 1 provides a clear numerical representation of the student performance and engagement over the seven weeks, showing how the student's work evolved over the seven Sprints.

Table 1: KPIs used to measure student performance during the Agile project

Sprint	The average task completion rate (%)	The average quality of deliverables (1-5)	The average meeting participation rate (%)	The average feedback incorporation rate (%)	The average team collaboration score (1-5)	The average learning outcomes (Quiz Scores %)
1	50	2.5	40	-	4	50
2	60	3	60	65	5	64
3	70	3.5	85	70	5	70
4	75	4	85	85	4	78
5	80	4	90	92	5	84
6	80	4.5	100	90	4.5	88
7	95	4.5	100	100	5	95

For the first Sprint, the average task completion rate was only 50%, as the students became accustomed to agile principles and did not realize in the first phase the importance of attending meetings and working constantly. The average quality of deliverables starts at 2.5, showing room for improvement. The average feedback incorporation rate could not be calculated in the first Sprint, because students received feedback only at the end of each Sprint. As the students understood their roles better, the average meeting participation rate and the average team collaboration score increased, which was reflected both in the quality of the tasks they completed in each sprint and the learning outcomes, reaching 95% at the end of Sprint 7. The steady increase in learning outcomes (Quiz scores) indicates a successful understanding and application of the concepts taught.

Agile methods are very based on collaboration, teamwork, flexibility, and participation. That was one of the main reasons why Student Teams with a good balance between creative thinking skills, communication, and organizational skills performed better than those with gaps in working as a team. It was a challenge that at the end of every Sprint they had to reflect on their participation during the Sprint, but also to offer consistent feedback on the activity of other team members. Another important aspect to mention is that Student Teams were randomly created, and students needed to work with colleagues with whom they had never worked before. It can be concluded that the agile approach was more easily assimilated by teams with well-developed soft skills, rather than teams with good technical knowledge. Keeping in mind that the project was developed using Scrum, the game-like activities that the students carried out implied a lot of decision-making, adaptability, and teamwork spirit. Based on student feedback, it was noticed that integrating gaming into their learning experience had a positive impact. They expressed that this approach made the learned concepts more tangible and accessible. However, some students faced initial challenges due to the limited time it took them to learn Agile and Scrum, which made them feel a bit overwhelmed, but this iterative approach ensured that the project path remained aligned with the needs and preferences of the target audience.

Furthermore, the agile gamified approach emphasized adaptability and responsiveness. Choosing this approach for the Computer-Assisted Manufacturing course enabled running regular retrospectives and feedback loops and incorporating new educational concepts or technological advancements from one Sprint to another.

However, even if agile methodologies offer numerous benefits, it is important to acknowledge that there are also some limitations and challenges associated with the implementation of an agile approach in education. There may be some limitations to the availability of some resources and curricula. Agile methodologies often require a significant investment of time and effort, and educators can face challenges in terms of training, access to technology, or availability of support systems. To enhance future experiences in using serious games for engineering courses, certain aspects will be considered to improve the measurement of student productivity and sustainability in developing manufacturing projects. These considerations aim to enhance the overall learning outcomes and assess student work. Nevertheless, it should be remembered that, for example, in manufacturing, teamwork skills and building strong work relationships with colleagues are extremely important, and innovative teaching methods are no longer optional but rather a necessity for the development of students' professional skills. Engineering courses are still crucial for developing a technical education.

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