DOI: 10.21134/n4srvs88

CYTEF XII Congreso Ibérico y X Congreso Iberoamericano de Ciencias y Técnicas del Frio
Universidad Miguel Hernández de Elche
26-06 28-06/2024
UNIVERSITAS Miguel Hernández

SCRUM METHODOLOGY FOR LEARNING: APPLICATION ON REFRIGERATION COURSE

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Abstract: *This paper discusses the applicability of an agile project management methodology called "Scrum" in postgraduate engineering studies, specifically for managing a refrigeration project. The main objective is to convert an educative project into a real-life project with different challenges and objectives. In this scenario, the teacher plays the role of the product owner, who creates a product backlog containing the main requirements for reaching an ultimate goal by groups of students called "development teams." The team leader, or Scrum master, organizes meetings, controls the workflow, and acts as a link between the team and the product owner. Within the Scrum framework, the project is divided into short work cycles of two weeks named "sprints." After each sprint, an intermediate result should be released and reviewed in accordance with the objectives established. This innovative methodology is expected to teach the students many values, such as awareness, focus, commitment, courage, and respect, besides promoting many soft, hard, and metacognition skills inside them.*

Keywords: Scrum methodology, University studies, Scrum master, Sprints, Development team

1. INTRODUCTION AND SCRUM METHODOLOGY FRAMEWORK

Scrum methodology was initially developed in 1990 as an agile project management framework that helps the development team build and manage the work through a set of values, principles, and practices [1]. The term "*Scrum*" or "*Scrummage*" comes from the rough-and-tumble game of rugby. Huddles, or Scrums, are formed by the forwards from one side pushing against the forwards from the opposing team (Figure 1). The ball is then thrown into the midst of this tightly condensed group of athletes. Although each team member plays a unique position, all team members play both attacking and defending roles and work together to move the ball down the field of play. Like rugby, Scrum relies on talented people with varying responsibilities and domains who work closely together in teams toward a common goal [2].

Figure 1. Scrum or scrummage of rugby [3].

Scrum methodology is based on three main pillars: *roles*, *ceremonies*, and *artifacts* [4]. The *product owner* is one of the main roles who initiates the project, defines its objectives, and provides the working teams, or *development teams*, with a list of requirements (product backlog). He also guides the development teams and monitors their progress. A typical development team consists of 3-6 members, of which the *Scrum master* plays a key role in linking his team with the product owner. The other responsibilities of a Scrum master include organizing the work and assigning tasks for the team's members or developers, planning and scheduling regular meetings during each sprint (sprint is a period of 2-4 weeks), and summarizing the obtained results, after each sprint, in a final report or a presentation.

To keep on the right track, development teams use *ceremonies*. *Sprint* is the key ceremony in which a specific objective of the project is satisfied toward the project's final goal. They are fixed events of one month or less; at the end of it, the team should release an intermediate product, result, or report. It is finished with a *review ceremony* in which the product owner comments on the results, asks for modifications, or assesses the quality of the product. After the review ceremony, the *sprint backlog* of each team is updated based on the feedback of the product owner; then, a new sprint period starts until the final goal of the project is achieved. During each sprint, daily short meetings (15-30 minutes) are organized (*Scrum meetings*). The main objectives of Scrum meetings are to inspect the progress toward the sprint goal and to address the challenges and potential problems in the early stages.

Artifacts are tools used by the development teams to visualize and track their progress. One of the main artifacts is the *product backlog*, which contains the main items or requirements needed to achieve the project's main goal. The Scrum master is responsible for describing and organizing these requirements based on their priority. Another key artifact is the *Scrum backlog* which is used by the development team to organize the sprint's tasks into three typical columns: *to-do*, *doing*, and *done,* to reach the sprint's goal. In summary, Scrum methodology generates an environment that starts with a main goal, stimulates mutual collaboration, and encourages feedback. Figure 2 shows the framework of applying a typical Scrum method to achieve the project's goal.

From the previous discussion, one can notice that the Scrum method can also be implemented in the learning process. It can provide the student with the necessary tools to keep focusing on the main goal, decrease the complexity of the project or tasks, and foster collaboration with his colleagues.

To the best of our knowledge, there are few studies in literature that deal with applying the Scrum method in the learning process. For example, a Scrum method for learning in a classroom of English studies at the University of Malaga (Spain) was developed and discussed by Jurado-Navas and Munoz-Luna [5]. It was implemented in a group of undergraduate students majoring in the humanities. The authors concluded that the Scrum method enhances communication, organizational, and self-confidence skills during the progress of the project. Also, they noticed flexibility in different final solutions delivered by the students. Vogelzang et al. [4] and [6] investigated the results of applying the Scrum method on students and teachers.

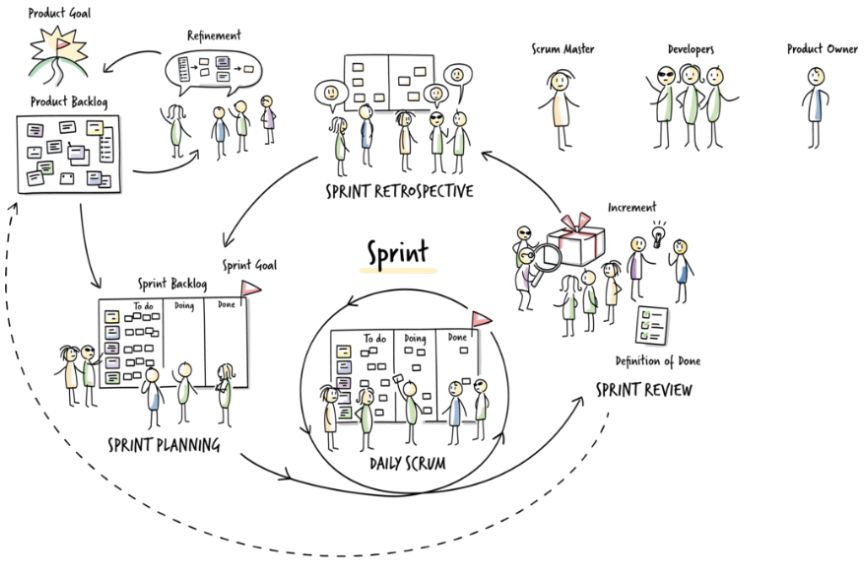

Figure 2: Scrum methodology framework [3].

The method was applied to a context-based chemistry course for high school students in grade 11. The results showed that the Scrum ceremonies and artifacts facilitate the students' collaboration and self-regulation. However, the authors pointed out that applying the Scrum method in the classroom puts high demands on teachers during the preparation and supervision.

One of the motivations for implementing this work is the lack of studies regarding applying Scrum methodology in learning, especially in postgraduate engineering studies. Another important motivation is that in engineering studies, it is very common to develop a product or project related to real applications. In this context, Scrum methodology could offer a very beneficial framework since it simulates in a more realistic way how students will face this type of work in real life. The main objective of the current study is to investigate and discuss the application of Scrum methodology in a postgraduate course that deals with designing cold rooms and refrigeration systems at the Universitat Politècnica de València (UPV). The Scrum method's roles, ceremonies, and artifacts are selected, defined, and detailed to reach a certain goal within the selected course. Finally, the key findings and recommendations are summarized to guide any teacher in a similar field on how to implement this innovative method in learning and what the expected outcomes are for the students.

2. SCRUM LEARNING METHODOLOGY IN POSTGRADUATE STUDIES

2.1. Defining the course and the project's main goal

As mentioned before, the idea is to apply the Scrum learning methodology to the course entitled "Industrial and Commercial Refrigeration" (FCeI), which is an elective course within the master's degree in "Energy Technologies for Sustainable Development" (MUTEDS) provided by the UPV [7]. The course is taught in the second semester and has ECTS credits of 4.5. It is divided equally between theory and practice. The main objectives of the course are:

- To design cold storage rooms based on Spanish legislation.
- To size and analyze the refrigeration cycle's components and accessories.
- To select and compare refrigerants and their regulations.
- To be familiar with industrial and commercial refrigeration systems.
- To understand how the control of refrigeration systems is implemented.
- To do a techno-economic study of refrigeration systems.
- To know the different strategies for energy saving in the field of refrigeration.

Based on this, an opportunity was found to convert a part of the course that deals with designing a commercial cold room for storing vegetables and fruits into a real-life project to prepare the students for challenges and obstacles during their professional careers as engineers. To do so, the students are divided into working groups, and each one has a main goal to "*design a cold room to store a specific product at a given temperature and*

specific location within Spain". The details of adopting and tailoring the Scrum learning methodology on this project are discussed next.

2.2. Assigning Scrum team roles

Firstly, the teacher plays the role of the *product owner*, who is responsible for preparing the project objectives and the total number of sprints to achieve the main goal for each group. He is also responsible for specifying the required number of development teams and their members based on the total number of students. The proposed course usually has an average of 15 students, so five groups are assigned, and each group has 3-4 students as developers. Secondly, five *Scrum masters* are nominated by their classmates based on their leadership and communication skills. The product owner prepares and distributes a self-evaluation list that contains the personal skills and abilities that each student can provide for his team. For example, planning, numerical programming, arithmetic, professional writing, and presentation skills. Each student will evaluate himself regarding each skill based on a level from one to five, for example. Finally, these lists are given to the Scrum masters so they can select their *development team* members based on the required needs and tasks that they expect within the project. It is worth mentioning that there are no sub-groups or hierarchies within a scrum team. The members of the Scrum team are cross-functional; they are also self-managing, meaning they internally decide who does what, when, and how [8].

2.3. Preparing Scrum ceremonies

Once the Scrum masters are assigned and their development teams are created, the product owner starts to prepare the number of *sprints*, their duration, and the goal of each one, as seen in Table 1. It is assumed that the students have the theoretical and technical data required for each sprint based on the planned theoretical classes during the course. The Scrum master is responsible for organizing the daily or regular *Scrum meetings* with his development team, planning the sprint to reach the goal in time, organizing the tasks and responsibilities, and keeping in regular contact with the product owner to clarify any missing information or doubts. To mimic real-life situations, the product owner could interfere within the sprint to provide the Scrum master with missing information or change some project inputs. This will generate challenges for the development team, fomenting dynamic thinking and continuous seeking for alternative solutions. At the end of the sprint duration, each team should release the sprint's goal. This could be in the form of a written report or PowerPoint presentation. The product owner reviews each group's release. To do so, individual meetings with team members are organized to discuss the results and refine the outputs (*sprint review*). At this ceremony, the teacher tries to answer these questions. Did students understand the main refrigeration concepts that were used to accomplish the sprint assignments? Were there any misconceptions or ambiguities present? Were all the team members engaged equally in the tasks during the sprint? Based on the answers to those questions, the teacher is free to accept or reject the sprint release. In the case of accepting, the development team can proceed to the next sprint; otherwise, the team should replan the sprint again and try to reach the required goal.

Table 1: Preparation of sprints with the proposed project.

Sprint Number	Duration	Sprint Goal
1	2 weeks	Cold room dimensioning and cooling capacity calculation.
2	2 weeks	Reviewing the legislation for selecting the proper refrigerant/s.
3	2 weeks	Sizing and selecting the refrigeration cycle's components.
4	2 weeks	Techno-economic analysis of the refrigeration installation.

2.4. Establishing Scrum artifacts

As discussed before, the main artifact of Scrum methodology is the *product backlog*, which contains the list of requirements to reach the ultimate project goal. Figure 3 shows a partial product backlog containing the main goal of the project and Sprints 1 and 2 goals and requirements. As mentioned in Section 2.3, the product owner could intentionally provide the Scrum master with ambiguous or missing data to simulate real-life challenges. For example, during Sprint 1, the product owner could, on the one hand, modify the total room capacity, the product replacement rate, or the number of working persons; and on the other hand, he can add new information, such as the type of machinery or the required lightning intensity inside the room, etc.

a. Main project goal:

To design a cold storage room in Valencia to store 100 tons of tomatoes at 5 °C.

b. Sprint 1:

b.1. Duration: 2 weeks

b.2. Sprint's goal: *To size an adequate cold room and calculate the required cooling capacity.*

b.3. Inputs/requirements:

- Input product temperature: 20 °C.
- Room capacity: 100 tons.
- Replacement rate: 10%/day.
- Working people: three.
- Reviewing the Spanish legislation for designing cold rooms.

c. Sprint 2:

c.1. Duration: 2 weeks

c.2. Sprint's goal: *Reviewing the legislation for selecting the proper refrigerant/s.*

c.3. Inputs/requirements:

- Reviewing the Spanish and European protocols and legislation regarding the approved refrigerants.
- Toxic refrigerants are not allowed due to the nature of the application.
- A detailed comparison study between potential refrigerants is required, considering the degree of flammability and the coefficient of performance, etc.

Figure 3. An example of a product backlog presented to a development team.

In the first Scrum meeting of the sprint, the development team should convert the corresponding product backlog into a *sprint backlog*, which contains the sub-tasks within the sprint organized based on their priorities. For example, the Sprint 1 backlog could be as follows:

- Reviewing the Spanish legislation for designing cold rooms.
- Revising the room requirements and its orientations.
- Preparing Valencia's meteorological data to select the design point.
- Calculating the tomatoes' properties, such as the moisture content and respiration rate, etc.
- Estimating the expected workers' metabolic rate based on their activities and determining how many hours they will remain in the cold storage room.
- Selecting and evaluating thermal resistance for construction material and isolation.
- Selecting the proper tool to simulate the cold room and evaluate the cooling load.
- Summarizing the results in a short report or presentation as a sprint release.

The Scrum master is the one responsible for updating this backlog based on the tasks to be done, in progress, and finished. He also supervises the work progress to ensure that the tasks are going as scheduled to avoid any delay. During the sprint, any missing data or unclear information in the backlog should be fulfilled by contacting the product owner.

Once the development team fulfilled all the sprint releases in time and acquired the acceptance of the product owner, the ultimate project goal is assumed to be reached, which is the successful design of a cold storage room. This project is planned to have 30% of the final note, which is distributed based on the good collaboration between the team members, respecting the time schedule of ceremonies, the quality of different releases, the good management of artifacts, and finally, the team's commitment to reach the project goal.

3. CONCLUSIONS

The current paper shows a detailed plan to implement the Scrum learning methodology into a postgraduate refrigeration course in the UPV. The three key pillars of Scrum methodology, *Scrum team roles*, *Ceremonies*, and *Artifacts*, are tailored to fit the requirements and nature of the mentioned course. The main conclusions of this study are summarized as follows:

- The Scrum learning methodology fits well in the postgraduate course under study since the FCeI course has a practice part that could be modified to mimic a real-life refrigeration project full of challenges and surprises. For example, the product backlog is something that is often defined in a general way by the client at the beginning of the project. However, it is not something rigid. It usually evolves as the project advances based on the intermediate released results after each sprint. Furthermore, many times, these specifications and requirements are not completely defined or could be ambiguous at the beginning of the project, and later, the client or product owner can interfere in the middle of any sprint to modify or add something new.
- This should be the first application of Scrum methodology in the MUTEDS program. It is planned to be applied next academic year (24/25), and it should take two months to finish the sprints and present the project's final goal.
- Scrum is a very useful agile and dynamic methodology that teaches students five main values: *openness and awareness* of the Scrum team about the whole work and the expected challenges, *commitment* of the team towards achieving the goals and supporting each other, *focus* on realizing the required tasks in each sprint, mutual *respect* of team members considering them capable and independent, finally, *courage* to work in a tough and challenging environment, and to propose out-of-the-box solutions.
- This methodology is expected to foster different skills in the students. Soft skills, such as time management, stress management, and critical thinking. Hard skills, such as project management, data analysis, and software knowledge. Metacognition skills, such as task orientation, definition of goals, and self-evaluation.
- Finally, to implement the Scrum methodology correctly, the teacher needs time and effort to develop adequate ceremonies and artifacts that help him, as well as his students, to reach the desired goal from the course. Also, a professional development and planning tool, such as Microsoft Planner, is recommended to facilitate the supervision and control of the time schedule of sprints and releases of different development teams.

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