



ISSN: 2230-9926

Available online at <http://www.journalijdr.com>

# IJDR

*International Journal of Development Research*  
Vol. 15, Issue, 09, pp. 69116-69120, September, 2025  
<https://doi.org/10.37118/ijdr.30131.09.2025>



RESEARCH ARTICLE

OPEN ACCESS

## INTEGRATIVE ENGINEERING PROJECT AND THE AGILE SCRUM FRAMEWORK

**\*Ciro Martinez Oropesa**

Universidad Autónoma Occidente, Colombia

### ARTICLE INFO

#### Article History:

Received 22<sup>nd</sup> June, 2025  
Received in revised form  
14<sup>th</sup> July, 2025  
Accepted 24<sup>th</sup> August, 2025  
Published online 30<sup>th</sup> September, 2025

#### Key Words:

Project Management; Cooperative learning, Scrum, Integrative engineering project, SCRUM ceremonies, Project Based Learning (PBL).

**\*Corresponding author:**  
**Ciro Martinez Oropesa**

### ABSTRACT

The research evaluated the effectiveness of cooperative learning and the development of soft skills within the framework of an integrative engineering project, managed through an agile framework (Scrum). The methodology consisted of a quantitative study with a descriptive approach, measuring soft skills through an interactive exercise integrated into the Scrum ceremonies, and the use of rubrics aligned with the guidelines of the Engineering Accreditation Commission (ABET). The results showed remarkable improvements in the soft skills of the students, with an above-average level in leadership skills, negotiation, etc. The iterative and continuous feedback allowed me to reflect with the students on motivation and how to overcome obstacles. In conclusion, implementing Scrum improved teaching, work dynamics and the strengthening of teaching practice, allowing a greater focus on the project's problems, and enriching the analysis of its causes.

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**Citation:** **Ciro Martinez Oropesa**. 2025. "Integrative Engineering Project and the Agile Scrum Framework". *International Journal of Development Research*, 15, (09), 69116-69120

## INTRODUCTION

Project-based learning (PBL) should culminate in a product or artefact (The Accreditation Board for Engineering and Technology, 2017); precisely, the product or artefact marks a distinctive difference from problem-based learning (Chen. and Yang, 2019). Project-based learning extends problem-based learning by adding a product or artefact. Creating a product involves authentic research, collaboration with team members, and the use of technology during the research process. According to Lehman et al., the creation of a real-life product is interesting for students and supports authentic research (Johnson, D. and Johnson R., 1989). In this educational context, hoping that students organized in teams can sustainably apply some soft skills is not necessarily promoting cooperation. Team members often oppose assigned roles or tasks, which can end up generating insurmountable conflicts. Hernández, Fernández and Baptista (2014) emphasized while team members respond to the demands of the task, the fulfillment of their responsibilities, the management of the processes involved in learning, or the way of dealing with contradictory opinions between members or with students who essentially loiter, little is contributed to the goal of the group. In fact, groups often implode because they lack the interpersonal skills needed to manage disagreements among their members.

**Cooperative learning:** Kagan (1994) highlighted cooperative learning refers to a series of instructional strategies that include cooperative interaction from student to student on some subject as an integral part of the learning process.

"Learning cooperatively represents a privileged opportunity to achieve very diverse learning objectives, not only related to the content but also oriented to the development of interpersonal skills and abilities, with clear benefits for student learning" (Kagan, 1994). According to Johnson, D. and Johnson, F. (2009) in the groups of students that are formed, the successful up and integration of the five key components of cooperative learning must be guaranteed, namely:

1. Positive interdependence within the learning situation, so that all members of the group understand that they are linked to each other in such a way that one cannot achieve success unless everyone achieves it, and they must learn to do so by synchronizing their efforts to ensure that this happens.
2. The interaction or willingness of group members to encourage and facilitate each other's efforts to complete their tasks in order for the group to achieve its goal.
3. The individual responsibility to ensure that each team member completes their part of the work while at the same time ensuring that others complete theirs.
4. Skills needed to manage disagreements between group members. These skills must be explicitly negotiated.
5. Group processing, which involves students reflecting on their relationships and progress in their work.

Kokotsaki, Menzies and Wiggins (2016) emphasized the integrative industrial engineering project and the engineering design process according to the Accreditation Board for Engineering and Technology (ABET) engineering design is the process of designing a system,

component, or process to meet desired needs. It is a decision-making process, production process, concurrent engineering design, and detailed system. In addition, it should include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics, and social impact. The stages of the engineering design process are iterative and require a series of decisions to advance the design. More often, a design oscillates back and forth, between stages, until it reaches an acceptable shape and can move on to the next.

A brief description of these steps is summarized in the following:

1. Identification and analysis of the problem or need
2. Research the background of the problem: collect information
3. Define requirements – Design constraints,
4. Analyze, evaluate and select solutions.
5. Design and prototype the solution.
6. Refine and test the model/prototype.
7. Communicate the results or final design.

Matteson, Anderson and Boyden (2016) found skills generally refer to skills that people have acquired over time through effort or training, and they always involve an element of execution or performance. Interpersonal skills are less tangible, difficult to quantify, and rather difficult to define. Unlike knowledge or technical skills, the term "soft skills" is loosely used in literature to denote a disparate set of personal attributes, traits, attitudes, and behaviours. Soft skills are more than social or interpersonal skills (such as effective communication, collaboration and cooperation) needed to relate to other people (Pratt, 2025, April 10). The term soft skills also comprises intrapersonal elements (skills such as adaptability and self-regulation that coexist within the individual), personality traits (kindness, among others), attributes (confidence, resilience, among others); and covers both the cognitive (analytical capacity, decision-making, among others) and affective domains (active listening, empathy, among others) (Lehmann, Christensen, Du. And Thrane, 2008). Prieto (2007) argues that the use of the three learning situations is necessary because, "students must learn to work independently, collaborate with others, and compete." Similarly, she emphasizes that cooperative learning promotes a series of values and skills very different from those fostered by individual and competitive learning. She states that "cooperative learning represents a privileged opportunity to achieve very diverse learning objectives, not only related to content, but also oriented toward the development of interpersonal skills and abilities, with clear benefits for student learning"

Pope-Ruark (2015). Highlighted since soft skills are non-technical and non-industry-specific, these are highly transferable between contexts and are widely applicable.

**The Agile Scrum Framework:** The Scrum agile framework is part of a novel management process that has important virtues, not only for the development of business projects in dynamic and changing contexts in a flexible way but also for the management of academic projects aimed at strengthening the learning process of students in the intervention of dynamic and complex business problems, fundamentally oriented by the following learning outcomes:

- Consistency in the statement of the question or problem under study.
- Clarity in the identification of needs, capture and management of requirements, and awareness of the need to manage changes and transition processes for change.
- Ability to apply design in engineering to produce solutions that meet people's needs, taking into account public health, safety and well-being, as well as global, cultural, social and economic factors.

Agile Scrum framework is increasingly used in educational contexts, although their extensive use will depend largely on training, the characteristics of the course design, the level of awareness and

preparation of the teachers responsible for the courses, and the students themselves, who will assume new roles and fulfill concrete tasks connected with the ceremonies defined by the agile framework.

The didactic and pedagogical experience supported in the agile framework Scrum improves teaching, the dynamics of teachers' work and the strengthening of their teaching practice, allowing the teacher greater focus on the problems that define his project and the changes that these present in dynamic environments, enriching the analysis of the causes of this problem and strengthening the search for better strategies. The Scrum agile framework includes ceremonies and roles and is concerted with internal and external stakeholders, directing to success the results achieved through the project artifacts, which should provide a structure and overview. Its iterative nature invites reflection on both the learning process and the progress of learning and evokes feedback between students and the teacher (Touloumakos, 2020). Control and ensure the quality of an intermediate product obtained through each sprint, as part of the work of the product owner (teacher and business advisor) and the development team (student team) aims to improve the quality of the solutions provided based on criteria of acceptance of the products at the development stage and at the project level. Generating, in response by the teacher and other stakeholders, feedback on the increase in value with each deliverable from a functional product that meets the committed attributes. The agile framework, in alignment with the delivery phases of the educational project advances, incorporates quality control at each stage or sprint of the life cycle to identify problems in a timely manner so as to validate that the functional and non-functional requirements were implemented as expected. The didactic and pedagogical experience of the teachers played a key role in the design process, through the project charter, in the process of planning and implementing the solutions, while the experience of the teachers in the subject and other factors such as the teaching context made the teaching experience less outstanding.

## METHODOLOGY

The methodology used consisted of a study with a quantitative cross-sectional approach and descriptive scope, which measured soft skills (leadership, negotiation and conflict resolution, initiative and motivation, organization and teamwork), through an interactive exercise that was integrated into the ceremonies of the agile scrum framework, and that was complemented with the use of rubrics aligned with the results of students (Student Outcomes) published by ABET's Engineering Accreditation Commission, previously socialized with students. A sociodemographic characterization was carried out, and an analysis of the behaviours of the students who participated formed the sample. For the characterization of the sample, a form was applied that described the profile of the students, and a checklist that guided the observation contained the skills (variables) and observable behaviours (dimensions) described in Table 1.

**Data collection:** A questionnaire prepared through the Google Form was used, which was shared electronically between several evaluators to collect the primary data.

**Data collection instrument:** In this research, an instrument was employed as a data collection method, utilizing the Likert scaling technique, which is recognized as one of the most effective approaches for measuring variables through scales (Vogelzang, Admiraal and VanDriel, 2019). This instrument was utilized by the instructor to assess the demonstration of soft skills through the evaluation of specific dimensions (behaviours) in each of the ceremonies conducted by the student teams. These teams were responsible for developing individual solutions (products or deliverables that addressed specific problems or needs of students), clarifying the doubts, and elaborating the necessary planning to achieve the fundamental objective of the Sprint.

**Table 1. Skills and behaviours observable through an immersive technique and individual observation of students**

Skill Skills	Observable behaviors
Leadership	Is active in the discussion and provides effective points.
	Express confidence through non-aggressive communication styles.
	Creates a positive environment for work
	Achievement-oriented
	Try to make decisions.
Negotiation and conflict resolution	Ask non-active participants about their opinions.
	Try to lead and coordinate the discussion effectively.
	Resolve the conflict between team members using a diplomatic style.
	Recognize the contributions of others.
	Motivate other members to contribute more ideas.
Initiative and motivation	It makes a good impression on others.
	Motivate the team to think about the future.
	It proposes high-quality ideas.
	You volunteer to perform unwanted tasks.
	Motivate the group to achieve the goals.
Organization	Manage discussion time effectively.
	Remind others of set times.
	He sets tasks for himself and commits to achieving them to the end.
	Define problems and establish methods to solve them.
	Ask others to focus when they have distanced themselves from the central point of the discussion.
Teamwork Build	Good relationships with other team members.
	He is tolerant of team members and accepts their requests or concerns.
	He works to solve the task and is fully involved in it.

Source: Own elaboration based on the collected data

Next, the spaces of the periodic meetings of at least 15 minutes in which the development team (team of students) answers the following questions are organized:

1. What did I do yesterday to contribute to the Sprint goal?
2. What will I do today to contribute to the Sprint goal?
3. Do I have an impediment that prevents me from delivering?

In the Scrum framework, both the review meetings conducted at the conclusion of the sprint and the subsequent retrospective meetings serve distinct purposes. During the review meetings, the product owner (the instructor) and the development team (group of students) examine the completed increment for inspection and adaptation. Subsequently, the retrospective meetings are held to identify potential improvements for the forthcoming Sprint. The Scrum Master (team leader) assumes responsibility as the facilitator, although various members of the development team (group of students) alternate in the role of facilitator during these retrospective sessions. In a complementary manner, during the two intermediate and final evaluative phases, a rubric designed in the form of a checklist was utilized to assess the quality of the report as well as the presentation and defense of the final report. This rubric was aligned with the student outcomes published by the ABET Engineering Accreditation Commission and was administered by the faculty members of the industrial engineering program.

1. Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. Capacity for application design engineering to produce solutions that satisfy specific needs, taking into account public health, safety, and well-being as well as global, cultural, social, environmental, and economic factors.
3. Ability to communicate effectively with diverse audiences.
4. Ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments that consider the impact of engineering solutions in global, economic, environmental, and social contexts.
5. Ability to function effectively in a team whose members collectively provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. Ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

7. Ability to acquire and apply new knowledge as needed, utilizing appropriate learning strategies.

## RESULTS

The research was conducted following the stages outlined below: determination of the population and sample, preparation of the instruments, application of the instruments to the selected sample, organization and tabulation of the information, quantitative analysis of data, and utilization of descriptive statistics. This research encompassed a sample of 134 students from a total of 398 students in the Industrial Engineering program who studied the integrated project subject since 2021, across 6 academic periods, by fulfilling the requirement of 110 credits and successfully completing the Planning and Control of Production course Table 2. Regarding skills and behaviors, 24 behaviors or dimensions related to 5 variables that represented the skills declared in Table 1 were considered. These were presented in the form of affirmations or judgments, to which the evaluators' reactions were requested. Each affirmation was presented, and the subject was asked to express their decision by selecting one of the five points or categories on the scale.

The categories of responses contained in the data collection instrument are as follows:

1. Strongly agree
2. Agree
3. Neither agree nor disagree
4. Disagree
5. Strongly disagree

The instructor elucidates the learning objectives, connects the real-world question with the business environment most proximate or familiar to the students, and provides the theoretical foundations of the agile framework. This encompasses the domain of ceremonies and artifacts, establishing goals in the calendar in the form of a product portfolio or deliverables, which will focus the work on each of the scheduled sprints in periods of up to 4 weeks, in alignment with the engineering design process.

The activities planned per Sprint are the following:

- Sprint planning.
- Meetings (reviews and retrospectives).

**Table 2. Results sociodemographic study**

Variables	Program	
	n	%
Gender		
Masculine	62	46
Feminine	72	54
Semester		
Ninth	47	35
Tenth	87	65
Marital status		
Married	14	10
Single	116	87
Free Union	2	1.5
Separated	2	1.5
Age (years)		
Less than 20	0	0
Between 21 - 30	115	86
Between 31 - 40	19	14
Social layer		
One	0	0
Two	5	4
Three	98	73
Four	20	15
Five	11	8
Six	0	0
Has worked		
Yes	92	67
No	42	33

Source: Own elaboration based on the collected data

**Table 3. Results at the level of soft skills**

Number of Items		Minimum	Maximum	Mean	Deviation Stándar	Cronbach Alpha
Leadership skills	05	2.33	5.00	3.7781	.95001	.897
Negotiation and conflict resolution skills	05	1.75	5.00	3.639	.91666	.896
Initiative and motivation skills	05	1.42	5.00	3.2478	.85183	.816
Organizational Skills	05	2.10	5.00	3.1111	.74444	.828
Teamwork skills	04	2.20	5.00	3.793	.63131	.881

Source: Own elaboration based on the collected data

Logbooks.  
Technical Visits.  
Consultancies.

Scrum provides ceremonies, roles, and artifacts to monitor progress, adapt to changing circumstances, and reflect on the quality of intermediate products. In the research, it was necessary to ascertain the level of development of soft skills by the students in training who comprised the sample, according to the measurement of the 24 behaviors that defined the 5 skills. See Table 3.

Statistics indicate that participants demonstrate a higher-than-average level of skills, including leadership skills ( $M = 3,7781$ ), negotiation and conflict resolution skills ( $3,639$ ), initiative and motivation skills ( $M = 3,2478$ ), organizational skills ( $M = 3,1111$ ) and teamwork skills ( $M = 3,793$ ). The Scrum agile framework offers several advantages in the educational context, particularly in cooperative learning. Scrum can enhance self-regulated learning by systematically structuring students' learning processes. Scrum ceremonies and artwork provide scaffolding to support student learning and the development of metacognitive skills. Furthermore, Scrum can decrease the perceived complexity of student-centered learning environments, enhance mutual collaboration between teachers and students, and enable both teachers and students to benefit from the Scrum methodology.

## CONCLUSIONS

The didactic and pedagogical experience supported by the agile framework Scrum improves teaching, the dynamics of teachers' work, and the strengthening of their teaching practice. It allows the teacher to focus more effectively on the problems that define their project and

the changes that these present in dynamic environments, enriching the analysis of the causes of this problem and strengthening the search for better-coordinated strategies with internal and external stakeholders, directing the results achieved through the project toward success. After implementing the agile framework (SCRUM), notable improvements were observed in the soft skills of the participants. The SCRUM framework offers several opportunities for students to exercise different skills through well-structured programs, events, roles, and artifacts. Writing, oral presentation, leadership, transparency, and organization were the improvements most frequently reported by the individuals involved. The agile Scrum framework becomes a powerful tool to enhance the educational context, provided that teachers are sensitized and prepared for its implementation. The research highlights the importance of successfully integrating project-based learning measurements and the effectiveness of developing and implementing the ceremonies and artifacts that Scrum demands.

Additionally, the need to design the course around the principles and criteria of project-based learning in order for it to be successful is emphasized. The implementation of Scrum not only improved the soft skills of the students but also offered opportunities for the teacher to discuss and reflect with the students on motivational topics and how to overcome obstacles. In conclusion, the implementation of the Scrum Agile Framework proved effective in improving students' soft skills as well as enriching teaching and teaching practice. Moreover, it provided an enabling environment for cooperative learning, continuous reflection, and collaborative problem-solving. Students gained practical knowledge and soft skills on how to manage a project using an agile approach, beyond what the project-based learning environment (PBL) can offer when applied in isolation.

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