

THE IMPACT OF SCRUM METHODOLOGY ON STUDENT MOTIVATION AND PROBLEM-SOLVING SKILLS

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ABSTRACT

This study investigates the impact of incorporating Scrum methodology into project-based learning on student motivation, knowledge retention, and problem-solving skills. Conducted with 40 third-year students, the research utilizes a combination of the Student Engagement Instrument, and custom survey questions developed by the authors. A pre-test and post-test were administered to assess changes in student engagement, collaboration, and project management efficiency. The results reveal a significant improvement in student motivation and problem-solving abilities, with a paired t-test showing a statistically significant increase in grades when comparing the Scrum-based course to a traditionally instructed course. Students reported improved teamwork and communication, particularly using daily stand-up meetings and retrospectives. Limitations of the study, such as sample size and specific course context, are acknowledged, and recommendations for future research are provided. The findings suggest that Scrum methodology can effectively foster a more engaged, collaborative, and productive learning environment in higher education.

KEY WORDS

project-based learning, Scrum methodology, soft skills, lifelong learning, higher education

CLASSIFICATION

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INTRODUCTION

Project-based learning (PBL) is an alternative to classroom-based instruction in which students are engaged in applying the knowledge they have acquired and developing critical thinking, problem-solving, and teamwork skills on real-world problems. Research has shown that PBL can improve student motivation and academic achievement, and it has been used as a successful model in primary and secondary education, as well as in post-secondary institutions.

Scrum is a well-known agile project management approach that has gained popularity in the software industry due to its success in improving teamwork effectiveness and quality results. With the growing importance of teamwork and project management skills in the professional profile of graduates, the application of Scrum in the educational context has become increasingly relevant. Higher education institutions are increasingly emphasizing student-centered teaching and learning approaches that focus not only on technical skills but also on interpersonal and social skills such as teamwork, leadership, and lifelong learning.

Fernandes et al. [1] analyzed the effectiveness of Scrum for project and team management in PBL teams in higher education. The study found that Scrum was effective in improving project and team management skills among students. Komar et al. [2] conducted an experimental study to assess the impact of Scrum methodology on developing competence in solving complex pedagogical situations among future primary school teachers. The results showed that Scrum had a positive impact on the development of competence in these students.

In [3] the authors explored the application of a teaching-learning model that combines active learning methodologies, specifically project-based learning, and the flipped classroom, in the management of teaching-learning projects. The implementation of the model was positively received by the students and the projects developed by the groups were considered relevant. The results of the anonymous questionnaire conducted at the end of the semester indicated high levels of satisfaction among students with the use of the non-traditional teaching method in engineering education, indicating its potential for future use.

The study [4] aimed to evaluate the application of Agile methodologies in an educational context. Its goal was to improve student engagement and facilitate the fulfillment of learning outcomes. The results showed that the adaptation and use of Agile methodologies in this context holds promise in achieving these objectives.

The authors of [5] created a VR video game to teach Scrum methodology in software engineering education. The purpose of this research was to create a more engaging and participatory learning experience for students to understand project management in a PBL setting.

In [6] the author presents PBL as a teaching approach that motivates and engages students in their learning process and highlights the benefits of PBL in developing not only subject-specific knowledge, but also essential life skills such as problem solving, creativity, collaboration, communication, time management and responsibility.

The study [7] explores the effectiveness of agile strategies in online higher education. The course redesign was carried out in the context of an undergraduate project-based learning course over two consecutive semesters. A total of 114 students were surveyed and two interviews were conducted to collect teacher opinions. The results indicate that agile strategies are useful to improve management and collaboration. However, no significant impact has been observed on student satisfaction or overall learning outcomes.

In [8] the authors show that using the Scrum project management methodology during PBL can improve project performance for student teams, especially for long-term projects with large teams. A student team in an Industrial Engineering and Management program used Scrum and gradually recognized its advantages, leading to better project management effectiveness and control.

The study [9] explores the effectiveness of PBL, Scrum, and rapid prototyping in teaching an introductory JavaScript programming course for IoT development. The results demonstrate that the use of these approaches helps address uncertainties, promote teamwork, problem solving, and creativity, leading to the successful development of IoT prototypes. In addition, smaller team sizes are found to perform better during the life of the project. The study suggests that a focus on increased knowledge, collaboration, interaction, constant feedback, and adaptability is crucial when implementing these teaching approaches.

In [10] the authors analyzed the use of Project-Based Learning Agile (PBLA) with electrical engineering students and its impact on knowledge formation. The study uses statistical analysis of questionnaire responses obtained over four consecutive semesters to understand how the learning process is connected to PBLA. Data analysis suggests that the PBLA approach is rooted in the humanist principles of ego and cooperation, which serve as a basis for learning. The study concludes that humanization is an important aspect of the education process for new electrical engineers.

Building on the theoretical foundation and existing studies on project-based learning and agile methodologies, this research aims to explore the practical impact of the Scrum methodology in higher education. Specifically, the study is guided by three key research questions: (1) Does participation in project-based learning with Scrum methodology lead to improved student outcomes, such as increased knowledge retention and problem-solving skills? (2) Does the implementation of Scrum practices, such as daily stand-up meetings and retrospectives, enhance collaboration and communication among students, leading to improved teamwork and group dynamics? (3) Does the use of sprints in Scrum methodology improve project management efficiency, resulting in higher student satisfaction and better overall project outcomes? These questions frame the investigation and structure the methodology and analysis.

The following section describes the methodology used to implement and evaluate these practices.

THEORETICAL BACKGROUND

AGILE PRACTICES IN EDUCATION

Agile methodologies, which were first developed for the software industry, have become more popular in education because they focus on flexibility, teamwork, and continuous improvement. Key principles, such as focusing on student participation rather than strict rules and emphasizing skill development instead of memorization, match current educational goals. In education, Agile promotes a student-centered approach, where collaboration, adaptability, and ongoing learning are essential parts of the teaching process.

The application of Agile practices in education often relies on frameworks such as Scrum, which is structured to encourage iterative progress, constant feedback, and teamwork. These principles are particularly effective in project-based learning, where students participate in real-world challenges that develop their critical thinking, problem-solving, and teamwork abilities.

The importance of communication between the development team and the client in software development is widely acknowledged. However, this focus on the client is often lacking in the educational setting. At the end of higher education, students are seen as clients. With this in mind, a set of guiding principles has been established for the application of agile practices in education, modeled after the Agile Manifesto in software development [13, 14]. These principles provide a useful reference in cases where there are conflicting interests among stakeholders in the implementation of agile practices in education. The principles are as follows:

- 1) Prioritizing teachers and students over administration and infrastructure: the educational process should be designed around the needs of the students and teachers.

- 2) Emphasizing competence and collaboration over compliance and competition: the educational process should focus on developing students' and teachers' abilities to work together effectively, rather than just requiring them to comply with a set of rules or compete against one another.
- 3) Focusing on employability and marketability over syllabus and marks: the educational process should focus on preparing students for their future careers, rather than just on academic achievement.
- 4) Valuing attitude and learning skills over aptitude and degree: the educational process should focus on helping students develop a love of learning and a growth mindset, rather than just focusing on their intellectual abilities or their academic credentials.

These guidelines offer a framework for implementing agile techniques in education so that the teaching and learning process is in line with the needs and goals of the student and teacher.

Agile methodologies have gained attention in education due to their ability to promote flexibility, teamwork, and continuous improvement. However, their implementation is not without challenges. Research highlights issues such as unequal participation among students with different skill levels and difficulties in adapting to new student-centered approaches. Some students may find that the change from traditional methods is demanding and requires additional support from educators [15-20]. Moreover, agile practices, such as iterative development and frequent feedback, require consistent effort from both students and teachers, which can sometimes conflict with fixed academic requirements. To overcome these challenges, educators must carefully adapt the Agile principles to align with educational goals and ensure effective integration into the learning process [15-20].

Key Principles of eduScrum

The key principles of eduScrum align with the guiding principles for the application of agile practices in education [21], as they prioritize student-centered learning and emphasize the importance of collaboration, responsibility, and continuous improvement [22]:

- 1) Education purpose outlined – this principle emphasizes the importance of focusing on the needs and goals of students in the educational process, which is consistent with the first principle of giving teachers and students priority over administration and infrastructure.
- 2) Autonomy and responsibility for learning – this principle aligns with the second principle of emphasizing competence and collaboration over compliance and competition, as it gives students the authority and responsibility to guide their own learning journeys.
- 3) Central focus on learning – this principle aligns with the fourth principle of valuing attitude and learning skills over aptitude and degree, as it emphasizes the importance of promoting a love of learning and developing positive attitudes towards education.
- 4) Improved academic results and skill development – this principle aligns with the third principle of focusing on employability and marketability over syllabus and marks, as it aims not only to improve academic results, but also to equip students with valuable life and employability skills.
- 5) Agile mindset for teachers – this principle aligns with the fifth principle of valuing attitude and learning skills above aptitude and degree, as it emphasizes the importance of teachers adopting an agile mindset and fostering a culture of continuous improvement and collaboration.
- 6) Continuous improvement – this principle aligns with the sixth principle of focusing on employability and marketability over syllabus and marks, as it emphasizes the importance of continuously improving the quality of student outcomes throughout the academic year.

These principles offer a structured foundation for applying eduScrum in educational settings, ensuring that teaching and learning processes align with student needs while promoting

collaboration and continuous development. To translate these principles into practice, it is essential to define and assign specific roles within the eduScrum framework. The following section outlines these roles and their importance in facilitating the effective implementation of eduScrum in a classroom setting.

Scrum Roles in Educational Contexts

In eduScrum, the roles are adapted from the traditional Scrum framework to suit an educational setting [21-23]:

- **Product Owner** – this role is played by the teacher who is knowledgeable about the desired product of the project. The teacher proposes the project topic and is responsible for deciding what to build, making it accessible to all students, validating submissions after each sprint, and setting priorities.
- **Scrum Master** – this role is taken on by students who function as facilitators in each team. The scrum master oversees meeting calls during each sprint and records meeting proceedings in the portfolio. Their responsibilities include facilitating communication between group members and the teacher, managing the self-regulated team, reporting important notifications in the portfolio, and planning and scheduling meetings during each sprint.
- **Scrum Team** – this team consists of all students on each team, including the scrum master. A scrum team typically has 4 to 5 members and works on the proposed project topic with the goal of submitting a concrete product. All members of the team are aware of each other's tasks and progress, leading to a cohesive and self-managed team effort.

By assigning these roles, eduScrum mirrors real-world project management environments, providing students with practical experience while reinforcing teamwork and accountability.

The principles and challenges of Agile methodologies discussed in this section provide a solid foundation for analyzing their impact in educational settings. By focusing on Scrum's implementation in project-based learning, this study seeks to explore how these practices influence student outcomes, collaboration, and problem-solving skills.

Knowledge Retention and Agile Principles

Knowledge retention has long been studied in cognitive psychology, particularly from the perspective of the forgetting curve (also known as the Ebbinghaus forgetting curve), which illustrates the exponential decline in memory retention over time without reinforcement [11]. Scrum methodology combats this decline by combining iterative cycles and regular feedback loops. These mechanisms allow students to revisit and apply learned concepts repeatedly, thereby enhancing retention. In [12], the authors introduced the concept of 'desirable difficulties', which suggests that introducing challenges during the learning process deepens cognitive engagement and promotes long-term memory. The structured approach, including sprint reviews and retrospectives, operationalizes these principles by requiring students to reflect on and integrate knowledge at regular intervals.

In addition to addressing the forgetting curve, research shows that strategies such as active participation, repetition, and practical application can further mitigate memory decay and improve learning outcomes [24-26]. Scrum methodology aligns with these strategies by structuring learning into iterative processes that encourage regular reinforcement of key concepts. Practices such as sprints, stand-ups, and retrospectives allow students to revisit and apply what they have learned in a continuous and meaningful way, ensuring that knowledge is retained over time [15-20].

One of Scrum's key strengths in supporting knowledge retention lies in its iterative cycles. Each sprint involves revisiting previously learned material, integrating new insights, and

refining understanding through team collaboration. Stand-up meetings ensure that students remain actively engaged with their tasks, while retrospectives provide structured opportunities to reflect on their progress and address areas for improvement. These iterative practices help consolidate knowledge and prevent the natural decay that occurs when material is not regularly reinforced [8, 19].

Active learning and project-based methods, integral to Scrum, further enhance retention by immersing students in practical tasks that require the application of theoretical knowledge. This active engagement strengthens neural connections, improving the ability to recall and transfer knowledge to new contexts. Research [7, 8] highlights that these structured approaches not only support teamwork but also enhance students' capacity to retain and utilize information effectively.

Scrum's emphasis on feedback-rich environments plays a crucial role in knowledge retention. Frequent feedback loops during sprint reviews and retrospectives allow students to identify gaps in their understanding and address them promptly, reinforcing learning through continuous adjustment. This adaptability ensures that knowledge remains relevant and deeply embedded, aligning with the principles of effective learning environments as discussed in [10]. By organizing learning into manageable cycles and emphasizing collaborative reflection, Agile frameworks such as Scrum help students engage with material more effectively, as noted in studies [24, 26].

This exploration of knowledge retention and Agile learning principles highlights the potential of Scrum methodology to improve educational outcomes through iterative, collaborative, and feedback-driven practices.

Building on this theoretical foundation, the following section defines the research questions and objectives that guide this study, focusing on the practical implications of Scrum in project-based learning environments.

Research Questions and Objectives

The following research questions guide the investigation:

- RQ1:** Does participation in project-based learning with Scrum methodology lead to improved student outcomes, such as increased knowledge retention and problem-solving skills?
- RQ2:** Does the implementation of Scrum practices, such as daily stand-up meetings and retrospectives, enhance collaboration and communication among students, leading to improved teamwork and group dynamics?
- RQ3:** Does the use of sprints in Scrum methodology improve project management efficiency, resulting in higher student satisfaction and better overall project outcomes?

The formulation of **RQ1** builds on foundational theories of cognitive psychology, such as distributed practice [27], and emphasizes the importance of 'desirable difficulties' introduced during learning, which have been shown to deepen engagement and enhance long-term memory retention [12]. Furthermore, agile practices such as Scrum promote iterative reflection and application, aligning with findings from studies on the cognitive benefits of active learning in digital and collaborative environments [24-26].

The emphasis in **RQ2** on improving collaboration and communication is consistent with the findings of [28], which highlight the critical role of interpersonal dynamics in team-based learning environments. Similarly, studies [7, 8] underscore the effectiveness of agile methods, including daily stand-up meetings and retrospectives, in fostering group cohesion and enhancing teamwork efficiency. Furthermore, research on agile games in education [20] suggests that structured collaboration practices, such as those integral to Scrum, significantly improve team dynamics and communication skills.

The focus of **RQ₃** on project management efficiency and student satisfaction is supported by [10], which demonstrates the positive impact of iterative project-based approaches on student organization and outcome quality. Furthermore, studies [8, 19] emphasize how sprints enable consistent progress and adaptability, both of which are essential to achieve superior results and improve participant satisfaction in educational settings.

The following section describes the methodology used to implement and evaluate these practices.

METHODOLOGY

PARTICIPANTS AND STUDY CONTEXT

All participants were third-year students enrolled in the Agile Development of Software Systems course during the winter semester of the 2023/2024 academic year at Subotica Tech-College of Applied Sciences. The course curriculum covers a variety of topics related to software development methodologies, with a primary emphasis on the agile approach. The course objectives include improving students' critical evaluation skills, technical communication skills, and understanding of agile practices for software development.

Participants were selected based on their enrollment in the Agile Development of Software Systems course, and all 40 students in the course were included in the study. No additional selection criteria were applied, as the study was aimed at including all students exposed to the Scrum methodology. Data were collected using pre-test and post-test questionnaires to assess student engagement, knowledge retention, and problem-solving skills. The Student Engagement Instrument (SEI) was used for both tests, supplemented by survey questions specifically designed by the authors to assess student perceptions of the Scrum methodology.

Quantitative data were analyzed using descriptive statistics (means, standard deviations) to summarize student responses. A paired t-test was conducted to compare student performance between the Agile Development of Software Systems and Programming Mobile Devices courses, with a focus on evaluating the impact of Scrum-based learning. This method was selected because of its effectiveness in comparing related samples in which the same students participated in both courses.

Before the study began, students were informed about the purpose and procedures of the research. During the first lecture, they received a document explaining that by taking part in the course they were also part of the study. Each student provided their informed consent, understanding that participation was voluntary and that they could leave the study at any time without any negative consequences. The study was conducted with full respect for their privacy and anonymity. No personal details were collected or mentioned in the paper, and the data were only used in general, without revealing individual identities. This approach ensured that all ethical rules were followed throughout the investigation.

A total of 40 students participated, with five female students (12,5%) and 35 male students (87,5%), and the average age was 22,1 years. The students were divided into nine groups, each group consisting of 4 to 5 members. The formation was based on students' self-selection, without any external influence or guidance from the instructors.

The Agile Development of Software Systems course, taken by students in the winter semester of their third year, builds on the Programming of Mobile Devices course from the second-year summer semester. The Programming of Mobile Devices course focuses on equipping students with the skills to develop Android applications, design user interfaces for mobile devices, consider device limitations, and create apps that can communicate with servers. Given that all participants in this project have successfully completed the Programming of Mobile Devices course, it is assumed that they possess the required background knowledge to undertake the

task of designing and developing a mobile application. In the Agile Development of Software Systems course, students apply agile practices through a practical project in which they are tasked with developing a mobile application using the agile approach. This foundation in mobile application development is crucial to effectively implement agile methodologies throughout the project.

Since all participants were students enrolled in the Agile Development of Software Systems course, no additional selection criteria were applied. This ensured that the sample represented the entire population of students taking the course, providing a complete picture of their engagement with the Scrum methodology. Although this approach offers a comprehensive view of the student's experience in the course, it is important to note that the relatively small sample size ($n = 40$) can limit the applicability of the findings to other educational settings or larger student populations.

DATA COLLECTION METHODS

Data collection for this study was carried out using two main instruments: the SEI and survey questionnaires. The SEI, a widely used tool in student engagement research [29-33], was specifically designed to measure student motivation, interest, participation, and activity. The SEI uses a five-point Likert scale to assess the cognitive, emotional, and behavioral aspects of participation.

To capture changes in student engagement, the SEI was administered twice: at the beginning of the semester (pre-test) and after nine weeks of project-based learning (post-test). The full list of questions used in both the pre-test and post-test can be found in the Appendix. Survey questionnaires were also used to collect additional information on students' experiences with Scrum, focusing on their motivation, collaboration, and satisfaction with teamwork.

The data collection process was structured as follows:

- Pre-test phase – at the beginning of the semester, students completed a version of the SEI to assess their initial engagement levels.
- Post-test phase – After completing the course and implementing Scrum in their projects, students completed a modified SEI and survey questionnaires to reflect on their perceptions and experiences.
- A paired t-test was used to compare the grades of the students in the Agile Development of Software Systems course with their grades in the Programming Mobile Devices course. This test was chosen because it explains that the same group of students was evaluated in both courses, making it possible to measure changes in their performance under different teaching methods.

PROJECT DEVELOPMENT

The students were assigned a Scrum-based project focused on designing and developing an Android application for language learning. They had the option to choose between two target language pairs: Hungarian-Serbian or Serbian-English. This project spanned a 9-week period and required the use of the Java programming language and Android Studio as the integrated development environment (IDE). The primary objective was to create a user-friendly and intuitive interface that would enhance the engagement and motivation of beginners learning these languages.

The project was structured into several phases to guide the students through the development process in a systematic and collaborative manner. Each phase was designed to allow students to progressively apply Scrum methodology and develop their skills while working toward the final application. The following outlines the phases of the project.

1. Research phase: In the initial phase of the project, students were tasked with conducting research on existing language-learning games available on Google Play. They had the freedom to select between 3 and 5 applications to analyze, rather than being assigned specific games by their professors. Students examined the strengths and weaknesses of these chosen applications, focusing on effective and ineffective features. Using their findings as a basis, they suggested their own solutions to resolve the issues they identified in the current applications.
2. Project management: For project management, the groups used the Trello platform, Figure 1. Each group created a Trello profile and invited the teacher for collaboration and supervision. Through Trello, the students managed their projects by creating a list of master stories, assigning tasks, and setting task priorities according to the Scrum methodology. This organizational approach allowed teams to efficiently track their progress during the development process.
3. Development phase: After completing the research and task planning, the students moved on to the development phase. Here, they applied their insights to design and build their own language-learning games. The applications were intended for beginners learning Hungarian-Serbian (Serbian-Hungarian) or Serbian-English, with the aim of helping users learn vocabulary in these pairs of languages. Figure 2 illustrates some of the applications developed by the students during this project.

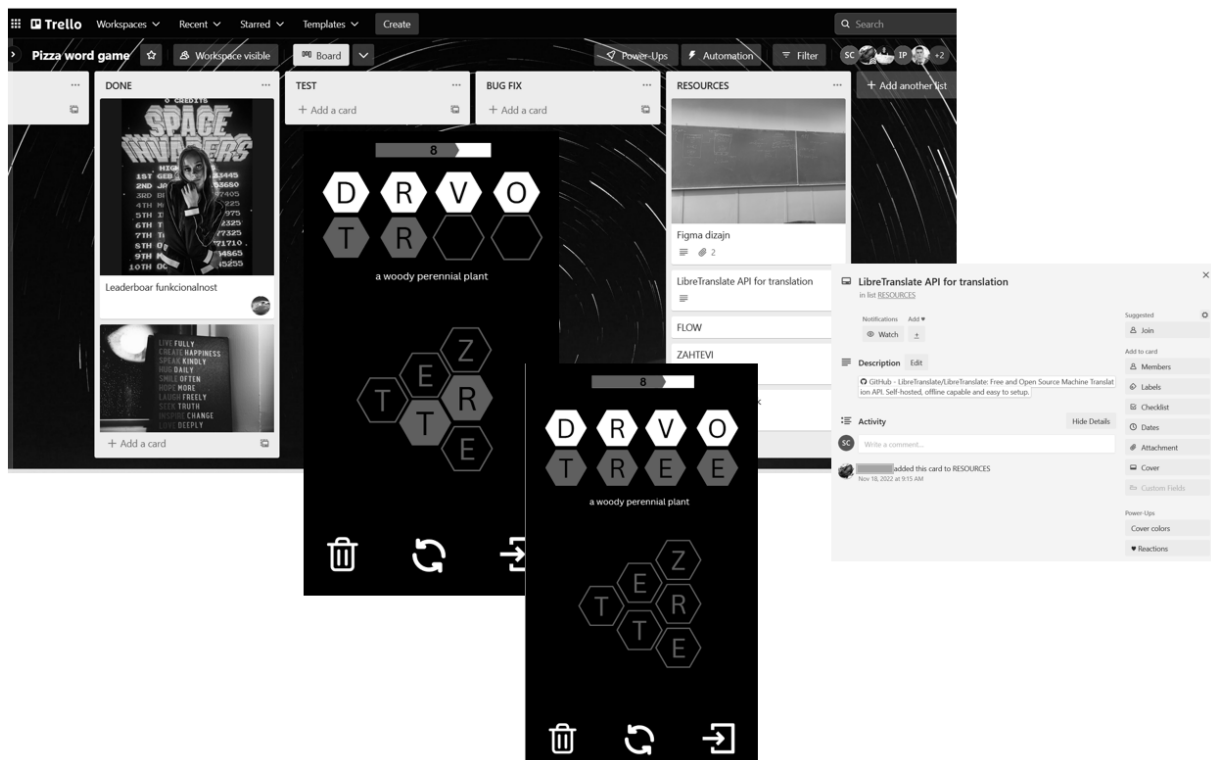


Figure 1. Student groups use the Trello board for project management, showing master stories, assigned tasks, and priorities for efficient organization and progress tracking.

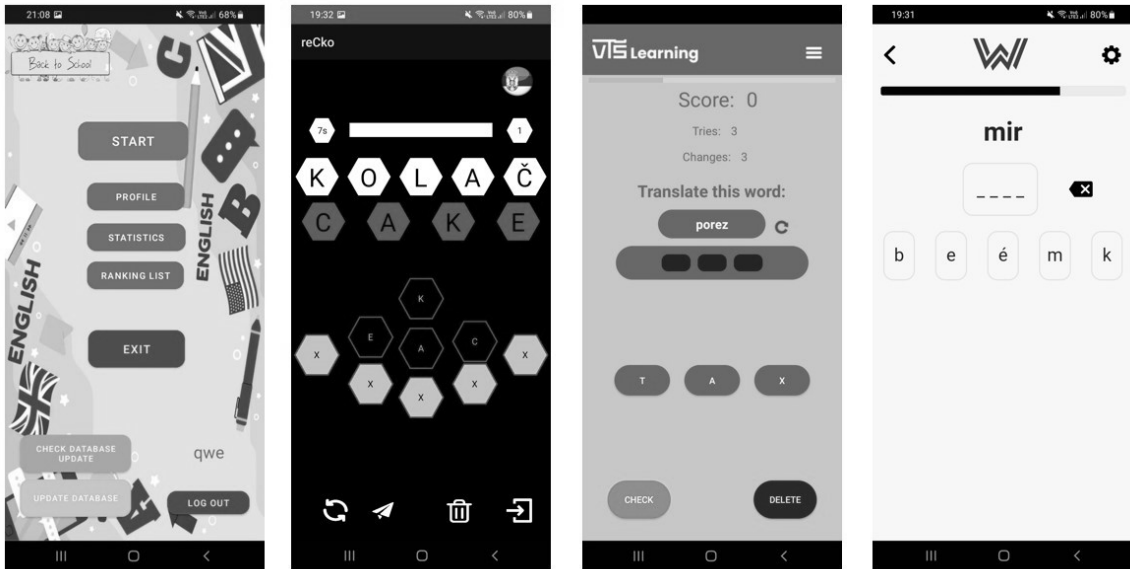


Figure 2. Screenshots of language-learning applications developed by student groups as part of the course project.

Sprint Structure and Weekly Meetings

According to the principles of the Scrum methodology, weekly meetings were held to assess progress and address any challenges encountered. These meetings, which lasted 15 minutes, were scheduled to align with the weekly class schedule. During these sessions, each team member was required to provide an update on his progress, discuss any difficulties encountered, and outline their plan for the next phase of the project. Teams were also required to present their progress using a burn-down chart, Figure 3. The Scrum Burn-down chart provides a visual representation of the daily progress of the completed work compared to the estimated completion rate for the current project release. This tool serves as an effective means to ensure the alignment of project progress with the desired outcome, that is, the delivery of the expected solution within the predetermined schedule. The utilization of the Scrum burn-down chart is crucial in maintaining the project's trajectory towards a successful conclusion.

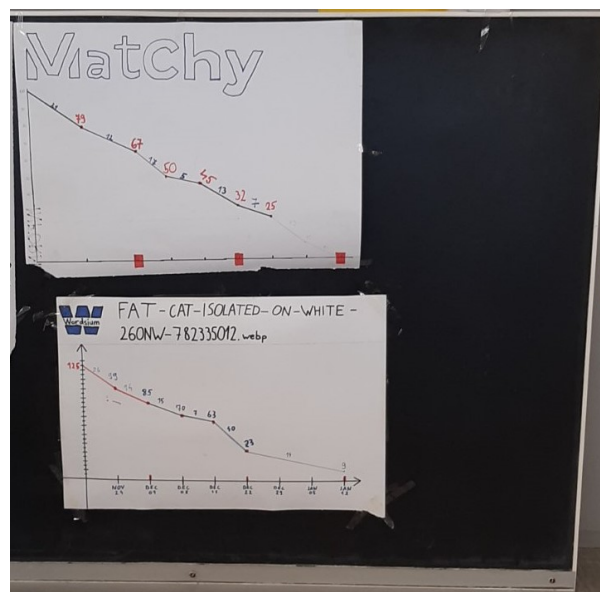


Figure 3. Scrum burn-down chart used by student teams to track daily progress and compare completed work with the estimated completion rate, helping to keep the project on schedule.

Project Management

The teams received a 9-week time frame to complete the project, which was executed in 3 sprints, each lasting 3 weeks. Upon completion of each sprint, teams were required to present their achievements up to that point. After every 3 weeks, a demo session was held in which each team presented the results of their completed sprint. All teams attended these sessions, listening to each other's presentations, asking questions, and offering suggestions on how to resolve various challenges, such as technical issues encountered during the project.

RESULTS

In this section, the findings of the data collected through the SEI and the survey questionnaires will be presented and discussed. The results will provide insight into how the Scrum methodology influenced student motivation and problem-solving skills in a project-based learning environment. We will examine changes in engagement, collaboration, and the development of problem-solving abilities, drawing conclusions about the overall effectiveness of Scrum in enhancing these key aspects of student learning.

PRETEST ADMINISTRATION

Before project-based learning using Scrum in the Agile Development of Software Systems course, a pre-test was administered to assess student engagement. This pre-test aimed to gather insights into students' perceptions of their study experience, including motivation, understanding of course material, and the value of their contributions. The pre-test, which was completed by all 40 students, focused on general study experiences rather than course-specific content. The questions used in the pre-test, developed by the authors, are provided in Appendix 1.

The results indicated that the students had moderate understanding of the material they had learned so far, with an average score of 2,88 for comprehension, Figure 4. They felt their contributions were valued, scoring an average of 3,05 in this area. However, the motivation for the assignments was lower, with an average score of 2,65, and the students struggled to see real-world applications of their learning, reflecting an average score of 2,83. Collaboration with classmates was rated on an average of 2,28, while the ability to apply their learning to future careers was rated 2,45.

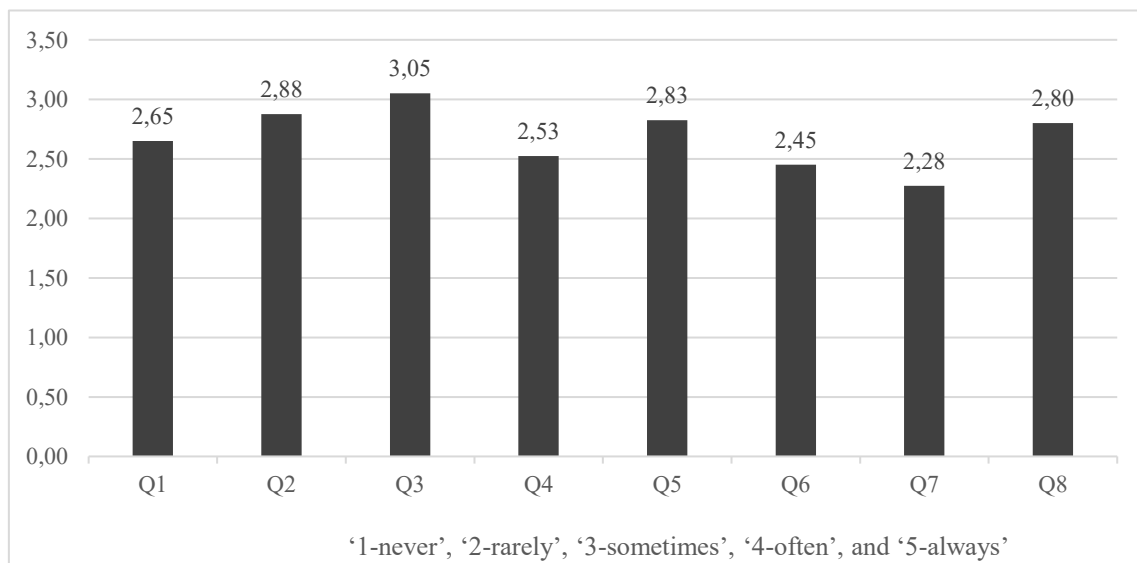


Figure 4. Average student responses to the pre-test questions on motivation, understanding of the course material, and perceived value of contributions ($n = 40$ students; Appendix 1).

These results suggest the need for a more engaging and collaborative learning environment, such as that provided by Scrum. The pre-test findings also indicate that students require more opportunities for hands-on experiences to improve their ability to set and achieve goals and apply what they learn to real-world contexts.

POST-TEST ADMINISTRATION

The post-test aimed to evaluate how project-based learning with Scrum methodology influenced students' knowledge retention and problem-solving abilities. A total of 40 students in the Agile Development of Software Systems course participated in the post-test, responding to questions on a Likert scale about their perceptions of learning outcomes and experiences. The post-test questions, developed by the authors, were designed to address each research question, as detailed in the Appendix. These questions focused on aspects such as knowledge retention (**RQ₁**), collaboration and communication through Scrum practices (**RQ₂**), and project management efficiency (**RQ₃**).

The following section presents the responses related to **RQ₁**, which are illustrated in Figure 5. The findings showed that many students, with average scores ranging from 3,53 to 4,08, believed that completing projects using the Scrum methodology helped them retain more knowledge and improved their problem-solving skills. The highest mean score was recorded for the question 'Was your learning experience better in project-based learning with Scrum methodology compared to traditional methods?' which had a score of 4,08 (Q₅). This suggests that students generally viewed project-based learning with Scrum methodology as a more effective learning method. Students indicated that participation in Scrum-based project learning helped improve their knowledge retention, with a mean score of 3,95 for the question 'To what extent do you think participating in project-based learning with Scrum methodology helped you retain knowledge better?' (Q₄). They also reported improvements in their problem-solving skills, with a mean score of 3,85 for the question 'In your opinion, did project-based learning with Scrum methodology increase your ability to solve problems in a more efficient manner?' (Q₃).

The findings provide clear evidence to support **RQ₁**, showing that participation in project-based learning with Scrum methodology significantly improved student performance. However, it is important to consider that these results are based on student self-reported perceptions, which may not fully capture objective improvements in knowledge retention and problem-solving skills. As such, further research is necessary to validate these findings and explore the underlying mechanisms through which project-based learning with Scrum methodology improves student learning outcomes.

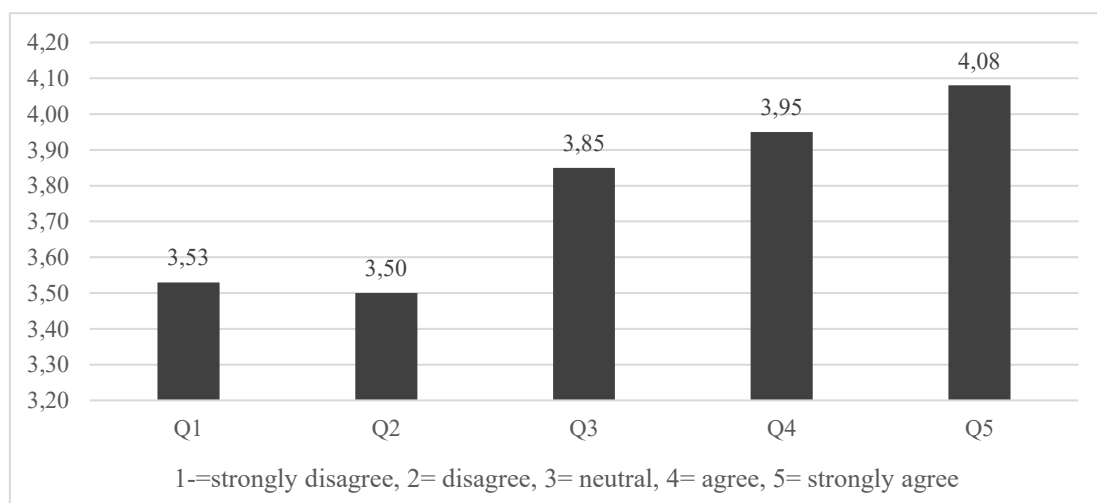


Figure 5. Impact on knowledge retention and problem-solving skills, as perceived by students ($n = 40$ students; Appendix 2).

The results of the survey (Appendix 3) related to **RQ₂** indicate that the implementation of daily stand-up meetings and retrospectives in the Scrum methodology has been effective in improving collaboration and communication among students, resulting in improved teamwork and group dynamics, Figure 6. With an average score of 4,60 (Q₁), most of the students agree that daily stand-up meetings helped improve collaboration and communication between team members. The question ‘Retrospectives were effective in identifying areas for improvement in our team dynamics’ received an average score of 4,52 (Q₂), indicating that some students are slightly less certain of the effectiveness of retrospectives in this regard. The question ‘The use of Scrum methodology improved our teamwork and group dynamics’ received an average score of 4,72 (Q₃), suggesting that most students agree that the use of Scrum methodology has had a positive impact on teamwork and group dynamics. The question ‘I feel that our team functioned more efficiently due to the use of Scrum methodology’ received an average score of 4,52 (Q₄), indicating that most of the students believe that their team performed better due to the use of Scrum methodology.

The survey results support **RQ₂**, highlighting improvements in student collaboration and communication through Scrum practices, such as daily stand-up meetings and retrospectives. Students reported greater efficiency and teamwork, aligning with the goals of the Scrum framework.

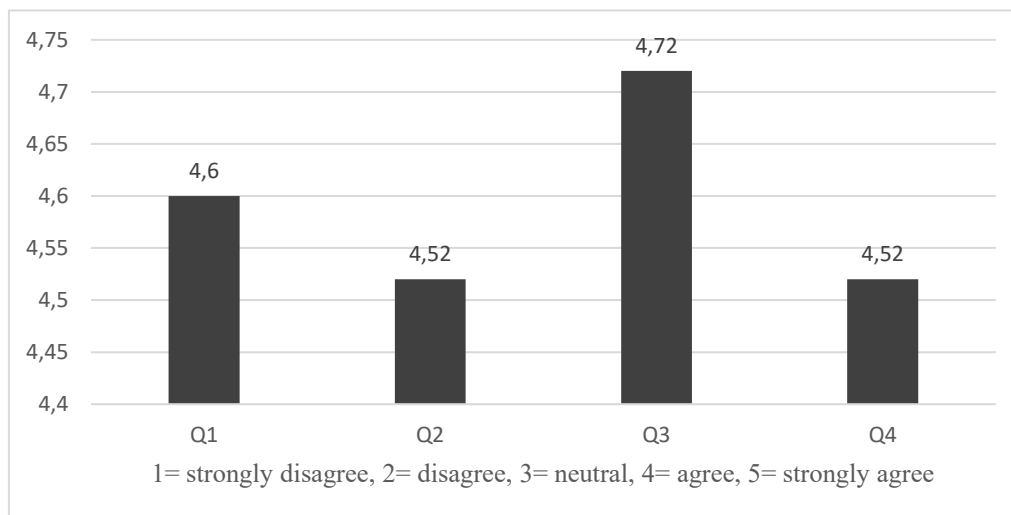


Figure 6. Student views on the impact of Scrum methodology on collaboration, communication, and team dynamics ($n = 40$ students; Appendix 3).

The results of the survey (Appendix 4) related to **RQ₃** suggest that most students agree that the use of sprints in the Scrum methodology has improved the efficiency of project management and resulted in better project results, Figure 7. With an average score of 4,60 (Q₁), students generally agreed that sprints improved project management. The question “I believe that using sprints in Scrum methodology resulted in better project outcomes” received an average score of 4,72 (Q₂), indicating strong agreement among students on this point. The students expressed positive feelings about their satisfaction with the project, with a mean score of 4,72 for Q₃, indicating that they believed that the use of sprints positively affected their overall satisfaction with the project. High average scores on all questions demonstrate a strong consensus among students on the effectiveness of sprints in improving project management, improving project outcomes, and increasing their satisfaction with the learning process. These results indicate that the implementation of sprints in the Scrum methodology has significantly benefited students in terms of collaboration, communication, and overall project success.

The use of sprints, as examined in **RQ₃**, also led to improved project management and greater student satisfaction, as evidenced by the strong agreement between survey responses and consistent project outcomes.

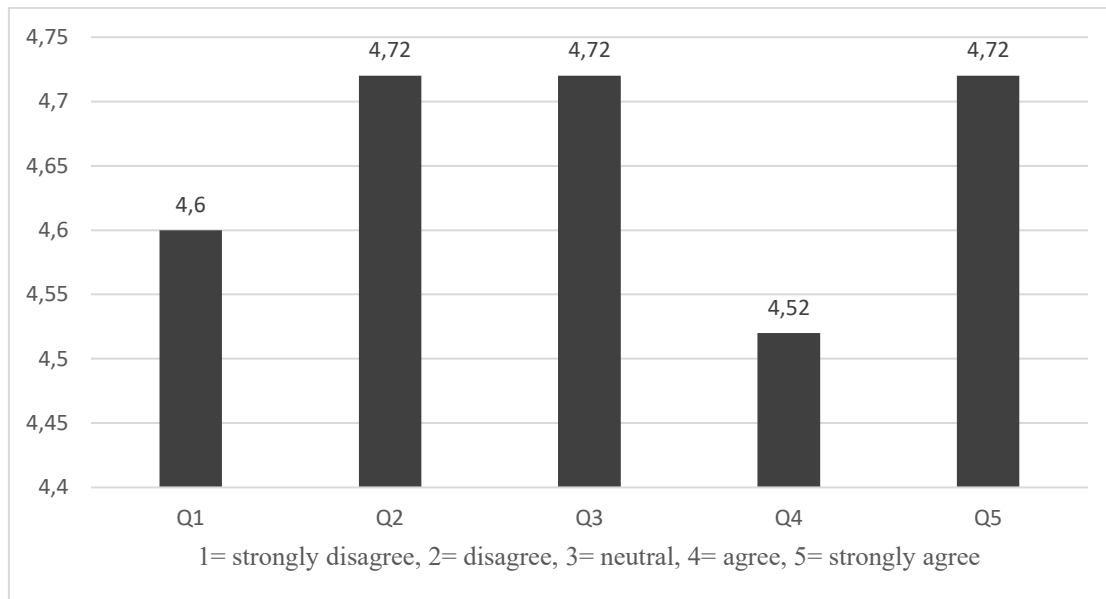


Figure 7. Student perceptions of the impact of sprints in Scrum methodology on project management efficiency, project results, and student satisfaction ($n = 40$ students; Appendix 4).

To further explore the impact of project-based learning with Scrum, we compared student performance in the Agile Development of Software Systems course with their performance in the Programming Mobile Devices course. Given that all students in this study had previously completed the Programming Mobile Devices course, this comparison provides valuable information on how different teaching approaches affect the same group of students.

The Mobile Devices course offered the technical foundation needed for the development of mobile applications, using a traditional lecture-based format. In contrast, the Agile Development of Software Systems course focused on project management, teamwork, and the application of Scrum methodology, which emphasizes collaboration and iterative development. By comparing the grades of both courses, our objective was to assess how the shift from a traditional approach to an agile project-based learning environment influenced student outcomes.

The final grades of both courses were analyzed. As shown in Table 1, the average grade in the Mobile Devices course was 7,28, with a median of 7,00, indicating average to slightly below average performance. The standard deviation (SD) of 1,54 suggests moderate variability in student performance. On the contrary, the average grade in the Agile Development of Software Systems course was 9,10, with a median of 9,00 and a lower SD of 1,06, indicating a higher and more consistent level of achievement among students.

Table 1. Descriptive statistics for final marks.

	Programming Mobile Devices	Agile Development of Software Systems
	$n = 40$	$n = 40$
mean	7,28	9,10
mode	6	10
median	7	9
SD	1,54	1,06

To analyze the impact of Scrum methodology on student performance, a paired t-test was performed. This method was selected to compare the same group of students in two different learning environments, one based on traditional teaching (Programming Mobile Devices) and the other using Scrum methodology (Agile Development of Software Systems). The t-test is appropriate here because of its ability to handle dependent samples, since students participated in both courses. The results of this analysis are presented in Table 2.

The results of the paired t test show a significant difference between the average grades students received in the Programming Mobile Devices ($M = 7,3$, $SD = 1,5$) and those of the Agile Development of Software Systems Development ($M = 9,1$, $SD = 1,1$). The test statistic, $t(39) = 7,5$, indicates a large gap between the two means and the very low p -value ($4,13 \cdot 10^{-9}$) confirms that this difference is statistically significant. The negative skewness ($-0,7223$) in the grade distribution suggests that most students performed better in the Agile Development of Software Systems course. This may indicate that the project-based learning approach using the Scrum methodology had a positive impact on student engagement and performance. The statistical power of the test was strong. The a priori power of $0,8694$ and the post hoc power of 1 indicate that the sample size of 40 students was sufficient to detect this difference with a high level of confidence.

Table 2. The results of the paired t-test.

Parameter	Value
P-value	$4,13 \cdot 10^{-9}$
t	7,5242
Sample size n	40
Average of differences (\bar{x}_d)	1,825
SD of differences (S_d)	1,534
Normality p -value	0,00204
A priori power	0,8694
Post hoc power	1
Skewness	$-0,7223$

While the comparison of grades between the Programming Mobile Devices and Agile Development of Software Systems courses shows promising results, certain limitations need to be acknowledged. The sample size is relatively small ($n = 40$) and consists of students from only one academic year, which can limit the applicability of these findings to other groups or educational settings.

Although this comparison provides useful information on how traditional lecture-based teaching and Scrum-based project-based learning affect the same students, it does not fully consider individual learning differences or external factors that may have influenced performance. The self-selection of teams and differences in group dynamics could also have played a role in the results, particularly in the Agile Development course, where teamwork was a central element.

Despite these limitations, the statistically significant results and the strong power of the paired t -test indicate that the Scrum methodology had a positive effect on student performance. Further studies with a larger and more diverse sample would help to better understand the impact of Scrum across different student populations and learning environments.

DISCUSSION

The results presented in the previous section demonstrate a significant impact of the Scrum methodology on student engagement, motivation, and problem-solving skills in the Agile Development of Software Systems course. The findings suggest that the Scrum-based project learning approach fosters a more collaborative and dynamic learning environment, positively influencing student outcomes compared to the traditional lecture-based approach.

SCRUM EFFECT ON STUDENT MOTIVATION AND PERFORMANCE

A key finding from the pre-test and post-test comparison was the noticeable difference in students' motivation and their ability to apply knowledge between the two courses. The higher

average grade and more consistent performance in the Agile Development course, where Scrum methodology was used, indicate that Scrum positively influenced student engagement. This finding aligns with previous research suggesting that project-based learning and agile methodologies can lead to higher levels of student motivation and performance, particularly in subjects that emphasize teamwork and real-world applications.

It is worth noting that students rated their motivation for assignments lower in the pre-test, with an average score of 2,65. However, after participating in Scrum-based project learning, their post-test responses reflected a stronger sense of engagement and perceived value in the learning process. This indicates that Scrum's focus on iterative development, regular feedback, and teamwork encouraged students to adopt a more engaged and proactive approach to their assignments, involving them more in the learning process. The increase in average grades from 7,28 to 9,10 offers substantial support for this conclusion.

The observed improvements in problem-solving and teamwork can be directly linked to the core principles of Scrum, such as iterative feedback and student-centered collaboration. These findings align with the theoretical propositions discussed above, highlighting the adaptability of Agile practices to diverse learning environments.

COLLABORATION AND TEAM DYNAMICS

The emphasis on teamwork and collaboration was also reflected in the students' responses to post-test and survey questions related to teamwork. With an average score of 4,72, most of the students agreed that Scrum improved their group dynamics, while a score of 4,60 indicated that daily stand-up meetings had a positive impact on their communication. These results highlight the value of organized team activities and the role of regular check-ins, such as stand-up meetings, in promoting shared responsibility and mutual support among team members. Previous studies have reported similar findings on Scrum, which have linked these practices to improved teamwork and productivity in project-based learning settings.

Although retrospectives also helped improve team communication, with a score of 4,52, the slightly lower rating compared to other Scrum practices suggests that there may be room for improvement in how retrospectives are conducted and how their results are applied in later project phases. This insight can help improve future versions of the course, making retrospectives more effective.

IMPACT ON PROBLEM-SOLVING SKILLS

The post-test results on problem-solving abilities also indicate that the Scrum methodology contributed positively to students' problem-solving skills. An average score of 3.85 was given in response to the question regarding the ability to solve problems more efficiently after participating in project-based learning with Scrum. This result suggests that Scrum's iterative approach, which encourages students to regularly reflect on challenges and adjust their strategies, fostered a deeper understanding of problem-solving techniques. The use of sprints, with an average score of 4.72, highlighted that the students felt more confident in their ability to manage and resolve project challenges efficiently, improving their overall satisfaction with the learning process.

Improvements in problem-solving skills are based on student self-reports, so they may not fully reflect actual performance. However, the high scores suggest that Scrum creates an environment where these skills can develop. Future research could investigate more objective ways of measuring problem-solving skills to better understand how effective Scrum is in improving them.

LIMITATIONS AND FUTURE DIRECTIONS

This study provides evidence that the Scrum methodology positively influenced student motivation, collaboration, and problem-solving skills. However, several limitations must be acknowledged.

First, the sample size was relatively small ($n = 40$) and limited to students of a single academic year at one institution. This restricts the generalizability of the findings to broader student populations, as they may not fully reflect diverse educational settings, disciplines, or larger groups of students. Additionally, the comparison of two courses, *Agile Development of Software Systems* and *Programming Mobile Devices*, could not have accounted for other variables, such as self-selection of teams or differences in group dynamics, which could have influenced the results.

Given that the authors of this study are professors at four different higher education institutions, future research could extend these findings by investigating limitations in diverse academic contexts. Studies that involve larger and more diverse student populations in multiple institutions and disciplines could provide more comprehensive information. Incorporating extended studies over time would also offer a deeper understanding of the long-term impact of Scrum methodology on student learning outcomes beyond the immediate academic semester.

The specific focus on mobile application development and project-based learning may further limit the relevance of the findings to other disciplines. Scrum's impact on student learning might differ in subjects that do not prioritize teamwork or iterative project work. Expanding research to include a variety of academic fields would help validate and extend these findings.

The use of Likert scales to capture student perceptions introduces potential biases, such as central tendency bias, or social desirability bias where students might overestimate the effectiveness of the methodology due to perceived expectations. To mitigate these limitations, future studies should combine quantitative data with qualitative methods, such as interviews or focus groups, to gain deeper insight into student experiences. Advanced analytical approaches, such as Rasch modeling [34, 35], could also improve the interpretability and reliability of Likert scale data.

Another possible source of bias is how the survey questions are written, as they might unintentionally imply that the Scrum methodology is better. For example, questions that emphasize perceived benefits of Scrum might lead students to provide overly positive responses. To address this, future studies should adopt a neutral phrasing strategy, ensuring that the questions allow for a balanced assessment of different methodologies. Employing cognitive interview techniques during the development of the survey could also help identify and eliminate subtle biases in the formulation of the questions.

By addressing these limitations and adopting the proposed methodological improvements, future research can provide stronger evidence of Scrum's impact and expand its applicability to a variety of educational contexts.

CONCLUSION

This study explored the impact of the Scrum methodology on student motivation, collaboration, knowledge retention, and problem-solving skills within a project-based learning framework. The results demonstrate that Scrum significantly improved student engagement and academic performance. Scrum-structured practices, such as daily stand-up meetings and retrospectives, facilitated better teamwork and communication, while sprints supported continuous learning and improved problem-solving capabilities.

Comparison of student performance between the Scrum-based Agile Development of Software Systems course and the traditionally taught Programming Mobile Devices course showed a notable improvement in grades, highlighting Scrum's effectiveness in fostering a collaborative and productive learning environment. These findings suggest that the use of Scrum in higher education can support the development of technical and interpersonal skills.

The limitations of the study, including the small sample size and focus on a single academic context, indicate that further research is needed to generalize these results. Relying on self-reported data may not fully reflect objective learning outcomes. Future studies should investigate the impact in different educational settings and incorporate a wider range of assessment methods.

Scrum methodology offers valuable pedagogical benefits by improving student motivation and teamwork, making it a promising approach to project-based learning in higher education. Expanding this research could provide deeper insights into the long-term effects of Scrum on student learning and professional preparedness.

APPENDICES

APPENDIX 1

Pretest questions:

1. How often do you feel motivated to work on the assignments given in class?
 2. How often do you feel like you understand the material being taught in class?
 3. How often do you feel that your contributions to class discussions are valued by your peers and instructors?
 4. How often do you feel like you are actively involved in your own learning in class?
 5. How often do you feel like you can see the connections between what you are learning in class and real-world applications?
 6. How often do you feel like you can apply what you have learned in your class to other subjects or your future career?
 7. How often do you feel like you can work collaboratively with your classmates in your class?
 8. How often do you feel like you can set and achieve goals in your class?
- (1 = never, 2 = rarely, 3 = sometimes, 4 = often, and 5=always)

APPENDIX 2

RQ1: Does participation in project-based learning with Scrum methodology lead to improved student outcomes, such as increased knowledge retention and problem-solving skills?

1. To what extent do you think that participating in project-based learning with Scrum methodology helped you retain knowledge better?
 2. Was participation in project-based learning with Scrum methodology effective in improving your problem-solving skills?
 3. Do you think project-based learning with Scrum methodology was more beneficial than traditional methods in retaining information?
 4. In your opinion, did project-based learning with Scrum methodology increase your ability to solve problems in a more efficient manner?
 5. Was your learning experience better in project-based learning with Scrum methodology compared to traditional methods?
- (1= strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree)

APPENDIX 3

RQ2: Does the implementation of Scrum practices, such as daily stand-up meetings and retrospectives, enhance collaboration and communication among students, leading to improved teamwork and group dynamics?

1. Daily stand-up meetings helped improve collaboration and communication among my team members.
2. Retrospectives were effective in identifying areas for improvement in our team dynamics.
3. The use of Scrum methodology improved our teamwork and group dynamic.
4. I feel that our team performed more efficiently due to the use of Scrum methodology.
(1= strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree)

APPENDIX 4

RQ3: Does the use of sprints in Scrum methodology improve project management efficiency, resulting in higher student satisfaction and better overall project outcomes?

1. I agree that using sprints in Scrum methodology improved the efficiency of project management.
2. I believe that using sprints in Scrum methodology resulted in better project outcomes.
3. The use of sprints in the Scrum methodology had a positive impact on my satisfaction with the project.
4. I think my understanding of project management improved because of the use of sprints in Scrum methodology.
5. The use of sprints in the Scrum methodology improved collaboration and communication within my project team.
(1= strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree)

APPENDIX 5

Q1: Have you encountered obstacles that you were unable to solve independently during the project? If so, have you requested the assistance of other members of the team?

- We were struggling to figure out how to integrate new words from the website into the application and how to make two requests within one activity. But then we realized that all the other teams were stuck on the same thing. After the class, we got together and talked about our issues, sharing ideas with each other. And it was super helpful when we presented our sprints and could ask other teams for their insights.
- With the help of XY, we were able to analyze and dissect the problem. Through collaboration and teamwork, we were able to successfully reach a solution.
- In addition, members of other teams also provided their support and expertise, which greatly contributed to our solution.
- I provided guidance and assisted with the problem-solving process by reviewing the code and offering suggestions for solutions.
- I received assistance from a student on a competing team. This solution was subsequently implemented in various *parts of our application*.

Q2: Did you think this project was not for you?

- Since we are all IT students, I don't think the work assigned to our team was improper for us. Based on our strengths, our team assignments were distributed, allowing each of us to contribute as much as possible. For example, even though I may not have advanced coding skills, I am a good designer. Working as a team was a satisfying experience for me.

- To be honest, I was unsure about working on this project because I don't like Java programming. But I decided to help my team and I tried my best to work on the project.
- I was surprised to find that I enjoyed and learned a lot from working in a team. I was interested in the project and really wanted to help make it a success.
- I think it was not for me because I did not know much about Java, which made it hard for me to help with some tasks. So, I focused on testing the application and preparing the documentation.
- Although I do not have a strong affinity for Java programming, I took on the responsibility because I had the highest knowledge among my team members. Additionally, my participation in the team resulted in an unsatisfactory experience, as I felt overwhelmed by the need to initiate action and guide the progress of the project. Sometimes, I felt that without my prompt, certain tasks may have gone unresolved.
- I was afraid to ask questions at the beginning of the project because I felt that I needed to finish a task before talking to others, but gradually I realized that all team members should be honest with their performance to finish on time. By discussing the goals of the team with your peers, you will be able to adapt to their ways faster and work effectively as a team.

Q3: During the project, did you consider the possibility that a team member would be unsuitable for the team?

- I was satisfied with the performance of all my team members, and I think they did a very good job.
- I am proud of my team for getting the application done so quickly and in such a short time. I think it is because we had clear goals and a solid foundation, and each person had a role in which they could excel.
- To be frank, I did not perceive any individual as lacking in their contributions to the game development project. It is possible that some team members may have a different opinion on my own level of participation, as I did a bit less work compared to my peers.
- I was feeling pretty discouraged about this project because I wasn't seeing the same level of dedication from my team members as I had. I was hoping to work with people who were just as invested in making this project a success as I was, but it didn't seem like everyone was on the same side.
- We tried to keep it simple and assign tasks that were easy to complete, but noticed a lack of teamwork. Unfortunately, it did not work as we hoped.

Q4: Do you think it was good that all teams were tasked with creating the same language learning application?

- Yes, it was a good idea. We had the opportunity to share ideas and perspectives with members of other teams. It was instructive to observe the progress of other teams and to gain insight into new ideas and solutions that contributed to the advancement of our project.
- It was beneficial for all teams to have the same project, as it allowed a diversity of solutions to be explored. Although our team did not have any problems, it would have been valuable for us to observe the progress and approaches of other teams in case we encounter difficulties in the future.
- In my opinion, working on the same project as other teams allowed for a more collaborative and supportive environment. We were able to exchange ideas and help each other when faced with difficulties. The opportunity to observe and learn from our peers was extremely valuable.
- I do not believe that working on the same project as other teams was particularly beneficial to our team. I prefer a more individualistic approach and find it disruptive to have to constantly be aware of what other groups were doing.

- On the one hand, it was useful to see what other groups were doing and how they solved some functionalities. On the other hand, it created a lot of pressure for us to keep up with the other teams and perform well.
- We were struggling to figure out how to integrate new words from the website into the application and how to make two requests within one activity. But then we realized that all the other teams were stuck on the same thing. After the class, we got together and talked about our issues, sharing ideas with each other. And it was super helpful when we presented our sprints and could ask other teams for their insights.

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