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Improving the Performance of Student Teams in Project-Based Learning with Scrum

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Abstract: The purpose of this paper is to analyze the effectiveness of Scrum for project and team management in PBL teams in higher education. To attain this goal, a study was carried out to analyze students' perceptions about Scrum as an effective method for PBL teams. Based on two different editions of PBL that used the Scrum method with different characteristics in each approach, this paper aims to identify the best practices for effective team and project management and draw recommendations for successful use of scrum in PBL approaches. The authors used an exploratory case study carried out within an engineering program at the University of Minho, Portugal. The research design was based on an explorative quantitative and qualitative approach. Implementing Scrum in PBL teams helps students to keep the project running smoothly and draws greater awareness on how to manage the project and teams in a more effective way. Findings show that task assignment, performance monitoring, visual management and regular feedback were considered the main advantages of using Scrum in PBL teams, which had a positive impact on student performance. However, for the success of Scrum, students recognize the role of the Scrum Master and Project Owner as vital to guide the teams in a sustainable way. Research on the application of Scrum in Education is scarce and mostly exploratory. This paper is among the very few empirical studies consolidating knowledge on the implementation of Scrum approaches to improve learning in higher education. More specifically, it brings a valuable contribution on how to improve specifically team performance in PBL teams with the use of agile approaches such as Scrum.

Keywords: higher education; project-based learning (PBL); scrum; team performance; project management; engineering education

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1. Introduction

With the increased importance of teamwork and project management skills for the professional profile of graduates, Scrum appears as one of the most known agile project management approaches. Its positive results in the software industry in terms of teamwork effectiveness and quality results have been shifted to the educational context in order to benefit from its main strengths, which include teamwork values such as commitment, courage, focus, openness and respect. Considering that Scrum is, nowadays, highly used and effective in project management practices, it is important to understand what application has been given to Scrum in the educational context. Higher education institutions focus more and more on student centered teaching and learning approaches, where students are involved in the development of not only technical skills of their field of expertise but interpersonal and social skills, such as teamwork, leadership and lifelong learning skills. Project-Based Learning (PBL) is one of these approaches. It is considered a powerful strategy not only for learning, but to promote the empowerment of citizens for the transformation of society. With PBL, students become more aware of social circumstances and

reveal deeper engagement in learning when they feel that their work could impact other people positively [1].

Problem-solving and teamwork are important competencies for graduate students in the 21st century [2]. However, when engaged in group work tasks or performing a project that lasts the whole semester, such as Project-Based Learning (PBL), students face several difficulties in dealing with project management and teamwork [3]. Traditional teaching and learning approaches do not seem to be engaging engineering students in project management education. Although the students acquire remarkable theoretical knowledge throughout their coursework, they lack transferable competences, such as soft skills, which are scarcely attended in educational contexts [4]. This study aims to address this research problem and discuss the effectiveness of Scrum for project and team management in PBL teams in higher education.

The first section of this paper presents a review of literature about Scrum and its use in the educational context, with particular focus on PBL approaches to teaching and learning. Based on this overview of the literature on Scrum's main principles and applications, the authors present the aim of the study in the methodology section, describing the context of the study where the empirical data were collected. The results are discussed according to findings from students' perceptions about Scrum as an effective method for project and team management in PBL settings. Based on two different editions of PBL that used the Scrum method with different characteristics in each approach, the paper provides empirical evidence about the effectiveness of scrum to improve team performance in PBL teams and draws recommendations for the successful use of scrum in PBL approaches.

1.1. Scrum in PBL

1.1.1. Project-Based Learning (PBL)

Project-Based Learning (PBL) is an active learning approach where students develop technical and transversal skills though project work. The project to be developed by a team of students in a PBL environment is the main driver for developing technical and transversal competences or skills. Students are organized in teams and each team must develop a project in a real context (or almost real) where most of the subjects covered by most courses in the semester should be developed/required. Students still have to attend some traditional classes, but most of the work effort is typically assigned to project work. During the semester, students develop key technical skills as well as transversal skills, crucial for real work environments. Teamwork, project-based learning (PBL) and close interaction with industry was emphasized in the Engineering Education Reform in the US by the National Science Foundation in 1997. These new directions in engineering education were based on employers' perceptions that apart from their technical knowledge, engineers also needed to be good communicators, good team members and lifelong learners. On the other hand, in Europe, Aalborg University in Denmark in 1974 was probably the first university adopting Project-Based Learning as the main pedagogic methodology to be applied in their degrees [5]. Another important published work regarding Project-Based Learning methodology was proposed by Powell and Weenk (2003) [6] under the name of Project-Led Engineering Education (PLEE). This work was later one of the main inspirations to the development of the PBL approach at the University of Minho, in Portugal, in the Integrated Master's Degree in Industrial Engineering and Management [3]. More details regarding this PBL approach are described further in this paper, namely, in the section related to the context of the study.

1.1.2. Scrum Approach

Scrum is an agile methodology [7] developed and mainly used in software companies to help teams in managing their project work in developing effective software applications in meeting customer expectations. Examples of agile methodologies are eXtreme programming (XP), lean software development, feature-driven development (FDD) and crystal methodologies [8]. Agile methodologies require less emphasis on detailed plans

and strict control and relies more on informal collaboration, coordination and learning [9]. Agile methods promote frequent inspection, continuous adaptation, frequent feedback from clients and emphasis in leadership, and stimulate teamwork, self-organization and accountability. Traditional development methodologies are based on extensive planning and categorized processes, but agile methodologies such as Scrum relies on "people and their creativity" [10] and deals with uncertainty, requirement changes and continuous improvement.

The word "Scrum" (short for scrummage) comes from the rugby game [11]. In rugby, it is a method of restarting play that involves players packing closely together with their heads down and attempting to gain possession of the ball. Jeff Sutherland had used Scrum for software development projects in 1993 for the first time and it is defined by its creators as "a framework within which people can address complex adaptive problems, while productively and creatively delivering products of the highest possible value" [12]. Scrum is very much inspired in the concepts and principles of the Toyota Production System [13], such as respect for people, focus on customer, continuous improvement, visual management, flow of work and waste reduction. Scrum, although originally formalized for software development projects, can also be applied in any complex, innovative scope of work [14].

The components of Scrum are the roles, events and artefacts. The most relevant roles of Scrum are the Scrum Team, The Product Owner, and the Scrum Master. The Scrum Team is normally small (5–9 people) and does not include the Product Owner and Scrum Master. These Teams are cross-functional, meaning that each member must understand his/her role as well as the tasks to create each product increment [15]. Given their autonomy, these teams are considered self-organizing and all the recognitions are never for individual team members, but for the team as a whole. The Product Owner represents the external stakeholder interests [11], allowing the maximization of the delivered value for the costumers and the approval of the performed work. He or she is the one responsible to define requirements and document them as user stories in the Product Backlog. The Scrum Master is characterized as a "servant-leader" [12], overseeing the Scrum process and ensuring that the team uses the full range of Scrum appropriate agile values, practices and rules. Bass [16] identified six Scrum Master activities in a large-scale distributed organizational context: process anchor, stand-up facilitator, impediment remover, Sprint Planner, Scrum of Scrums facilitator and integration anchor. Thus, the Scrum Master aims to maximize the value created by the Scrum Team, working constantly to reduce product risk through the incremental delivery of features, rapid response to development obstacles and continual tracking of the delivery of backlog items [15].

The type of events in Scrum [12] are the Sprint, the Sprint Planning, Daily Scrum, Sprint Review and Sprint Retrospective. A Sprint is the development of the set of tasks planned at the Sprint Planning. A Sprint can vary from 1 to 4 weeks. The Sprint Planning is a meeting in the beginning of a Sprint where team members define the set of tasks that will be performed in the Sprint. The Daily Scrum is a daily meeting where team members update one another on their progress, difficulties they have experienced and their future goals. In the Sprint Review, the team inspects what happened in the Sprint and if the tasks were performed according to the plan, and update the Product Backlog. In the Sprint Retrospective, the team reflects upon what went wrong and plans improvements to next Sprint.

The Product Backlog, the Sprint Backlog and the Burndown Chart are the Scrum main artefacts. The Product Backlog is managed by the Product Owner and is an ordered list of everything that is known to be needed in the product. The Sprint Backlog is the set of Product Backlog items selected by the Scrum Team for one Sprint. The Burndown Chart is a way of representing the velocity of the team, showing in a graphic how the team is performing according to what was planned for the Sprint.

1.1.3. Scrum in Education Contexts

A Scrum-based approach for educational purposes was developed by Willy Wijnands, a professor of Physics and Chemistry at Ashram College located in the Netherlands [17]. In this method, the students' teams perform Sprint Planning based on a product backlog defined by the teacher (who acts as the Product Owner). The main difference of EduScrum when compared with Scrum is that the pace of the students must be very much influenced by the teacher in order to follow the teacher's plan. There is also less uncertainty because of the course syllabus that is very strict in schools. On the other hand, the Sprint Reviews and Sprint Retrospective create an adequate platform for continuous improvement in student teams.

Publications referring to the application of Scrum or EduScrum in higher education are scarce and mostly exploratory. Based on the five papers considered in a systematic review [18], four main dimensions were identified:

- EduScrum had positive impact in the development of students' soft skills such as such as writing, ability to conduct oral presentations, punctuality, leadership, decision making skills and transparency [19]. An increase in structured and self-organized teamwork, time planning, leadership and a greater awareness of the teamwork by the students was reported by Van Hout and Gootjes [20], who also found that students playing the Scrum Master role showed greater responsibility for the outcome and for the self-organization of the team.
- EduScrum improves students' satisfaction, engages students on the learning process, develops meaning in learning and creates significant learning [21].
- Scrum should be adapted and integrated in academic environments [19–22]. Scrum can be used as a very effective project and team management tool in assisting teams of students in project work and EduScrum can be effective in more traditional learning formats.
- Scrum applied in project work carried out by student teams improves the engagement of the teacher in the learning and teaching activity process as a motivational factor for the team cohesion. Regular tutor feedback and frequent communication amongst group members were considered as very significant factors that helped in achieving group cohesion [21]. Regular feedback from the teacher was considered by students as the most important factor for group cohesion, according to the survey results. Students emphasized the importance of the close collaboration with the teacher to clarify the project requirements and regular meetings with the teacher to obtain feedback and help in understanding expectations and solve the problems arising.

Based on this, one of the first, but not surprising, conclusions is the important role of the Scrum methodology to enhance the development of teamwork skills and collaboration, both by students and by teachers. In project-based approaches, teamwork is highly valued and enhanced. Scrum contributes to the development of teamwork, leadership and lifelong learning skills, as addressed in the studies analyzed. This confirms the perspectives discussed in a recent study developed by Cabedo et al. (2018) [1], calling attention to the social role and responsibility of universities, which need to be more than centers for preparing qualified professionals and generating knowledge. Universities should become places where individuals can acquire the competences for the transformation of society and promote the empowerment of citizens to live sustainably at different levels. In this study, PBL was considered an effective strategy to attain this goal. Results showed that students became more aware of social circumstances and that when they felt their work could impact other people positively, their engagement was deeper.

Taking into consideration that Scrum has been used in student-centered teaching and learning processes in higher education, with special emphasis on PBL approaches, it could be useful to develop a specific framework for Scrum adapted to the PBL contexts of higher education. As aimed by Dinis-Carvalho, Fernandes and J. C. R. Filho (2017) [22], comparing and combining Lean Teaching and Learning (LTL) features with EduScrum and vice versa,

proposing a set of guidelines based on the best practices of each approach, it is important to develop a Scrum model suitable for PBL approaches.

Although the studies provide evidence of the effectiveness of Scrum to develop student skills, mostly the generic competences known as the 21st century skills, issues regarding effective teamwork skills require further developments and research, especially matters related to improving communication, group formation and leadership, as found in the results of Cubric's [21] study. The development of an evaluation framework for Scrum, including the design of rubrics and tools, for the assessment of student skills is a fundamental issue. Future work should focus on addressing this need as a way to facilitate the continuous improvement process.

1.1.4. Scrum in Project-Based Learning Context

A published paper already reported the study conducted in a PBL project [23] where two teams of students applied Scrum as a tool to help them manage the project and the team. That was the first time teams of students used Scrum in the PBL program in the Integrated Master's Degree in Industrial Engineering and Management at the University of Minho. The need for effective project and team management techniques and methodologies was becoming more and more obvious as the student team size was increasing every year in this engineering program. Scrum methodology makes a lot of sense in PBL environments since many dimensions of the projects are unpredictable and this methodology diminishes this high-risk perception and enhances the need and focus on tasks that are smaller, more predictable and attainable. In most cases, no one knows how the project will evolve. Neither students nor most companies have any experience with this type of projects and therefore, little knowledge exists about what will happen. The projects are evolving as they happen, depending on feedback from companies, feedback from teachers or from unexpected restrictions. This kind of uncertainty requires very adaptive approaches with very frequent feedback from different stakeholders. The project associated with the work developed on a daily basis showed us the need to have a specific methodology that could act on people skills and their organization. Scrum provides many important features that are effective for teams of students performing project work, such as visual representation of the tasks to be performed by the team, constant monitoring of the work, fair distribution of the workload, tools to plan the work to be performed (Sprint Planning), priority assignment to tasks, frequent feedback from Product Owner (Sprint Reviews), avoidance of many traditional conflicting situations, continuous improvement imposed by the Sprint Retrospective, transparency and others.

Recent related work, such as [4,24–34], shows the importance of new project management education approaches and methods to develop the current Generation Z students' competences. Findings from current research developed on this topic focus on project management competencies, enhanced with Scrum methods, and recent trends in teaching approaches that are aligned with student-centered educational perspectives. Besides the engineering field, research shows that Scrum has also been successfully applied to other field areas in higher education with positive results [35–37]. For instance, in the field of Initial Teacher Education, findings from [36] reveal that the Scrum methodology promotes the development of students' ability to resolve complex pedagogical situations and increases the quality of education and student motivation to learn.

2. Materials and Methods

2.1. Context of the Study

This study takes place in a PBL-oriented semester in the fourth year of the Integrated Master's Degree on Industrial Engineering and Management at the University of Minho, Portugal. This PBL approach involves all the curricular units of the semester and companies providing the real context. Each team of students carries out a different project in a different company. One particular curricular unit, named "Integrated Project in Industrial Engineering and Management II" (IPIEMii), assumes the leadership of the project and

manages the communication between all curricular units, student teams, companies, tutors and teachers (Figure 1). The curricular units included in the semester are (i) Manufacturing Systems Organization II, (ii) Integrated Production Management, (iii) Production Information Systems, (iv) Ergonomic Study of Workstations, (v) Simulation and (vi) Integrated Project in Industrial Engineering and Management II.

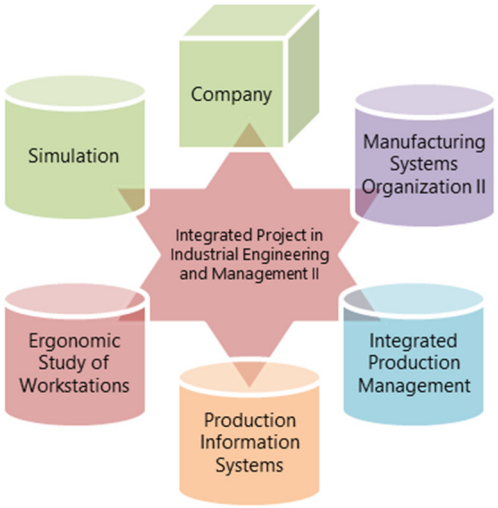

Figure 1. Illustration of the interdisciplinary relationship between curricular units and the company.

The project is divided into three stages (Figure 2): (i) company exploration/recognition, (ii) analysis and diagnosis of the production system and (iii) improvement proposals; each stage's end was characterized by a milestone.

Figure 2. The three stages of the project.

Students should characterize and diagnose the existing production system on a company and evaluate its performance, identify waste, identify and model planning processes and production control, partially analyze how the implemented systems meet the functional requirements and the production system information and create simulation models of the production system. Furthermore, students should also characterize workstations from the ergonomic point of view and their physical environment and identify possible alternative actions and expected results. Throughout the semester, students must develop the learning skills listed on the six curricular units directly involved in the project as well as other professional skills more linked to the real context project work. Student teams are encouraged to strive to implement the improvement proposals, but it is not compulsory for the project approval. Ideally, the improvements should be implemented within the semester, but in many cases, the improvements are implemented afterwards, and in some cases, the improvement proposals are never implemented.

This study was conducted over two consecutive years with the Scrum methodology, introduced as a tool to help students manage their teams and projects more effectively. In the first year, only two teams adopted the Scrum methodology, and in the second year, all eight teams adopted Scrum. One of the teams that applied Scrum with great success in year 1 (2017/2018) helped all teams in year 2 (2018/2019), providing training and playing the role of Scrum Master for each of the teams. An overview of the description of the Scrum approach, introduced in the PBL program, is presented in Table 1.

Table 1. Overview of the Scrum introduction in year 1 and year 2.

	Year 1	Year 2
Number of Teams	2 teams (10 students per team)	8 teams (9 students per team)
Scrum Master	1 PBL Team Tutor (Lecturer) played the role of Scrum Master in both 2 teams.	6 students (*) with experience in Scrum from previous year played the role of Scrum Masters in all the 8 teams.
Initial Training	The two teams had short training in Scrum organized by one lecturer and one Scrum Master from a software company. The training was based on presentations, discussion and simulations.	The 6 students from previous year trained the new students by using presentations, discussion and Scrum simulations. They also created Scrum boards and other templates developed from their previous experience.
Scrum Board	Evolving throughout the project	Framework defined at the beginning
Task Assessment	Scrum poker; assigning number of hours for tasks	Scrum poker; assigning number of points for tasks
Burndown Charts	Yes	Yes
Sprint Reviews	Yes	Yes
Sprint Retrospectives	Very light	More formalized
Task Classification	Stories; Tasks	Epic; Stories; Tasks

(*) These 6 students carried out these roles through a Scrum project in the context of a curricular units named "Project and Team Lean Management". Their project objective was to develop the Scrum environment specific for student team's projects. This project included the development of a Scrum board template, time assignment to tasks and Sprint Planning framework.

2.2. Data Collection and Analysis

This paper aims to analyze the effectiveness of Scrum for project and team management in PBL teams in higher education. To attain this goal, a study was carried out to analyze students' perceptions about Scrum as an effective method for PBL teams. Based on two different editions of PBL that used the Scrum method with different characteristics in each approach, this paper aims to identify the best practices for effective team and project management and draw recommendations for successful use of Scrum in PBL approaches.

For data collection, an online survey to students was applied at the start and end of the PBL projects. This survey addressed questions related to students' expectations about the Scrum method (e.g., what is Scrum, strengths/weaknesses, difficulties, role in project management, utility of Scrum) and also their perceptions at the end of the project, regarding the importance of Scrum for project and team management (e.g., task distribution, project workload, individual effort, team conflicts, utility of Scrum, weekly planning, strengths/weaknesses, difficulties encountered, Scrum Master, intention to continue to use Scrum).

Other methods, such as direct observation (e.g., regular visits, by the Scrum Master, the researcher and the PBL staff members, to observe the teams working in the project rooms and group meetings), document analysis (e.g., Sprint Planning, burndown charts, Scrum boards) and informal conversations were also included in the study, although with less attention. Data reported in this study refer to the academic years of 2017/2018 (year 1) and 2018/2019 (year 2).

The total number of participants in the study was 92 students. In year 1, only two PBL teams used Scrum (about 20 students). In year 2, all eight PBL teams used Scrum (72 students).

The results from the online surveys were subject to an exploratory analysis. The quantitative results presented were retrieved directly from the Google Forms survey (frequencies and mean average) and the qualitative data from the open-ended questions were analyzed through a content analysis [38]. Based on this analysis, the authors identified categories and established connections to interpret the data and explain findings. An integrated approach, combining qualitative and quantitative data, is presented in the next section [39].

3. Results and Discussion

The results of the study provide an overall view of the impact of the use of the Scrum method to improve PBL team performance. These findings, which emerge from the data collected from participants and the analysis of Scrum artefacts, can be organized and discussed based on a set of categories, mainly related to the features of Scrum applied to the PBL context. Findings are presented and discussed according to three main dimensions: (i) organization of PBL teams with Scrum; (ii) benefits of Scrum for PBL teams and (iii) the role of the Scrum Master.

3.1. Organization of PBL Teams with Scrum

3.1.1. Year 1 of Scrum—2017/2018

From the existing six teams in the PBL project semester, two teams were randomly selected to adopt the Scrum methodology to manage their projects and their teamwork. The selected teams were briefly trained on the main features of Scrum and a teacher was assigned to both groups to play the Scrum Master role. A teacher playing the traditional tutor role is always assigned to each PBL team [40,41], but in this case, a teacher with motivation and some degree of Scrum experience was assigned to play the Scrum Master role [23].

The Product Owner role was performed by the responsible for the "Integrated Project in Industrial Engineering and Management II" course. Regarding the Sprint Length, both groups decided upon using Sprints of a one-week period (see Figure 3). A board was assigned to keep Scrum information in both teams that adopted Scrum methodology (see Figure 4).

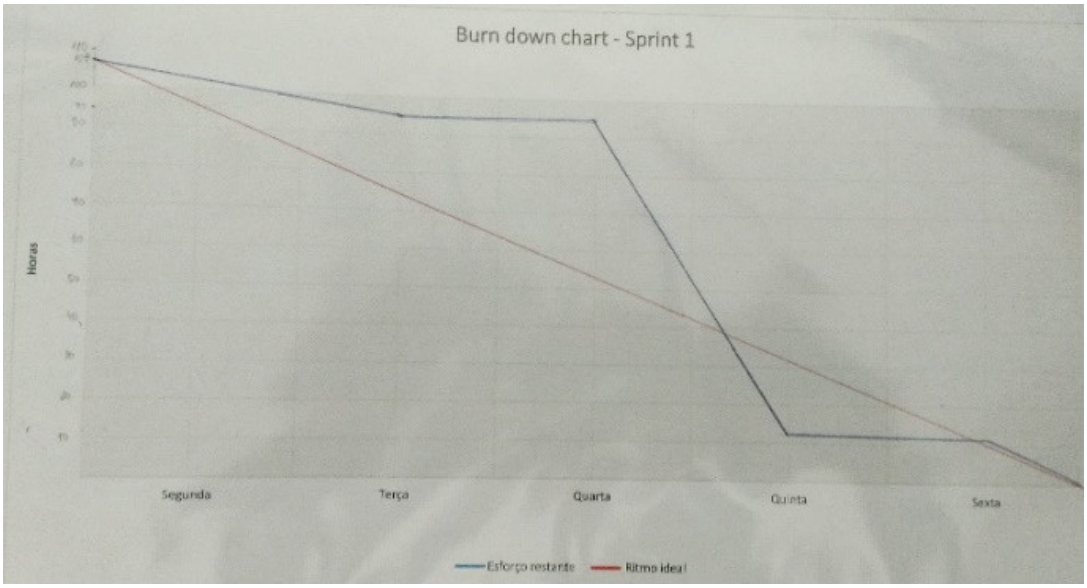

Figure 3. One example of a burndown chart.

Figure 4. The Scrum board of one team.

3.1.2. Year 2 of Scrum—2018/2019

Based on the good results obtained in first edition with Scrum in PBL, one team of five students from year 1 (Scrum Training Team) accepted the challenge of training new students (on year 2) on the use of Scrum in their project work. In addition, these students would also have to take on the role of Scrum Master in the first half of the semester. This challenge was, in fact, their own project in the context of one curricular unit at the fifth year (final year) called "Lean Enterprise". The Scrum Training Team performed Scrum training and acted as Scrum Masters as part of their project in the context of a specific curricular unit of the final year of their integrated master's degree. These five students started to train all eight PBL teams about the main features, principles and concepts associated with the Scrum approach. The team of five students from year 1 created a template for Scrum board to be used by all eight PBL teams of year 2 (see Figure 5). They trained all the PBL teams and acted as a Scrum Master during the first 6 weeks of project.

Each team had to continue using Scrum, assigning one of its members the role of Scrum Master on the Sprint Planning meeting as well as on the daily meeting, Sprint Reviews and Sprint Retrospective Meetings (see Figure 6). The Scrum Master (senior PBL team member) also delivered questionnaires to all PBL students at the beginning and the end of the semester in order to evaluate the effect of Scrum in their project work.

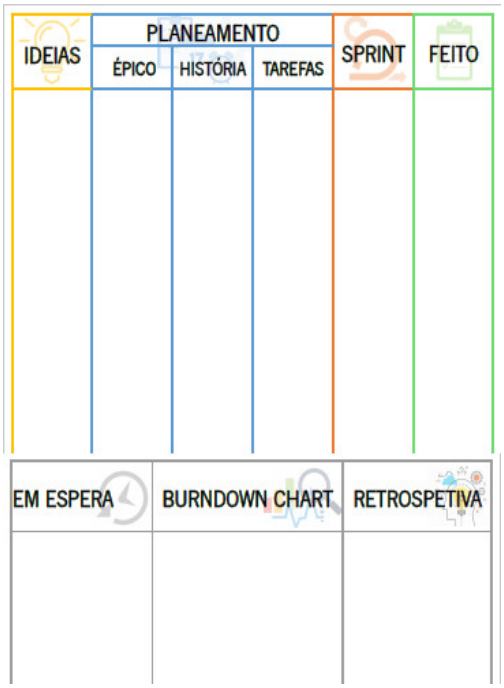

Figure 5. The Scrum board of teams.

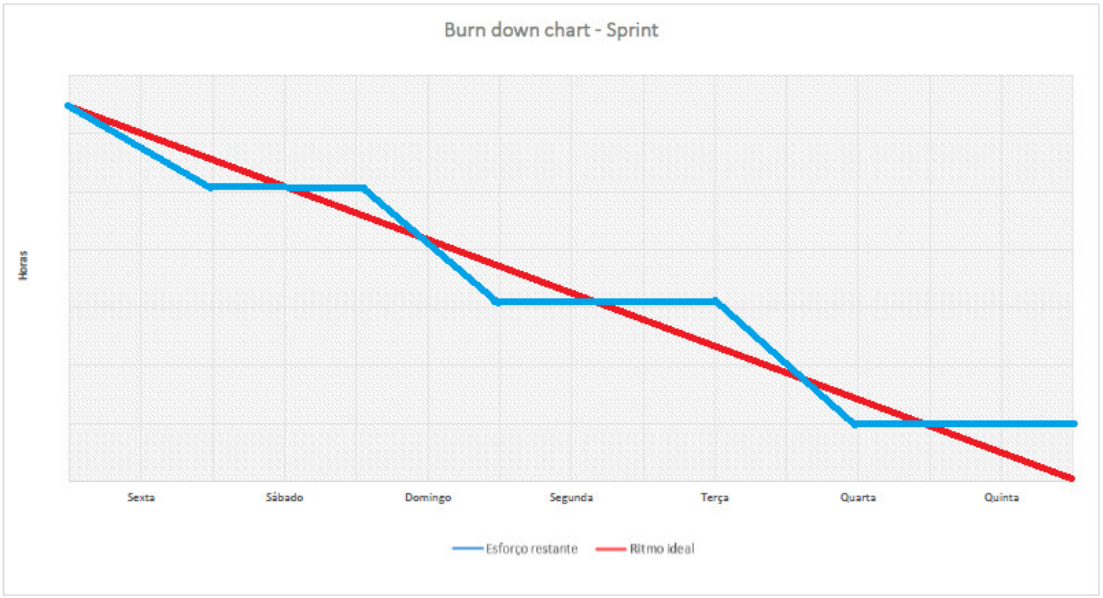

Figure 6. Example of a burndown chart.

3.2. Benefits of Scrum for PBL Teams

3.2.1. Visual Management

The visual management information available in the Scrum board is valuable for the PBL management process. Not only are teams more aware of their own performance and task assignment, but teachers and other stakeholder can easily grasp the state of the project. Sprint Planning was considered by PBL teams as the most important Scrum event. Although in the beginning, most students did not see its value, as they gained greater experience in defining the tasks, they became more aware of its effectiveness. Students soon realized that the time spent in defining the tasks in detail, its workload and responsibility gave them the advantage in achieving very good performance every

week. The burndown charts were created in every Sprint Planning meeting according to the man-hours available and the amount of hours required for the planned tasks to the next Sprint, and then updated as tasks are completed. The Sprint Planning became such an important tool for groups that some students admitted that they could not manage their project without it [23].

These findings are aligned with the principles of agile methods, which promote frequent inspection, continuous adaptation, frequent feedback from clients, emphasis on leadership, stimulates teamwork, self-organization and accountability [7].

3.2.2. Task Assignment

Students reported that task assignment, weekly planning and definition of deadlines were the main advantages of Scrum for PBL teams. The difficulty in defining the duration of tasks was one of the main difficulties found, probably due to the lack of experience of students in using this method. However, after acquainting with the method and the Sprint Planning, one of the teams admitted that the Scrum method was truly effective for project management and that the team felt highly committed to its use. For example, this team mentioned that they took pictures of the board so that they could see it even when they are not in the room. This shows how much they became dependent on it. Some of students' quotes from the online survey confirm this.

> *"It helps the organization of work. There is no doubt about that. The fact that we analyze problems and transform them into tasks and, at the same time, we make each member responsible for the achievement of each task, in the timeframe of a week, encourages the team to work effectively. Setting goals to keep up with this method is, in my opinion, an encouragement for the group".*
>
> *"It helps mainly to distribute tasks in a balanced way and to ensure that work is done continuously over time."*
>
> *"To distribute tasks evenly."*

In terms of workload balance and evaluation of individual performance, the surveys applied by the senior PBL team in year 2, at the end of the project, reveal that students clearly recognized that individual effort and work was more evenly balanced by all team members with the use of the Scrum approach (Figure 7).

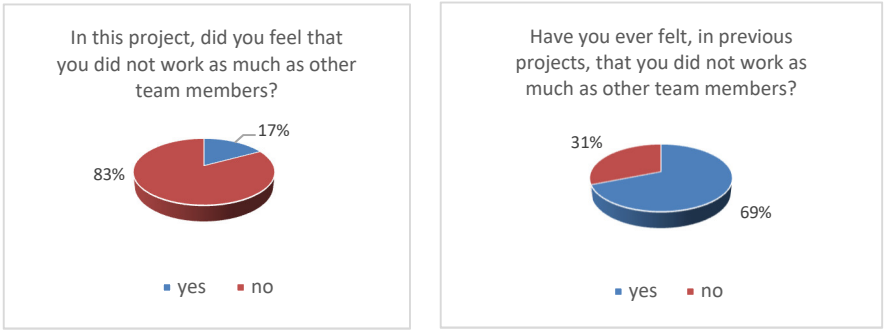

Figure 7. Results from the online survey.

This is one of the main challenges regarding PBL [6]: how can we ensure that all students contribute equally to the project? The consolidated experience of the PBL practitioners at the University of Minho shows that, beyond other strategies implemented, such as peer assessment [42,43], Scrum can contribute in an effective way to keep all team members engaged and responsible for the project results.

3.2.3. Team and Personal Organization/Management

One of the goals of PBL, as stated by Barrows [44], is the development of effective self-directed learning skills, including the development of team skills. These goals require that

PBL approaches be student-centered and allow students to be able to determine, on their own, what to learn and from what resources, guided by a facilitator or tutor. The Scrum approach provides this learning environment for student.

According to students' answers, Scrum supports PBL teams in the project management process by providing a better organization of the team, a better planning and management of tasks and also the fulfilment of deadlines in the stated dates. Individual responsibility is also enhanced through this process. The following quotes from students confirm this.

> *"It encourages personal organization and fulfilment of deadlines, resulting in a better management of the project".*
>
> *"Since there are many members in the team, the use of Scrum helps to keep the team focused".*
>
> *"I hope it helps the team not to procrastinate and to be more organized and work as a team".*
>
> *"Improve my team management skills."*
>
> *"Allows better organization of the team, helping at the time management level."*
>
> *"It helps the group to organize itself."*
>
> *"Have things defined and start thinking in the long run."*

In regard to conflict situations, which usually appear in teamwork and project environment, it was also possible to verify that with the use of Scrum, conflict situations between team members are less frequent than in traditional project approaches, where 91% of students confirmed to have witnessed conflict situations between team members. When asked about the reasons for this to happen, the greatest change can be found in regard to the item "poorly defined roles" (see Figure 8).

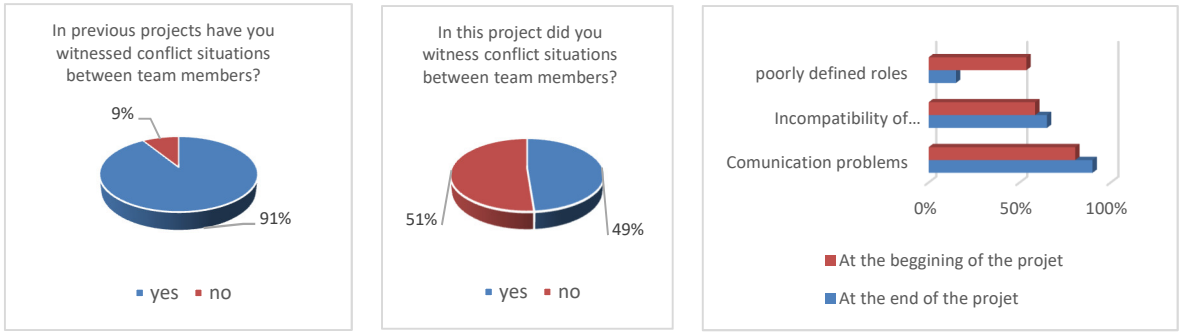

Figure 8. Results from the online survey.

3.3. The Role of the Scrum Master

The Scrum Master, as characterized by Schwaber and Sutherland [45] and Bass [16] ensures that the team uses the full range of Scrum appropriate agile principles and develops a set of activities such as the Sprint Planning with the team. The role of the Scrum Master, carried out by the senior PBL team, was organized according to a set of tasks that were defined as a strategy for the effective use of Scrum in year 2.

1. Select one Scrum Master for each team.

Weekly random selection of a Scrum Master for each project team.

2. Schedule the Sprint Meeting with teams.

Send an email, each week, to the project teams with the next Sprint Meeting scheduled.

3. Check the Team Performance sheet.

Each Scrum Master should check the team performance sheet for which they are responsible during the week to keep up-to-date in regard to the group's current situation.

4. Sprint Meeting.

A weekly meeting takes place where the Scrum Master guides the project team.

5. Complete of Team Performance Record.

At the end of each meeting, the Scrum Master should record the team's performance.

When questioned about the importance of the Scrum Master in the PBL team, students from year 2 agreed that he/she played a very important role in the project. The following quotes from students confirm this.

> *"No doubt. Taking into account the initial difficulties in adapting to the method, the SCRUM Master was crucial to get quickly acquainted with the Scrum method and also to teach and guide the group right pathway".*
>
> *"Because they helped keep the group calm and do things head-on."*
>
> *"To be able to apply the method as soon as possible, in an appropriate manner."*
>
> *"To guide us in how to do; and the fact that they have already worked with the method, allowed us to do it more quickly."*
>
> *"It helped to understand the concepts of task distribution, helped to maintain a certain order at the beginning and helped mainly to support the decision about the next steps of the project."*
>
> *"It is the engine for the planning dynamics."*

4. Conclusions

The findings reported in this paper suggest a high level of student satisfaction with the use of Scrum to improve PBL team performance, mostly in regard to the development of project management skills. Scrum appears to be an effective tool for PBL teams as it provides regular feedback about the project. Implementing Scrum in PBL teams helps students to keep the project running smoothly and draws greater awareness on how to manage the project in a more effective way by the teams. Findings show that task assignment, performance monitoring, visual management and regular feedback were considered the main advantages of using Scrum in PBL teams, which had a positive impact on team performance.

These findings confirm other studies, such as those of Mahnic and Rozanc [46], that reported that students enjoyed learning Scrum in a close to real world environment. Their perceptions about Scrum were positive, and the empirical evaluation based on surveys conducted after each Sprint and at the end of the course confirmed the anecdotal evidence about the strengths of Scrum reported in literature. Mahnic [47] also concludes that teaching agile is best executed through project and practical work and emphasizing the role of "Product Owner" in the teaching process.

The main differences between this study and other studies on the use of PBL approaches are as follows:

- The management of teams in a project context is not left to the students' intuition and ability to improvise, but rather assumed to be a fundamental aspect in the development of the project.
- In addition to the project's technical skills and classic transversal skills associated with PBL, much emphasis is given to the development of skills related to project management, team management, leadership, time management, conflict management, negotiation, etc.
- In addition to improving the effectiveness and efficiency of group work and the quality of project outcomes, students also develop Scrum skills that are valuable in companies.
- Selected students from the previous year train the current year's students in Scrum methodology. This knowledge is passed on with teachers' supervision.
- The role of "Scrum Master" is carried out by a student of the previous year so that these skills are passed on from those students to the students of the current year.

Another important conclusion of our study is that students tend to recognize the advantages of Scrum but need supervision to follow it in a sustainable way. In this case, the role of the Scrum Master and Project Owner are vital to guide the teams. Other studies have discussed the role of the Scrum Master, discussing the pros and cons of rotation of the Scrum Master role [48], for instance. Although this dimension was not deeply analyzed in our

study, it also seems not to have a significant impact on the performance of PBL teams. Results from the qualitative study carried out by Bolloju, Chawla and Ranjan [48] indicated that there was not much difference in perceptions regarding the pros and cons of rotation of Scrum Master role. It is relevant to enhance that this is an exploratory paper that uses exploratory statistics, thus, no validity studies were developed, and this can be seen a limitation of this paper. However, the paper is very relevant because it was designed to be exploratory, bringing about this very specific approach—Scrum in PBL, using mixed methods. Considering they are both innovative in education, and despite earlier studies that shed some light on these topics, there is still scarce research to our knowledge, namely instruments with validity studies. Therefore, despite this being exploratory research, it has relevant data and theoretical developments that can provide ground to future work. Future work should address larger data collection that contributes to the validation of instruments on these topics. The systematic review carried out by Fernandes, Dinis-Carvalho and Ferreira-Oliveira [18] shows that research on the application of Scrum in education is scarce and mostly exploratory. Most of the publications that simultaneously have the term Scrum and education are related to the process of learning Scrum. When Scrum is used with the intention to give support to the learning process, it is mainly in software-related courses. Few papers focus on the implementation of Scrum approaches to improve learning in higher education. The results of this study contribute to understanding the effectiveness of the application of Scrum to complex PBL learning environments. It provides important inputs to improve the way PBL student teams manage themselves as well as their projects.

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