SCRUM applied to Problem-Based Learning: a hybrid model for managing the teaching-learning process

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***Abstract*—This complete work on innovative practices, presents the proposal of a hybrid model between Problem-Based Learning (PBL) and the SCRUM agile project management framework, which seeks to facilitate the control and management of the teaching process, during the activities of students' learning, in the face of difficulties still encountered such as: I. material support; II. students' responsibility in the task; III. division of tasks; and IV. contribution and performance in tasks. We carried out a case study to validate the proposal, including SCRUM practices (such as the structure of the Daily Scrum), during the performance of PBL activities in an undergraduate class in Software Engineering, during the second semester of 2019. To investigate what was accomplished and discuss its results, we used the technique of Discourse of the Collective Subject (DCS) as a way to capture the impression of the students who participated in the study. Through the study of the resulting DCS, it was possible to identify that SCRUM practices enhanced the PBL process with regard to the control and management of teams in the projects developed in the discipline, which allowed us to conclude the adequacy of the proposed model and its potential to contribute to the student's teaching-learning process.**

***Index Terms*—Problem-Based Learning, SCRUM, Team management, Teaching-learning.**

I. INTRODUCTION

Technological advances have imposed new challenges on education. The integration of technology into university educational practices implies a redefinition of the very idea of a university [1]. Today we know that each student has different aptitudes, different learning abilities and time. In addition, they are connected to a real-time information network. Indeed, the contemporary university is losing its status as an autonomous center for the production, transmission and preservation of knowledge. In its place, a new sociocultural dimension is born in which the university is just a node in a global network of knowledge construction. This is because the power to communicate knowledge has shifted from those who produce it, from the centers of production, to be returned to the structure and dynamics of the society itself that gives it meaning [2]. Understanding these relationships is important to start reshaping teaching, so that it becomes more efficient in the learning process.

In Brazil, the National Council of Education (NCE) approved in January 2019 the new national curriculum guidelines (DCNs) for Engineering courses. This act provided higher education institutions with the possibility of structuring the curriculum for undergraduate courses, based on the development of important technical and socio-emotional skills for the exercise of the engineering profession. It is no longer necessary, nor desirable, for courses to be supported only in conventional disciplines that are not interrelated with other knowledge and that do not challenge the student with practical activities and real problems.

This modernization of curricula is directly related to the didactic-pedagogical organization that starts to bet on multiple innovative learning experiences. One of these is maker spaces. The maker movement is a technological extension of the do-it-yourself culture, which encourages ordinary people to build, modify, repair and manufacture their own objects, with their own hands. These practices are being incorporated into engineering and have generated a change in the way of thinking. One of the most well-known maker spaces was the Fab Labs - construction sites - the first being founded in 2003 at the Massachusetts Institute of Technology (MIT) [3]. Students are no longer seen as passive spectators, but protagonists of their learning, as they are active agents of a personalized construction of knowledge.

The methodological experiment presented by this article covers some methodological paths aimed at the problematization of the acquisition of knowledge through the resolution of problem situations. The main idea is to use problems common to the universe of student education as motivating agents for the learning process, creating through them an integrated, multidisciplinary, interactive knowledge base oriented towards the emergence of theoretical-practical formative relationships

[4]. In order to do so, we verified how a set of project management strategies in a computational environment can facilitate and/or accelerate the teaching-learning processes when combined with the investigation of real problems.

The use of real-world problems to motivate learning - called Problem-based Learning (PBL) - is one of the educational approaches of Active Learning whose objective seeks to position students as protagonists of their learning processes [5]. Although the problem is the starting point, that is, the motivational trigger by which the student starts his learning process. For [6], it is essential to consider the combination of 3 (three) different perspectives of how students structure their mental model for problem solving: (i) PBL as an investigation process; (ii) PBL as learning to learn; and (iii) PBL as a cognitive-constructivist approach. This means that the resolutive paths make it possible, in addition to the discovery of new knowledge, incorporated into the informational repertoire of the students, also the development of a specific behavior for learning, which relates knowledge developed with the emergence of learning of the proposed solution. All this, considering that each human being is unique in their individual formation, but, at the same time, needs to perceive themselves as part of a collective system that produces and solves problems and social experiences.

From these perspectives, in addition to a ”good” problem, it is necessary to observe how teaching and learning occurs in small groups, how the mediating relationship between teacher-student in the tutoring routine can motivate the task; how the time available to develop a solution can affect the success of the task and how the self-learning ability of students can also affect the success of the process [7].

Faced with the complexity of analyzing each of these factors mentioned, this article is limited to problematizing some behavioral aspects related to the student's responsibilities in the face of their self-learning process. According to [8], the action of bringing people together to work on the same subject can lead to the success or failure of a project. Self-learning, for example, emerges as a potential ability to regulate study according to learning needs. Make the student independent and responsible for identifying what, where, when and how to build a knowledge base [6]. This activity, even though it is the student's extreme responsibility, does not occur alone, as the work is usually carried out in a group and mediated by the tutor/teacher.

Faithfully maintaining the PBL philosophy requires not only full compliance with its principles, but also that its processes are managed efficiently [9]. Given this challenge, this work aims to present a management model for PBL practices that can: (i) assist in the design and execution of possible solutions (since they do not represent simple tasks in the development of a project); (ii) enable the tutor/teacher to pay special attention to the control and management of the group; (iii) provide material support for students' self-learning; (iv) identify the student's affinity with the task; and (v) organize and distribute the students in the tasks, demanding individual responsibility and commitment, to guarantee the collective contribution. In summary, a model with a strategic protocol for project management, which enhances the realization of PBL in its most faithful philosophy of results.

Among a set of process management methodologies, SCRUM is a software development system used in projects where the requirements are not very stable or known [10]. This is because, despite being a flexible method in the face of necessary changes during project execution, it maintains processes of continuous review of the project scope [11], adding effectiveness to teamwork [12]. In the educational context, [13] shows that SCRUM contributes, among many factors, to the autonomous learning of students. In this sense, based on the analysis that management processes can help in the implementation of PBL throughout its life cycle, this work focuses on innovation processes in university education, aiming to present a hybrid pedagogical proposal between the methodological approaches of PBL and of SCRUM.

Therefore, this article is organized as follows: in section II, the related works are presented; in section III, the proposed model is presented; section IV presents the methodology used in the development of the work and the case study carried out; in section V, the results of the case study are presented and discussed, quantified using the Discourse of the Collective Subject technique by [14]; and in section VI, the final considerations about the objectives achieved by the study are presented and the future stages of the research are outlined.

II. Related Work

A review of works that proposed methodologies to control and manage the teaching process using Problem-Based Learning (PBL) is timely. Educators are interested in PBL because of its emphasis on active, transferable learning and the clear potential to motivate students. However, there is a need to adopt management mechanisms so that the steps of the PBL methodology are correctly executed, and there may be problems if monitoring and feedback between educators and students are not carried out at the appropriate time. A possible analysis was the review of articles published by the community at the Frontiers in Education (FIE) Conference.

Doerschuk (2004) proposes to incorporate a UML-based team project into an object oriented software engineering course [15]. Although not the focus of the paper, the case study addressed many aspects of problem-based learning. This paper describes how to incorporate team software development and quality assurance, giving students hands-on experience in developing software in a team environment. The use of an object-oriented design tool gives them experience using UML and design tools that are likewise valuable additions to their resumes.

Bell and Prabhu (2014) propose an approach in which students worked on two half-projects in parallel during a semester [16]. They implemented a design proposed by students from previous semesters while simultaneously developed a new design to be implemented in the next semesters. A development project followed the waterfall approach, and one coding project used the scrum approach. According to the authors, the students experienced two different approaches in software engineering, working on problems in two different domains. This team-based approach can easily be applied to any field in which a design is employed, with little adjustment for a given area of application.

Nejmeh and Weaver (2014) propose an adaptation of a Scrum-based, software-tools enabled process used in international Service-Learning (SL) project courses in the Computer and Information Sciences and other disciplines [17]. The authors present a number of projects using this approach over a period of eight years. Overall, their experience has shown that an adapted form of Scrum is suitable for the SL course and co-curricular environments.

Oliveira and Santos (2016) present a virtual teaching and learning environment, called PBLMaestro, which has been designed to support the workflow of a methodology for the implementation of PBL in teaching Computer Science (called xPBL) [18]. The tool proved to be suitable for xPBL processes, with promising results on regarding the difficulties for adoption of PBL in classroom.

Rodrigues and Santos (2016) propose a framework based on Demig´s PDCA cycle to facilitate the adoption of PBL in Computing area education [19]. In the case study, it was possible to show how this PBL framework can be applied in educational practices, which elements should be planned, and the follow-up in an educational project on an under-graduate modular Computing course are also presented.

Lau *et al.* (2021) present a group project framework incorporates key features from Kolb's Experiential Learning Theory and principles of active learning to achieve active and experiential learning through active supervision [20]. This framework was applied for a second-year programming course, which was conducted during the COVID-19 pandemic, offering stages of the group project which allow students to work on their choice of a real-world problem. The framework was evaluated through a comprehensive analysis of student research, asking specific questions at all stages of the group project. They also presented findings and lessons learned for framework improvements.

Neumann and Baumann (2021) present the experience of the process to perform a Master of Science class with eduScrum integrating real world problems as projects [21]. They prepared, performed, and evaluated an agile educational concept for the new Master of Science program Digital Transformation. The eduScrum method has been used in different educational contexts, including higher education. They present the lessons learned from the application of this methodology in two years, one during the COVID-19 pandemic.

According to the articles presented, it appears that the management of projects that address problem-based learning is a recurring subject of research in the field of education. The integration of agile methods in teaching practices for the execution and monitoring of activities associated with projects has shown, over the years, to be a promising field of research that still has goals to be achieved, given the analysis of the works in the light of the 5 challenges present in the area (Table 1), already described in the introduction of this work. Alternatives are also being investigated, such as concept maps [22] and gamification [23], being opportune for future discussions on what advantages and disadvantages they present in relation to agile methods.

III. PBL-SCRUM Hybrid Model Proposal

To improve the control and management of teams in teaching-learning projects, we adapted the use of the SCRUM framework to the PBL methodology, seeking to facilitate the management of activities in groups of students, we developed a hybrid model of project management and problem solving that brings together the PBL process presented by [24], with the managerial increment of SCRUM practices.

SCRUM is an agile management model that seeks to develop a project through Planning, Sprint and Backlog practices to organize and ensure its realization [25]. For the Planning stage, an initial checklist is created where all the known characteristics of the process to be executed are gathered. In addition, possible solution estimates are elaborated. During the practice of the Sprint, the suggested solutions are tested in the development of the system, each Sprint cannot exceed 30 days and must be accompanied by daily meetings, called Daily SCRUM. A Daily SCRUM, with a maximum duration of 15 minutes, is held at the beginning of each day of development of the Sprint, aiming to review the previous activities and plan the next phases of work. Finally, the Backlog is the practice of recording project requirements and defines two products: (i) Product Backlog - General list of project requirements; and (ii) Sprint Backlog - List of requirements to be developed during a Sprint.

In the proposed hybrid model (Fig. 1), the first activity considers the definition of working groups by affinity, as well as the presentation of the problem (PBL practice) and its identification through a list of items that will guide the solution of the problem (Product Backlog). From this list, the teacher/tutor and students discuss the definition of sets of solutions (Sprint Backlog) that will be developed in 30-day cycles (Sprint). From this defined Sprint, students move on to the Sprint execution phase, learning, reflecting, cooperating and applying their knowledge to develop the Sprint items and solve the problem.

During the execution of the Sprint, daily structured meetings are planned, in the Daily SCRUM format, in which the project manager (tutor/teacher) meets with his team (group of students) to review, with each team member, how the activities of the previous day were carried out. Bearing in mind that the PBL disciplines meet only once a week, and that these meetings also represent the moment when the teacher/tutor clarifies doubts and stimulates the students' reflective sense, we proposed an adaptation of the Daily SCRUM. We structured the artifact we call Weekly Meetings as a monitoring and control tool, providing support for students to manage their work schedule and the collective learning process. Part of the weekly meetings are used by the teacher/tutor for meetings with each work group, in which the evolution and

TABLE I
ANALYSE OF THE RELATED WORKS, GIVEN THE FIVE CHALLENGES DEFINED IN THIS PAPER.

	Assist in the design and execution of possible solutions	Enable the tutor/teacher to pay special attention to the control and management of the group	Provide material support for students' self-learning	Identify the student's affinity with the task	Organize and distribute the students in the tasks, demanding individual responsibility and commitment
Doerschuk [15]	✓	✓	×	✓	✓
Bell and Prabhu [16]	✓	✓	✓	×	✓
Nejmeh and Weaver [17]	✓	✓	✓	✓	✓
Oliveira and Santos [18]	✓	✓	×	✓	✓
Rodrigues and Santos [19]	✓	?	×	✓	✓
Lau *et al.* [20]	✓	✓	✓	✓	✓
Neumann and Baumann [21]	✓	?	✓	✓	✓

motivation of each student are individually reviewed to carry out the planned activities. As a priority, the difficulties faced are reviewed, the next actions are planned and a schedule for the recovery of overdue activities is defined. For a second moment of the same meeting, discussions are planned between the participants of each team, with the aim of evolving the solutions proposed for the development of the system. At the end of the Sprint, students must deliver and present the Sprint product so that the teacher/tutor can provoke reflection on the content learned with the class. From this analysis, the next Sprint Backlog is generated based on the discipline's schedule and the next Sprint is started. The execution of Sprints is cyclical, until the Final Sprint is completed and presented at the end of the course for final reflections on the learning process carried out.

IV. METHODOLOGY

Since the objective of this work is to propose a methodology for building project management strategies in a computational environment that can facilitate and/or accelerate the teaching-learning processes when combined with the investigation of real problems. This study only considered the mediating relationship between teacher-student in the tutoring routine for task motivation. The quantification of this stage was carried out through an interview with a sample of subjects and subsequent analysis through the Discourse of the Collective Subject (DCS) [14].

To investigate the contribution achieved by the work, we carried out a case study using the Weekly Meetings created in the proposed model. During the classes taught in the PBL modality, the teacher/tutor met with the group, and individually filled out a form with information about what the student had done with the planned tasks under his/her responsibility, what difficulties and impediments he had faced for possible delays and/or non-accomplishments, as well as planning new tasks for the next week and recovery activities for overdue tasks. The case study of the work was carried out with undergraduate students in Software Engineering and Computer Engineering from two Federal Universities in Brazil, during the years 2019 and 2021. In all, 64 students participated in the study and solved problems where the topic was focused on the development of games and applications for mobile devices, using the hybrid PBL/SCRUM model as a methodological approach.

For descriptive purposes, the study was carried out to evaluate and understand whether the Weekly Meetings were able to improve the team management process, providing improvements in material support for problem solving, in the control, division and responsibility of tasks, as well as for the contribution and individual performance of each student.

To analyze the study data, at the end of the courses, a survey of the students' opinions about the experiment was carried out. For this collection, we asked the question: "How do you evaluate the contribution of the Weekly Meetings during the course?". Their answers were grouped into a single subject, with the construction of the Discourse of the Collective Subject (DCS) proposed by [14], and its result is presented and discussed in chapter 5 of this article.

Discourse of the Collective Subject (DCS) proposed by [14] is a qualitative method that allows the researcher to know and describe opinions and representations of a descriptive nature, enabling the design of behavior profiles. The DCS is a proposal for the organization and tabulation of data that were obtained from testimonies, configuring itself in a qualitative analysis of a verbal nature that presents as a result a synthesis speech written in the first person singular presenting the thought of a group or collective [26]. It consists of selecting, from each individual answer of the utterance, the Key-Expressions, which are the most present and significant passages. In addition, the

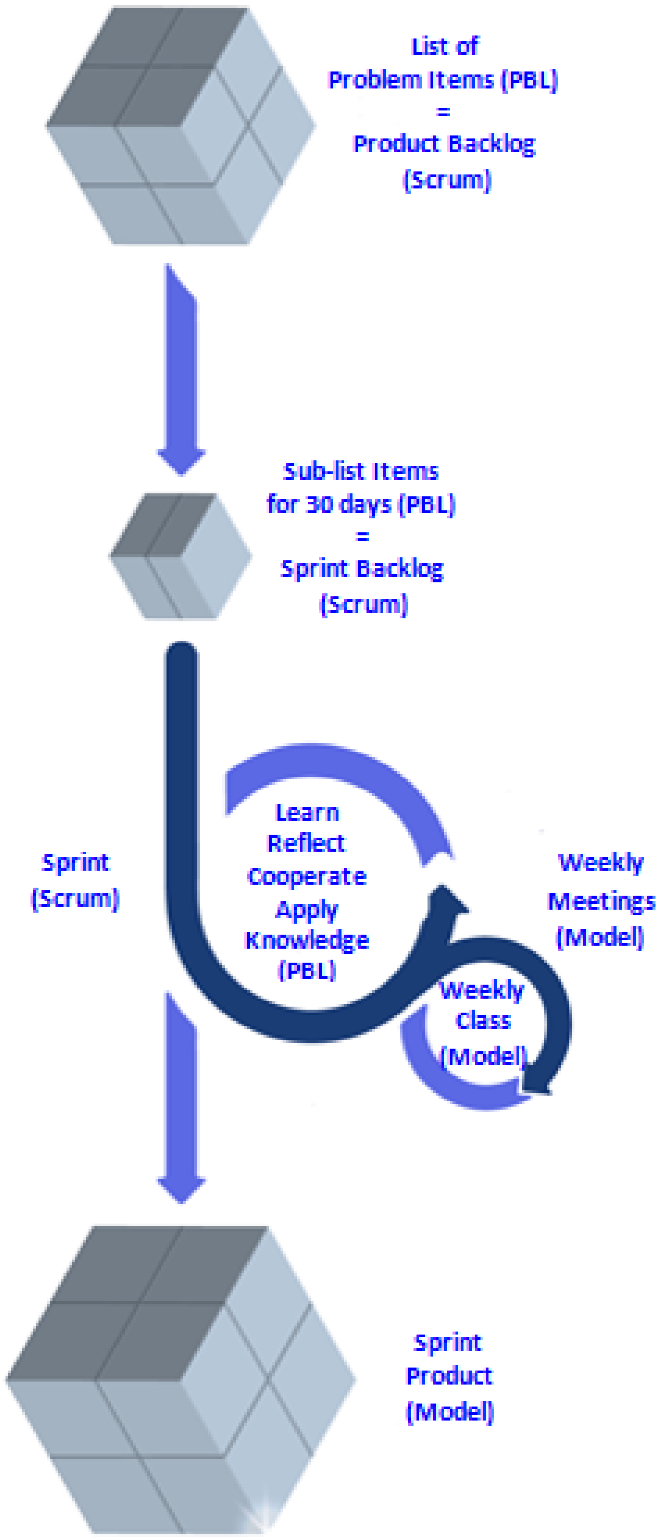

Fig. 1. Proposed Hybrid Model PBL-SCRUM Process

Central Ideas that are the synthesis of the discursive content manifested in the Key Expressions are also selected. The excerpts from the testimony (Key Expressions) are organized into synthesis discourses based on the Central Ideas.

After transcribing all the interviews, we performed the analysis of the answers to the question that were tabulated and analyzed in order to identify the central ideas and anchors present in the speeches of the individuals, directed to the objectives defined for the experiment, such as: (i) assistance in the design and execution of tasks; (ii) group control and management; (iii) material support for self-learning; (iv) student affinity with the task; and (v) organization and distribution of students in tasks.

The analysis of these speeches was used to know and describe the opinions and representations of a descriptive character of the students, allowing us to visualize the scope reached by the work, so that its results and conclusions could be presented and debated.

V. Results and Discussions

So that we could investigate the real reach that the proposed model had at the end of the course, we carried out an opinion survey with the students about the contributions of the use of the Weekly Meetings. To collect this opinion, the following question was asked: "**How do you evaluate the contribution of the Weekly Meetings during the course?**". The DCS resulting from the responses is shown below.

DCS of the students - "*I positively evaluate the contributions of the Weekly Meetings, being a good way of communication between the student and the teacher. With the Weekly Meetings, it was possible to monitor the progress of the project and the development of the product on a weekly basis. It was important to understand the involvement of the groups, where their members had space during the classes to tell how the work was during the week. In each of the meetings, the difficulties encountered during a development phase were presented to the group and the teacher and, depending on each case, there was the possibility of assigning a different task to each student, enabling the establishment of feasible goals.*

The objectives clearly represented which part of the development each member was responsible for performing and should focus on, providing students with a better understanding of the tasks assigned to each and not harming students who worked, by students who did not perform their tasks. If any of the students had not done their part, they were asked how they would make up for lost time and do the new tasks. This approach allows the student to expose the difficulties with the tasks assigned to him, encouraging the exchange of information both between the group and the teacher, and internally within the group. Naturally they divided the group into subgroups, based on similar goals, where the most complex tasks were for the more experienced and the less complex for the less experienced. It allowed some members to readapt themselves to continue working, so that when one highlighted the problems encountered, the others *became aware of parts of the project that they should help, thus keeping the project in constant evolution.*

The meetings contributed significantly to the organization of tasks and the work flow of the groups, making it possible to plan what the next week would be like and to deal with problems before they became critical to the progress of the work. Having a project plan, the teacher was able to give his tips as the project and the class evolved, knowing how the students were understanding and clarifying their doubts. Collecting weekly deliveries provided a breakthrough in development, in addition to checking the performance of each student weekly where members reported what they worked on, how they worked and what they actually accomplished. It was very useful for the teacher as it provided important information, keeping the students well oriented.

In the general context, the applied method gave the expected result, although it did not solve all the problems, because at times it should have a more specialized service in the technologies used in the discipline. Even so, it proved to be efficient, helping all groups to present a system that corresponded to the requirements and allowing us to have more experience of what it is like in the job market, not only knowing the theory, but also experimenting and improving the practice."

Based on the DCS presented, we analyzed the evidence, in the light of the students' statements, about the benefits of the proposed model, in view of the challenges pointed out at the beginning of this work regarding the difficulties of planning and managing group work.

Executing what was planned is often a difficult task. When students become protagonists in their learning processes, this management of what to do, thinking about the group as a whole and their individual activities, becomes of paramount importance for the success of the project [9] and [12]. With the analysis of the students' discourse, we can see with the excerpts "it was possible to follow the progress of the project and the development of the product weekly", "contributed significantly to the organization of tasks and workflow" and "made it possible to plan like the next week and deal with problems before they become critical to the progress of the work", that support the desired management and control with the use of our tool, had a satisfactory result.

As for the **sense of contribution and responsibility among the group members**, necessary for the collective development of the listed solutions [8] and [6], the Weekly Meetings were presented as a good proposal for use, evidenced by passages such as "do not harm students who worked for students who did not perform their tasks", "If any of the students did not do their part, they will be charged on how they recovered", "the members had space during the classes to tell how it was the work during the week", "allowed some members to readjust, continue with the work" and "when one highlighted the problems encountered, the others became aware of parts of the project where they should help".

Seeking to **ensure students' motivation** to solve the problem, an important factor for the success of learning [6] and [13], the Weekly Meetings provided a way to distribute tasks by affinity of interest and knowledge. This range could be observed in the words "they divided the group into subgroups, based on similar objectives", "making it possible to establish viable goals", "depending on each case, there was the possibility of assigning a different task to each student", "objectives that clearly represented what part of development each member was responsible for carrying out" and "a better understanding of the tasks assigned to each one".

In order for the **tasks to be carried out** within the expected time of the discipline, without delays that discouraged students [13], the model used Weekly Meetings to monitor the weekly performance of students, which was of great importance as the following reports "the collection of weekly deliveries provided a breakthrough in development, in addition to checking the performance of each student weekly" and "members must report on what they worked on, how they worked and what was actually accomplished".

During the execution of the work, it is important that **the interventions of the teachers/tutors are efficient** [11], providing the student with the desired support when he needs it. In our analysis, we can see that the Weekly Meetings were able to meet this need in most cases, evidenced by the excerpts "the teacher can give his tips as the project and the class evolve", "solving your doubts" and "very useful for the teacher, as it provides important information, keeping students well oriented". On the other hand, we also identified that adjustments to the model still need to be made, in view of the statements "although it does not solve all problems" and "there should be a more specialized service in the technologies used in the discipline", which point out that this item does not it was fully covered.

CONCLUSIONS

With this work, we seek to present a proposal for a hybrid model between PBL and SCRUM, developed to improve the control and management of teams in development projects, used in their teaching-learning process. During the initial studies, we could see the need to devote special attention to the adoption of project management practices, in order to particularly cover activities such as group control and management, individual responsibility for each task, division of students into tasks, etc.

In our proposal, we defined a process structure that adapted the practices of the SCRUM model to the teaching-learning activities of the PBL methodology, which was analyzed in a case study, to prove the hypothesis that the proposed model was able to improve performance. of students, helping them to better direct their studies and efforts, in addition to contributing more effectively within their work groups.

With the use of the Discourse of the Collective Subject (DCS) technique, we can identify and expose the students' opinion regarding the model used, because in excerpts of their opinions such as "it proved to be efficient in helping all groups", "I evaluate the contributions of the Positive Weekly Meetings", "good form of communication between student and teacher" and "in the general context, the applied method produced the expected result", we can conclude that the proposal was valid and effective in achieving the objectives established for the work, since when our study is included in the challenges quantified in Table 1, we can see, with the excerpts analyzed in section IV, that the model is an option capable of meeting the needs that engineering education currently presents.

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