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RESEARCH ARTICLE

Using PBL and Agile to Teach Artificial Intelligence to Undergraduate Computing Students

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ABSTRACT Project-based learning (PBL) is an active learning methodology focused on developing both soft and hard skills by solving real-world problems. In PBL, teachers act as facilitators while students take charge of their own learning. While the practice of this methodology in computing education has been growing in recent years, it still poses some challenges that need to be addressed. Integrating Scrum and Agile methodologies into PBL can be a valuable addition when teaching computing subjects to students. Therefore, this paper presents a case study of a successful implementation of PBL with Scrum, applying Agile values and principles to teach Artificial Intelligence to undergraduate students. This study contributes to the limited research on Scrum in education, as well as helps bridge the research gap in AI teaching and learning. The case study involved 30 students from an undergraduate computing program, divided into five groups, who successfully developed five different Machine Learning (ML) models to tackle the challenging real-life problem of breast cancer prediction for the Cancer Institute of the State of São Paulo. The findings of the study indicate that the students effectively utilized Scrum and Agile methodologies throughout the process and expressed satisfaction with the approach. Additionally, they developed problem-solving abilities, critical thinking and communication skills, teamwork capabilities, and gained experience in working with real-life situations and problems. The study also demonstrates that the proposed technique aligns with the foundations of the PBL approach in computing education discussed in previous literature. It serves as a valuable resource for future research on PBL implementation, by comparing similarities and differences with existing literature and discussing the strategies employed to address implementation challenges.

INDEX TERMS Agile, case study, computing education, computer engineering, PBL, predictive model, scrum.

I. INTRODUCTION

Project-based learning, known as PBL, is an active learning methodology, which encourages students to develop self-learning skills, based on resolutions of real-life problems [1]. Under PBL, traditional lectures allow self-directed student learning where instructors and teachers become facilitators in the classroom [2]. Among the benefits of PBL are the development of problem-solving abilities, critical-thinking and communication skills, and teamwork in addition to course content [3].

In project-based learning, the learning is organized around problems [4]. To explain or resolve a problem in PBL, students follow seven steps. They start by analyzing and discussing the problem in groups. Then, they use the unexplored issues generated by these discussions as guidelines for their self-directed learning activities. During this learning, students find more information to help to solve the problem. After that, they come together and each one shares the findings so they can gather and compile all information in the context of the problem [5].

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Over the past two decades, several studies were published about PBL applied in computing education, with applications mainly in the courses of software engineering and programming [6]. Several applications of PBL were reported in different undergraduate programs, such as control engineering [7], [8], chemical engineering [9], materials engineering [10], robotics [11], [12], power electronics [13], blockchain technology [14], mobile app development [15], and many others. The studies previously mentioned argue that project-based learning can be a feasible alternative to traditional lectures to bring students more engaging classes, a self-initiative to learn, and the development of both hard and soft skills by the resolution of real-life problems.

Even though Agile approaches and Scrum have been previously applied in software engineering courses [16], [17], discrete mathematics [18] and mechatronics [19], game development [20], and a real-life problem from a company [21], to the best of the authors' knowledge, there is no study case involving Agile, Scrum and PBL to teach Artificial Intelligence.

This study contributes to the limited research on Scrum in education, as well as helps bridge the research gap in Artificial Intelligence (AI) teaching and learning. The approach was experimented with a case study involving 30 students from an undergraduate computing program, divided into five groups, who successfully developed five different Machine Learning (ML) models to tackle the challenging real-life problem of breast cancer prediction in 10 weeks.

The remainder of this paper is structured as follows. Section II presents the fundamental concepts supporting this work. Section III presents the related work, existing gaps, and research questions. Section IV describes the adopted methodology. Section V describes the project and assessment results. The discussion is presented in Section VI with a comparison with existing literature. Finally, Section VII presents the final conclusions of this study.

II. BACKGROUND KNOWLEDGE

In this work, both Agile and Scrum are used to address PBL challenges to teach Artificial Intelligence to undergraduate students. In this section, some fundamental concepts that support this work are presented.

A. PBL CHALLENGES

Even though it provides many benefits, there are still some challenges in the implementation of PBL. Chen et al. [22] divide these challenges into three categories: individual level, institutional level, and culture level. At the individual level, there is a lack of training for teachers to become facilitators, the choice of proper assessment methods when using PBL, and the need for continuous training for students regarding PBL's unique characteristics. Teachers face the challenge to adapt their materials and teaching strategies due to the lack of theoretical knowledge and skills regarding PBL. Also, they have to come up with assessment methods that evaluate not only the students' content knowledge but also their soft skills developed by PBL. On the other hand, students with no experience in teamwork and PBL tend to struggle when working on a team. In addition, the effectiveness of PBL and teamwork could be in check if students show a lack of learning motivation or self-reflection.

At the institutional level, the main challenges are more time and effort devotion, lack of support from departments and institutions, challenges for effective PBL design, and limitation of external conditions. In a course using PBL, teachers have to put more time and effort to provide teamwork facilitation, practical experiences, and professional guidance for their students, while the students have to deal with issues, both expected and unexpected, during the project development. The lack of support makes it difficult for teachers to improve the effectiveness of PBL and for students to have better guidance. The biggest challenge for the institution is the development of an effective PBL course curriculum because they have to deal with how to come up with learning objectives and principles, which PBL models could be implemented into their institutions, and how to balance PBL projects with the traditional courses when designing the curriculum. Finally, institutions that used traditional lecture methods have to deal with the lack of teamwork in project development infrastructure, technical and financial help, and a high student-staff ratio if they want to change to a PBL curriculum.

At the cultural level, the main challenges are the variety of cultural and language backgrounds for non-native students. When working in a group each team member could be from a different country or course, each one with its own beliefs. The lack of understanding of the other's perspective challenges the teamwork, especially at the beginning. Also, in international PBL projects, those with low language proficiency or who do not understand the terminologies of other courses could have difficulty in teamwork.

Moreover, for some students, the shift from high school — where the teacher takes a more active role — to higher education — where the student is expected to be more independent — is neither seamless nor simple. In fact, certain students may be expected to exercise more independence and self-control in their learning process, and as a result, the conventional approach of a master class followed by a straightforward written exam for the purpose of assessing the gained knowledge may be dropped. Furthermore, because communication between the teacher and the students is less open in larger groups, implementing fresh learning techniques may be more challenging. However, implementing more individualized evaluation systems may come at a larger expense [23].

B. AGILE AND SCRUM

The principles of the Agile Manifesto [24] indicate iterative and collaborative development with constant customer feedback, and related Agile methodologies have been used successfully in professional software development [25]. Stewart et al. [26] present a mapping of Agile values and principles to Education. The following Agile Principles in Education were identified:

1) Students over traditional processes and tools;
2) Working projects over comprehensive documentation;
3) Student and instructor collaboration over rigid course syllabi;
4) Responding to feedback rather than following a plan.

In addition, the following Agile Values in Education are presented by Stewart et al. [26]:

1) High priority to prepare the student to be self-organized, continuously delivering course components that reflect competence;
2) The instructor and students can adapt to changes at any time to facilitate learning and better develop marketable skills;
3) Working deliverables from the students over short time periods allowing for frequent feedback;
4) Iterative interaction between the instructor and students (or student groups);
5) Give students the environment and support necessary to be successful;
6) Allow for direct face-to-face interaction with students or student groups;
7) Working deliverables (e.g., models, software, project deliverables, presentations) are the primary measure of student progress;
8) The cooperative learning environment is the basis for teaching the skills needed for life-long learning;
9) Continuous attention to technical excellence and good design enhances learning;
10) Understanding the problem and solving it simply and clearly is essential;
11) Student groups and teams should self-organize, but all should participate equally in the effort;
12) At regular intervals, the students and instructor reflect and offer feedback on how to be more effective, then the stakeholders adjust accordingly to be more efficient.

The Scrum framework suggests the development of software in a series of fixed length intervals defined as sprints [27]. There are some roles in the Scrum, such as Product Owner, who acts as the interface between the development team and the customers; the development team; and the Scrum master, who acts as a facilitator to ensure adherence to Scrum best practices and ceremonies. These ceremonies are sprint planning to select what must be prioritized from the product backlog, daily meeting for quick update among the development team and the Scrum master, Sprint demo to show progress to the Product Owner, and sprint review where a discussion regarding sprint successes and failures is held [25].

III. RELATED WORK

This section presents the related work and the research questions considered in this work.

A. PBL OPPORTUNITIES

Hutchison [28] brings elements to make PBL successful. First, it is vital to provide students with enough information about the project and about how it will be developed through a specific time frame, such that they can complete all tasks needed in time. This can be achieved by thorough planning and preparation to deconstruct, build and complete the project. Second, students must have enough time to complete their tasks well by having time during classes to work in collaboration or simply ensure that they know how much work and meetings will be required for success. To ensure that everyone stays on task and each member has a contribution to the project, self, and group evaluations can be done. These evaluations will be part of the grade. Furthermore, after each class, each group could write the tasks needed, assigning a responsible for each one; students could be asked to evaluate themselves on how complete and well their task was performed.

Dogara et al. [29] found a significant positive correlation between PBL preparation and the integration of soft skills among technical college students. Adequate preparation in project-based learning, including the availability of learning materials, activity guidelines, and selection of learning objectives, is critical for the incorporation of soft skills. Additionally, the technical teachers' positive view on PBL application was identified as having a significant positive association with the integration of soft skills among technical college students, as it provides an opportunity for hands-on training, problem-solving, interaction, and collaboration.

However, facilitation in PBL was found to have a significant negative association with the incorporation of soft skills among technical college students. The challenges of managing a large number of students in a classroom, coupled with the complexity of facilitation in PBL, can affect its efficiency. On the other hand, commitment and PBL assessment were found to have significant positive connections with the integration of soft skills among technical college students. Commitment in PBL fosters emotional attachment, a continuation of purpose, and an obligation to the group's goal, while assessment methods such as individual and group presentations, reports and assignments, and discussions and seminars provide motivation, feedback, and effective participation.

B. AGILE AND SCRUM

Salza et al. [25] presents how Agile methodologies were used to attract and retain students' attention and commitment. There are some examples of successful application of Agile methodologies in online courses [30], in electrical engineering [30] and in software engineering courses [31], [32], [33]. However, as far as the authors are concerned, there is a lack of study cases involving a transdisciplinary project with a combination of different traditional course concepts and teacher expertise.

Regarding the application of the Scrum framework in Education, [34] present eduScrum, a guide that translates the

Scrum to the educational context. eduScrum states that daily meetings of fuve minutes must be held in the beginning of each class. Planning, review and retrosprective ceremonies are also valid in the educational context.

Fernandes et al. [35] investigated if Scrum is effective for PBL teams based on students perceptions. Task assignment, performance monitoring, and regular feedback are the main advantages of the proposed approach, and the roles of Product Owner and Scrum Master are essential for success. One interesting feature is that the role of Scrum master is carried out by a student of the previous year so that skills are passed on from those students to the student of the current year.

Scrum has been successfully applied in software engineering courses [16], [17], discrete mathematics [18] and mechatronics [19]. Even though there is a study case of an interdisciplinary project (two courses) for game development using Scrum [20], and a study case of a real-life problem from a company in a project combining six courses for a MSc course [21], to the best of the authors' knowledge, there is no study case involving a transdisciplinary project with a combination of different traditional courses concepts and teacher expertise to teach Artificial Intelligence.

C. RESEARCH QUESTIONS

Considering that research on the application of Scrum in Education is scarce and mostly exploratory [35], the first Research Question (RQ1) aims to contribute to close this research gap.

- RQ1: To what extent are Scrum and Agile Methods suitable approaches in an educational context using PBL in computer engineering courses?

Our methodology uses Scrum and Agile Methods combined with PBL. This study will present how they are implemented alongside PBL. Then, it will be evaluated to what extent these methods can be used to improve a PBL approach and if they do have a positive impact.

Additionally, motivated by the case study of a real-life problem from a company in a project combining six courses for a MSc course presented by Dinis-Carvalho et al. [21], the second Research Question (RQ2) aims to investigate which teacher profiles are necessary for the proposed approach.

- RQ2: Which competencies teachers must have to conduct a PBL approach with Agile methodology to undergraduate students?

This question aims to discuss the best ways a team of professors can be formed to best conduct a PBL approach. The discussion will focus on the opposition of professors, in a multidisciplinary curriculum, being specialized in some contents or having a multidisciplinary background, as PBL approaches tend towards multidisciplinary classes, both in skills (hard and soft skills) and in course content.

Regarding Artificial Intelligence (AI) literacy, Ng et al. [36] presents a systematic literature review from 2000 to 2020. Most of the studies were focused on undergraduate students (39 out of 49). Among the pedagogical approaches of PBL, collaborative learning, and learning with game elements, the most applied approach was PBL. Only three studies [37], [38], [39] mentioned the following ideas of AI literacy: know and understand AI; use AI technologies; and critically evaluate AI technologies by applying them with more effective communication and collaboration.

Ng et al. [36] stated that future studies would critically examine the pedagogies and standards needed to foster AI literacy among people of various ages and across diverse cultures. Considering such context, the main Research Question (RQ3) aims to investigate which technical skills can be learned with a PBL approach.

- RQ3: Which technical skills related to Artificial Intelligence can be learned with the PBL approach with Agile methodology?

This is our main research question. This paper presents a case study where PBL was used to teach computer engineering concepts. This study will discuss the results of this approach, the project results, and both students' and teachers' performances. Then, an evaluation is presented analyzing if this approach was successful and whether it can be used as a model for future research.

Different Machine Learning (ML) techniques present different accuracy rates, which also vary for each dataset being used. Some ML techniques used in the literature are Support Vector Machines (SVM), K-Nearest Neighbors (KNN), Logistic Regression (LR), Naive Bayes (NB), MultiLayer Perceptron (MLP), and Decision Tree (DT) [40]. Therefore, breast cancer prediction is considered a problem whose solution requires advanced computer engineering concepts, a challenge complex enough to support learning with the PBL approach.

IV. METHODOLOGY

A. PBL APPROACH

Chen et al. [22] classify the PBL implementation in four different levels: Course, Cross-course, Project, and Curriculum levels. At the course level, PBL is used only in an existing course and it is implemented as: PBL for knowledge management, PBL through activity, project-led PBL, PBL for practical capabilities, and PBL for design-based learning. Also, at this level, the forms of evaluation still use some traditional assessment methods and the problems to be solved are identified by the students or given by the teachers. At the cross-course level, PBL is implemented in multidisciplinary courses for the students to have the experience of transferring their abilities into different contexts and solving real-world problems proposed by companies. At the project level, students can decide to participate in these projects (short-term or long-term) based on their interests, as the projects are developed outside the curriculum. The assessment is focused on elements of the project's development such as reports and group meeting records.

The last level is at the curriculum level, which is the base of the PBL approach described here. Our methodology is similar to what Chen et al. [22] discuss in their article regarding PBL practice and students' assessments at the curriculum level. At this level, students solve real-life, interdisciplinary problems, in groups of two to eight students, which can be defined by teachers, students, and even by real companies. In the approach described here, the four-year computing program is divided into sixteen modules; each of these modules involves a project intending to solve a real-life problem proposed by a company or client and each class has five groups with five to eight students, each one with a different approach for the same problem. This brings the opportunity to listen to clients' needs and communicate with outside stakeholders.

Regarding students' assessment, Chen et al. [22] cite different methods, including peer evaluation, oral presentations, project report posters, and weekly group relationship assessment to evaluate the groups and attendance, essays, exams, and individual project reports to evaluate each student. Our assessment is similar. To evaluate each student, there are two exams, weekly activities, individual project reports, and self-assessment. To evaluate each team there are weekly project technical artifacts and group assessment.

One major difference regarding our PBL methodology is that it uses the Agile methodology and Scrum framework. Scrum is a framework for software development that utilizes an agile and adaptable approach, emphasizing teamwork and addressing complexity within a volatile process. The methodology includes planning, daily scrum meetings, and retrospectives to identify and solve problems as they arise [41]. Daily scrum meetings provide feedback on project progress and opportunities for issue resolution, and aid in measuring daily individual productivity. Scrum is commonly used in software development and application management and is divided into several sprints. It is an ideal choice for projects requiring flexible adaptation to changes during the development process. The framework includes three main roles: the Product Owner, Scrum Master, and the Scrum Team [42].

Agile is a broad term that encompasses various approaches to software development. It is a conceptual framework that prioritizes a flexible, iterative, and incremental approach throughout the project life-cycle, starting with planning and ending with deployment [43]. Agile methods aim to minimize overhead in the software development process by allowing easy adoption of changes without disrupting the process or requiring excessive rework. Agile was first introduced and promoted by a group of 17 software engineering consultants in 2001, who published the "Agile Software Development Manifesto". This manifesto outlines a set of values and principles that define the essence of agility in software and systems development. The four principles are Individuals and interactions over processes and tools, Working software over comprehensive documentation, Customer collaboration over contract negotiation, and Responding to change over following a plan [44].

Our methodology unites PBL, Scrum, and Agile at its core, using the basics of each approach (Fig. 1). PBL is present in the learning process, where students learn actively by working on projects based on real-life problems proposed by real companies. The project development follows Scrum and Agile; it has five sprints of two weeks each (ten weeks total), with daily meetings, sprint planning, and sprint retrospectives for each sprint. At the final sprint, there is a project pitch to present the final product. These sprints make the project iterative and incremental, allowing changes during the process. In this project, we used CRISP-DM, a specific methodology to make data mining and develop predictive models. This methodology comprehends all the processes in six phases: business understanding, data understanding, data preparation, modeling, evaluation, and deployment [45].

As mentioned before, the Scrum framework includes three main roles: the Product Owner, Scrum Master, and the Scrum Team. In the adopted approach, the Product Owner is a teacher, named teacher-advisor, responsible for supporting all groups during the project development. Each of the five groups is a different Scrum Team, while the Scrum Master is a student from the team.

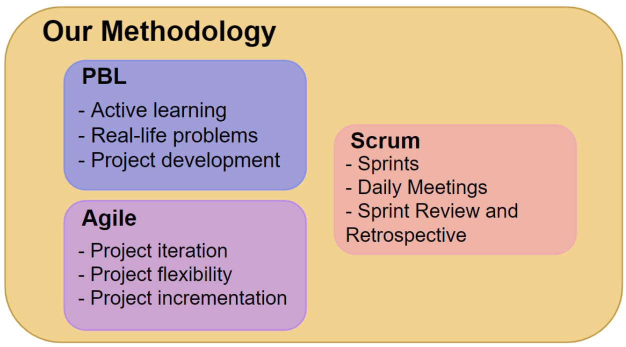

FIGURE 1. Composition of our methodology.

B. PROJECT DESCRIPTION

The project has been developed for the Instituto do Câncer do Estado de São Paulo, a unit of Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, in order to address the lack of standards and the great variability in the evolution of breast cancer and its response to conventional treatments; the final purpose was to help the target audience: women who have this type of cancer. Patients who have the same sub-type of breast cancer or are in the same risk range have different responses to the same treatments, some live longer than expected while others pass away early.

The main objective was the development of a predictive model from a group of female patients followed up in research projects at the Instituto do Câncer do Estado de São Paulo. The model should show a risk score (color scheme) that would help in deciding the most appropriate treatment, as well as provide increasing objectivity in the follow-up of patients with more accurate data.

TABLE 1. Number of women and men in each group.

Groups	Women	Men	Total
Medicinia	2	4	6
Smart Health	2	4	6
Pink A.I.	1	5	6
Connect IA	0	6	6
USP I.A.	0	6	6
Total	5	25	30

This project is important because it aims to bring one more tool to help doctors make decisions, making follow-up and treatment more efficient and accurate by finding hidden patterns and trends. Potentially, it will learn over time by using Artificial Intelligence, becoming more efficient and generating more solid results. Furthermore, it is a product that could be used to treat other types of cancer. In this way, the project can generate great value for society by improving the health and technology area, bringing direct value to doctors, hospitals, and patients.

To develop this project, the thirty students were divided into five groups, whose composition is presented in table 1.

This project was developed in ten weeks by undergraduate students in their first year. So, this article is not focused on the model results - as there was no expectation to have high results - but on the learning process of these students.

Students were evaluated accordingly to four categories, each one with a different weight in the final grade:

- The first one is two tests that together compose 20% of the grade.
- Second, there are weekly activities related to self-studies from each subject (35% of the grade).
- Third, self-assessment weights 5% in the grade.
- Finally, the project itself is divided into the technical artifacts (seen in table 2) and the group assessment, composing 40% of the grade.

At the end of the module, each student took a satisfaction survey to evaluate each instructor and the class advisor regarding the following parameters: lecture organization, quality of the material, relationship with students, ability to teach, and availability outside the classroom.

TABLE 2. Project activities for each sprint.

Sprint	Activity 1	Activity 2
1	Business Understanding	Data Understanding
2	Feature Engineering	Persona and User Journey Map
3	Model Evaluation	Preliminary Result Documentation
4	Model Comparison	Comparison Documentation
5	Final Model	Documentation Conclusion

V. RESULTS

A. PROJECT RESULTS

This subsection describes the results achieved by each group of students.

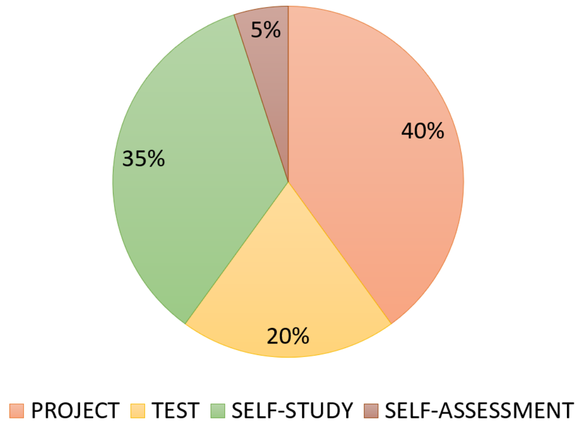

FIGURE 2. Composition of students' assessment.

Group Medicinia developed a predictive model that would predict a score to classify the survival time as high or low. In a primary analysis, they chose four models to be compared: Decision Tree [46], Random Forest [47], K-nearest neighbors (KNN) [48], and Support Vector Machines (SVM) [49] using the following metrics: precision (fraction of relevant instances among the retrieved instances), recall (fraction of relevant instances that were retrieved), f1-score (harmonic mean between precision and recall), AUC (area under ROC curve) and accuracy [50]. To select the best model, they focused on the accuracy (shown in table 3), then choosing the Random Forest model as the final one; this model had an accuracy of 77%. They developed also a web application where new data are input and the model is used to predict the survival time considering this new data.

TABLE 3. Values of each metric for the four models created by medicinia.

	Decision Tree	KNN	Random Forest	SVM
Accuracy	72%	76%	65%	77%
Precision	72%	76%	77%	73%
Recall	72%	79%	80%	84%
f1-score	72%	76%	78%	78%
AUC	72%	76%	77%	76%

Group Smart Health proposed a solution dividing the survival time of the patients in three groups, represented using colors: red, yellow and green, indicating low, mediu and high survival times. The following models were tested by the group: Random Forest, Decision Tree, Logistic Regression [51], KNN [48], and Naive Bayes [52]. After an analysis of the accuracy of each model, they chose the Random forest (70%) and the Decision Tree (81%) models as the best for the problem. Also, they created a form in Google Collaboratory where the user can insert new data and have a prediction for this data with three possible outputs: low, medium, and high survival times.

Group Pink A.I. decided to predict the patients among four possibilities, each one being a quartile of time in ascending order, 1 represing the patients with the shortest survival times and 4 with the longest ones. For the application of machine learning, they used the following methods: Decision Tree, KNN, Neural Networks [53], and SVM. Using accuracy, precision, quadratic error, and recall as metrics, KNN stood out among all (as seen in table 4). The group also developed a web application with a form with questions related to the features used in the model; the application returns the predicted number of survival days for the patient.

TABLE 4. Values of each metric for the four models chosen by Pink A.I.

	Decision Tree	**KNN**	NN	SVM
Accuracy	72%	**75%**	65%	72%
Precision	75%	**78%**	64%	61%
Quadratic Error	40%	**34%**	43%	42%
Recall	59%	**71%**	33%	69%

Group Connect IA also divided the survival time of the patients into four quartiles. They analyzed four models: KNN, Decision Tree, SVM, and Random Forest. Using the accuracy of each model as an evaluation metric, they concluded that the Decision Tree model was the best with an accuracy of 64%. An interface was created in Google Collaboratory where the user can insert new data; the program outputs three possible colors: green for low risk (fourth quartile), orange for medium risk (second and third quartiles), and red for high risk (first quartile).

Group USP I.A. developed a solution that would provide a classification according to the degree of priority and urgency of the breast cancer patient using a predictive model. After training many models, they chose three for final analysis: Logistic Regression, Random Forest, and Boosting. Fig. 4 shows the percent of false positives errors (predict risk as low when it is high) from all errors and Fig. 3 shows a comparison between the accuracy of the three final models both before and after the use of hyperparameters, as these were used as metrics. Both graphs were used to compare the models and decide the best one. With an accuracy of 66% and the least amount of errors in false positives - 35% of all errors - the Random Forest was the best model for the solution. Furthermore, the group created an interface where the user can insert data of new patients; the output is a color system with green for patients at low risk who do not need a regular follow-up and red for patients at high risk who should be followed up closely.

Table 5 summarizes the models tested by each group and the ones that were chosen to resolve the project's problem. The models analyzed were: Random Forest (RF). Decision Tree (DT), K-Nearest Neighbours (KNN), Support Vector Machines (SVM), Logistic Regression (LR), Bayes, Neural Network (NN), and Boosting (BS). The bold symbol • represents the final model (s) chosen by the group.

B. STUDENT GRADES

The students' final grades were in a wide range between 3.3 and 9.0 (over a maximum of 10.0) with a gradual increase and not many equal grades. The class mean grade was 7.6,

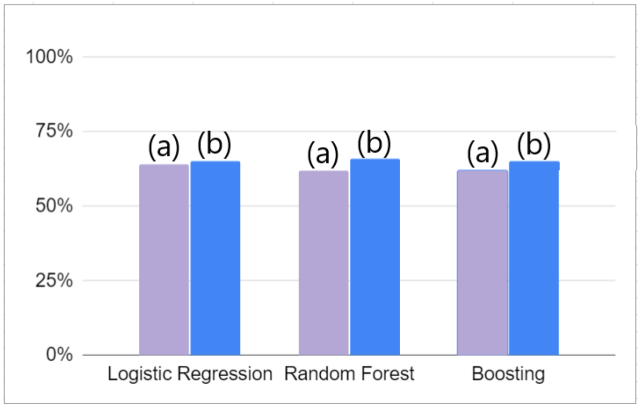

FIGURE 3. Accuracy of the different models (a) without hyperparameters and (b) with hyperparameters.

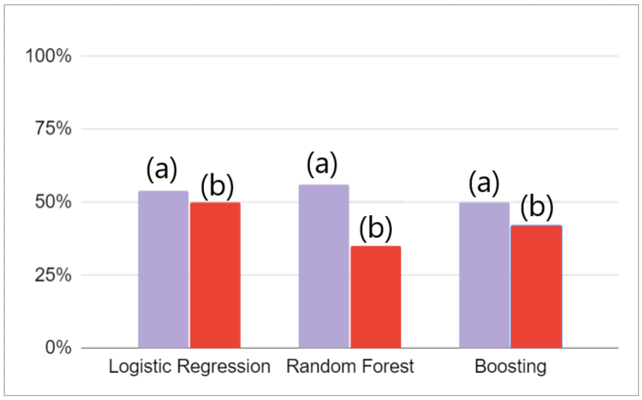

FIGURE 4. False positive errors of the different models (a) without hyperparameters and (b) with hyperparameters.

TABLE 5. Models tested (○) and chosen (•) by each group.

Model	1	2	3	4	5
RF	•	•		○	•
DT	○	•	○	•	
KNN	○	○	•	○	
SVM	○		○	○	
LR		○			○
Bayes		○			
NN			○		
Boosting					○

which shows that most students were above the acceptance grade of 7.0. According to Figure 5, the absence rate of the students did not significantly impact the grades, students with almost 25% of absence (the maximum allowed) or almost none can be seen in different grade levels - except those who had more than 40% that got the worst grades. However, when the comparison is made between the means, an 18% of absence (which is a considerable amount for the 25% maximum) resulted in a grade close to the minimum one.

C. STUDENT SATISFACTION SURVEY

In general, the students gave high grades to their teachers - four of them received a mean grade above 9.6 out of 10.0.

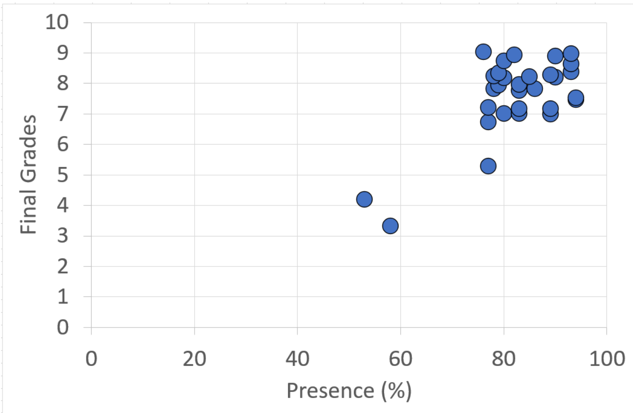

FIGURE 5. Dispersion of student grades according to presence.

The exception was an instructor who received a mean grade of 5.4. Also, the high standard deviation can be explained because the grades for the survey topics had a higher range, as some topics had good grades and others had very low grades, compared to the others where all the grades were similar. This survey showed that the students were generally very satisfied with their teachers except for one. Furthermore, textual suggestions from the students were received and will be used by all teachers to improve their lectures.

TABLE 6. Average grade for each instructor and advisor.

Teacher	1	2	3	4	5
Mean Grade	9.8	9.9	5.4	9.6	9.8
Standard Deviation	0.8	0.5	2.9	1.0	0.7

VI. DISCUSSION

In the following, we provide a discussion and answers to the research questions based on the case study. Each question is repeated here and then discussed. Afterwards, the contributions of this work are highlighted.

A. THE FIRST RESEARCH QUESTION

• RQ1: To what extent are Scrum and Agile Methods suitable approaches in an educational context using PBL in computer engineering courses?

Project development is an important aspect of project-based learning. Therefore, it seems reasonable to combine PBL with methodologies and frameworks developed especially to improve projects in software and engineering areas, such as Scrum and Agile. The results of this paper show that all groups presented a satisfactory outcome to the project's problem by using Scrum and Agile Methods during the process.

Regarding the Agile values identified by Stewart et al. [26], the following ones were successfully applied in the present work:

1) Students over traditional processes and tools: all activities were designed considering the student as the center of the process. Self-studies were selected by the teachers, and all artifacts and problem scope were within the appropriate scope for first-year students. For example, the CRISP-DM model [54] was presented as a guideline for the data science project by the Programming teacher;
2) Working projects over comprehensive documentation: all deliverables were delivered in a public GitHub repository, and the main focus of presentations was the live demonstration of working prototypes. These prototypes were presented to the Cancer Institute representative in Sprints 3, 4 and 5;
3) Student and instructor collaboration over rigid course syllabi: the collaboration was achieved with daily interactions in a messenger tool (Slack), meaningful and timely feedback over the artifacts created by the students. For example, the User Journey Map could be validated much faster using Direct Messages between the User eXperience (UX) teacher and the students;
4) Responding to feedback rather than following a plan: the students were encouraged by the teachers to consider the non-paying customer feedback in previous sprints in addition to the teachers' feedback to enhance the quality of the deliverables. For example, some insights from the Cancer Institute specialist regarding the Feature Engineering deliverable from Sprint 2 were valuable to obtain a higher performance in the Model Evaluation deliverable in Sprint 3.

In addition, the following Agile Values in Education presented by Stewart et al. [26] were also taken into consideration in this work:

1) High priority to prepare the student to be self-organized, continuously delivering course components that reflect competence: the application of the Scrum ceremonies and roles motivated the students to be self-organized while collaborating in groups, and the project was delivered in an iterative way over the sprints;
2) The instructor and students can adapt to changes at any time to facilitate learning and better develop marketable skills: customer feedback from each sprint provided learning opportunities for both students and teachers. The opportunity to practice communication skills in the preliminary and final presentations is a highlight;
3) Working deliverables from the students over short time periods allowing for frequent feedback: all groups could deliver the artifacts successfully, which supported more learning opportunities based on the feedback. The formal feedback of the deliverables are always given before the next sprint, so students may have the opportunity to correct some aspects;
4) Iterative interaction between the instructor and students (or student groups): also applied in the iteration over the sprints. This is relevant whenever the students have technical questions, for example regarding Scrum or Machine Learning models and their evaluation matrics;

5) Give students the environment and support necessary to be successful: all necessary material was gathered from the non-paying customer (dataset) and the teachers (algorithms);
6) Allow for direct face-to-face interaction with students or student groups: the advisor teacher is held responsible for face-to-face interactions, to make sure the Scrum ceremonies are being occurring properly;
7) Working deliverables (e.g., models, software, project deliverables, presentations) are the primary measure of student progress: these deliverables were evaluated by the group of teachers, often in a collaborative way. For example, the advisor and the Programming teachers worked together to evaluate the quality of the Model Evaluation, Model Comparison and Final Model deliverables;
8) The cooperative learning environment is the basis for teaching the skills needed for life-long learning: the students could deal with situations that resemble the real-world work environment: adherence to deadlines, communication, and collaboration in the group;
9) Continuous attention to technical excellence and good design enhances learning: these quality aspects are continuously monitored by the teachers. The non-paying customer gives feedback over the end result considering the underlying business constraints, and the teachers evaluate if good design and technical excellence are being targeted by the students;
10) Understanding the problem and solving it simply and clearly is essential: this is the main activity of the first sprint, as the problem and the solution's value proposition are described using Osterwlader's Value Proposition Canvas [55];
11) Student groups and teams should self-organize, but all should participate equally in the effort: this is suggested by the teachers, but it is a challenge to deal with students with low proactivity. This free-rider attitude may result in a burden for the group in Sprints 3, 4 and 5;
12) At regular intervals, the students and instructor reflect and offer feedback on how to be more effective, then the stakeholders adjust accordingly to be more efficient: this is applied between the 5 sprints.

It is important to emphasize the utter importance of all students deeply understanding these methods and willing to participate in all phases of the process. The challenge to use these methods, especially Scrum, which has some specific steps to follow every sprint, is how to encourage students to follow these steps naturally without feeling obligated in order to explore their benefits in the project. For example, students had to complete an online daily meeting every day. As a result, each member wrote their own daily and there was not a group discussion, and the process did not have its purpose secured. So, the advisor teacher decided to leave this online writing and proposed a discussed daily meeting as it should be.

Despite this challenge, Scrum and Agile Methods are a suitable combination with PBL to improve the development of the project and help in group cohesion. They can decrease possible overwork, help creating optimized project planning and promote constant discussions in the group regarding each member's feelings and task completion.

Students practiced project iteration in the daily meetings, by reflecting on the feedbacks obtained in Sprint Reviews, and addressed in Sprint Retrospectives. For example, the feedbacks obtained in the Activity "Model Comparison" of Sprint 4 were used to the model selection of Activity "Final Model" in Sprint 5.

B. THE SECOND RESEARCH QUESTION

• RQ2: Which competencies teachers must have to conduct a PBL approach with Agile methodology to undergraduate students?

Dahms et al. [56] describe the use of the study activity model(SAM) to evaluate the teacher's role in a PBL environment. The SAM quantitatively illustrates a variety of different teaching and learning activities divided into four quadrants and two axes ('Participation' and 'Initiation'). Quadrants C1 and C2 are initiated by teachers while C3 and C4 are initiated by students. Both students and teachers participate in C1 and C4 and only students in C2 and C3.

To answer this question we will focus on Dahms et al. discussion about the C4 quadrant because here are the teachers who will have the role of facilitators, their main role in PBL. In this context, teachers may take the role of consultants to help the groups when information about the teacher's area of specialization is needed. Thus, the interdisciplinarity of the project can be secured by the union of specialized teachers' expertise.

Based on this discussion, the answer to the question is that teachers need to have the technical competencies in their areas to contribute to the project within their own specialization, and, most importantly, to collaborate with the other teachers to help the students in different aspects of the project to optimize the final result, which is the students' learning. Furthermore, knowledge of competencies related to Scrum and Agile is essential for the full operation of the institution's methodology.

Our methodology includes teachers specialized in the areas of Programming, UX and Design, Business, Leadership, and Mathematics. Each one of them can help in specific parts of the project's development. Programming teachers will help in the development of the codes and the technological part of the solution, UX will help in the users' visualization, Business will help in understanding the company, and so on. Together they develop the module content to best address students' needs. As a result, the PBL approach is successfully conducted.

For example, students learned Osterwalder Value Proposition Canvas in self-studies of Sprint 1, and Persona Identification and Description in self-studies of Sprint 2. The Business-related canvas and Persona description techniques were discussed with the Business and User eXperience (UX) specialist teachers in their respective classes of Sprints 1 and 2. This knowledge was applied in the project in the Activities 'Business Understanding' and 'Persona and User Story Map' of Sprints 2 and 3. This theory-practice relationship proved to be effective because, when evaluated, the students demonstrated their knowledge of the different Business and UX questions in both tests that make up 20% of the final grade.

C. THE MAIN RESEARCH QUESTION

- RQ3: Which technical skills related to Artificial Intelligence can be learned with the PBL approach with Agile methodology?

Terrón-López et al. [57] describe a project-based engineering school (PBES) approach to improve student retention, motivation, and learning. The most significant difference between their approach and our approach is how to implement the projects. PBES has engineering capstone projects, individual projects for each course, or groups of similar classes taken during a degree. Also, they have a final presentation for the entire faculty, students, and company representatives with a 2-minute video and judges to award the best projects. On the other hand, our approach involves many projects during the course (four projects per year) with small presentations for the company representatives every two weeks and a final presentation to show the project's final result for the students and advisor of the class, without any award involved.

Regarding the results of the approach, Terron-López et al. cite a quantitative survey on the students regarding their feelings about motivation, professional future, and gain of knowledge after doing the capstone projects. Additionally, to analyze qualitative results, they conducted interviews with students and teachers where they could share their experiences in more detail. We also used quantitative surveys, but to evaluate the group work, student work, and student satisfaction regarding their teachers. Our results focus more on students' and teachers' performance during the project rather than their feelings and motivation.

Another important point to evaluate the effectiveness of our methodology is to know how the students perceive their development, both in technical knowledge and soft skills, during the module. Kolmos et al. [58] research how students from systematic PBL universities self-assessed their preparedness regarding competencies acquired during their undergraduate and those they think were important in the work environment. They conclude that students felt more prepared related to generic and contextual competencies, but less prepared for traditional and domain-specific competencies.

Our self-assessment survey aims to detect how students evaluate themselves on the gain of theoretical knowledge and how they used soft skills within the group. Questions related to the project components' quality and knowledge acquired during the module focus on the hard skills assessment. The soft skills are covered in questions about self-knowledge, communication, collaboration, and critical thinking. All these questions are important to know if the students are developing the necessary skills for the work environment and how they see themselves in those skills.

As mentioned previously regarding AI literacy, Kandlhofer et al. [39] mentioned the following ideas: know and understand AI; use AI technologies; and critically evaluate AI technologies by applying them with more effective communication and collaboration. Sprints 1 and 2 are more closely related to knowing and understanding AI, while using AI technologies is related to sprints 3 and 4. AI evaluation with effective communication and collaboration begins in sprint 4 and is concluded in the last sprint.

Among the different ML techniques used for breast cancer prediction presented by Fatima et al. [40] (Support Vector Machines (SVM), K-Nearest Neighbors (KNN), Logistic Regression (LR), Naive Bayes (NB), MultiLayer Perceptron (MLP) and Decision Tree (DT)), the students could experiment with all these different algorithms. An interesting feature is that the Random Forest (RF) model was chosen by three out of the five groups.

Regarding the technical skills related to those in AI literacy, it is safe to assume that the students learned them effectively. All groups delivered a satisfactory project, which was reflected in a mean grade of 8.6, with most students having grades above 8.0. Also, technical skills aimed at Artificial Intelligence related to Leadership (ethics and AI), UX (graph and data visualization), Business, Math and Programming were effectively learned.

Students learned about Machine Learning models (e.g., Decision Tree, Regression, KNN and Naive Bayes) in self-studies of Sprint 2, and evaluation (e.g., recall, accuracy) in the self-studies of Sprint 3. These models and evaluation metrics were discussed with the Programming teacher specialist in the Coding classes of Sprints 2 and 3. This knowledge was applied in the project in the Activities 'Model Evaluation' and 'Model Comparison' of Sprints 2 and 3. This theory-practice relationship proved to be effective because, when evaluated, the students demonstrated their knowledge of the different ML models and metrics in both tests that make up 20% of the final grade.

D. MAIN CONTRIBUTIONS

This subsection highlights the main contributions of our PBL approach in comparison with existing literature.

Table 7 presents a summary of the comparison of this work with the related work. This analysis is performed considering the year of the presented case study, the total project duration in weeks, the total number of students, the total number of groups, the maximum group size, the number of releases, total number of sprints, the total length of each sprint in weeks (Sprint Duration), and the total length of the preparatory phase in weeks (also referred as pre-Scrum phase).

The first difference is related to the total project duration: the 10-week period of this work is shorter than the average duration presented in the literature. This aspect shows how

TABLE 7. Comparison with related work.

Reference	Year	Course	Duration (weeks)	Students	Number of Groups	Group Size	Releases	Sprints	Sprint Duration (weeks)	Prep Phase (weeks)
Scharf and Koch [16]	2013	Software Engineering	20	70	8	8	4	8	2	4
Dinis-Carvalho et al. [21]	2019	Industrial Engineering	15	11	6	11	8	15	1	n/a
Noguera et al. [30]	2018	Multimedia	15	114	12	4	4	5	1	4
Ozkan et al. [33]	2022	Software Development	3	48	n/a	9	1	1 to 3	1 to 3	7
Fernandes et al. [35]	2021	Industrial Engineering	15	92	9	5	n/a	n/a	1	6
This work	2023	Artificial Intelligence	10	30	5	6	5	5	2	1

TABLE 8. Similarities and differences of the present work in comparison to the existing literature.

Similarities	Differences
Real-life problems	Agile methodology
Small groups of students	Scrum framework
Peer evaluation	Quantitative assessment
Oral presentations	Variety of projects
Project reports	Project incremental and iterative
Development of soft skills	Leadership experience

it can be challenging to propose the combination of Scrum and PBL to teach Artificial Intelligence in a short timeframe, as Artificial Intelligence is a subject that has not been investigated yet with Scrum and PBL, as far as the authors are concerned.

The number of groups is aligned with Dinis-Carvalho et al. [21], because the group size is under average. The number of releases are also under average, as well as the number of sprints and sprint duration.

The total number of students is lower than the selected related works. Another key difference is related to the Prep Phase, which is shorter than the presented in related work. Instead of longer preparatory pre-Scrum phases, the learning itself is iterative and aimed to support synergy between theory and practice.

Overall similarities involve solving real-life, interdisciplinary problems in small groups with different approaches, using methods such as peer evaluation, oral presentations, and project reports for assessment, and the effective development of soft skills. One of the main differences is our use of the Agile methodology and Scrum framework in a variety of projects during the degree, which are iterative and developed incrementally. Additionally, results evaluation focuses more on the students' and teachers' performance than on students' motivation and feelings. Furthermore, students can have the experience to be in a leadership position during the project, learning how to communicate with others and to organize the team. These contributions of the present work are summarized in Table 8.

This work contributes to the body of knowledge by presenting a case study of a successful implementation of PBL with Scrum and the application of Agile values and principles. This is relevant because the existing research on the application of Scrum in Education is scarce [35]. This research also presented how elements of AI literacy could be achieved by using the PBL approach with a case study of breast cancer prediction in Brazil, thus contributing to closing the research gap identified by Ng et al. [36].

VII. CONCLUSION

This paper presented a PBL approach in a computing undergraduate institution, evaluating students' and teachers' performance during the development of a predictive model project. This project was developed in ten weeks and students worked collaboratively with each other to accomplish a final goal.

The analysis of the academic results and qualitative surveys indicated that the 30 students were successful in the project development, using efficiently Scrum and Agile during the process, and the overall satisfaction related to the module and teachers was high. As a result, students did not only learn course content, but also developed problem-solving abilities, critical thinking and communication skills, teamwork capabilities, and the ability to work with real-life companies and problems.

This paper presented a case study of how Scrum and Agile could be combined with PBL to teach Artificial Intelligence to undergraduate students, and contributed to enhance the scarce research on the application of Scrum in Education. As future work, it is possible to increase the number of experimental results by applying the proposed method in other classes and institutions, and enhancing the literature with statistical analyzes.

This project can be used as an additional resource for future research. Following the basis of PBL, its differences can be significant to researchers and educators who want to compare different approaches or for those who wish to use project-based learning in their institution or class. One such opportunity is to use the discussion of the necessary teacher profiles to support the creation of multidisciplinary teams of specialized professors to implement PBL in other institutions.

STATEMENTS

The authors report there are no competing interests to declare.

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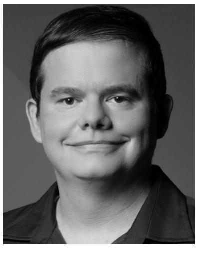

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