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Teaching Web Programming based on Interdisciplinary Projects: An Experience Report

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Teaching Web Programming based on Interdisciplinary Projects: An Experience Report

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Abstract

To develop an effective teaching-learning process is a challenging task for teachers. Among other initiatives, it is necessary to identify what holds the student's attention and motivates them to learn. Several studies have been successful in using a project-based approach, especially in case of programming teaching. It is common to see students questioning the application of concepts being taught by asking where they are applied in practice. When a student learns for the purpose of applying knowledge to something that he can see in practice, he/she has an increasing motivation to study. This work presents the results obtained from the application of a teaching approach for web programming students of the Secondary Technical Education, which is entirely project-based. The appraisal shows that the employed approach impulses the professional evolution of students, enabling them to exercise other competences such as teamwork, problem solving, and leadership.

Keywords: Interdisciplinary, Problem-based learning, Project-based, Scrum, Teaching.

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Introduction

The Brazilian Federal Institute, as a network of schools, offers traditional high school learning together with technical courses. It aims to provide free public quality teaching. However, most students encounter great difficulties to complete their courses due to some relevant factors. Many students use to take deficient elementary school. Others are not so sure about their course choices. Some of them need to stop their studies to work. All these relevant factors add up to a very large evasion in courses.

In order to minimize these difficulties, it is essential to enhance the quality of teaching and learning technical courses. Searching for new approaches and teaching methods, as opposed to the traditional teaching, can be a mechanism to achieve this purpose. One of the most challenges issues when dealing with the teaching process is to hold student's attention.

In general, students who enroll in technical courses are teenagers, aged from 15 to 17 years. The traditional way does not easily motivate students to become interested in courses. It is not clear to students the importance of certain content for their training (Borges, 2000).

This paper presents and discusses the main results obtained from the application of a project-based teaching approach. Students could choose to develop any project, provided it was to solve a real problem, using some pre-established requirements addressing skills they already had and also new ones.

The exercise was conducted in the last semester of the course (the whole course lasts three semesters), with four enrolled courses, during the first half of 2016. Students were divided into two teams. The development was organized by using the Scrum agile development method, its best practices, usability assessments, and also some web development technologies. Both team projects were committed to use the problem-based learning method either "to improve the quality of life" and/or "to improve public utilities".

Students evaluated a set of assertions to compare their abilities and motivations during all courses, contrasting traditional teachings to project-based ones. We also have analyzed and compared students' performance among course periods. The results have shown that the average grade increased and the number of class absence was reduced when a project-based teaching was employed. The results also pointed out that students' motivation and organization have significantly improved when using the project-based teaching approach.

This paper is organized as follows. Next section shows the fundamentals related to this work. In section "Research Methodology", some details of the methodology are explained. Section "The Main Research Results" presents the major results and findings, corroborated by the application of a surveyand a student performance analysis. Discussion section promotes a discussion about both projects, and if they really meet its objectives. Next comes the literature review related to this work, and finally the conclusions, recommendations and future work are described.

Research Background

The main concepts from Interdisciplinarity, problem-based learning, and Scrum were applied in this project-based teaching approach and this section briefly discusses these issues.

Interdisciplinarity

To understand the world, interdisciplinary is one of the most widely accepted methodologies in an educational environment. It favors discussions, exchanges of thoughts, and arguments, by aiding students in a meaningful learning atmosphere (Hersam et al., 2004).

Interdisciplinary work is favored, when approaching issues permeate students' reality. In case of both developed projects, working on a real project and direct contacting with everyday problems, have allowed students for troubleshooting, using the modern technologies available from the market. For students, the discovery of some existing alternatives has proved to be challenging.

Some confrontation and accommodation ideas were supported through the use of individual and group studies, classes, and weekly labs that allowed for larger and more complex difficulty analyses at the level of simpler elements. These elements subsequently would reconnect through the Scrum agile development method and its best practices, forming a structure with some functionality delivered to the customer.

The effective participation of teachers and students from different courses allowed relationships of content previously taught in isolation. This allowed for the exchange of knowledge necessary for application and development. Along with interdisciplinarity, constant contact with the team also has enhanced primary collaboration for the success of this new approach.

Each discussion has produced iterations for the development process that uncovered new platforms, which did not take part of the unit by itself. This interaction was based on a systemic view of the process because it favored connecting the key points from each course.

Problem-based Learning (PBL)

Problem-based learning (PBL) is perhaps the most innovative instructional method conceived in the history of education. PBL was originally designed to respond to the criticism that traditional teaching and learning methods fail to prepare medical students for solving problems in clinical settings (Hung et al., 2008). PBL proposes that students deal with real-life problems, rather than hypothetical situations.

PBL can be defined as an instructional method that initiates students' learning by creating a need to solve an authentic problem. During the problem solving process, students construct content knowledge and develop problem-solving skills as well as self-directed learning skills while working toward a solution to the problem (Hung et al., 2008).

After its successful implementation in various fields of medical

education, PBL is now being implemented throughout higher education as well as in high school and elementary education. Various results showing the effectiveness of implementations of PBL in high school and elementary education settings have been widely reported.

The PBL learning process normally involves the following steps (Hung et al., 2008):

- Students in groups of five to eight encounter and reason through the problem. They attempt to define and bound the problem and set learning goals by identifying what they know already, what hypotheses or conjectures they can think of, what they need to learn to better understand the dimensions of the problem, and what learning activities are required and who will perform them.
- During self-directed study, individual students complete their learning assignments. They collect and study resources and prepare reports to the group.
- Students share their learning with the group and revisit the problem, generating additional hypotheses and rejecting others based on their learning.
- At the end of the learning period (usually one week), students summarize and integrate their learning.

The Scrum Agile Method

Scrum is an agile method sometimes considered as a framework for agile software development, in accordance with the Agile Manifesto, which outlines a series of principles and values, which prioritize customer satisfaction (Cohn, 2017; Kniberg, 2007).

It is designed for scenarios needing to adopt empirical control processes, where problems are unpredictable and their corrections or denials from late deliveries of customer are more expensive than deploying and maintaining such processes (Schwaber, 2004).

The three main roles of Scrum used in both projects were: Product Owner (PO), Scrum Master (SM), and Scrum Team (ST). The PO represented the client and his primary responsibility was to define system requirements and prioritize them. He called attention to the importance for the acceptance criteria to be met and for the added value of process quality. The SM has acted as a facilitator and his primary responsibility was to implement and maintain the process, removing obstacles and distractions, maintaining and even increasing teams' performances. The ST was responsible for product development.

Setting up a sprint as a cycle of development, its duration can vary from one to four weeks, depending on the project, the client, and the team. You can not change the duration of the sprint during its execution. You can change the start of the next sprint, but it is not advisable to stay up changing it all the time. During a sprint, it may occur four ceremonies: the sprint-planning meeting, the daily meeting, the sprint review, and the sprint retrospective. All of them have their length proportional to the duration of sprint, except for daily meetings, which have a maximum duration of 15

(fifteen) minutes.

The sprint-planning meeting is one of the most important events of Scrum and provides the development team with enough information to work on a sprint (Kniberg, 2007). On a sprint-planning meeting, two questions are answered: "what and how should be done". As a result of the meeting, one must obtain the sprint backlog, which involves the requirements to be met in the sprint, in order to achieve the sprint goal, as another artifact generated from the meeting.

The daily meeting aims to display the transparency of the work being performed by the team and allows the lifting of inhibitions that must be removed by the SM (Schwaber, 2004).

The sprint review takes place at the end of the sprint. Its main purpose is to make a partial delivery of the project, be submitted and be accepted by the end of each sprint, collecting feedbacks from stakeholders (Schwaber, 2004).

The sprint retrospective must take place right after the sprint review and to determine what worked well and what can improve the product performance, by defining some actions to keep what is good and improve what is not. At this point, the process is revisited. The team should not take it personally about questions raised in this meeting.

To adapt Scrum to both academic projects, it was necessary to analyze their differences and verify some corporate practices, which could be used. The details of this adaption and how these concepts were applied in practice are explained in the next section.

Research Methodology

This section presents the adopted methodology on this interdisciplinary project, as case study, addressing PBL in teaching technologies and programming languages for web development (Barak and Maymon, 1998).

In this project, various competences were developed and explored. Four different courses were directly involved on the third semester: Electronic Business Solutions, Information Security, Web Language II, and Interdisciplinary Project. The last course was responsible for organizing project activities.

Scrum was adopted as a framework for activity management, using its artifacts, roles, and meetings. In this work context the Interdisciplinary Project teacher assumed the PO role, students were part of the ST and one of the team members played the SM role.

The project was developed in two phases: the Pre-game Phase was the initial phase of thematic definition, teams organization, products vision, backlog initial definition; and the Game Phase was the project requirements implementation phase of the sprints, as shown in Figure 1.

In the Pre-game Phase, the theme definition was implemented in a web solution capable of contributing to an improvement of the quality of life, by creating innovative solutions that adopted the main current web technologies.

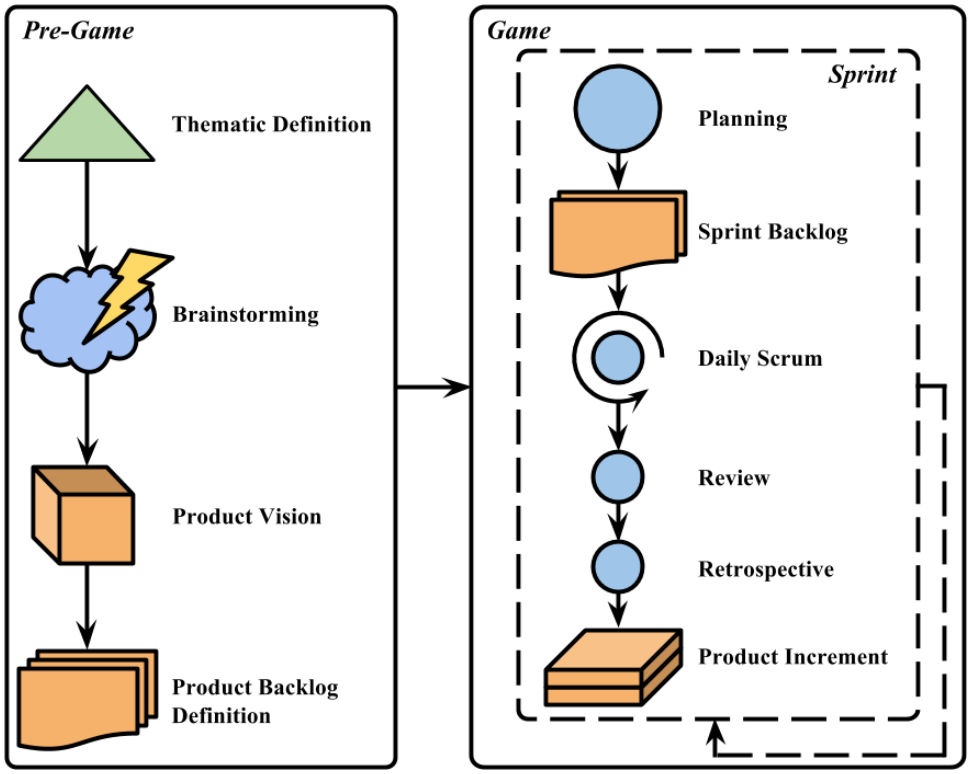
Firstly, according to the theme definition, a collective reflection on quality of lives and their main influences was carried out, involving students

and the teacher from the Interdisciplinary Project course. In this reflection, students highlighted topics such as: food, practice of physical activities, entertainment to reduce stress, and good social relationships.

Based upon this reflection, two themes were listed, as a project proposal: the practice of physical activities, and the practice of music. Starting from these themes, each team performed a brainstorm, proposing solutions that would encourage the practice of physical activities and the involvement with the music.

After the brainstorm, two web systems were selected as the best proposals by students and the course teacher: The Map Sport, a system based on maps for georeferenced location of points for the practice of physical activity in the city; and YouCover.TV, a social music network for sharing musical covers.

Figure 1. *Project Development Workflow*



Still in the Pre-game Phase, students developed a product vision by using the elevator pitch technique, a short text containing the main topics of the project as a target audience, the main requirements, and the differential related to the competitors and categories.

Starting from product vision, product backlogs were defined and prioritized for each project. Sprints time boxes were later stipulated with five sprints of three weeks reserved for the project development.

Later in the Game Phase, in each sprint cycle, students held the Scrum meetings and at the end of each three-week development cycle a product increase was delivered and made available on the Internet.

Each course has defined some requirements for the projects that were inserted and prioritized in its product backlog to be implemented in later

sprints.

During the last semester, two presentations were performed as seminars, where the students presented their projects in a public auditorium. The involved teachers evaluated project requirements. At that time, classmates and the general public asked questions and suggested improvements.

The following technologies to develop both projects were explored: markup languages, style sheets, frontend and backend programming languages, databases, version controls, web application security, interface usability, and project management. Interpersonal skills were also developed for working in teams, solving real problems, as well as, oral and written communication.

The Main Research Results

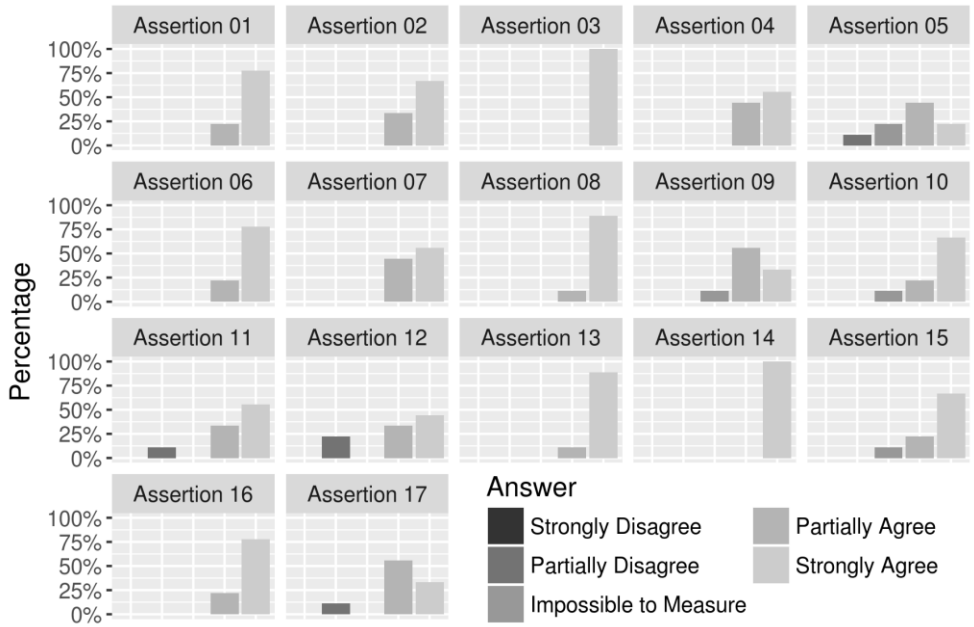
In order to analyze our project-based teaching approach, we provided seventeen assertions to be evaluated by students as: Strongly Disagree, Partially Disagree, Impossible to Measure, Partially Agree, or Strongly Agree. These assertions are listed below:

1. The interdisciplinary project made me feel more motivated to study the proposed technologies than before;
2. Team members worked collaboratively to solve problems and develop the project;
3. The Scrum method has contributed to project activities management;
4. The Scrum method has contributed to the team's self-management;
5. The workload was well distributed among ST members;
6. The number of ST members was adequate;
7. There was collaboration between the ST in classroom environment;
8. The courses have contributed to the necessary knowledge for project development;
9. All knowledge obtained from courses had some kind of practical application on projects' development;
10. Theme definition by students has motivated the project development;
11. The team remained motivated and committed during all project development;
12. Project-related activities conducted outside classes period did not result in work overload;
13. Applying theoretical concepts in practice on a project made it easier to learn and assimilate web technologies;
14. I was able to contribute to the project by using skills I have greater control;
15. I was able to discover other skills I did not know I had such as teamwork, leadership, communication skills, conflict solvers, and others;
16. Interdisciplinary project was an opportunity to apply knowledge developed in different courses to solve a real problem; and
17. The functionalities the team committed to develop were implemented

within the project execution period.

Figure 2 shows the answer percentage from each assertion provided by students via an virtual questionnaire.

Figure 2. *The Main Results Obtained from Student's Evaluation*



Results from the assertions' evaluations show students had the opportunity to discover important abilities as teamwork and leadership (assertions 2, 5, 11, 15, and 17). Motivation andcollaboration into a team and between different teams also were important points improved with a project-based approach (assertions 1, 7).Besides, according to students, the Scrum was considered an appropriate method to manage all project activities within a team (assertions 3, 4, 6). assertions

It is noticeable from the assertions' evaluations that relationship between courses provided sufficient technical and theoretical foundation for students to develop their projects (assertions 8, 9, 13, 16). The course contents and students difficulties were verified and updated every week through a meeting with all course professors, which reflects in the students satisfaction and on the project success.

An important consequence of these weekly meetings motivated by the project's continuous feedback was the decision making about reformulating the whole course to adapt to new technologies and teaching approaches made after the project conclusion. This discussion is out of the scope of this paper.

Besides, teamwork is an important professional feature, the project also motivated the individual abilities from students, which could be explored by students (assertion 14) during the project development. Students' creativity and independence were stimulated to define a project theme relevant to themselves, which impacts their motivation (assertion 10). Another relevant point is the avoidance of extra activities overload to acquire the desired knowledge (assertion 12). Finally, a result-oriented profile was developed by students during the project execution period (assertion 17).

To complete this analysis, the performance of students was also compared among the course semesters. On this comparison, it was considered students' course grade averages and students' absences only for those who have successfully concluded all semesters.

Figures 3 and 4 illustrate the maximum and minimum values at top and bottom of draw, respectively. The average is represented with a black point at draw middle, the standard deviation with the line crossing the black point representing average, and the data concentration by draw width. Therefore, Figures 3 and 4 summarizes maximum, minimum, averages, standard deviation, and data concentration of the student's course grade averages and absence, respectively.

Figure 3. *Summarizing the Course Grade Averages of Approved Students*

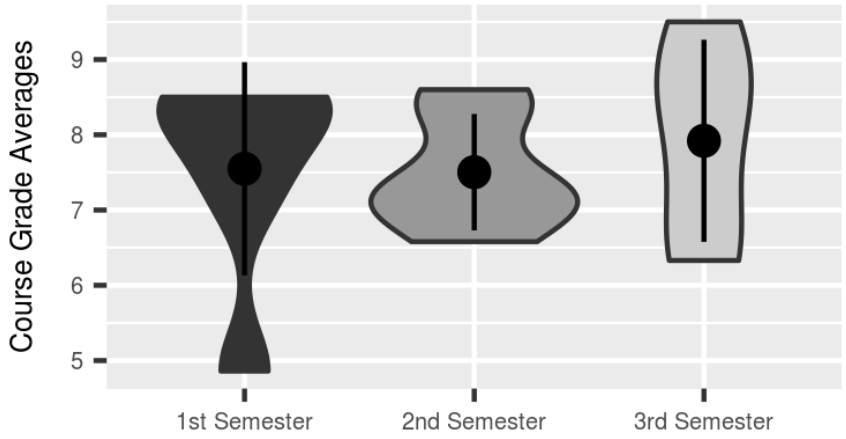
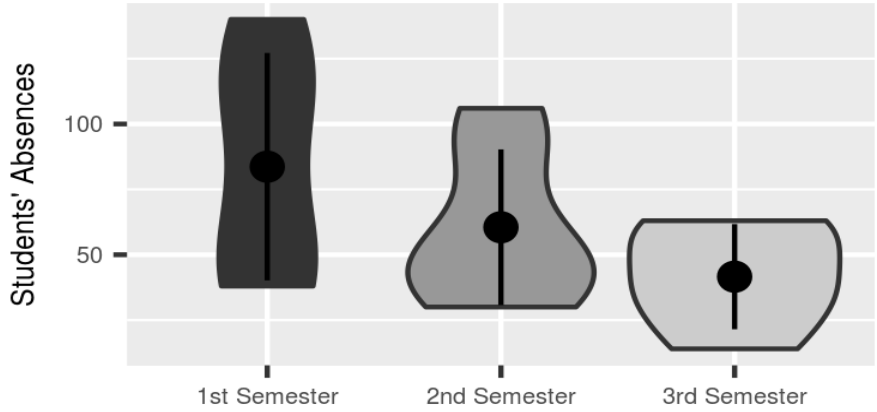


Figure 4. *Summarizing the Course Students' Absence*



Visually, it is remarkable that both course grade averages and students' absences have improved in the third semester, where the project-based approach was employed, compared to the other two. These results represent a major finding from this research and also a relevant effectiveness evidence of this project-based teaching approach.

In order to confirm these findings, it was applied hypothesis tests over our dataset. First, we have applied the F-test of Fisher to verify if the variances of samples are equals. This test was applied between datasets

from the first and second semesters and between the second and third ones. The hypothesis tests resulted on p-values from 0.3 for grades and frequencies. Then, the null hypotheses was accepted considering 5% of significance level for all cases, meaning that variances are equal for students' course grade averages and absences among semesters.

Following up, it was applied the upper tail t-Test in order to statistically determine if the course grade average of the previous semester is greater than or equal to the current one or not. The low tail t-Test method was applied to verify the differences between absences among semesters.

The t-Test comparing course grade averages from the first and second semesters resulted p-value of 0.3511443. It implies that grade average from first semester is statistically equal or greater than the grade average from the second semester. The t-Test between second and third semesters resulted in p-value of 0.000364874. It implies that grade average from second semester is statistically lower than the grande from the third semester. By transitivity, it is possible to conclude the semester with a project-based teaching approach had grade averages statistically greater than previous semesters.

Finally, t-Test comparing students' absences from the first and second semesters resulted p-value of 0.279423. It implies that absences from first semester is statistically less or equal than the absences from the second semester. The t-Test between second and third semesters resulted in p-value of 0.03520036. It implies that absences from second semester is statistically greater than the grande from the third semester. By transitivity, it is possible to conclude the semester with a project-based teaching approach motivated students' participation, as the absences are lower in the third semester.

Discussion

In this section, the main outcomes of the work carried out within nineteen weeks are discussed. It has involved agile methods for the development of interdisciplinary projects, where students were submitted to problem-based learning. This effort has resulted in the implementation of two web systems: YouCover.tv and Map Sport.

Both projects aimed to explore themes for contributing to quality of life of the local population. Based on this proposal, students carried out a reflection about which major factors influence quality of life, such as: food, physical activity, stress reduction, among others.

YouCover.tv (youcover.tv) has followed the proposal of stress reduction, cultural development, and social involvement. They have implemented a social network specialized in sharing music videos. The system aims to encourage amateur and professional musicians to spread their musical culture. Besides, the visitor can explore the songs by category, create a profile, send covers, follow other members, enjoy and comment videos.

Sport Map (mapesporte.com) has followed the proposal of encouraging the practice of physical activities, offering to the residents and tourists of Caraguatatuba, an interactive map to explore the main public and private points to practice an assorted number of sports. The site allows the visitor to

find information about places through the computer or mobile devices. Sports companies in the region can also register and advertise their locations on the map.

The results have generated significant evidences that a project-based teaching approach can improve different qualities of a student. Teamwork, leadership, motivation, organization, and communication are some examples of abilities that could be observed by applying this approach. Another important aspect was the opportunity to improve the dialog between the different topics explored during the courses.

With statistical rigor, we can notice there is no difference in the student's performance when not applying a project-based teaching approach. Our methodology was statistically verified, resulting in better grades and absences reduction from students when comparing to semesters with traditional teaching approaches.

Literature Review

Other initiatives applying interdisciplinarity and/or PBL in development of systems conducted with students were carried out, according to what we have found in the literature review.

Freitas (2014) described an academic development of an embedded system project named *Sistema Embarcado de Tempo Real para Repressão de Acessos Indevidos e Fraudes* (SETRAIF), which was performed during the second half of 2012, by students and professors of Computer Engineering courses at the Brazilian Aeronautics Institute of Technology, combining the use of interdisciplinarity, Agile Methods, and Model Driven Development. OnSETRAIF project, the work with a real project and the direct contact with the client have allowed students from four different courses (Embedded Systems; Real-Time Embedded Systems; Software Quality, Reliability, and Safety; and Advanced Topics in Software Testing) to develop a software with quality, reliability, security, and testability, using modern technologies available on the market. The challenge for students was to discover an alternative to what existed at that time. As a result, a prototype of an embedded system for improper access and fraud suppression was developed using: arduino hardware, quick response code, the Google AppEngine, an Android application, and an encrypt/decrypt algorithm.

Doppelt (2003) has applied PBL in order to extract pupils and their teachers from the ongoing cycle of failure, and to promote pupils cognitively and emotionally. Four steps were taken: defining significant goals for the pupils as well as for the teachers; changing the learning environment; carrying out original projects taking advantage of the pupils' special skills and abilities; and changing assessment methods for PBL activities in a computerized environment. This work presents a continuous field research that has used qualitative and quantitative tools for exploring pupils' progress in the affective and the cognitive domains. The research tools were: analysis of pupils' portfolios, observations of class activities, interviews with pupils, teachers and school management, achievements in the matriculation examinations, and assessment of pupils' projects. The

findings indicate that scientific- technological PBL elevated pupils' motivation and self-image at all levels and achieved significant affective learning. The activities over three years are summarized and show an increase in the number of students achieving the college admittance requirements.

Some other research results show good performance of students in several issues. Polanco et al. (2004) investigated the effect of PBL on engineering students' academic achievement. They found that, when compared to their counterparts, PBL curriculum significantly enhanced engineering students' performance on the Mechanics Baseline Test, in which the focus of the test was on understanding and application of the concepts rather than recall of factual knowledge. Woods (1996) reported that employers praised McMaster University's PBL chemical engineering graduates' outstanding problem-solving skills and job performance. Compared to other new employees who typically required 1 to 1-1/2 years of on-the-job training to be able to solve problems independently, "[the PBL graduates] think for themselves and solve problems upon graduation".

All studies indicate that students had improvements in some way, when applying Interdisciplinarity and/or PBL.

Final Remarks and Future Work

This paper has presented and discussed an education approach based on agile software and problem-based learning methods, for the development of web systems, applied to the Secondary Technical Education. The interdisciplinary projects have explored teaching web programming languages, cascading style sheets, markup languages, database, and other web development techniques.

Two projects were developed by students of the last semester of the Internet Computing course, lasting nineteen weeks. At the end, two web systems were produced: the Map Sport, a map-based system for locating georeferenced points for practicing physical activity in the city and YouCover.TV, a social music network for sharing covers.

In order to analysethis project-based teaching approach it was provided a set of assertions to be evaluated by students. We also have compared the student's grade and frequency along the three semesters of the whole course. The results pointed out that a project-based teaching approach is effective as it improves the learning and teaching experience. Consequently, we can infer that our approach is committed to Instituto Federal de São Paulo (IFSP) mission: to consolidate an educational praxis that contributes to social insertion, integrative formation, and the production of knowledge.

Future work suggests the use of complementary methods in the initial phases of the projects, such as design thinking, to give a comprehensive understanding about the problem, as well asthe main requirements observed by users' perspectives. In this way, the development will have an emphasis on User-Centered Design (Ferreira, 2011). A complete reformulation of the whole course grid should be elaborated to embrace a project-based teaching approach during all semesters in order to reduce student evasion.

This action may also allow the involvement of public and private companies in educational process, allowing students to have contact with real and current challenges. These companies can also benefit from the knowledge generated in the institution by providing scholarships and financial support, and students can solve the problems proposed by these companies during the course. It could provide a better cycle between local community, companies, schools, and colleges.

We recommend to apply the problem-based interdisciplinary teaching approach that uses agile methods such as management of project activities at other academic levels such as undergraduate and graduate.

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