# Advances in Designing a Student-Centered Learning Process using Cutting-Edge Methods, Tools, and Artificial Intelligence: An E-Learning Platform

Camelia Serban
camelia@cs.ubbcluj.ro
Babeş - Bolyai University
Cluj-Napoca, Cluj, Romania

Andreea Vescan
avescan@cs.ubbcluj.ro
Babes-Bolyai University
Cluj-Napoca, Cluj, Romania

## ABSTRACT

It is well known the fact that learning process is difficult for learners and at the same time it raises problems for those who teach. Teaching Software Engineering for undergraduate students is an assiduous and a challenging task due to its level of abstraction, to frequently changes that appear in programming paradigms and in software development methodologies.

In this paper we provide a novel approach in teaching Advanced Programming Methods, the third introductory course in Software Engineering that is being taught at our faculty within the Computer Science Curriculum for undergraduate students.

The contribution of this paper is threefold: firstly, we design a student-centered learning process intertwining cutting edge methods like for instance project-based learning, self assessment-based learning and students engagement. Secondly, we design an E-learning platform to provide for students an automated assessment and appropriate feedback and, most important, to offer them support throughout the learning process. Thirdly, we provide a quantitative and qualitative analysis over 3 years of teaching Advanced Programming Methods course, by applying the proposed methodology.

Our analysis results show the effectiveness of our approach. Key contributions in this paper are our proposed E-learning platform and the analysis findings.

## CCS CONCEPTS

• **Social and professional topics** → **Computer science education**; **Student assessment**; • **Applied computing** → **E-learning**; • **Software and its engineering** → **Software design engineering**; • **Computing methodologies** → *Learning paradigms.*

## KEYWORDS

Project-based learning, formative assessment, summative assessment, multiple choice exam, experience report, student experience


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## 1 INTRODUCTION

The learning process is complex and assiduous at any stage in the life of an individual and in any field. The main goal of teaching and learning at any level of education is to bring a fundamental change for the learner. To facilitate the process of knowledge transmission, teachers should apply appropriate teaching methods that best suit the proposed objectives and the expected outcomes. Traditional learning methods widely used teacher-centered approach and their effectiveness are questionable [19].

Nowadays research-based on learner-centered methods has consistently raised considerable interest in the thematic field of educational research [10], [11].

These methods have started to be used more and more in primary school, gymnasium and high school, but in academic environment, less emphasis is placed on active involvement of the student during the learning process. Thus, game-based learning, project-based learning, applying a design thinking approach and other student-centered learning methodologies [14], are missing in academic environment being replaced with lectures exposure in front of many students, self learning, few discussions and feedback being offered. Because the evaluation is done only at the end of the semester when the information received is highly quantitative, many students fail to accumulate the knowledge they receive. Moreover, it is well known [7], [18], [5] that the speed at which our brain is acquiring knowledge is the same as the brain forgets.

In Computer Science domain changes appear frequently thus applying traditional learning methods is not working anymore. Many students from our faculty have dropped out college. Lately, our faculty has made important effort in order to develop a student-centered approach for the learning process. Each course coordinator was encourage to propose innovative methods in order to increase students result, their experience in learning process and to avoid school dropout.

The current paper proposes a novel approach in teaching Advance Programming Methods, the third introductory course in Software Engineering that is being taught at our faculty within the Computer Science Curriculum for undergraduate students.

The contribution of this paper is threefold: *firstly*, we design a student-centered learning process intertwining cutting edge methods like for instance project-based learning, self assessment-based learning and students engagement. Students are encourage to design their assessment throughout the entire learning process, being actively involved, and using a design thinking approach [2, 4].

*Secondly*, we design an E-learning platform to provide for students an automated assessment and appropriate feedback and, most important, to offer them support throughout the learning process. The proposed E-learning platform integrates Artificial Intelligence components that offer valuable support in learning and teaching process. Also, this platform is build by means of students' engagement in building the learning process design, these ones being coordinated by the course instructors.

*Thirdly*, we provide a quantitative and qualitative analysis over 3 years of teaching Advance Programming Methods course, by applying the proposed methodology.

The rest of the paper is organized as follows. Section 2 details the theories relating to learner-centered teaching and assessment. Section 3 states the course description and goals, presents the proposed learning and assessment methods and outlines the research questions. Section 4 presents the developed E-learning Platform. Section 5 encompasses the quantitative and qualitative analysis. Section 6 states the results and outcome of our exploration regarding learning and assessment strategies and outlines future developments.

## 2 LEARNING STRATEGIES

Traditional instructional theory [15] assumes that learning of complex competences could be broken down into discrete skills learned separately and that each component of the complex skill is fixed, not depending on the context where it is used. Current learning theory [17] suggests that decontextualization is inappropriate: learned isolated facts quickly disappear from the memory because they have no meaning and do not fit into the learner's conceptual map. Thus, the knowledge learned in this way is of no use because it cannot be applied, generalized or retrieved.

Cognitive theory suggests that learning is a process of knowledge construction: learning occurs not by recording information but by interpreting it so that instruction must be seen not as direct transfer of knowledge but as an intervention in an ongoing knowledge construction process.

This new conceptions of learning require a new assessment methodology, requiring a more diverse assessment [8] and to assess in more depth the structure and quality of student's learning and understanding. Multiple choice tests or short answer type test are efficient at sampling the acquisition of specific knowledge gained from teachers, while more intense assessments like essays or small group tasks or projects are needed to get and encourage a deeper level of learning.

The theoretical framework of learner-centered assessment [10] asserts problem solving and higher order thinking skills, a sense of ownership in learning. The primary goal of assessment is to see how much the students have already learned, increased by getting students to learn [11] while they are completing the task you are given them.

Various strategies may be used for implementing learner-centered assessment, some of them during the didactic activities as formative assessments and other at the end of the semester as summative assessment, a synergy of them increasing the learning performance of the students. Practice exams, laboratory work both in class and take-home assignment, project-based learning, short answer questions are just a few of the strategies that could be combined to increase students involvement and learning.

Assessment for Learning [12] is one of the distinct approaches regarding formative assessment that occurs as part of ongoing classroom practices, that is viewed as a social and contextual event and that focuses on the quality of learning process. Feedback is continually incorporated in this process to guide future learning, and is aimed at the class or individual level. A systematic review of prerequisites for implementing assessment for learning in classroom practice is provided in paper [9].

Regarding project-based learning, paper [20] explored the learning process alongside students' perceived outcomes within an interdisciplinary project-based learning task. Students from three different undergraduate courses were assigned a project that spanned across all three classes. The paper sheds light on the importance of interdisciplinary collaboration among instructors when designing a project-based learning experience that pushes students to crosses disciplinary boundaries.

Referring to self-assessment, paper [1] discusses and introduces criteria-referenced self-assessment, describes how it is done, and reviews some of the research on its benefits to students. The purposes of self-assessment are to identify areas of strength and weakness in one' s work in order to make improvements and promote learning.

In what follows we present our approach regarding the proposed learning design for teaching Advanced Programming Methods course, describing also the activities used both for formative and summative assessments as part of the learning process.

## 3 CONTEXT: A STUDENT-CENTERED APPROACH IN TEACHING ADVANCED PROGRAMMING METHODS

### 3.1 Course Description and Course Goals

Advanced Programming Methods – APM is the third introductory course in Software Engineering domain that is being taught at our faculty as part of the Computer Science Curriculum.

The main objective of this course, comprised in the course syllabus, states that "Students have to be able to develop small to medium applications using the main concepts and mechanisms defined by object orientation programming paradigm - OOP, together with design strategies expressed in terms of principles, heuristics and rules, and use/build well defined software architectures for these applications." The languages used are Java and C#. Fore more detail see the APM course Syllabus [3].

Therefore, three important knowledge areas are identified to be considered in order to reach the above mentioned objective:

(1) The main Fundamental concepts, principles and mechanisms defined by OOP paradigm;
(2) Design, principles, heuristics and rules that act as strategies implied in designing the system;

(3) Software Architectures that aim to define the main constituent elements of the system architecture and to establish rules to wire them together in order to build the system having satisfying both functional and non-functional requirements.

Beside the three important knowledge areas comprised in APM course syllabus, the proposed learning design aims for the students to acquire knowledge and skills in in communication, teamwork, active listening, moderation techniques, interactive presentations, oral and nonverbal communication, conflict management and related issues in a holistic way.

## 3.2 Research Questions

In this paper, we seek to investigate and validate the following two high level research questions.

**RQ1:** How do we design the learning process in software engineering for undergraduate students?

**RQ2:** How is the effectiveness of our proposed learning process design?

The following section aims to respond to the first research question whereas Section 5 responds to the second research question.

## 3.3 Learning Process Design

As we have mentioned earlier, designing the learning process by incorporating modern methods that are student-centered represents the first step in attaining success in this activity. This because, a student-centered approach encourages students to "discover" knowledge by themselves, working at their own individual speed or in groups in a minimally guided environment, with the lab instructor offering support, encouraging their imagination and creativity.

The proposed learning process design is conducted based on some assignments that students need to accomplish during the semester and in the exam session period. In this respect, they are coordinated by the course instructors using an E-learning platform that automate and optimizes this activity, helping both students and instructors.

In teaching APM course we divided the learning design process into four components each of them contributing with a given weight for the final grade of the student. Three of the learning components are applied during the semester and two of them is applied at the final semester in the evaluation period of the semester. The proposed approach incorporates also a "continuous" and "comprehensive" evaluation in which students should not be able to tell whether they are being taught or assessed. This means that the evaluation and learning processes are intertwined.

*3.3.1 Project-based Learning.* The first assignment for APM course, as part of the learning process, is to develop a project written in Java language and then translated it in C#. The developed methodology is an iterative one. Thus, students guided by the course coordinator, decompose requirements in iterations, each week out of fourteen weeks of the semester the students have to accomplish an iteration. The students can bring their own ideas, being encouraged to ask questions, to proposed new design for the project they build or even to come with their own idea of project. Also, we aim to attain cross-curricular connections, inquiry-based learning, skill building and linking curriculum with life.

*3.3.2 Continuous Comprehensive Evaluation-based Learning - Quizzes and Test-based.* The second part of the learning process gives the students the opportunity to build their own test for the *written exam*. This is a multiple choice written test sustained in the exam session period, as part of their formative assessment during the semester. Each students has to come with at least one multiple choice question to enhance the database containing quizzes for the written exam. These quizzes emphasise on understanding of concepts and are used as data set for the artificial intelligent component that is part of the proposed E-learning platform described in the next section.

*3.3.3 Written Exam.* The students have to sustain a written exam in the exam session as one of the part of summative assessment. As we have mentioned earlier, the test is build by the teacher coordinator of the course and contain the questions proposed by the students during the semester as a requirement for continuous comprehensive evaluation learning component.

*3.3.4 Practical Exam.* The students have to sustain a practical exam in Java and C# languages in the exam session as one of the part of summative assessment. They can use any documentation source, excepting chats or communication channels. This practical evaluation component has very high constraints of time. Several students encounter difficulties at this step of the assessment.

*3.3.5 Extended Lab Project - Workshop based Learning.* The last component of the learning process design offers the students the possibility to extend their project developed during the semester with some extra functionalities that overcome the difficulty level required for the course or even some of them are not covered in the course syllabus. It is a challenging task, the students have to improve their project to be as much similar as a real one project in terms of some quality attributes that are established by the course coordinator, like for instance, usability, security, maintainability, reusability, etc. Extending the project, the students have the benefit to skip the practical exam or the written exam. Every student has to prepare a public presentation for the extended project that will be part of the organized workshop at the end of the semester.

**Response for Research Question 1.** The learning process in software engineering is designed considering various modern methods that are learner-centered: project-based learning, multiple choice test for self assessments as formative assessment, practical exam, and written exam as summative assessment.

# 4 PROPOSED E-LEARNING PLATFORM

The proposed platform aims to enhance the management of learning process for both the learners and the instructors/teachers. The idea was born from the need to gather all the information in a single place, as the current systems are not very well organized and are missing some important features. We want to provide the

individuals involved in training sessions with testing, feedback, schedule management, supervised learning, all in one place. The assessment and the learning processes are crosscuted even from the beginnings, the platform offering feedback for students throughout the entire learning lifecycle. Also, the proposed platform contains an intelligent component that apply methods from Artificial Intelligence domain to make predictions, recommendations, build tests, automates grading assignments etc. Similar systems to our idea are [6] or [16].

The graphically representation of the E-learning component are provided in Figure 1 and described in details in the next subsections.

## 4.1 Test-based Learning Component

From the point of view of a teacher, choosing relevant problems, reviewing proposed solutions and preparing quizzes to be used during the lectures and seminars classes is a time-consuming part of the preparation process, especially concerning Computer Science topics.

On the other hand, regarding the student, solving a sufficient number of problems with varying and progressive difficulty is the vital part of the any learning process, offering an in-depth understanding of previously related topics. Collecting the appropriate problems can be both time-consuming and challenging.

The first component of the proposed E-learning platform refers to interacting with the course's concepts that need to be understood by the learners. Thus, the students can find electronic learning materials on the platform and also a set of multiple choice questions are available for the students as a way of learning by means of self assessment method. The questions that form a test are added to the platform in a collaborative way: every student have to contribute to the questions pool of the platform, together with course instructors. Every year the number of questions increases at least with the number of students following AMP course (each students has to contribute with at least one question.

*4.1.1 Multiple Choice Questions Pool.* In order to increase the number of questions that the platform offers, students have to propose questions regarding the concepts contained in the course syllabus. Thus, every year questions pool is increasing within a great extent. All the questions are public for the students.

In order to assure a high level of difficulty, each question should pass thorough a revision process made by the teacher in charge. Thus, the following steps are needed:

- the student add a question to the platform;
- the teacher will be able to edit the question: establishing the subjects covered by that question from the syllabus, enclosing it into a category, setting its level of difficulty or making minor changes in order to accept the question;
- the teacher can ask for the student to revise the question if something is unclear or simply reject it if it is totally wrong or it is not unique;
- once a question is accepted it will be added to the database, named *questions pool*.

We recall here that the questions are used by the teacher to build the written test for the final exam. If the number of new questions added every year by the students is not consistent, the teacher could add some new questions for the final exam, but within the limit of fifty percents, or some questions proposed by students can be lightly decorated or edited by the teacher. In this way, the students are motivated to propose questions due to the fact that these questions are part of their final exam, in other way the students build their own exam.

*4.1.2 Building Tests.* The questions pool can also be used to build tests. Teachers will be able to create tests in order to make easier for the students to prepare for their evaluations. They can configure the sections of the test by selecting different criteria such as the number of questions, their difficulty level etc. The questions can be automatically selected or they can be chosen one by one. Students can see all the tests created by their teachers and use them for self-evaluation. If they feel the need to practice more, they can even generate their own tests by configuring relevant sections for their needs. After, completing a test, the student can see all the references of a question in case he/she needs clarification about it, receiving appropriate feedback and suggestions in order to improve its knowledge.

## 4.2 Project-based Learning Component

*4.2.1 Project as Laboratory Assignment During the Semester.* As we have mentioned in Section 3, the first requirement for this course is to develop a project during the entire semester, every week the students have to implement an iteration and the teacher have to assess that iteration and give valuable feedback. Also a grade is obtained by the student for each iteration. Thus, the teacher have to complete an assessment report that comprises questions considering the way the requirements are design and implemented, tests that were made and if the iteration met the deadline. After completing this assessment report, a feedback is sent to student by email or it can be seen by students in the platform in a private way.

Also the students can ask help regarding the way a feature from the current iteration could be implemented, the teacher being notified in this respect in order to offer support.

All these guides are offered to students through the proposed platform, in this way the students have the possibility to view their feedback whenever they want and to correct their mistakes in time. It is well known the fact that we learn better by our own mistakes.

*4.2.2 Extended Project as a Final Examination.* The E-learning platform, offer also the possibility for those students who meet all the deadlines of the laboratory requirements to be enrolled, if they want, for the extended project described in Section 3.

The students have to write on the platform all their problems encountered and the way that are solved. This data is to be used by the Artificial Intelligent component of this platform for making recommendations for other students in solving similar problems.

At the workshop presentation of the extended project, organized at the end of the semester, the students have to complete a questionnaire regarding some aspects in implementing their extended project. These feedback is used in order to improved the learning process for the next year.

## 4.3 Artificial Intelligence Component

The Artificial Intelligence - AI component is interwoven with the features of all components comprised in the proposed E-learning

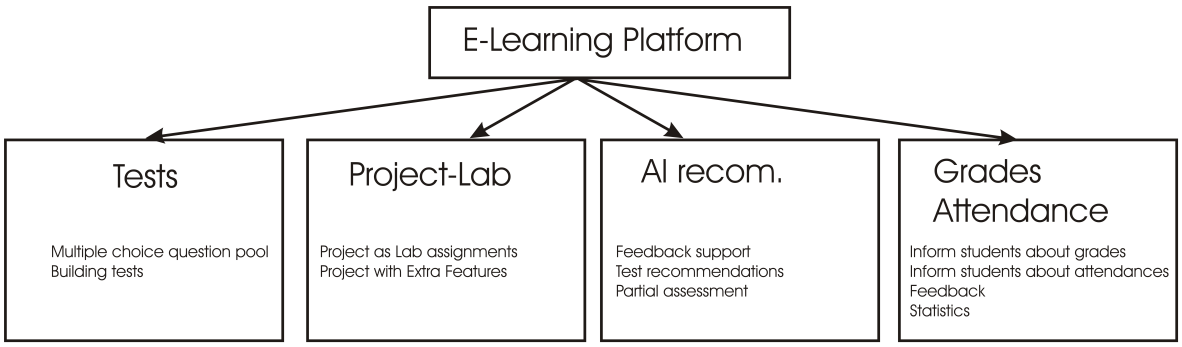


**Figure 1: Components of the E-learning platform**

platform. This section highlights these feature. It is important to mention here that the AI component uses as data set for training, all data gathered by the others components of the E-learning platform, like for instance the questions (problems) added by students and teachers every year, all tests taken by the students, all feed-backs offered by instructors and so on. So, the proposed AI component offered the following functionalities, being described in details in the next paragraphs.

*4.3.1 Feedback Support.* Students solve tests and obtain a feedback; this feedback is automated generated based on others similar tests solve by the student and of the similar tests solve by others students. This feedback contains information regarding the student strengths, his weaknesses, and those concepts from the subject that he/she need to practice more to obtained better results.

*4.3.2 Test Recommendations.* Based on the results obtained by a student, the system can recommend him other tests that the student can solve it in order to increase his level of knowledge for that subject. This recommendation is based on test similarity and on the level of knowledge regarding that concept.This functionality focus on the individual skills and particular characteristics of students during the learning process, thus being a student-centered approach.

*4.3.3 Partial Assessment.* The system can recommend a grade for the solution developed by the student for each required iteration of the project developed during the semester. The grade is computed having into account several assessment criteria: the feedback introduced by the instructor, written using natural language or completing a questionnaire, the deadlines that students have to meet, and the similarity with the same task implemented by other students.

## 4.4 Grades and Attendances Component

The last component of the proposed approach is referred to some administrative issues or some rules that the teacher needs to obey in the teaching process. U.E. has recently signed up for a new law. GDPR refers to how personal data should be manipulated. It has brought up changes into our university too. Now, those large tables with all the students' grades, attendances, bonuses, feedback and so on are no longer allowed to be made public. Students should be privately notified about their own situation. Thus, the necessity to build a platform in order to reach this goal and to save time for instructors and teachers became a necessity.

Our idea is intended to be a solution for these problems. Thus, the proposed platform comprises a component which would make it possible for teachers to inform and to notify students about their *grades*, *attendances*, *bonuses* and other private information, available only for them.

Furthermore, the student will be notified every time a teacher give him o grade and offer him a feedback. The received feedback is refers to both the project that the student developed it as laboratory requirements, and the feedback regarding the test that the student created/solved it. In this way, all the activity of the student during the semester, can be viewed by the teacher and by the student, every time is needed to be known.

Another feature implemented by the feedback component would be *statistics* which would help both students and teachers in their process of learning/teaching. Students can monitor their progress on every subject in order to manage in a better way the effort invested in learning. They will see where their performance is low and can choose to focus on it. On the other hand, the teachers can use statistics in order to auto-evaluate themselves in terms of teaching. All this data is then used by the AI component of this platform.

# 5 QUANTITATIVE AND QUALITATIVE ANALYSIS

This section aims to respond to the second research question, *RQ2: How is the effectiveness of our proposed learning process design?*

This question is broken down into two specific sub-questions:

(1) **RQ2.1:** What do students (report to) learn and take away from a course on?
(2) **RQ2.2:** How did students perceive the time for *Project-based learning* and what is the difference between *Project-based learning* and *Exam-based learning* in terms of learning time?
(3) **RQ2.3:** Which experiences do students consider to be significant from their perspective?

## 5.1 Quantitative Analysis

The current section describes the various approaches used to consider the formative and summative assessments into the final grade

formula computation, presents the average values for each considered class and interprets the findings.

The number of students enrolled in all considered years exceeds 600, thus having for 2016-2017 #201 students enrolled, on 2017-2018 and 2018-2019 having for each #213 students enrolled.

Table 1 contains values for various formative and summative assessments and the associated obtained grades (mean value).

**Table 1: Average values for each constituent activities: Average Laboratory (Lab), Practical Exam (PracticalEx), Written Exam (WrittenEx) and Project Extra Features (PrjExtra) for each considered class.**

| Class | Lab | PracticalEx | WrittenEx | PrjExtra |
|---|---|---|---|---|
| 2016–2017 | 9.07 | 8.47 | 3.04 | 9.93 |
| 2017–2018 | 8.33 | 7.58 | 6.58 | 9.81 |
| 2018–2019 | 8.83 | 7.64 | 6.00 | 9.90 |

Analyzing the results obtained in Table 1 we can conclude the following:

- The weights for the Written Exam increased substantially over the years. This shows the effectiveness of the proposed method for learning by continuous and comprehensive assessment during the semester. For the first class from the considered study, 2016-2017, this learning component did not exist.
- The results obtained at the project development-based assessment are very good for all the three considered classes.
- More students selected the Extra Feature Project instead of the final examination: 22 in the first year, 44 in the second and 38 in the last year and their results are very good; also their experience reported in the next section is promising in order to continue this kind of activity.
- More effort should be implied in the next year for Practical Exam, where the results are not as satisfactory as in the others cases.

## 5.2 Qualitative Analysis

Qualitative research [13] is conducted through intense and/or prolonged contact with participants. Most of the analysis is done with words that can be assembled or broken into segments. They can be reorganized to permit the researcher to compare and contrast, and finally to construct patterns out of them.

This section presents the student's experience in learning APM.

The current section presents the students' preferences regarding using the *Project-based learning* with Extra Features.

An online survey regarding the *Project-based learning* with Extra Features was provided at the end of the semester.

The asked questions are next presented:

- To what extent has this Extra Project helped you to strengthen your knowledge of APM?
- How long do you think you worked extra?
- How much do you think is the estimated time to extend the project from the lab to the time spent on preparing for the final exam?
- Why did you choose the project-based evaluation method in return for your written assessment or practical test?

Figure 2 contains the results about how students perceived that developing the extra project helped them to increase there knowledge regarding concepts related to APM.

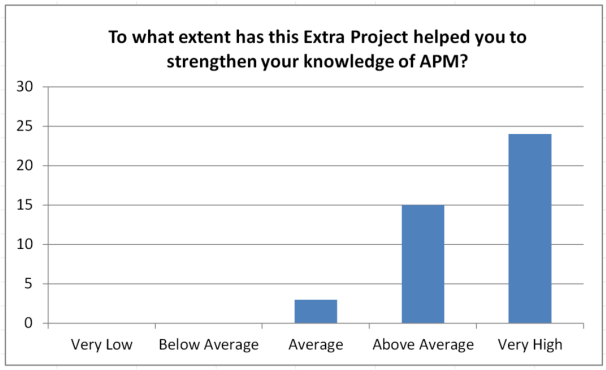


**Figure 2: Results of the survey regarding knowledge strengthening by creating the Project's Extra Features.**

**Response for Research Question 2.1.** Applying *Project-based learning* with extra features is effective in teaching APM, most of the respondents of the survey have the opinion that the knowledge was in this way reinforced.

The survey contains two questions that are related to the time needed to finish the Extra Features of the Project-based assignment and also the comparison between the time spent on preparing for written exam and the time needed to extend the project. Figure 3 and Figure 4 contain the opinions of the respondents for both perspectives.

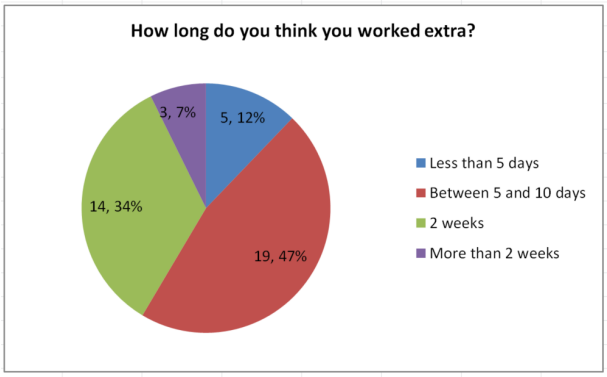


**Figure 3: Results of the survey regarding extra time needed to complete the Project - Extra Features.**

**Response for Research Question 2.2.** The time needed to implement the extra features of the *Project-based learning* was perceived by the students as being longer (majority's opinion being around 10 to 14 days), and that when comparing time needed to complete the project and the time needed to study for the written exam the respondents revealed that the time doubles.

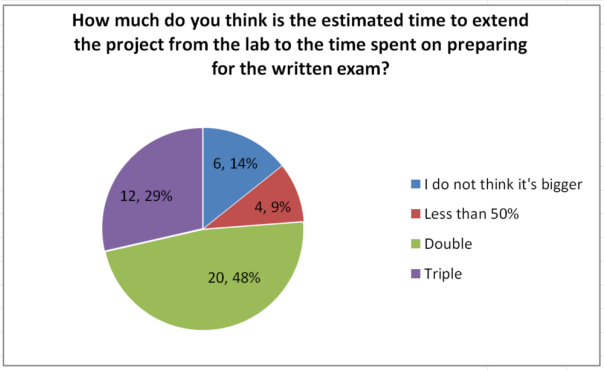


**Figure 4: Results of the survey regarding time needed for preparing for Extra Project and Exam.**

Figure 5 contains the results about the perception of the students regarding the differences about assessment using *Project-based learning* and/or *Classical Written Exam*. Most of the students considered that *Project-based learning* "stimulates creativity and involves higher cognitive processes such as investigation, analysis, critical thinking" and that learning based on project is "motivating because you have the opportunity to come with your own contributions".

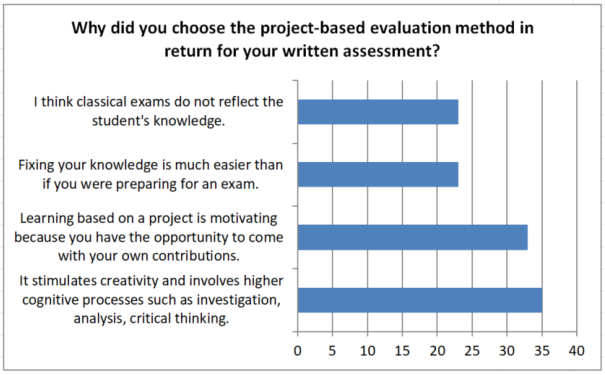


**Figure 5: Results of the survey regarding the reasons why students selected the Extra Project instead of the Classical Exam.**

**Response for Research Question 2.3:** The students considered that *Project-based learning* is a significant experience from their perspective, it stimulated creativity and is also motivating because they see the final product as their own.

## 6 CONCLUSIONS AND FUTURE WORK

Traditional instructional theory is no longer applicable in the today teaching-learning environments, especially in the computer science domain and moreover to the software engineering disciplines.

New strategies are required for teaching/learning, efforts invested in applying various techniques and E-learning tools to properly provide feedback and recommendations support to students. Automatic grading of assignments and providing multiple choice questions to exercise the learned concepts are some of the implemented functionalities in our E-learning tool for APM. As for the future improvements we aim to use the feedback offered by the students to be considered for the next classes in order to improve the learning process.

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