Student Projects towards Project-Based Learning for Teaching Computer Science in Secondary Schools

Silvio Giaffredo [1], Luisa Mich [2]✉, Marco Ronchetti [1]

[1] DISI – University of Trento, Trento, Italy
{silvio.giaffredo, marco.ronchetti}@unitn.it
[2] DII – University of Trento, Trento, Italy
luisa.mich@unitn.it

Abstract. Student projects are core activities for a project-based learning approach. However, introducing projects in classes does not automatically imply the adoption of such a method. In this paper we propose a scheme as a tool to analyse if and how much student projects are introduced and realised according to a project-based learning method. As part of a larger research, the scheme has been applied to six student projects for teaching computer science in Italian secondary schools. Results of the study highlight some critical issues and suggest some best practices to support teachers to exploit student projects towards a project-based learning method.

Keywords: Project-Based Learning, Teaching Methods, Student Projects.

1 Introduction

Student projects are a common practice for teaching computer science in secondary schools and possibly the most renowned for an activity-based teaching method [1]. The nature itself of the discipline suggests to propose projects to have a hand in it. Student projects are mandatory for a project-based learning method (PBL), an effective method to education [2], [3]. Teachers introducing PBL are as well "changing the culture of the classroom from the transmission-and-acquisition style that students expect" [4], an objective that might be not easy to obtain.

The goal of our work is to investigate what a project must have to be considered an instance of PBL. To this end, we propose a scheme to analyse student projects in the light of PBL. The scheme has been applied to six different projects realised in two Italian secondary schools, in order to identify projects attributes and recommendations useful for providing methodological support towards the adoption of a PBL method.

The rest of the paper is organised as follows. Section 2 introduces the definition and the main principles of the PBL method. Section 3 describes the research method. The six cases of student projects and the application of the scheme to highlight the

characteristics of the projects in terms of PBL are described in section 4. Section 5 concludes the paper with the main results.

2 Project-Based Learning: Definition and Main Principles

Kilpatrick, named "Mr. Project Method" in [5], started from the beginning of XX century to push for adoption of student projects. He claimed that teachers must steer the process, to avoid two "opposed dangers […] on the one hand that the child may not come out master of the process, on the other, that he may waste time" [3]. According to the author, we have a proper application when it is efficient both in achieving the project goal, usually the product to obtain, and in "securing the learning" potentially contained in that activity. Nevertheless the two suggested efficiency objectives, product and learning, are only general objectives for student projects, whereas it remains to define how to achieve them. The PBL method suggests an operative answer, a "model that organizes learning around projects". To understand "what must a project have in order to be considered an instance of PBL" J.W. Thomas [6] proposes five characteristics, as summarised in Table 1.

Table 1. Five criteria for a project to be considered an instance of PBL [6].

Centrality	PBL projects are central in curriculum, because "students encounter and learn the central concepts of the discipline via the project", which is not an 'enrichment' for overtime out of school: "projects are the curriculum".
Driving Question	PBL projects focus on questions driving towards central concepts and principles of a discipline. As a consequence, students deal with these central aspects.
Constructive Investigation	PBL projects must involve students as main actors, aware of on-going transformation and construction of their own knowledge, in terms of new understandings and new skills: PBL "is based on the constructivist finding that students gain a deeper understanding of material when they actively construct their understanding by working with and using ideas".
Autonomy	"PBL projects are student-driven to some significant degree" and "incorporate a good deal more student autonomy, choice, unsupervised work time, and responsibility than traditional instruction and traditional projects"
Realism	PBL projects "embody characteristics that give them a feeling of authenticity"

PBL is an inductive method, based on an active-learning approach: "PBL begins with an assignment to carry out one or more tasks that lead to the production of a final product – a design, a model, a device or a computer simulation" [7]. Additional elements characterising PBL are [8]:

- Production required to students must be realistic, i.e. it "answers a real-world question or responds to an authentic challenge".

- The kind of product to realise can widely vary, including also outcomes which are less material as “presentation or performance”, besides “a design, a model, a device or a computer simulation”.
- Learning activity has not to be trivial. As a consequence, the project “occurs over an extended time period”.
- Students can be involved in different project phases, variously participating to “select, plan, investigate and produce” the final result.

Many techniques and tools have been introduced to support PBL activities. In [9] Patton suggested a working sheet, the Project Planner, summarised in Table 2.

Table 2. Main aspects of a project [9].

Products	What do you want students to do/write/create/build?	
Learning goals	What do you want students to learn?	Identify the curriculum content that students will learn in this project.
		Identify key skills students will learn in this project. List only those skills you plan to assess
Timeline/ milestones	List the key dates and important milestones for this project. (e.g. check-ins, critique sessions, deadlines for drafts and specific product components)	
Exhibition	Exhibition venue	Where will the exhibition take place?
	Exhibition plan	How will exhibition be promoted? How will your students exhibit their work? Who will you invite?
Assessment criteria	How will you be assessing the learning goals you identified?	Curriculum content Skills

Elaborating from the criteria proposed in literature, in section 3 we introduce a scheme to analyse student projects in the light of the PBL method. In particular, the scheme was defined to investigate in what way student projects of computer science proposed in secondary schools do support PBL.

3 Method of Research and Analysis

This section collects and defines both the research method adopted for a qualitative description of the student projects investigated in the study, and the scheme applied to summarise the PBL aspects of each student project.

The qualitative analysis of the projects included an initial and a final interview to the teachers and direct observation of teachers working on their student projects. To support them we defined a semi-structured questionnaire. Teachers have been met individually. Over a six months research, we observed teachers in various situations, including lessons in class and, more often, in laboratories. Then, we had the opportunity to reflect with teachers on the projects. We discussed some possible change to

the group working. The student projects have been described in a structured way, using the software system OPLÀ [10].

To investigate if and how much student projects were PBL, we designed a scheme combining the five criteria in Table 1 [6] and the main elements adopted by Patton in the Project Planner [9]. The scheme collects criteria in terms of characteristics that should be found in the learning design and implementation of a student project to be considered a PBL activity (Table 3).

Table 3. The scheme with criteria for student projects to be considered PBL.

plan and design		
driving questions and learning goals	centrality	
	learning goals definition	
	learning goals assessment	self-assessment
		assessment by school
		external assessment
realism		
constructive investigation		
autonomy		

Plan and Design. According to PBL method, a clear timeline has to be defined for the student project, and milestones have to be announced to students.

Centrality. Projects have to focus on questions, which are part of the curriculum, and questions have to drive towards central concepts and principles of CS discipline.

Definition of learning goals. Curriculum content and skills which students will learn in the project are part of the learning design, and need a formal definition.

Assessment of learning goals. Learning goals assessment includes three different kinds: self-assessment which students have to do; school assessment, mostly done by teachers proposing the project; and external assessment, by people outside the school, i.e. citizens, business people, experts.

Realism. Projects have to simulate a realistic activity, primarily engaging students in obtaining a product required or useful to someone.

Constructive investigation. Students have to actively be involved in "doing with understanding" [11], also called learning when or by doing.

Autonomy. Students are required to show products of their projects. Exhibitions usually are planned. A positively given an exhibition is a proof of autonomy.

Criteria shown in Table 3 represent characteristics required for a project to be a PBL.

4 The Research

This section introduces the student projects investigated in our research. Subsection 4.1 describes the projects, detailing for each of them the product to realise, eventual commissioner and possible feedback from out of the school, criteria to forming working groups, assignment to the groups, working methods and standards, assessment of students for their project activity. The second subsection analyses the PBL characteristics of the six projects.

4.1 Student Projects

This section describes the case studies investigated in our research, based on student projects realised in two secondary technical schools in which CS is taught. A technological and an economic school have been requested of collaboration sending a letter to the Principals to gain the official permission [12].

Ten teachers accepted to be involved in the research. One of was leader of a multidisciplinary student project involving CS. Six student projects to be run within six months and involving 121 students of six different classes have been identified. Each project has been developed only in one class (Table 4).

Table 4. The student projects.

School Technical sector	Student project number and name		No. of students	Course year
Economic (Istituto Tambosi-Battisti)	1	Garden furniture (Comune di Lavis)	18	4th
	2	Workers clocking in and out management (l'Adige)	17	
	3	Audit monitoring visits (GPi Group)	21	
	4	Critical factors and enhancements at school[1] (Istituto Tambosi-Battisti)	21	
Technological (Istituto Buonarroti-Pozzo)	5	WikITT	20	5th
	6	TicTacToe	24	3rd

Five of the student projects focused on CS, with the goal to develop a software application, whereas number 4 was a multidisciplinary project, whose goal was to produce a statistical analysis. While the two student projects developed at the technological school were proposed by teachers, student projects of the economic school had been commissioned by external subjects:

- the municipality of a 9 thousand inhabitants village (Comune di Lavis);

[1] The full name of the activity is "Inquiry on critical areas and hypothesis for quality improvement actions at school", in *Italian Indagine sulle aree di criticità e ipotesi di azioni di miglioramento della qualità della scuola*.

- a local newspaper, published in the Trento province (l'Adige);
- a private group of companies with headquarter in Trento (GPi Group);
- the Principal office of the school (Istituto Tambosi-Battisti).

A short description of each student projects follows here.

Student project 1 – Garden furniture (*Attrezzature Parchi*). Students had been requested to design and to develop a software application to manage the public gardens of a municipality. Management of gardens involves many characteristics, including the kind of terrain, games for the kids, furniture, ordinary and extraordinary maintenance interventions to be planned and realised. The software was named "GreenPark Lavis", after the name of the municipality commissioning the application. A relational database had to be populated quite early to simplifying the testing using realistic data. As different student workgroups had different part to develop, modules integration required some efforts.

Student project 2 – Workers clocking in and out management (*Gestione timbrature*). A desktop software application has been requested to manage clocking in and out of the newspaper workers. The existing attendance clock devices recorded the clocking data into a text file, but the management was able to partially use these data, resulting in a lack of information and a time consuming activity of data processing for personnel management. All data recorded by the devices needed to be adapted to be managed by a relational database. Requirements included a friendly interface, to let users applying the functionalities of the database. The application offers a set of features and reports including work time, total of hours per worker or per working category, overtime, and more.

Student project 3 – Audit monitoring visits (*Visite e verifiche ispettive GPi group*). The GPi is a group of companies distributed in Italy, in Germany, and in Switzerland, working in 40 industrial branches with 4000 employees; 300 employees are in headquarter of Trento. The group sells full services in the health field and realises also hardware systems and medical tools. The audit function has more than 5000 working places to visit, both stable and temporary. Data were recorded on spreadsheets, but this was no more acceptable for the audit responsible. Planning, documenting, and reporting of audit visits were the features requested for the software application. The application had to manage a relational database, partially integrated to the database of the NcResolutions application realised by a previous class of the school for another order commissioned by the same company [13].

Student project 4 – Critical factors and enhancements at school (*Criticità e miglioramenti a scuola*). It is a multidisciplinary project including Economics, Mathematics, an CS. The Principal of Istituto Tambosi-Battisti commissioned to the class an order of a statistical analysis for the quality improvement of the school. The project included design, realisation, and submission of a survey to more than 300 students of

the school. The survey focused on quality perception of teaching and school-life. At the end, the presentations of the survey results and of the study were shown in two different exhibitions to the Principal office staff and to the school committee (*Consiglio dell'Istituzione*). The student project benefited also from collaboration with the Economics Department of the University of Trento.

Student project 5 – WikITT. Students on last course year of CS branch at Istituto Buonarroti-Pozzo had to develop a software application during the last semester. The two involved teachers defined the general characteristics for the software: a website to share pills of video lectures, created by students for students. Students were requested to design and develop the website and the database for it, along with the standard layout for video lectures and a prototype of short video lectures choosing CS topics [14]. A set of protocols were defined: in order to be published on the website, video must be compliant with these protocols. A template had to be produced. Technical requirements for structure and contents of presentations had to be defined as well.

Student project 6 – TicTacToe. Class addressed a well-known game, called *Tris* in Italian, adopting an object-oriented approach. First students' goal was to analyse the game and to define properties and methods of classes representing the game. The completion of this phase was required in time for the Doors Open Day of school, to give a presentation during the event. The implementation of a software program in C# was planned for a further phase. However, for various reasons, the program was not fully implemented in time for the January deadline and the project could be only partially investigated.

4.2 Student Projects and Project-Based Learning

This section examines the six student projects in the light of the PBL method and gives the results of the application of Table 3.

Student project 1 – Garden furniture. Teachers assessed students through various tests, both in classroom and in laboratory, but these tests were loosely connected to the student project. Hence, assessment of the students' work for the student project have been obtained mainly by the direct observation in laboratory. The project, together with student projects 2 and 3, had a public exhibition attended by external partners representatives, school teachers, and students. The local media followed the event.

Student project 2 – Workers clocking in and out management. Students worked all together, to realise the data analysis and to define the database structure. To implement the application, smaller working groups were created. Project results had been shown in the public exhibition described for student project 1.

Student project 3 – Audit monitoring visits. The students filled in a short self-evaluation questionnaire assessing their performance in three soft-skills - creativity skills, communication skills, and practical skills - and their abilities in designing and coding a software. Questionnaire results helped teachers to grouping students into three groups, further divided into smaller operative units. Teachers asked groups to define individual assignments for single members. Students proposed a daily short meeting among the group leaders of the three large groups. Practical tests had been assigned to mark students on same topics developed with the student project, together with direct observations by the teachers. Project results have been presented in the same public exhibition for student project 1 and 2.

Student project 4 - Critical factors and enhancements at school. A written plan identified competences expected to be developed by students through the student project, referred to the different disciplines involved. The plan assigned tasks to the teachers and time expected for each task to be completed with students. Design did not include any rubric for assessment. Both self-evaluation of learning diary and student relation had been used as input to assess the students. Some topics of the project have been assessed as well through class exercises or tests. Citizenship competences have been assessed by direct observation during school work.

Student project 5 – WikITT. Two large groups of students had been formed, then divided into sub-groups of two or three persons. As regards self-assessment, each sub-group had to clearly define its own objectives and deadlines, and each individual student had her/his personal objectives. In each lesson students have been invited to show the work done to achieve weekly objectives, with short presentations which teachers marked applying two grids shared with the students. Each student also gave a final presentation, assessed through a third grid. The project has not been assessed through traditional tests.

Student project 6 – TicTacToe. Students worked in couples and received a group assessment for each step of the work. Couples did not change until the end of the first activity phase.

Table 5 summarises the application to the student projects of the scheme defined in section 3 with characteristics of a PBL method. The more a project conforms criteria, the more that project can be considered a PBL. Accepted values are: *A*, highly conforming to criterion; *B*, conforming to criterion; *C*, poorly conforming to criterion; *N*, not conforming to criterion. *A*, *B*, *C* represent decreasing values accepted for projects and related to table criteria. For example if project α scores *A* value on centrality, and project β scores *B*, it means that learning goals of project α are part of the curriculum more than learning goals of project β. Value *N* means no value, i.e. project does not conform to related criterion.

Table 5. PBL characteristics for the student projects.

			Student projects					
			1	**2**	**3**	**4**	**5**	**6**
plan and design			*C*	*C*	*N*	*B*	*C*	*C*
driving questions and learning goals	centrality		*A*	*A*	*A*	*C*	*A*	*A*
	learning goals definition		*C*	*C*	*C*	*A*	*C*	*C*
	learning goals assessment	self-assessment	*N*	*C*	*N*	*N*	*B*	*N*
		assessment by school	*C*	*C*	*B*	*N*	*N*	*B*
		external assessment	*C*	*C*	*C*	*C*	*C*	*C*
realism			*A*	*A*	*A*	*A*	*A*	*B*
constructive investigation			*A*	*A*	*A*	*A*	*A*	*A*
autonomy			*B*	*B*	*B*	*B*	*A*	*B*

Five student projects show to similarly conforming characteristics of plan and design, centrality, and learning goals definition. None of them had a written plan neither a design. Observing the projects, these activities were overlooked partially due to a long process to detail the agreement among the school and the commissioning subject or company.

These five projects focused on main principles of the discipline, highly conforming the centrality criterion, but with a poor definition of learning goals. On the contrary, project 4 defined a plan and design, partially conformed the centrality criterion for involved disciplines, and was the only one, which included a clear learning goals definition. Learning goals have been poorly assessed in all but project 5 with self-assessment, and projects 3 and 6 with an assessment by the teachers. External assessment was implicitly applied in the projects that were presented to the public (projects 1, 2 and 3). The best results were achieved for the last three criteria: realism, constructive investigation and – even if to a lesser extent – autonomy.

5 Conclusions

The research described in this paper is part of a larger project which goal is to investigate if and how a PBL method could induce a competence-based approach. Highlighting the most critical issues of projects to be considered in line with a PBL method is the first step to answer the related research questions. Not surprisingly, and accordingly with the authors' personal experience, the most critical criteria resulted those associated with the planning and design of the student project and with the assessment of the results. In the six cases investigated, the problems proposed to the students were real problems, for real companies or organisations, demanding a final presentation. The reasons of the limited application of the criteria for the "driving questions and learning goals" have to be further investigated. They are possibly due to the lack of support to teachers in the labs and to some conflictual requirements for assessment and reporting activities mandatory for Italian secondary teacher, an explanation supported by the direct observation of the teachers' work.

Riferimenti bibliografici

1. Hazzan, O., Lapidot, T., Ragonis, N.: Guide to teaching computer science. An activity-based approach. Springer, Heidelberg (2014). doi: 10.1007/978-0-85729-443-2
2. Dewey, J.: How we think. Boston, USA: Heat & co. (1910)
3. Kilpatrick, W.H.: The project method: the use of the purposeful act in the educative process. Teachers College Record, 16(4) 319–335 (1918)
4. Krajcik, J.S., Blumenfeld, P.C.: Project-based learning. In R.K. Sawyer (ed.) The Cambridge Handbook of the Learning Sciences (pp. 317–333). Cambridge University Press (2006)
5. Knoll, M.: "I had made a mistake": William H. Kilpatrick and the project method. Teachers College Record, 114(2) 1–45 (2012)
6. Thomas, J.W.: A review of research on project-based learning (2000). Retrieved June 23, 2016, http://www.bobpearlman.org/BestPractices/PBL_Research.pdf
7. Prince, M.J., Felder, R.M.: Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. Journal of Engineering Education, 95(2) 123–138 (2006)
8. Holm, M.: Project-based instruction : A Review of the Literature on Effectiveness in Prekindergarten through 12th Grade Classrooms. InSight: Rivier Academic Journal, 7(2) 1–13 (2011). doi: 10.1177/1365480216659733
9. Paul Hamlyn Foundation: The Teacher's Guide to Project-based Learning: Work that matters (2012)
10. Ronchetti, M., Valerio, A.: OPLÀ, a tool for helping teachers with problem-based learning and competence-based education. In INTED2016 Proceedings (pp. 4509–4517). Valencia, Spain (2016). doi: 10.21125/inted.2016.2126
11. Barron, B., Schwartz, D., Vye, N., Moore, A., Petrosino, A., Zech, L., Bransford, J.: Doing with Understanding: Lessons from Research on Problem and Project-Based Learning. Journal of the Learning Sciences, 7(3) 271–311 (1998). doi: 10.1207/s15327809jls0703&4_2
12. Cohen, L., Manion, L., Morrison, K.: Research methods in education (6th ed.) (2007)
13. Giaffredo, S., Mich, L., Ronchetti, M.: From the project-based learning method towards the competence-based approach to education. In Proceedings of the 6th Computer Science Education Research Conference (CSERC'17) (pp. 56–65). New York, USA: ACM Press (2017). doi: 10.1145/3162087.3162099
14. Giaffredo, S., Raffoni, L.: Verso la costruzione di un Peer-MOOC: l'esperienza di WikITT (2017). In Italian. Retrieved from www.aicanet.it/documents/10776/1476921/ Didamatica17_paper_77.pdf/318dab4d-14d7-4fe8-ad6b-fbae41be727c