Project Thinking as a Strategy for University Education

Guttorm Sindre ¹, Michail N. Giannakos ¹, Birgit R. Krogstie ², Robin Munkvold ³, Trond Aalberg ¹
¹ Department of Computer and Information Science (IDI), Norwegian University of Science and Technology (NTNU), Trondheim, Norway
² Department of Informatics and e-Learning, Høgskolen i Sør-Trøndelag (HiST), Trondheim, Norway
³ Department of Media Technology, Høgskolen i Nord-Trøndelag (HiNT), Steinkjer, Norway

ABSTRACT: To prepare IT graduates for professional careers, their education must provide them with “real-life” experience. There are many tasks beyond those of core software engineering and development for which students need training: project management, team building, software estimation and planning, progress tracking, and communication. Project-based learning offers ways to transfer learning of foundational and practical knowledge into “real projects for real clients”. The Department of Computer and Information Science at the NTNU has a long tradition for relying heavily on project courses in the education of candidates, both in its 5 year integrated study program (Master of Technology / siv.ing.) and its Bachelor Informatics program. The emphasis on projects follows naturally from the fact that projects are the main working style in the IT industry. The amount of project work in the study plan is scheduled to increase further by study program changes currently being implemented. The programs in question however also maintain a share of more traditional courses where the dominant learning activities are textbook reading, lectures and weekly exercises, so the education as such is not entirely project-based. Furthermore, it is difficult to turn to an entirely project-based style when there are courses from different departments, for instance generic mathematics courses with a huge number of students. Hence, despite the numerous benefits of project-based learning, several practical challenges need to be addressed as we attempt to implement this strategy in a hybrid educational context. The question posed in this article is: Could it be possible, in spite of maintaining a mixture of project-based and other learning styles in a program, to take project-based learning a step further than being applied in single courses? There are several ways projects can be extended between or across different courses, each with potential advantages and disadvantages. For instance, projects can be supported from the contemporary learning systems for fast feedback and continuous monitoring of the progress. Projects can also be shared among several courses taking place in the same semester, or among courses taking place in subsequent semesters. Even more radically – extrapolating the idea of a student e-portfolio – one could consider each student’s entire university education as a project, the project goals being the learning goals for the study program in question and single courses being considered as work packages contributing to these overall goals. This might motivate students and allow them to appreciate the whole picture rather than looking at courses as narrow and isolated achievements with a strong focus on exams and grades. The paper provides a classification of different ways in which project learning can be taken beyond the single course context even in study programs where it is (at least in the short term) unavoidable to have a mixture of projects and more traditional teaching.

1 INTRODUCTION

There is a growing demand for computing professionals; the U.S. Bureau of Labor Statistics predicts that by 2020 one of every two STEM (Science, Technology, Engineering, and Mathematics) jobs will be in computing ¹. By 2015, it is estimated that there will be a shortage of 864,000 ICT professionals across the EU and the European Economic Area (EEA). Norway will also face an increase in demand for ICT professionals, in particular the need for ICT professionals is anticipated to rise to over 55,000 by 2030 (from 17,000 by 2000) ². With a projection of the current rhythm of ICT graduates, the public

² Dimensjonering av avansert IKT-kompetanse: https://www.regjeringen.no/nb/dokumenter/Dimensjonering-av-avansert-IKT-kompetanse/id762445/
and private sector will lack more than 10,000 ICT professionals by 2030\(^2\). However, students seem reluctant to pursue a CS career. In particular, the number of female students in CS subjects is low\(^1\), and studies have shown that isolation, lack of community support, and lack of creativity are significant factors of discouragement and decrease females’ interest towards classes, activities and careers related to CS.

It is widely accepted that one of the most important skills for the 21st century is the ability to “construct” and “create” meaningful artifacts using computers. This should be reflected in the training of future university students, particularly in CS for which training should be more than attaining technical skills. The needs of the CS/IT sector today go far beyond those of core software development. CS/IT students need to develop computational thinking, critical thinking, and creativity through “real-life” experiences. These skills will lead them to attain the needed competences, like, project management, team building, software estimation and planning, progress monitoring and communication.

Project Based Learning (PJBL) is a pedagogical technique that is frequently used in CS education. Many educators have designed and successfully applied PJBL approaches. There are many suggestions on how to influence parameters like motivation, problem generation or presentation, limitations, expectations etc. in order to achieve better results [5]. Educators and researchers have distinguished between Problem-Based Learning (PBL) and PJBL, although no single distinction is universally adopted. Indeed, it can be argued that the two share much more similarities than differences. Barron et al. [2] suggest that PBL is the scaffold to PJBL. PJBL approaches often start with a “driving question” where the task has authenticity because it is based in real-world problems [13].

In engineering education, PJBL has been found more appropriate than PBL, because projects are representative of the way engineers work and fit the hierarchical nature of engineering syllabus [7]. Software can be developed with cheap equipment which students nowadays have anyway (e.g., PC's), and has no cost for raw materials. Hence CS/IT studies lend themselves particularly well to engineering projects, as students can make applications for real stakeholders to perform useful tasks, which helps for motivation [3]. For instance, students of marine or civil engineering are less likely to make real ships or buildings, only scaled down models.

Although PJBL has a great potential, an effective implementation needs to be carefully considered along many parameters. Examples include the project type (e.g. an industry or a made – up), group features (e.g. size), group management and student motivation. Also, class organization might influence PJBL effectiveness. A class could be formed with a traditional top – down approach, where instructor first gives the theory and then the problem in order to allow students to put the theory into practice. Alternatively, in a bottom-up approach the instructor introduces the theory within a project framework. Moving away from the single course approach PJBL can also be applied across many courses, semesters and even departments with different objectives, competences, preconditions and standards. Hence, despite the numerous benefits of PJBL, several practical challenges need to be met while attempting to implement this strategy in higher education. The aim of this article is to present different PJBL strategies employed at IDI/NTNU, HiST and HiNT, in order to guide:

*How project-based courses can be implemented under different educational contexts to support IT professionals’ development.*

### 2 Putting Project-Based Learning into Practice

The Department of Computer and Information Science (IDI) at the Norwegian University of Science and Technology (NTNU) has a long tradition of including team projects as an essential component in the education of bachelor and master candidates in computing. Such projects range from quite big ones where the entire course is a group project, as is the case for the 7.5 ECTS credits Experts in Team project taken by all our students in the 8th semester [5], the 15 ECTS credits “customer-driven project” taken in the 7th semester for the computer science students [1], and in the 6th semester for the bachelor informatics students [6], these bachelor students have also had a full course team project in their 3rd semester. In addition, to the pure PJBL course, there have been experiences with many smaller projects in the context of more traditional lecture courses. Those projects where either across several courses, taking place in the 4th semester of both the mentioned study programs [12], or embedded inside single courses, exploring more focused tasks like programming [9], requirements
elicitation [10], and document review [11] - and other unpublished initiatives. PJBL classes have also offered in a more flexible manner, using the form of an intensive course. IDI has provided numerous two or three days PJBL tutorials on game/animation development (e.g. [4]). The latter courses are not considered as official courses/education, but students’ normally receive ECTS credits for participation and completion.

Within the institute for Media Technology at Nord-Trøndelag University College (HiNT), students experience PJBL already for the first semester. HiNT’s bachelor program Games and Experience Technology gives the students a real world experience through a concept called Game Lab. This is a video game company simulator where the students are given different roles as in a real company, and where they are required to show up for work and produce according to weekly goals. The work and progress is evaluated each week by an executive committee, consisting of teachers from the school and people working in the industry. If the production and progress is evaluated as being too poor, the company may be dissolved and the students will either have to come up with a different project or they will have to “apply” for a job at one of the other Game Lab companies at the school.

The Game Lab runs every semester during the bachelor program. It functions as an “umbrella subject” where we expect that the students will be using knowledge and skills from other subjects taught in other classes within the bachelor’s program to solve different issues within Game Lab. There is a strong focus on defining real projects in collaboration with the region that are implemented as work challenges within Media projects and Game Labs (mmt.hint.no).

The department of Informatics and e-Learning at Sør-Trøndelag University College (HiST) similarly includes PJBL as a cornerstone approach in their Bachelor and Master IT programs. The computer science engineer bachelor program includes intensive agile programming projects. Concurrent Design (CCD) is a research area for the staff and is also used a framework for implementing PJBL for students. Furthermore, the school has successfully made use of special lab facilities designed to support a flipped classroom approach: in the room, students are organized in groups provided with infrastructure for easily sharing information contents with the entire class through large screens.

3 CLASSIFICATION OF PROJECT-BASED LEARNING

As aforementioned; although PJBL has been very effective teaching strategy; there are many substantial differences/needs and many facets across disciplines, educational levels and other more or less important contexts. In making a classification for PJBL, it might therefore be possible to utilize our experience. Hence, on this article we provide a classification (Figure 1) of different ways in which project learning can be applied:

1. Teaching context: A project can be the entire course, or be a smaller part of a course which also includes more traditional teaching like lectures over a textbook.
2. Range of implementation: A project can range from one to many courses, and then either courses being taught in the same semester, or courses being taught in subsequent semesters.
3. Learning context: A project takes place after students have learnt relevant theory about necessary technology and methods (top-down approach), or instructor introduces the theory within a project framework (bottom-up approach).
4. Institutional context: A project can be implemented locally to one organization (typically the university), or involve other organizations (e.g. cross institutional), furthermore projects’ might also involve stakeholders (e.g. companies).
5. Personnel composition: A project can focus on individual team projects, or even larger constellations with large teams composed of smaller teams. Also, teams could be homogeneous (consisted of same course/field students) or heterogeneous.
6. Grading: Projects typically use Pass/Fail or a more granular grading scheme. In a team project, the policy could either be to give the same grade to all team members, though possibly with exceptions for extreme cases of non-contribution, or grades could be individual in spite of the deliverable being a team effort. Individual grades require explicit information on who has written what, close teacher tracking or student self-reporting about individual contributions to the team effort, thus being more demanding than giving a joint grade.
7. Project Variety: Same project for every student/team, or unique, personalized, self-selected by the students’ project.
8. **Degrees of Freedom of the Process:** Project process can range from a well-specified (e.g. what methods to be used, steps to be undertaken and deadlines) to a more flexible one, where the only thing that matters is the final deliverable.

9. **Degrees of Freedom in the Deliverables:** Projects deliverable can range from very strict and well-defined, where instructors have specified in much detail what problem is to be solved and what should be delivered; to a more flexible one, where each team is completely free to decide what to develop as long as it relates to the learning goals.

![Diagram of project categorization on PJBL approach](image)

**Fig. 1.** Categorization of projects on PJBL approach

## 4 CONCLUSIONS

In summary, the many variables in PJBL can produce wide variations in quality and in the educational objectives that can be achieved in IT/CS education. A categorization is proposed to facilitate an awareness of these differences and help teachers choose a PJBL method most appropriate for their students and courses. The categorization and the discussion developed in this article help shed light on different ways in which project learning can be taken beyond single educational context, and better support IT professionals’ development.

Despite the apparent different forms of PJBL, there are several topics that are addressed by any PJBL strategy. In particular, PJBL improves creativity and teamwork competences, which in turn allow students to create more original projects and obtain better academic results. Well defined organizational issues, knowledge preconditions and learning goals allow students’ to deliver complete and of high level projects. Carefully selected supportive materials, technologies and methods provide flexibility and independency to the students, which in turns allow them to be more creative. Another benefit of PJBL in CS education is the deeper understanding of the role that computer tools can play in our lives, especially in supporting creativity.

Despite the fact that there have been several and important developments in PJBL in CS/IT education during the last years, there is still much that can be done. The contribution of this article might foster
this by exchanging experiences among universities and assisting national stakeholders and educators on their future decisions and plans. In this endeavour, the extracted categories could be used as a common ground and allow researchers and educators to better understand, compare and improve the value of their PJBL initiatives. Future research is expected to empirically analyse the effectiveness of the different PJBL categories as well as combinations of them on students’ outcome, attitudes, learning style and creativity.

REFERENCES


