# Proper selection of learning projects in teaching Telecommunications Engineering

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## Structured abstract

### BACKGROUND
At the Department of Telecommunications Engineering of the National Autonomous University of Mexico (UNAM), a rising demand for highly qualified graduates, competition at the labour market and evolving global economic crisis urge the academy to teach telecommunications engineering more effectively than it had been done in the past. That is why we intended to modernize our current education pedagogy. However, it was not easy to decide which of the modern pedagogies was the most effective in our conditions. Such situation motivated us to study feasibility and potential effectiveness of a number of modern educational pedagogies in the specific conditions of our career and university.

### PURPOSE
The main objective of this work was to find out optimal characteristics of the learning projects, establish feasibility of large-scale implementation of the Project-Based Learning (PjBL) at our career at the UNAM, and derive recommendations for the faculty about the implementation of PjBL.

### DESIGN
The PjBL was implemented in form of a 12-week long project together with the theoretical Optical Communications Systems course and teaching laboratory on the same subject. The PjBL started on the second week of the semester and ended three weeks before the end of the 16-week semester. The students worked in teams of 3 to 5 persons. All teams developed projects on the same topic. Each semester the topic was different, so we could evaluate strong and weak points of different kinds of projects. We did not watch the progress of the projects closely in order to promote self-learning, autonomy, and responsibility of the students for their learning. We evaluated the effect of the PjBL by means of surveys. We conducted one survey before the students started to work on the project and another one after completion of the projects.

### RESULTS
We have found out that projects that comprised the design, prototyping, and evaluation of fully functional devices were educationally very effective. For example, the project topics, such as the barcode reader and intrusion alarm system stimulated the students to look for new solutions of the optical sensor or reader, analogue and digital signal processing etc. Such projects generated a lot of interest and enthusiasm among the students, as well as stimulated competition between different student teams. While the projects consisting in the development of pieces of telecommunications equipment were less popular among the students and educationally less effective.

### CONCLUSIONS
According to our results, the interdisciplinary learning projects were more effective than strictly telecommunications-oriented projects. Also, the projects aimed at the development of fully functional devices were much more effective than purely theoretical projects. It was highly essential for the project success that project topics and content created enthusiasm among the students and stimulated competition between student teams. Competition makes projects much more interesting for the students and thus educationally more productive.

### KEYWORDS
Work-integrated learning, project-based learning, practical skills development.

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# Introduction

The Telecommunications Engineering career is quite popular among young people. Also, the demand for graduated telecommunications engineers is quite high among potential employers. A big part of this popularity is due to fast advance of technology, such as mobile phones, Internet, satellite, microwave and optical communications, etc. That is why the academy has to review and modify the subject content of the career in accordance with fast technology advance. At the Department of Telecommunications Engineering of the National Autonomous University of Mexico (UNAM), the traditional educational methods were successfully employed for a long time. Nevertheless, a rising demand for highly qualified graduates, competition at the labour market and evolving global economic crisis urge our academy to teach telecommunications engineering more effectively than we did it in the past. This is why we intended to modernize our education pedagogy.

However, it was not easy to decide which of the modern pedagogies described in literature (e. g. Awang (2006), Barron and coauthors (1998), Bruce and Reiser (2010), De Graaf and Kolmos (2006), Lamancusa (2006), Lipson and coauthors (2007), and Lissenden and Salomon (2004)) was the best in our conditions. To the best of our knowledge, only a few of such pedagogies are tested with regard to our career by D'Andrea et al. (2008) and Bonior et al. (2012), while Morris (2003), and Potts, Moore, and Sukittanon (2011) tested two other methods in other fields of electrical engineering. Such situation motivated us to study feasibility and potential effectiveness of a number of modern educational pedagogies in the specific conditions of our career, university, and country.

Following are results of implementing Project Based Learning (PjBL) in teaching the telecommunications engineering at the Faculty of Engineering of the UNAM during several consecutive years.

# Purpose

The main objectives of present study were to find optimal characteristics of teaching projects. We were interested in projects that would considerably enhance students' learning of a range of engineering topics. Also, we wanted to establish feasibility of large-scale implementation of Project-Based Learning (PjBL), and derive recommendations for the faculty on implementation of the PjBL in our conditions. The particular educational objective was to integrate the previously obtained knowledge with practical experience, as well as to promote self-learning, autonomy, and responsibility of the students for their learning.

# Design

With these objectives in mind, we analysed the teaching plan and content of teaching subjects of our career. We found out that, in principle, the PjBL could be introduced in two consecutive semesters, such as the 7$^{th}$ and 8$^{th}$ semester of a 9-semester teaching plan. It would establish a solid base for implementing the career final project at the last, 9$^{th}$ semester. However, a large part of the faculty staff has no previous experience with the PjBL and, due to this reason, is rather cautious with regard to rapid changes of the teaching plan. Therefore, we implemented and tested the PjBL within the framework of a single course that is taught during the 8$^{th}$ semester of the 9-semester teaching plan of our career.

The course Optical Communications Systems comprises 48 hours of lectures and, concurrently, laboratory of 32 hours. During preceding semesters, the students learned analogue and digital electronic circuits, digital signal processing, radiofrequency electronic devices and circuits, radio transmitters and receivers, microwave circuits etc. Therefore, they know, or are supposed to know a lot by the time they are at the 8$^{th}$ semester. However, they typically have not yet integrated the knowledge learned in different subjects. Also, there are usually some gaps between different teaching subjects of the curricula. Due to the mentioned

factors, we consider the 8th semester to be the most suitable for implementing the PjBL and achieving the maximum educational outcome from it.

The PjBL was implemented in the form of 12-week long project together with the theoretical Optical Communications Systems course and teaching laboratory on the same subject. The PjBL started on the second week of the semester and ended three weeks before the end of the 16-week semester. Due to such provision, it did not interfere with other student activities at the end of the semester.

We recommended the students to work in teams of 3 to 5 persons. All teams developed projects on the same topic. Each semester the topic was different, so that we could evaluate strong and weak points of the projects of different types. Following are some project topics that we offered to the students within the framework of PjBL during the last five years:

- Wireless optical communication link
- Optical power meter
- Optoelectronic liquid-level gauge for a tank
- Optical or optoelectronic intrusion alarm with RF communication link
- Optical barcode reader.

In our experience, the design of an operating version of the optical barcode reader was the most efficient project topic from educational point of view. It comprised many important features that together contributed to its efficiency:

1. A barcode reader is a widespread device. Its applications in modern life are well known. Therefore, the students feel their activity is useful and important.
2. It is a relatively simple device. It is feasible to design and develop a barcode reader in several weeks, well before the end of a semester.
3. It is cheap. Therefore, any student can afford its implementation.
4. The operation of a barcode reader is based on the principles and technologies that belong to different areas of knowledge and different engineering fields: optics, electronics, analogue and digital signal processing; elements of computing and programming, as illustrated by its block diagram in Figure 1. Therefore, the learning content is very rich and the students have a good opportunity to integrate this content while working on the project.

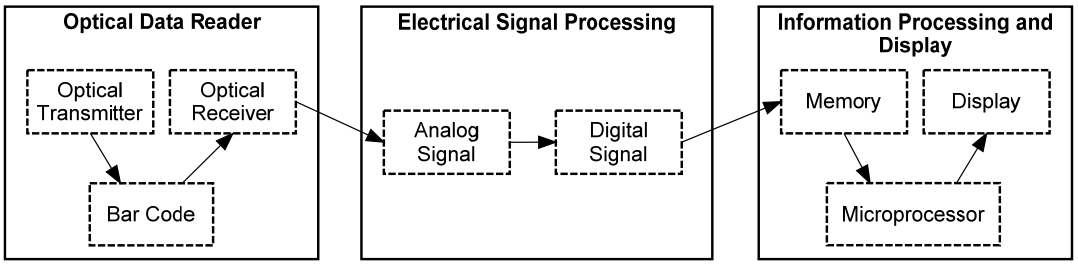


**Figure 1: Block diagram of generic barcode reader**

5. The design and implementation of a barcode reader involves technical issues that are not covered by the curricula, such as negative effect of the background illumination, DC drift of electronic amplifiers, pros and contras of using the modulated light, details of interfacing and other. All this stimulates self-learning and promotes autonomy of the students.
6. There are many design options for each and every element and subsystem of a barcode reader. Such situation stimulates critical attitude of the students to the technical literature, textbooks, industrial information etc., and effectively stimulates self-learning.
7. The students can easily compare the performance of the devices which they developed, by trying to read the same barcode, which may be of previously known or

unknown content. It makes the evaluation of developed barcode readers very simple and transparent for the students.

8. All together, the described features of barcode readers stimulate strong competition between the teams. Therefore, the students take this project very seriously. Most of them dedicate a lot of their time and effort to the project. This, in turn, contributes to a high educational output of such project.

We did not watch the progress of the projects closely in order to promote self-learning, autonomy, and responsibility of the students for their learning. However, we analysed the progress of all teams every three weeks at a special seminar. The final session was dedicated to presentation of completed projects, demonstration of barcode operation by the teams, and overall evaluation of project results. As such activity required a lot of time, we conducted three seminars, 1.5 hours each, during the final 12$^{th}$ week of work on the project. A committee of professors who delivered the theoretical course and conducted concurrent teaching laboratory evaluated the reports, operation of developed bar-code readers, and quality of presentations in front of the group.

# Results

We evaluated the effect of the PjBL by means of surveys. We offered printed respondent-friendly questionaries of several closed–ended dichotomous questions to all students of a cohort. Some closed-ended questions had an opened-ended compliment. We surveyed all students of each cohort during ten consecutive semesters (that is, for five years). The number of students in the cohorts varied from 9 to 33 in different semesters, totalling 200 surveyed students in five years. We conducted one survey before the students started to work on the project and another one after completion of the projects. The surveys intended to access the degree of theoretical and practical knowledge of students, and their interest in particular areas of telecommunication engineering.

In the first survey, the most interesting results were obtained with regard to the two following questions: 1. Do you feel your theoretical knowledge is sufficient for developing and completing of the project? 2. Do you feel your practical knowledge is sufficient for developing and completing the project?

The results are shown by graphs in Figure 2. According to the survey, only 37 % of students considered their previous theoretical knowledge sufficient, while only 10% considered their practical knowledge sufficient for developing and completing the project task. We attribute such situation to insufficient amount of practical training that our students get while studying the career.

The second survey intended to find out how the students worked on the project, identify possible difficulties in project development and access educational outcome of the PjBL. The survey revealed that more than 50 % of students worked on the project for more than 3 hours per week, 75 % of students worked in groups, and 80 % consulted special technical literature while working on the project.

In what refers to the weak and strong points of different project topics, we have found out that projects that comprised the design, prototyping, and evaluation of fully functional devices were educationally very effective. Also, the interdisciplinary projects were more effective than strictly telecommunications-related projects and had a stronger impact on the practical knowledge of the students. For example, the projects topics, such as the barcode reader and intrusion alarm system stimulated the students to look for new solutions of the optical sensor or reader, analogue and digital signal processing subsystem etc. Such projects generated a lot of interest and enthusiasm among the students as well as stimulated competition between different student teams. Competition made the projects much more interesting for the students and thus more productive. While the projects consisting of the development of pieces of telecommunications equipment were less popular among the students and educationally less effective.

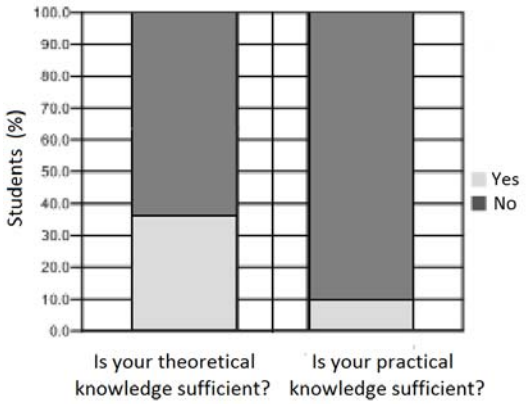


**Figure 2: Students' evaluation of their previous theoretical knowledge and practical skills**

The learning outcome of PjBL was estimated by means of the two following questions of the second survey: 1. Did the project significantly enhance your knowledge: Yes/No? Provide arguments. 2. Did the project significantly enhance your self-learning skills and autonomy: Yes/No? Provide arguments.

The results obtained from the closed-ended questions are illustrated by graphs in Figure 3. Despite rather pessimistic evaluation of their initial capacity to develop the project, the students succeeded in obtaining significant learning benefits from their work on the projects.

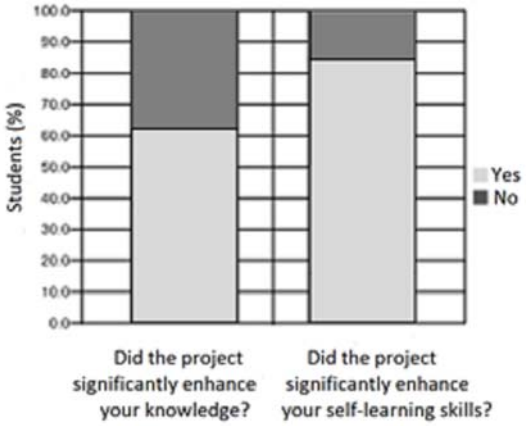


**Figure 3: Learning outcome of PjBL as viewed by the students**

According to the second, final survey, 62 % of students acknowledged that work on the project significantly enhanced their knowledge, while 84 % of students acknowledged that PjBL significantly enhanced their self-learning skills and autonomy.

The arguments provided by the students in their answers to the two aforementioned complementary opened-ended questions of the second survey revealed that both theoretical and practical knowledge was enhanced during the project.

Among other results, we expected that the interest and enthusiasm of the students for the project aimed at the design of an optical device would result in their greater interest in optical communications technologies. However, the surveys showed no significant change in the preferred areas of specialization, before and after completing the project. One possible explanation is that the formation of professional interests of students occurs at some earlier stage of personal development and learning.

## Recommendations to professors

In this section, we address the most important issues in the implementation of the PjBL in the electrical, electronic, and telecommunications engineering career.

First, the monitoring of the project work revealed that development of functional devices was a rather complex and hard task that even the best teams could not complete in its full form, to say nothing about improvements to the basic design or its optimization. Therefore, in our opinion, it would be better to develop such projects during two consecutive semesters. This, however, would involve many organizational difficulties. In particular, it would be virtually impossible to maintain the same composition of teams.

Second, it is important that the students themselves decide on the composition of teams. Many of them already know the skills and qualities of their peers, which contributes to the effective collaboration within the teams.

Third, the choice of problem – the device or system to develop – is perhaps the most essential element in the successful implementation of the PjBl. The problem should be interesting to the students, promote competition (and collaboration) between teams, and its level of complexity should be moderate.

Fourth, the deadline for the project should be several weeks before the end of the semester, in order to avoid the interference of the project with a lot of other tasks that students have at the end of the semester.

## Conclusions

We implemented the PjBL in teaching Telecommunications Engineering at the UNAM and studied its effectiveness during several consecutive years. As a result, we identified particular reasons for success or failure of seemingly interesting and educationally useful design projects. According to our results, the interdisciplinary projects were more effective than strictly telecommunications-oriented projects. Also, the projects that comprised the design, prototyping and evaluation of fully functional devices were much more effective than purely theoretical projects.

It was highly essential for the project success that project topics and content created enthusiasm among the students and stimulated competition between student teams. Competition makes projects much more interesting for the students and thus educationally more productive.

Students highly appreciated the learning experiences obtained from such projects. They also provided the students with a practical way of recognizing their weaknesses and strengths, a way of recognizing their real knowledge and the possibility to put it in practice. Thus, PjBL is educationally very effective, provided the singularities of particular careers are taken into account, so that project topics, content and development properly match the peculiarities of each career, university and country.

### References


Awang, M. (2006). Cooperative learning in reservoir simulation classes: overcoming disparate entry skills. *Journal of Science Education and Technology*, *15*(3), 220-226.

Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., Jr., & Bransford, D. (1998). Doing with understanding: lessons from research on problem- and project-based learning. *Journal of the Learning Sciences*, *7*(3/4), 271-311.

*B*onior, J. D., Corum, S., McNew, B., Piras, A., Witherspoon, B., Qiu, R. C., Guo, N., & Hu, Z. (2012). Using software-defined radio network test bed to enhance undergraduate education and encourage graduate level studies. Paper presented at the Institute of Electrical and Electronic Engineers SoutheastCon, Orlando, FL.

Bruce R., & Reiser, S. (*2010*). Take chances, make mistakes, get dirty. Paper presented at the Institute of Electrical and Electronic Engineers SoutheastCon, Concord, NC.

D'Andrea, A. N., Giannetti, F., Manara, G., Michelini, M., & Nepa, P. (2008). A virtual educational laboratory for telecommunications engineering. *International Journal of Engineering Education, 24*(1), 144-152.

De Graaf, E., & Kolmos, A. *(Eds.)* (2006). *Management of change: Implementation of problem-based and project-based learning in engineering.* Rotterdam: Sense Publishers.

*Lamancusa*, J. S. (2006). Design as the bridge between theory and practice. *International Journal of Engineering Education, 22*(3), 652-658.

Lipson, A., Epstein, A. W., Bras, R., & Hodges, K. (2007). Students' perceptions of terrascope, a project-based freshman learning community. *Journal of Science Education and Technology, 16*(4), 349-364.

Lissenden, C. J., & Salamon, N. J. (2004). Design project for advanced mechanics of materials. *International Journal of Engineering Education, 20*(1), 103-112.

Morris, H. A. (2003). A web based electronics laboratory for tertiary engineering education. Paper presented at the Institute of Electrical and Electronic Engineers SoutheastCon, Ocho Rios, Jamaica.

Potts, J., Moore, N., & Sukittanon, S. (2011). Developing mobile learning applications for electrical engineering courses. Paper presented at the Institute of Electrical and Electronic Engineers SoutheastCon, Nashville, TN.

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