Practice shows the way

Tatiana Balbi Fraga, Universidade Federal de Pernambuco, tatiana.balbi@ufpe.br

Short Abstract

This article presents a university teaching strategy, grounded on a practice-based learning approach, through which the concepts of Mathematical Modeling and Optimization are passed on to students by applying important group work tools and the indissociality between teaching, research, extension and technology.

Introduction

Problem-based learning (PBL) is a pedagogical approach applied worldwide, especially in nursing and medicine courses. This approach has been successfully put into practice in several ways, however it always uses a real-world problem as a starting point in order to facilitate student learning and to increase motivation for courses as well as real-life competencies (Aslan, 2021; Fernandes, 2021). This article presents a university teaching strategy, based on a practice-based learning approach, through which students learn mathematical modeling and solution techniques for real-world optimization problems. Although both focus on real problems and pursue the same goals, the concept of practice-based learning differs a little from the concept of problem-based learning, since practice-based learning focuses on the teaching a specific content and not a broader training. In addition, the strategy proposed deals with two current issues of great importance in the academic environment:

1) Is it possible unite research, extension, technology, collaborative work, information technology and transparency in the quest to improve undergraduate engineering education ?

2) Is it possible to disclose information about work in progress without this compromising the authenticity of the work carried out ?

In the next sections, I present the teaching approach and some work tools that make it possible for such questions to be answered in an optimistic way.

Practice-based teaching approach

Mathematical Modeling and Optimization are extremely relevant sciences for students in production engineering. Especially when we experience the expansion of Industry 4.0 (Ram, 2021).

Through Mathematical Modeling it is possible to accurately understand any industrial or organizational problems in which process optimization is sought and, once a model is built, in order to find the desired answer to the problem, or at least a somewhat close answer, Optimization, and so Programming, simply becomes indispensable. Through my experiences at the university where I work, I developed the following strategy for joint teaching of Mathematical Modeling, Programming and Optimization, combining teaching, extension, research and technology:

Teaching: the fundamentals of mathematical modeling and optimization can be taught to students in two different subjects: 1) Mathematical programming; and 2) Mathematical Modeling. In the first course, modeling mathematical programming problems is taught along with mathematical methods of solution. Modeling problems close to real problems can and should be motivated through case modeling exercises such as those proposed by Hillier and Lieberman (2010). In the second course, students should learn how to model standard optimization problems (e.g. allocation problems; balancing problems; routing problems; and scheduling problems) in addition to some heuristics used to solve such problems. In both courses, students must be motivated to understand and present scientific papers with the modeling of real problems.

Extension: the extension applies in four moments: 1) students look for a company to develop their work, know the company, understand the company's operating process, and help to identify optimization problems within the company; 2) an Applied Programming course is offered to students, through which students learn object-oriented programming; 3) the students work with the company in the search for ideas and the refinement of the proposed solution; 4) students take the solution developed for different companies, conducting data collections and testing the solver.

Research: once a real problem is identified; it is necessary to carry out a vast bibliographic survey, identifying mathematical models and proposed solution approaches for problems close to the one studied, and it is necessary to develop new solution algorithms, through the adaptation of solutions proposed in the literature. The research must be carried out through research projects, and possibly in parallel with the development of course conclusion works and scientific and technological initiation projects.

Technological: once the solution is developed and tested, it is recommended to develop a solver, with a good graphical interface, that can be easily used by company employees. This step can be carried out through technological projects, developed in parallel with graduation projects for students in the technological area, and projects of technological initiation. At this stage, it is also possible to develop partnerships with startup companies, and acquire financial resources to support research and innovation developed within the university.

The four lines of action are related as follows: through teaching, students acquire the basic knowledge necessary for the development of research and extension activities; through the extension, students deepen their knowledge of programming, help identify new optimization problem and approaches applied by the company to solve these problems and test the solutions developed, also qualifying company employees; through research, students participate in the development of solutions to identified problems; and through technological projects, students can participate in software development. Both research and extension works contribute to teaching, as they allow students to understand and expand all the content presented in the classroom, through practice. It is important to emphasize that throughout the process, students must work together with teachers who have extensive knowledge and practice regarding the subjects covered. So, the teachers involved also deepen their knowledge, which significantly improves the quality of teaching.

About work tools

This learning proposal model can be facilitated by the use of tools that support the development of group work. Among such tools, two deserve to be highlighted: google meet and GitHub. Through google meet it is possible to virtually hold collective work meetings.

These meetings must be periodic and frequent to clarify doubts and delegate tasks. GitHub is an advanced development platform that allows effective management of the work developed by all group members, using the git version control language. Using GitHub for the development of group work, it is also possible to make the work public (even in the development phase), thus increasing the project's visibility and bringing the possibility of identifying important partnerships. It is also possible to attach licenses to the directories of each project that control how the available files can be used by third parties. As an example, we have licenses from the creative commons family (https://creativecommons.org/licenses). Emphasis on the license Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International Public License that allows the material made available to be copied and distributed, but not modified or marketed. This license also informs that the source and authors must always be cited. This alone guarantees the authorship of the materials provided.

Results

Through the application of this approach, relevant scientific contributions were obtained such as the identification of new optimization problems not previously addressed in the literature, as well as the proposition of mathematical models and solvers for the identified problems (e.g. Andrade & Fraga, 2016; Freire & Fraga, 2017; Fraga et al., 2021; Fraga et al., 2022). However, the most important result was to verify that in fact the students were able to understand in depth the modeling process, the mathematical language and the methodological approaches that are applied to solve real optimization problems and, in some cases, they have acquired a good knowledge of programming. This knowledge opens new opportunities for students, creating a highly specialized professional profile with great possibilities of success in the competitive job market.

Concluding remarks

This article presents a practice-based teaching strategy, through which it is possible to improve the teaching of Mathematical Modeling, Programming and Optimization sciences. Important tools for the development of group work were also presented. With this we conclude that yes, it is possible to unite research, extension, technology, collaborative work, information technology and transparency in the quest to improve undergraduate engineering education. We also concluded that it is possible to disseminate the work developed from its idea, without this generating losses related to the authorship, through platforms for the development of team projects and the adoption of appropriate licenses.

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