Mini-Project of Ethanol Production from Waste as a Teaching Methodology

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Abstract

The development of sustainable alternative fuel, energy and chemical products is happening all over the world. Some of the main reasons for this increase are the increasing demand for fuel and energy due to population growth and economic development; climate change and the need for decreasing greenhouse gas (GHG) emissions; enhancement of waste recovery efforts to redirect waste away from landfills and decrease the reliance on primary raw materials. Thus, it is important to make students aware of these aspects and explore the development of alternative fuels, while giving them the tools to be creative and autonomous.
The aim of this paper is to show how the implementation of a mini-project can improve not only students' knowledge about the production of a biofuel from waste, but also their development of the theoretical and basic skills needed to carry out the mini-project.
This paper presents in addition to the methodology used, some results to the implementation of the mini project, specifically the students' points of view.

Keywords: teamwork, mini-project, laboratory work.

1. Background

Laboratory classes are essential for students to put into practice what they learn in theory. These classes are primarily aimed at developing students' scientific, communication, critical analysis, and writing skills, in addition to teamwork (Hodgson et al., 2014).

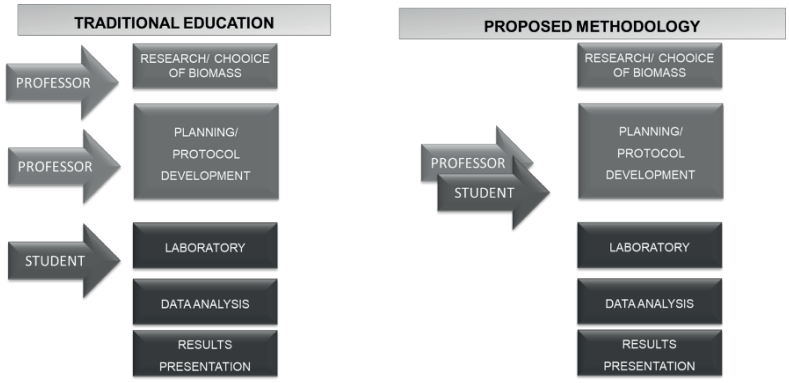
Four descriptors to differentiate laboratory classes have been listed: i) expository (has predetermined outcomes and the approach is deductive), ii) discovery (outcomes are predetermined and the approach is inductive), iii) inquiry (outcomes are unanticipated and the approach is inductive), and iv) problem-based (outcomes are predetermined and the approach is deductive). The first two descriptors (i and ii) refer to traditional laboratory classes where students follow a protocol which has been provided to them, while descriptors iii) and iv) refer to classes where students write their own protocol (Domin, 1999). In the latter case students might be able to achieve higher autonomy.

It has also been indicated that certain factors inhibit student learning such as: traditional laboratory classes, where the teacher writes and delivers a detailed laboratory protocol to the students ("follow the recipe" style class). This type of lesson does not allow the students to reflect on the goals of the investigation, nor on the task sequence they must complete to achieve the goal(s) (Hofstein & Lunetta, 2004).

Project-based learning (PBL) mini-projects result in a heightened engagement in the topic, and in research in general. In this class type, the teacher's responsibility for planning the experimental protocol is passed on to the students, who must conduct their own research to acquire and/or write a protocol.

To partake in a mini project that aims to create novel solutions and/or technologies, students must enhance their awareness and autonomy, for the subject matter. They must also learn how to deal with their frustrations during laboratory experiments. The present work shifts from the traditional classes, as the student is the central figure, and the teacher has a supervisor/advisor role rather than a leadership role, as shown in Figure 1.

Figure 1
Comparison between traditional laboratory teaching and the proposed methodology



2. Educational Methodology

Acquiring scientific knowledge by developing new techniques, that can be applied to local conditions, is highly significant for motivating students and enhances their critical education. Awareness of the importance of laboratory practice as an educational tool encourages the application of theories taught in the classroom (Perez, 1969)(Anderson et al., 2005). This strategy is applied in mini projects developed by different authors, who observed that students became more engaged and motivated, than in traditional laboratory classes, where students have the protocol and just follow the steps (Carriazo, 2011)(Peixoto

et al., 2012)(Simoni et al., 2012). Problem-based learning mini projects have already been used by other teachers with 2nd year undergraduate students in Physics and Life Sciences (McDonnell et al., 2007).

With this work we proceeded to the implementation of a mini project and the analysis of the results of the students´ perception about it. The mini project consisted of conducting experimental work through the mini project methodology where students had to perform research work in order to understand the process, propose the experimental work, namely the choice of biomass, taking into account the sugar content and availability of the same for the production of ethanol, as well as plan the determinations to be performed, execute the proposed tasks, make a critical analysis of the results and finally write the work report.

Moreover, the theme chosen presents an excellent opportunity to discuss cross-cutting issues in bioprocesses, (agro)industrial waste and its relationship with the Sustainable Development Goals (SDGs) advocated by the United Nations (UN).

In the present study, the mini project focused on the theme of ethanol production. The term mini project has been defined as a laboratory experiment lasting 4 to 5 weeks or more. The exact duration depends on the students' performance (Carriazo, 2011).

This paper presents a multidisciplinary tool that gives students (of higher education level, or in advanced stages of education) the opportunity to develop their proficiency in: theoretical knowledge, procedures for preparing a literature review, knowledge on the state of the art of the subject studied, preparation of a process flowchart, data analysis and interpretation of results, and the final phase writing skills (when writing the final report and/or scientific article) (Carriazo, 2011).

The implementation of novel pedagogical practices, with greater student involvement, have proven to be more effective, simulating research work in a laboratorial/industrial level.

2.1. Objectives and target audience

The objective of this work is to demonstrate (given this method has a high research component) that by adhering to the proposed methodology, students can, simultaneously with skills development, acquire more knowledge about the production of a biofuel from selected waste.

The participants were degree-seeking students in Petroleum Technologies of the Superior school of technology of Barreiro/Polytechnic Institute of Setubal of the Curricular Unit of Petroleum Technologies Laboratories IB of the academic year 2021/2022.

2.2. Methodology

Student participants

The Mini project was implemented in one of the modules of the Petroleum Technologies Laboratory course, taught to third year students of the Petroleum Technologies degree course. The students were divided into workgroups of 3-4 students.

Mini project Implementation

The theme of the multidisciplinary mini project was based on a current topic chosen by the teacher according to the syllabus of the theoretical classes. In the present implementation the theme addressed was waste valorisation in bioethanol production.

The mini project involved several stages:

- Literature review - This review was based on scientific papers and current legislation on waste valorisation (biomass) and biofuel production. At this stage students selected the biomass required to produce bioethanol.
- Protocol development - In this phase students wrote a protocol for bioethanol production, considering risk assessment. The protocol was expected to include a pre-treatment step of the chosen biomass.
- Execution/Laboratory practice - Taking into consideration the acquired knowledge, and following the written protocol, students performed the necessary laboratorial work.
- Result analysis - In this step students analysed and evaluated the results obtained. They were expected to be able to establish if the results were within expectations. If any problems were detected in the protocol, they were corrected, and the students repeated the practice. If the results were as expected, students moved on to writing a report and preparing the final presentation.

The entire process took about 5 to 8 weeks.

It was intended for the students to improve their research skills, learn to develop, write a protocol, and manage laboratory frustrations. Frustrations management contributed to the improvement of critical thinking (students investigated why the results did not come out as expected).

The results analysis step, writing the report, and preparing a presentation, facilitated the development of writing skills and results' critical evaluation.

Pre-lab work

In this project the student groups were given a theme. Previously, in a theorical class, indications were given about the subject to be addressed, the objectives and the expected results. The teacher met with each group to provide guidelines in project planning.

The workgroups performed the necessary research, identifying existing publications within the theme of the work. Bibliographic research is important to elevate the student's level of critical analysis.

Experimental work

After the literature research, students wrote the protocol considering risk assessment regarding the instruments, equipment and chemicals used in the work development. Before the laboratory practice the teacher validated the written protocols. The experimental work began after 3 weeks of research work and protocol writing.

In the second lab practice class, the students began to feel frustrated because some groups were getting unsatisfactory results. In these cases, they had to go back to the protocol, readjust and then move on to new experiments. In this phase the students learned patience, learned to work through frustrations, and developed logical reasoning and evaluation of results.

Students' Evaluation

Students were evaluated on the following points:

- Laboratory notebook containing project research, protocol, and results - 15%.
- Protocol - 20%.
- Report - 25%.
- 15 minute PowerPoint presentation - 20%.
- Individual Assessment - 20%.

2.3. Assessing the effectiveness of the PBL mini project.

Evaluation of students' perception of the PBL mini projects was done through a questionnaire, done with MS Forms in MS Teams. The final question pertained to the students' overall perception of the mini project. This facilitated the evaluation of the project impact on the academic curriculum.

Questionnaire

The questionnaire used a Likert-type scale, with a scale from 1-5 where: 1- strongly disagree, 2- disagree, 3- neither agree nor disagree, 4- agree and 5- strongly agree. The text of the questions can be found in table 1.

Students' comments

In addition to these questions there was also a space for students to give overall feedback on the mini project.

3. Results and recommendations of the mini project implementation

The average results for each question are shown in table 1.

Table 1
Results and recommendation of the mini project implementation by the students

Questionnaire	Average result
The PBL teaching and learning methodology, applied in this Curricular Unit, helped me learning to correctly research a topic.	4.75
The PBL teaching and learning methodology, used in the course, allowed me to improve my problem-solving skills.	4.67
The PBL teaching and learning methodology, used in the course, helped me to improve my teamwork skills.	4.75
The PBL teaching and learning methodology, used in the course, allowed me to learn how to plan my work ahead of time.	4.58
With the PBL teaching and learning methodology, used in the course, I felt highly involved in this project.	4.83
The PBL teaching and learning methodology, used in the course, helped me to improve my data analysis skills.	4.75
Using the PBL teaching and learning methodology, I learned how to research a scientific subject, write a protocol, plan (and execute) the laboratory experiments and analyse the resulting data.	4.75

Since the average overall result is higher than 4, it is considered that the impact of the mini project was strongly positive in all aspects.

Students' comments

When given the opportunity to express their thoughts on the mini project in their own words, the responses from students were only minimally varied. Some of their comments were translated from Portuguese, and are shown as follows:

- "The project with the purpose of producing bioethanol, besides having a vision that carries the weight of responsibility when we think of fuel, instils in us at the same time a vision of bioenergy as well as technological awareness, (...). This project helped me to develop my RESEARCH CAPACITY AND AUTONOMY".
- "The curricular unit of Petroleum Technologies Laboratories IIIB, taught by Prof. Dr. Nilmara Dias, was extremely important for the DEVELOPMENT OF RESEARCH AND RESEARCH CAPABILITIES, due to the mini project developed on the production of ethanol through biomass".
- "The mini project was very BENEFICIAL TO OUR LEARNING, since it allowed us to be AUTONOMOUS in the elaboration of the experimental protocol, it forced us to RESEARCH in several scientific articles so that we could proceed with the elaboration of our own experiment".
- "This mini report allowed us to PERCEIVE ALL THE METHODOLOGY REQUIRED TO WRITE A FINAL RESEARCH REPORT, and for this reason it was an asset to all the students who had this experience".
- "The Mini - Project Lab experience was a unique chapter, ENRICHING, PROMOTING TEAM SPIRIT, RESEARCH AND KNOWLEDGE, but that does not close on this page, because it will support us in future experiences, professional and personal".

4. Conclusion

The success of this study indicated, not only by the questionnaire's result and students' comments, but also by the teacher's evaluation of the students' progress, that it should be intended to continue with this system of PBL mini projects in the coming years and if possible, to extend it to other curricular units.

From the questionnaire, and from the results, it was found that this methodology contributed to increase student interest and motivation, as well as their autonomy. It also contributed to the improvement of their work, research, planning, organization, analytical and critical skills.

The next paper will address the students' difficulties in terms of mini project planning, group work, laboratory practice and results presentation.

For the success of pedagogical practices, their monitoring is crucial to assess their impact on student learning and increase their knowledge and skills in each area. In this case it is relevant given the need to make practices of future more sustainable frameworks.

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