Teaching statics of fluids in Bioengineering:
a multidisciplinary proposal based on competences

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Abstract. The aim of this work is to share the findings of an educational experience undertaken by first-year university students of bioengineering, oriented towards the model of Competence-based Education. Different aspects on integrative education pursued in the subject goals are explicitly focused here by designing a strategy within a contextualized and multidisciplinary approach that combines knowledge from Physics, Chemistry and Biology. The topic chosen for the work is Static of Fluids, because it allows relating pressure to its biological effects on human beings. After evaluating a pre-test, new interrelated strategies are implemented. Due to the motivation audiovisuasl generate in adolescents, we start showing an argumentative film entitled ‘The Big Blue’, and continue with different individual and/or group activities, finishing with a post-test to assess the development of the competences proposed. Results are encouraging as regards the level of specific competences acquired and, complementarily, basic and professional competences in general. Besides, the experience met expectations as regards student motivation, interest and commitment to learning, which ensured the path taken by the academicians by means of implementing innovative strategies.

Key words: competence, meaningful learning, multidiscipline, contextualization.

1. Introduction

When facing the new challenges set by the ever-changing globalized world, it is noticeable that the entrepreneurial field is dissatisfied with the level of competence and capacities evinced by the scarce level of training of newly graduate university professionals. Almost instinctively, the blame is set upon high-education institutions which do not yet respond efficiently to the expectations of the productive sector of society, namely, the job-generating machinery for newly graduated or future professionals. To account for these weaknesses, it is though essential to foster, from the early academic years of university degree careers not only the development of specific competences in students (such as, knowledge, capacities and skills necessary for each field of specialization), but also the development of basic competences (language, reading comprehension, and mathematical logic), as well as professional mind-formation (personal development and values associated with professional performance) [1], [2].

Although some competence is gained through everyday life experience, other aspects, in contrast, need to be formally trained at the classroom, by emphasizing an explicit intention for educative action.
linked to the achievement of said competences [3]. Within this intended framework for better performance of professional individuals graduating from the University, the concerned academia is currently and steadily looking for adequate strategies to reach the above goals. Therefore, it becomes mandatory to provide university students with tools that allow them to detect and solve problems, at first, during their academic formation and training, and later, in their professional performance [4].

A small -though not less important- step on this direction is the one we take here by implementing the strategy detailed in this presentation. Specifically, the proposal is linked to statics of fluids, a study unit within the syllabus of physics I. After a brief discussion, this subject was agreed upon by the work group of academicians [5], [6], because it can be dealt with in a multidisciplinary way, altogether with chemistry and biology [5], [6], and because of the effects that hydrostatic pressure causes on divers (and people in general) when they submerge to into different depths.

Various activities were carried out, but, for the sake of this presentation, this work is focused only on the triggering source, namely, the argumentative movie ‘The Big Blue’.

Why a movie? —Because it is an attractive audiovisual resource for teenagers and it is contextualized, which makes the information memorable, and favours comprehension [9]. Why this movie? —Because it favours the integration of concepts of physics, chemistry and biology, based on an event that took place in real life and is presented as a story, which makes the movie attractive. Without being a true biography of the main characters, the release shows life aspects of competitive apnoea divers Jacques Mayol and Enzo Molinari (Enzo Maiorca in real life), who practiced diving since early childhood. Mayol’s obsession with sea and dolphins (with whom he identifies and considers his family) leads him to perfect his deep-immersion techniques up to such an extent that he ends up being subject of scientific research, due to the fact that he surpasses normal strength and resisting limits known for humans. Jacques, making use of yoga techniques, is able to hold his breath for several minutes and to reduce his cardiac rhythm to make the blood from his limbs flow to the thorax and brain. The physician that studies Mayol notices that this is a characteristic phenomenon of dolphins, which would be indicating that Mayol has a similar behaviour to that of these animals. This allows the athlete to keep conscious with the minimum physical effort. In addition, the movie shows different biological effects caused by practicing competitive apnoea diving that, if not taken into account, may lead to risky situations, even to death (as was the case of Enzo). In real life and at age 57, Jacques Mayol broke the World record for immersion in apnoea in 1983, by diving to a 105 m depth. The film is a French production directed by Luc Benson with excellent soundtrack by Eric Serra, that invites to enjoy the secrets of sea and share Jacques Mayol’s existentialism.

This is one of the possible strategies for delving into Competence-based Education (CBE). Systematic work with an institutional project for the development of the academic programme, taking into account different types of competences, may then be an answer for what the job-world demands.

On what the university is concerned, most teachers of the so-called 'hard sciences' careers promote the use of specific competences, connected to the content of their courses, rather than general ones. Teachers of Physics are not an exception, despite the fact that the topics of this course “are extensive and meaningful, with a large amount of information available and easily linked to society” [10].

2. Methodology

This work is developed within the research field of teaching sciences; in this instance, Physics for Bioengineering. This case has the characteristic of exploratory research, whose tests were turned into strategies for the development of the topic statics of fluids.

2.1. Research sampling and resources

The experience was made for the subject Physics I with an enrolment of 102 first-year students: bioengineering (33 students), and chemical and food engineering (69 students). All the students took place in this experience, during the time the topic was being studied. The resources used were:
A pre-test (to find out a panorama of previous knowledge) before developing the topic under study.

A post-test, to find out the achievements gained, at the end of the experience. The same test was used in both cases. It consists of seven multiple-choice items with specific questions about the topic, some of which are contextualized.

Power Point: for the explanation of the specific theory of physics, designed for this purpose. This tool was used to save time due to the fact that the content to be developed is the last topic of the syllabus and of the term.

The film ‘The Big Blue’: it was shown after the pre-test and before the theoretical development of the topic. It was not only used as a means of motivation, but also as a base of later work done to gather specific data about physics and chemistry related with the biological effects caused when practicing competitive apnoea diving.

Guided practical work: it was used with the aim of having students investigate and discuss about what they had seen in the movie in relation to the topics of physics, chemistry and biology involved. Students presented a written report with the information they were asked for.

Contextualized and traditional problems: students had to work on a guided practical task consisting of several problems, some of which were contextualized according to the specifications mentioned above.

2.2. Competencies and Capacities

The competences assessed were elaborated on the grounds of the proposal made by the Consejo Federal de Decanos de Ingeniería (CONFEDI) [11] – Federal Council of Engineering Deans. They were not stated literally, but were adapted to the proposal suggested by keeping the classification given by this organization. These competences, broken down into capacities (as constituted by the achievement indicators), are detailed in the section ‘Analysis of Findings’.

3. Findings

In order to assess the achievement of the proposed competences and their respective capacities, three categories are taken into consideration: totally achieved (TA), partially achieved (PA), and not achieved (NA).

The instructions of competences and capacities tally with those in the table of findings, annexed for each case.

3.1. As regards Competences and Capacities

Competence 1. To identify, formulate and interpret multidisciplinary situations.

- Capacity 1.1 Identify the particular context of the situation presented. The findings are: 47.1 % (TA), 47.1 % (PA) and 5.8 % (NA)
- Capacity 1.2 To identify and interpret physical, chemical and biological phenomena and processes in terms of concepts, principles and scientific theories. The findings are: 41.2 % (TA), 53.0 % (PA) and 5.8 % (NA)

Most students identified, interpreted, and contextualized physical situations related to chemical and biological processes in a correct way, which were presented both in the scenes of the movie and in the contextualized problems. The PA percentage corresponds to students that had some sort of difficulty in the interpretation of the problems.

Competence 2. To plan, execute, manage and control the different stages to implement, in an efficient way, and to find the alternatives for solving the stated situations.

- Capacity 2.1. To be capable of planning and executing the different stages with an appropriate time management to comply with what is requested. The findings are: 53.0 % (TA), 35.3 % (PA) and 11.7 % (NA)
The majority of the students planned and executed the different stages in a timely and proper manner (TA). The percentage of PAs is related to a students’ failure to meet the deadlines established for handing in the reports. The percentage of NAs represents the number of students that did not fulfill the task given.

Competence 3. Working effectively in work teams.
- Capacity 3.1. To meet commitments (tasks and terms) accepted within the group. Found values are: 23.5 % (TA), 53.0 % (PA) and 23.5 % (NA).
- Capacity 3.2. To listen to and to accept the existence and validity of different points of view. Result values are: 23.5 % (TA), 41.2 % (PA) and 35.3 % (NA).

A high percentage of PAs was observed, as well as an important number of NAs. These data allow us infer that the majority of students find it difficult to commit themselves with their work team and everything that has to do with it, especially to listen to and accept their peers’ opinions. Due to this situation, students were asked about the time they devote to studying outside school. The findings derived from this inquiry are as follow: by themselves 84%, in groups 8%, and alternatively 8%.

Competence 4. Communicating effectively.
- Capacity 4.1. To be able to communicate concepts and scientific findings in clear and accurate written language. The findings are: 23.5 % (TA), 58.8 % (PA) and 17.7 % (NA).

Generally speaking, the students communicate concepts and findings with appropriate language for a university level. The difference between TAs and PAs is based on the clarity of wording of the reports submitted. As regards the NA group, it can be perceived an inadequate use of scientific language and incoherent wording.

Competence 5. Continuous and individual learning
- Capacity 5.1 To find resources and/or strategies to improve personal learning. The findings are: 11.7 % (TA), 64.8 % (PA) and 23.5 % (NA).
- Capacity 5.2 To search relevant information through different means, by reading it with a comprehensive and critical stance. Recorded values were: 11.7 % (TA), 47.1 % (PA) and 41.2 % (NA).

Most PA students make use of the Internet as the only source for information, introducing scarce elaboration on it. In the case of the students of column NA, there is also lack of capacity to express critical judgements. It should be pointed out that TA students not only show ability in looking for and selecting resources, but also maturity in expressing critical judgement about the information they get and the appropriateness of their conclusions.

3.2. About the pre-test and post-test
The test used to do the pre-test and the post-test is shown below:

Topic: Hydrostatics
Questions are followed by possible answers, one of which is correct. Circle the appropriate answer.

Exercise 1. When sucking up water through a small pipe, water goes up because:
   a) The pressure inside the pipe is lower than atmospheric.
   b) The pressure inside the pipe is higher than atmospheric.
   c) Water is less dense than air.
   d) Water is denser than air.

Exercise 2. A shark is submerged 10 m in the sea, whereas a dolphin is submerged 5 m deeper:
   a) Both support the same hydrostatic pressure.
   b) Hydrostatic pressure is lower on the dolphin.
   c) Hydrostatic pressure is lower on the shark.
Exercise 3. Atmospheric pressure is higher on a person that is:
   a) 70 m above sea level.
   b) 100 m above sea level.
   c) 50 m above sea level.

Exercise 4. The three containers below have the same liquid. In connection with the pressure caused at depth h, we can conclude that:
   a) On I it is higher than on II.
   b) On II it is higher than on III.
   c) The one on II is higher than on I and III.
   d) They are the same in the three cases.
   e) It can only be said that they are different.  

Figure 1. The three containers have the same liquid.

Exercise 5. What is the volume of the submerged part of a floating body?
   a) All its volume.
   b) No volume.
   c) Half its volume.
   d) It depends only on the weight of the body.
   e) It depends on the weight and density of the liquid.

Exercise 6. An object sinks into a liquid without reaching the bottom when the pressure exerted is:
   a) Higher than the weight of the object.
   b) Lower than the weight of the object.
   c) The same as the weight of the object.

Exercise 7. The inserted figure depicts two cylinders, M and N, connected through a pipe. The surface of plunger M is four times the area of plunger N. On exerting a force F onto plunger N, the resulting force on plunger M is:
   a) Four times higher.
   b) Twice higher.
   c) The same.
   d) A quarter of it.

Figure 2. Two cylinders connected through a pipe.

Figure 3 shows the findings corresponding to the pre-test and post-test. They are presented in percentages placed on each column. The item corresponding with the tests are indicated along the horizontal axis.

Figure 3. Percentages of the findings obtained in the pre-test (black) and post-test (grey).
As regards the pre-test, a wider spread of wrong answers is noted (from 1 to 3), even in contextualized ones. This would be pointing to deficient inferring criteria to relate physical phenomena to the real world. In general, a low percentage of correct answers is noted for questions 4 and 7, which are linked to specific concepts of statics of fluids.

By comparing the findings of the pre-test and the post-test ones, a significant improvement is noticed in most items, especially the specific-topic ones. If this situation were compared with traditional tests taken by the student group (on other topics that we will not mention now), it would show a favourable impact on the strategies used as for specific competences are concerned.

4. Conclusions
From the analysis of the findings on different competences and capacities, it is inferred that the activities developed here have produced a change in attitude as regards the commitment on the teaching and learning process. Moreover, it is noticed that significant construction of concepts has been favoured by contextualized multidisciplinary situations.

It is also inferred that students of this level offer different degrees of resistance to work in teams. This characteristic does not favour the development of competences, thus impeding significant learning. In addition, this attitude results in students not paying attention to the instructions suggested to carry out the activities that require group interaction with peers. This would be indicating the need for more time available to achieve a better integration of work teams. In spite of all this, it was generally seen that most students performed the tasks assigned willingly. At the time of making the final reflections on the work done, students expressed their enjoyment for the proposal, and suggested to extend it other topics of the course.

It is worth mentioning that there was only one group that failed to comply with all the tasks proposed.

5. Final reflections
What was stated above, together with the analysis of results and discussion, indicates that it is possible to activate competences -especially non-specific ones- that are not normally acquired with traditional activities; mainly, motivation sustained in time.

Finally, this is one of many experiences carried out in isolated groups that pursue the training of competent subjects. Indeed, and in a broad reach, what has become essential is to count with university policies committed to the integral education of future professionals. But, in order to make this possible, it is important that every teacher of every educational level becomes aware of the needs imposed and their associated changes to make on outdated teaching paradigms.

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