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Experimental Activities-Integrated Problem-Based Learning in Biology Classes Promoting SSI and STSE Discussion

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Abstract

Learning initiation occured by introducing a problematic situation that included several questions, designed to trigger learning and promoting discussion focused on water-related challenges faced by plants within a whole approach correlating global climatic changes and the interactions between Science, Technology, Society and Environment (STSE education). One question that promoted discussion of social-scientific issues (SSI) was the possibility of excessive water and beverages intake could lead to death in humans; while STSE-related questions were eliceted by the potential use of reverse osmosis technology in large-scale to produce drinkable water from sea water, in a a global warming scenario, and the consequences of contamination of soils with salts by the use of fertilizers in agriculture to increase yields and of the increase of sea level.
This action research project was performed with high school students (with age from 14 to 16 years of both genders, and a medium age of 15 years) of a portuguese public school, that worked in collaboration in small-groups, of 3 or 4 students (n=20), during 2012/2013 academic year. So the corresponding learning unit was presented in the context of the International Year for Water Cooperation (defined by UNESCO as 2013), the decade Water for life (defined by UNO as 2005-2015) and the decade for Education on Health and Sustainable Development (defined by UNESCO as 2005-20014).
In this study we used Pelargonium x hortorum, native of South Africa, commonly used as an ornamental plant in Portugal, and the experimental setup consisted in three groups of plants maintained at different salinity conditions. So students were asked to describe the morphological aspect of plants watered with mineral water (commercial avaiable for human consuption) and of plants watered with 12% NaCl and to predicte the aspect of the third group watered with deionized water.
Our strategy was successufull as we observed that students developed the adequate oral communication, critical thinking, argumentation and colaborative skills as observed in the analysis of the answers povided to the problems and the positive classification obtained in the corresponding lab report of 70% of the students (in which 26% of the students obtained a classification of 86 or higher, out of 100).
Therefore this constitutes a successful implementation case study of a novel inquiry strategy, integrated experimental activities-PBL, that may constitute an example to facilitate the implementation of active inquiry strategies by other teachers, as well as the basis for future research.

1. Introduction

Problem-based learning (PBL) exists in a variety of forms, depending on the discipline and the goals of the curriculum, it tends to include features such as learner autonomy, active learning, cooperation and collaboration, authentic activities and reflection and transfer [1]. This teaching-learning strategy is a based on PBL that integrates an experimental and laboratory activity, within an inquiry learning model framework.
Osmosis and diffusion concepts have been described to be difficult to learn, may be due to the fact that these processes involve invisible particles and constitute abstract ideas [2]. National textbooks certified to use in the discipline Biology and Geology of the portuguese 10^{th} grade (high school) include a laboratory activity that consists in microscope observation of the epidermis of petals in the presence of a solution of NaCl or distilled water and suggest the students to make a description of the variation of colour of vacuoles observed [3, 4], with no correlation of osmosis concept with the physiological processes, and the importance of water balance or homeostasis of plants.
Since non-integrated classes have been described not bridge the gap between what students learn during PBL classes and the adequate laboratory skills [5] and integrated classes have shown to be an efficient learning strategy for university students of the discipline Plant Physiology [6], I used for high school students an integrated PBL approach that included an ill-structured problem with adequate guidance by the author/teacher according with age and unfamiliarity with PBL of the students and with the objective of promoting the development of the desidered skills. While PBL focus on a whole

scenario, the laboratory activities integrated in the problem are focus in specific questions to facilitate meanfull learning and developing critical thinking, questioning, collaborative and laboratory skills in the students.
Learning initiation occured by introducing the designed problematic situation that included a core question, consisting in a conceptual change eliciting question, designed to trigger learning: "Is it beneficial for the organisms that life is based on the existence of water?". Other essential questions of different types were also included, such as conceptual change and motivation types [7] focused on water related challenges faced by plants within a whole scenario correlating global climatic changes and the interactions between Science, Technology, Society and Environment (STSE education).
One question that promoted discussion of social-scientific issues (SSI) was the possibility of excessive water and beverages intake could lead to death in humans including a case-study of a young woman that died after drinking 6 L of water in 3 h as part of a radio contest included in the ill-stuctured problem [8].
STSE-related questions were eliceted by the potential use of reverse osmosis technology in large-scale to produce drinkable water from sea water, in a a global warming scenario, and the consequences of contamination of soils with salts by the use of fertilizers in agriculture to increase yields and of the increase of sea level. Another STSE-related question is about the potential advantages of biotechnology producing aquaporin-overexpressing plants that are drought tolerant.
This learning unit was presented in the socio-scientific context, also mentioned in the problem, of the International Year for Water Cooperation, defined by UNESCO as 2013, and the proclamation by UN of the period 2005-2015 the International Decade for Action 'Water for Life', as well as the proclamation by UNESCO of the decade for Education on Health and Sustainable Development (2005-2014).

2. Methodology

This action research study was performed with high school students (with age from 14 to 16 years of both genders, and a medium age of 15 years) of a portuguese public school (n=20), that willing to partcipate in the study had the corresponding informed consent signed by the parent/person responsible for education. This unit consisted in an one-week period during 2012/2013 academic year. The PBL methodology used included an ill-structured problem with adequate guidance by the author/tutor according with age and unfamiliarity with PBL of the students. Hence the author/teacher promoted the discussion and the questioning by the students using an eletronic presentation in each lab-class (≤14 students) prior to the laboratorial activity. Students worked in small-groups, of 3 or 4 elements, and on the first day the duration of the activities was 135 minutes, then students worked in collaboration in small-groups outside class, and in an additional session of 45 minutes, occured at the end of the week, presented and discussed their answers.
The model organism used in the experimental acivity was *Pelargonium x hortorum* (Fig. 1), a native plant of South Africa, commonly used as an ornamental plant in Portugal.In this study the experimental setup consisted in three groups of plants maintained at different salinity conditions (as summarized in Table 1).

Table 1 - Experimental conditions

Group A	mineral soil + mineral H_2O (H_2O total mineralisation: 47.7mg/L)
Group B	mineral soil + 12% NaCl (in deionized H_2O)
Group C	mineral soil + deionized H_2O

Fig. 1 - *Pelargonium x hortorum*

3. Results and discussion

Students discussed, in small groups (≤4 students), and proposed new questions and possible solutions to the open-ended question proposed "Is it beneficial for the organisms that life is based on the existence of water?". All the groups of students proposed several adequate and interesting questions, of high order, some of which were selected for further study, such as: "In what way is water essential to life?", "What happens at the cellular level responsible for human death by overdigestion of water?", "Why is the distribution of water in the planet non uniform?" and "Is it possible that drinkable water ends in the near future?". At the end of the class, all the students were able to propose a possible solution to the central question, refering to the benefits and the challenges of water to known living organisms.

Students described the morphological aspect of plants watered with mineral water (commercial avaiable for human consuption) and of plants watered with 12% NaCl and were able to predict the morphological aspect of the third group watered with deionized water as similar to the group A. More than 80% of students were able to quantify the vacuole volume in both samples, and representing correctly in a graph as part of the individual lab report. Students were able to write a text, as part of the discussion in the lab report about osmosis, refering the interactions science-technology-society-environment in a future cenario of increase of sea level by climatic changes (50% of students obtained the full classification).

The students' laboratory skills were assessed by the author/teacher, by observing during the class the complying with safety rules and laboratory manuals, communication skills and productive working skills, and the results were: Excellent for 32% of students, Good for 47%, and Satisfactory for 21% of the students.

This strategy was successufull as I observed that students developed the adequate oral communication, critical thinking, argumentation and colaborative skills as observed in the analysis of the quality of their argumentation and the positive classification obtained in the corresponding lab report of 70% of the students (in which 26% of the students obtained a classification of 86 or higher, out of 100).

The analysis of the responses to a questionnaire that evaluates the perceptions of the students about the PBL process, adapted from Senocak (2009), shows that the learning environment was adequate and sucessfull, since their responses, given in a five-point format ranging from Always to Never (5-Always, 1-Never), corresponded to positive results (≥3) in 83 to 100% of students.

The analysis of the responses of students on self-perception of contributes to their learning showed that 47% of students considered as corresponding to the higher contribute the powerpoint presentation by the author/teacher with class discussion and the work in small-groups on the problem while 41% of the students considered the higher contribute of the experimental work.

4. Conclusions

The designed problem described here constitutes a good example to introduce STSE themes and to promote a multi-disciplinary discussion of the causes and consequences of environmental changes and ways of reducing their negative impacts [10]. With this learning unit based on an ill-structured problem I expect students in the future will be able to apply their scientific process skills in reading contradictory information about several issues, such as global warming and transgenic plants [11], and being able to support the stronger argumentation position based on scientific evidences.

Therefore this study constitutes a successful implementation case study of a novel inquiry strategy, integrated experimental activities-PBL, that may constitute an example to facilitate the implementation of active inquiry strategies by other teachers, as well as the basis for future research.

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