Integrated Physics Learning using an interdisciplinary Inquiry Learning Space - an exploratory study using computer programming

ABSTRACT

In this work we try to understand how the use of problem-based learning in an interdisciplinary perspective, can enhance the integration of concepts in different disciplines. We also tried to verify if the use of computational programming can increase this integration. In this sense, we implemented an interdisciplinary Inquiry Learning Space (ILS) in the Physics discipline of some classes of Engineering courses. For our study, we analyzed the learning evolution in two classes, the first with the application of ILS without a programming component and the second with the same ILS but with a programming component in MATLAB. ILS was organized around Newtonian Mechanics, focused on the problem of planetary orbits and the possibility of orbiting around a black hole. From the observation carried out and the results of a survey, we conclude that this type of approach can enhance the learning of Physics, not only by increasing the motivation to learn, but also by using computer programming [1].

AIMS

In this work we intend to observe and analyze the process of implementation of a project-based learning (PBL) [2] in the classes of the first discipline of Physics of two Engineering curricula: Electronics Engineering (EE) and Industrial Engineering and Management (EGI). This is an exploratory project in which we follow the scheme of an "Inquiry Learning Space" (ILS) proposed by [3] based on gravitation, focused on the issue of planetary orbits. With this ILS we want students to confront ideas from Physics those of Newton and Einstein regarding the possibility of orbiting around a black hole. This topic is not addressed in Physics classes and is not within the Mathematical reach, by the students, of an analytical resolution. The choice of the subject is also related to the misconceptions that students have on the subject, the result of a disjointed basic education, combined with great speculation provoked by non-scientific popularization articles.

METHODS

The project, which we called the Universal Gravitation Law, was built in the form of an ILS, developed on the GO-Lab platform (http://graasp.eu) , following the typology proposed by [3] being the work built by four main phases: Orientation, Conceptualization, Research, Conclusion and Discussion. At each of these phases, different challenges are posed to students, such as answering questions and questionnaires, producing texts, pictures, and programs, among others. In the Orientation phase, we start by leading students in the search for information about orbital movements, stars, and black holes, always looking for a historical approach to these issues. Also in this phase, we lead students to review the basic concepts of Mechanics, introducing computer programming as an aid to solving problems in Physics. The semi-implicit Euler method is presented in this stage, leading students to a reflection on the feasibility of this numerical method for solving the differential equations associated with Dynamics. The Mathematical concept of vector is developed at this stage, linking it with the concepts of velocity, acceleration, and force in Physics. Also at this point, students are guided in the construction of an orbital simulation program, with which they perform simulations for the Earth's orbital movement around the Sun, using real data. The program is built on Newton's Law of Universal Gravitation.

RESULTS

From the point of view of the performance of each group in the answers to the various questions posed throughout the ILS, we can see that it is irregular in each of the classes, being weaker in the Industrial Engineering and Management class, as is clear in the percentage of correct answers given by each group, regarding the questions asked, as shown in Table 1, and the satisfaction levels of an anonymous survey in Table 2. Note that the only three groups with a good performance in the answers were EE-1, EE-2, and EE-3, which had percentages higher than 65%.

Table 1. Performance of each group in the answers to the 26 questions of the ILS.

Group	Correct answers (%)
EE-1	86.5
EE-2	69.2
EE-3	67.3
EE-4	28.8
EE-5	25.0
EGI-1	48.1
EGI-2	15.4
EGI-3	53.8
EGI-4	21.2
EGI-5	42.3
EGI-6	51.9
EGI-7	50.0

Table 2. Answers to the first 17 questions of the anonymous survey.

Question	Subject	Agree	Disagree
1	Importance of Theme	100%	0%
2	Satisfaction with ILS	96%	4%
3	Relevance to studies	96%	4%
4	Motivation for Physics	96%	4%
5	Use in other subjects	78%	22%
6	Use by others	87%	13%
7	Communication with colleagues	74%	26%
8	Concepts of Physics	91%	9%
9	Contribution to learning	96%	4%
10	Effectiveness of ILS	96%	4%
11	Knowledge value	100%	0%
12	Concept of Force	87%	13%
13	Concept of trajectory	96%	4%
14	Velocity and Acceleration Concepts	96%	4%
15	Concept of Vector	74%	26%
16	Concept of Derivative	65%	35%
17	Programming Utility	87%	13%

DISCUSSION

It is important in this section to start by noting that the time devoted to this activity seems to have been insufficient, which may have limited the completion of the work by most groups. Note that this point not only appears in the students' answers to the last question of the anonymous questionnaire but was also expressed by the students throughout the activity. An issue that we also tried to observe is related to the level of autonomy that students acquire with this type of activities. If, on the one hand, students show a lack of interaction with educators that may show some lack of autonomy, on the other hand, the capacity for autonomous research, as well as the ability to solve complex problems, some with the use of simulation programs, they are indicators of a level of autonomy above what is expected by students at this level of education. As a synopsis of what was stated during the discussion, we can consider that the use of an ILS assisted by programming enhanced the interest in learning Physics, in-creasing students' autonomy, and allowed for the interdisciplinary of Physics and Mathematics.

As a future work, this ILS will be used again, increasing the extent given for its accomplishment, and the period for discussion among students and educators, as pre-sent results seem to indicate that these aspects could lead to further meaningful ones. We also believe that the scope of this project can be larger, emphasizing the positive aspects found so far in the education of Physics.

REFERENCES

[1] Nogueira J.R., R. Alves & P.C. Marques (2019). Computational Programming as a Tool in the Teaching of Electromagnetism in Engineering Courses: Improving the Notion of Field. Education Sciences, 9 (1), 64. doi:10.3390/educsci9010064

[2] Duarte J. & Nogueira J.R. (2019). From the Hidden Protest of Students towards Problem-Based Learning. Education Sciences, 9 (3), 215. doi: 10.3390/educsci9030215

[3] Pedaste et al. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle, Educational Research Review, 14, 47-61. doi: 10.1016/j.edurev.2015.02.003.

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