Teaching Scientific Practices Through Low-Cost Tools: An Experiment with High School Students

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Abstract. A Teaching-Learning Sequence (TLS), designed to promote scientific practices in high school students, is presented. The TLS included laboratory experiences on linear motion using low-cost tools, such as Arduino, which were easy to replicate in other schools. The focus was on the process of laboratory work, the use of different representations and the development of arguments based on evidence. Collaborative working methods were used, and the TLS was modified to fit the teaching method of the teachers involved. The TLS was tested in three classes and will be replicated in two more. Preliminary results suggest that the TLS helped students to achieve the intended goals.

1. Introduction

The University of Padova's Research Group in Astronomy and Physics Education arranged a course named CoLLABORA (2018- 2020), which was focused on building a community of learners for enhancing the use of the laboratory in secondary school physics teaching [1]. As a result of this course, several teachers wished to disseminate the proposed approach within their own schools, and from there to the broader local school context.

This contribution describes an action-research project carried out by one of these teachers, who wanted to rethink laboratory activities not only as a means of transmitting disciplinary content but also to promote the development of scientific practices [2]. Therefore, attention was focused not only on the final product, but also on the process that students use to design, carry out, and interpret the laboratory, in line with national and international guidelines and a spirit of inquiry-based learning (IBL) [3].

More specifically, a Teaching Learning Sequence (TLS) on linear motion was designed and experimented in three classes at a computer science technical institute. The characteristic of this TLS was to propose laboratories that were easy to replicate in other schools. The objective was to export the learning experience to different contexts, disseminate it, and evaluate its efficacy.

2. Background and research questions

The focus of the Teaching and Learning Sequence (TLS) was the development of scientific abilities, specifically the use of different representations and argumentation based on evidence [2]. To achieve this goal, the TLS included laboratory activities inspired by the ISLE model [4].

In the design of laboratory experiences, various instruments were used, ranging from Tracker to position sensors, from “poor” materials (stopwatch and tape measure) to Arduino connected with ultrasonic sensors. The use of these tools was chosen to allow all students to work independently; typical school lab instruments such as the air-cushion rail were excluded as they did not allow for such autonomy. Furthermore, the material had to be easily available and low-cost.

The TLS began with students' direct experience in constructing the concept of a spatial and temporal reference system, together with the idea of linear motion. Through more laboratory experiences, students learned to describe linear motion using various representations (graphic, verbal, mathematical, and pictorial). Experiments on uniform and uniformly accelerated linear motion were conducted, where students utilized the collected data to recognize and describe motions through a critical reflection on their underlying assumptions. All the work was carried out using collaborative methods, with students working in groups of three and guided through inquiry using a series of questions. Rubrics [5] were used to assess the development of scientific abilities.

The TLS was first tested in the IT technical institute where the teacher-researcher works, with good results regarding the developed competencies and student engagement. The same experience was then proposed in two other classes in a different type of school (a scientific high school), belonging to two different curricula within the school (general science vs applied sciences). The goal was to evaluate how the same TLS could work in different contexts and involve more teachers in the innovative teaching approach.

The research questions that guided the experimentation were:

- To what extent did the TLS enable students to develop scientific abilities, and in particular the ability to use different representations and to develop arguments based on evidence?
- What are the challenges encountered when exporting the TLS to a different context?

2. Methodology

Altogether, the conducted experiment involved three classes of an IT technical institute and two classes of a scientific high school, with a total of 110 students. Two teachers from the scientific high school were involved beyond the teacher-researcher. To share the TLS, several meetings were organized to discuss the activities and agree on the expected learning outcomes. Checkpoints were identified for each learning goal, and laboratory work was assessed using evaluation rubrics. In order to fit the proposed laboratories into the workflow of the teachers, some minor modifications to the TLS were introduced while maintaining its focus on scientific practices.

The plan for evaluating the effectiveness of the TLS included an analysis of students' work, classroom observations and interviews with the teachers.

4. Results and further development

The experimentation is ongoing, but so far, the results indicate that TLS on motion helps students understand the meaning of graphs and the transition from one representation to another, such as from a pictogram to a graph or to formulas. Additionally, students appear to be more able to ask questions during the labs and to argument on their results based on the graphs rather than on preconceived ideas. However, the introduction of TLS in another school has highlighted some difficulties, as students' way of thinking is heavily influenced by their relationship with the teacher and their expectations. The final teacher interviews in May 2023 will help us to how the teaches have evaluated the experience, if they recognize an improvement in the scientific practices of their students and if the introduced innovations have become part of their teaching practice.

References

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