Development and transferability of scientific abilities in an ISLE-based lab course

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Abstract. We will report on how students' scientific abilities as measured by Rutgers scientific abilities rubrics changed over the course of two semesters. In each semester students do one lab per week. For each lab, they submit a report, receive feedback and then submit a revised version. We investigated two research questions: 1) How did students' scores on each ability change between the initial and revised submissions? 2) How did students' scores on each ability change between the initial submissions for different labs over the course of two semesters?

Introduction and motivation

University of Ljubljana Faculty of Mathematics and Physics offers a programme called Applied Physics. The programme is rarely the students' first choice and has been suffering from high attrition. The Recovery and Resilience Facility project [1] enabled us to completely reform the programme using the framework of the Investigative Science Learning Environment approach (ISLE), which emphasises learning physics by doing physics [2]. Instructional laboratories are an integral part of the process where students apply knowledge that they have developed in whole-class meetings (lectures) or create new knowledge that is later solidified in whole-class meetings.

In the labs, students work in groups of three or four. They submit one group report. The groups change every week. The lab instructions clarify the goals to achieve, but not the path to achieve them. The processes that students are involved in during an ISLE-based lab mimic processes that physicists are involved in during research. Etkina and colleagues identified these processes through research and labelled them scientific abilities [3]. They developed and validated rubrics for (self)-evaluation of these abilities [4]. A rubric for one ability is shown in table 1.

Table 1. An example of a rubric for (self) assessment of the ability labelled C8.

Ability	**0: Missing**	**1: Inadequate**	**2: Needs improvement**	**3: Adequate**
Is able to determine specifically the way in which assumptions might affect the results.	No attempt is made to determine the effects of assumptions.	The effects of assumptions are mentioned but are described vaguely.	The effects of assumptions are determined, but no attempt is made to validate them.	The effects of the assumptions are determined and the assumptions are validated.

For each lab, between three and four abilities are chosen to be evaluated. Students receive the corresponding rubrics with the lab instructions so that they can use them to prepare their report. After submission, the instructor evaluates the reports using the same rubrics. The abilities are evaluated only to the degree to which they are reflected in the report. Students have the opportunity to revise the report based on the feedback twice.

For example, ability C8 (table 1) has been evaluated in three labs: lab 6 – free fall and impulse; lab 7 – collision of a cart with a sponge; and lab 8 – energies on an incline. We have investigated the following research questions:

1. How did students' scores on each ability change between the initial and revised submissions for each lab?
2. How did students' scores on each ability change between the initial submissions for different labs over the course of two semesters?

These questions have been investigated before [5–7] in different settings and environments. We want to compare our findings with those of the previous studies and look for similarities that would give further insight into how students develop their abilities.

Methods and findings

A total of 13 students are enrolled in the lab course. We have collected scores on the rubrics for each report and the communication between the instructor and the groups over the course of one semester and will continue for another semester. Our research design allows us to answer the research questions quantitatively only for the whole class, but qualitative analysis might give further insight into the development of the abilities.

Preliminary results show that there is a consistent increase in scores within resubmissions for one lab, while the relation between initial submissions for different labs is more complicated. Figure 1 shows that ability C8 (in table 1) appears to be efficiently transferable between contexts of different labs. As a contrast, we give the example of ability C5–"to evaluate the results by means of an independent method", which appears to be more context-dependent. In our presentation we will provide more details on all analysed abilities.

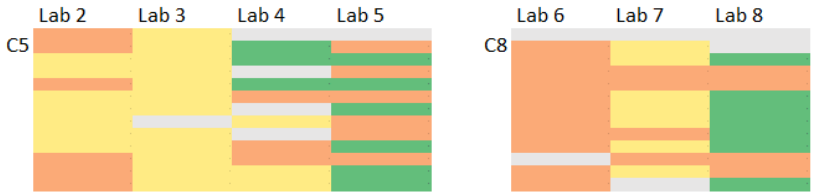

Fig. 1. Scores on rubrics C5 and C8 for each student for the initial submissions of the reports over several labs. Red: 0 points; orange: 1 point; yellow: 2 points; green: 3 points; grey: missing.

Conclusion

Our findings indicate that students are able to improve most of their scientific abilities between revisions of the same report (average normalised gain 0.82). The transfer of these abilities to other contexts is occurring, but to a lesser degree (average normalised gain 0.30).

These results are important for the physics education community, because it is often silently assumed that soft skills/scientific abilities/process skills are transferrable between contexts, which appears not to be always the case. Any insight that we gain about what might be the contributing factors in the transferability of a scientific ability will be an important result for developing a framework for teaching transferable skills.

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