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Proposal Submission for JURE2020

An Interdisciplinary Approach to Addressing Naïve Conceptions in Life Science Education

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Abstract

Applying the Biological Concept Inventory (BCI, Klymkowsky et al., 2010) to biology bachelor students in their first and third semester at University showed that the understanding of biological concepts does not increase substantially despite 1.5 years of instruction (Queloz et al., 2016). Interestingly, students struggle most with biological questions requiring knowledge transfer from other STEM (science, technology, engineering and mathematics) disciplines, which are also taught during the first year of studies (Queloz et al., 2017). We think that one of the reasons for the persistently poor performance in the BCI might be that there are a lot of naïve conceptions or misconceptions in the STEM concepts themselves. This makes it even harder, if not impossible, to acquire new knowledge based on those concepts. Therefore, in this project we aim to identify fundamental concepts from physics and chemistry that play a crucial role in the holistic understanding of biology. We will then develop an assessment tool to measure students' understanding of these concepts in a strictly physical or chemical context at different intervals during their studies. We will compare the results obtained in a standard approach to teaching STEM subjects in life sciences to those obtained in a new, more integrated and interdisciplinary life science curriculum. Results from the assessment of students' naïve conceptions will hopefully pave the way to designing effective interventions to address interdisciplinary concepts and allow us to improve the interdisciplinarity of lectures in life science curricula in general.

Extended Summary

Usually, 1st year biology bachelor students are subject to a very broad curriculum, including different STEM subjects like mathematics, computer science, statistics, physics and chemistry taught in separate, rather isolated, lectures. Alongside these subjects, students repeat most of what they have already learned about biology in high school and broaden their knowledge – again in a separate lecture. Although fundamental STEM concepts are taught, the students performance in biophysical and biochemical concepts does not increase significantly during the first year of study (Queloz et al., 2016). This leads us to wonder whether students are not taught the relevant concepts in the first place, whether they do not understand them or whether they cannot apply those concepts in a biological context.

As a first step towards a more integrated way of teaching about chemistry and physics in a life science curriculum, the department of biology at ETH Zürich is developing a new curriculum (the first principles curriculum). Instead of starting with cell biology of multicellular organisms, students will first learn about basic physical and chemical processes that were essential at the very origin of life (e.g., first principles). This should lay the foundation for students' interest and appreciation of the importance of these processes for biology. In this way, students are required to understand physical and chemical basics in their biological context much earlier than before.

With the introduction of a new curriculum, we are in a unique situation to compare students understanding of the physical and chemical underpinnings of biology in a standard versus an integrated curriculum. To assess students' conceptions of physical and chemical concepts necessary for a more holistic comprehension of biology, we will design a tool, the first principle concept inventory (FPCI).

In order to find STEM concepts that are crucial to understanding biology, we will conduct interviews with biology lecturers and perform a link analysis on basic university level biology textbooks (Carley et al. 2004). These methods will provide a plethora of interdisciplinary concepts from which we will choose the most reappearing and fundamental ones for a preliminary version of the concept inventory tasks, each of which will address one sole concept only. Nevertheless, one concept could be addressed by multiple tasks. Using open questions for our tool will allow students to express their individual thoughts and approaches to the problem, which in turn provides material to improve teaching methods and design appropriate interventions (Taber, 2008; Laverty et al., 2016; Stowe et al., 2019).

The tasks will be based on knowledge students have or will acquire during their first semester of study (or may have acquired before). The concept inventory will contain between twenty and thirty tasks which require students to apply their current knowledge about physical and chemical concepts. For each task a preliminary sample solution will be developed. As additional resources the participants will have access to a periodic table of the elements and a formulary. A preliminary version of the FPCI and its scoring system will be iteratively improved on the basis of biology students', complete novices' and experts' think-aloud interview data. The final version of the FPCI will be distributed to a large number of experts and novices to verify discriminative validity for the FPCI.

Using the FPCI, two cohorts will be tested: Students from the (old) standard curriculum and students from the (new) first principle-based curriculum. Students who went through the standard curriculum (starting in autumn 2019) will take the FPCI before their 3rd semester. Simultaneously, students attending the first principles curriculum (starting in autumn 2020) will take the FPCI before starting their studies. The data from the 1st semester will serve as a base-line for students' knowledge at the beginning of their studies. The cohort from the new curriculum will re-take the FPCI just before starting their third semester (*Fig. 1*). Using the gathered data, we can compare the performance of students after one year of study in the standard and the first principles curriculum.

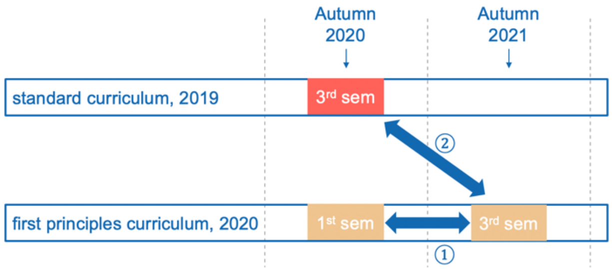

Fig. 1: Assessment of students' performance in the FPCI. We will be able to assess students' improvements over the first year of study (1) and compare students' performances after one year of study between the two curricula (2).

The FPCI will provide a tool to assess students' performance in physical and chemical concepts fundamental for university level biology. Results from the study will show whether a first principle-based curriculum contributes to a more holistic understanding of chemical and physical concepts underlying biological processes, and may help to guide us in developing lectures, interventions, and curricula that foster interdisciplinarity.

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