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Promoting experimentation and modelling competencies

Metrological concepts in biology courses in higher education

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Theoretical background or rationale

Measurements are central in scientific research and development activities. Unfortunately the concepts of metrology - the science of measurement - are obscure to most biology researchers (Houle and al., 2011). However, adjustments should be done to the subjects studied in biology and their features (Montevil, 2019). Lange (2000) pinpoints a key question about meaningfulness and reliability of a measurement. This issue is linked to the nature of science and to the representational measurement theory which discriminates against the different kinds of attributes, or scales type of measurement (Houle and al., 2011; Lange, 2000). Therefore, developing a culture of concepts of metrology might improve future researchers' skills but also students' confidence in scientific results. Regarding biology education, this reflection is central to teach how a discrepancy between a measurement and its meaning could lead students to mistakes in the analysis and the interpretation of data. Actually, the metrology issue is introduced in the high school physics and chemistry curricula and the French national standards for bachelor's degrees of experimental sciences (2015) mention related skills such as "identifying error sources to calculate uncertainties for an experimental result". Despite this, it appears that few biology course syllabi include metrology concepts.

Some science education studies dealt with the teaching and learning of quantities and measurement concepts at primary, secondary school and university level in physics and mathematics (Caussariou & Tiberghien, 2015, Auteur 2, amongst others). Only one comparative research dealing with biology education was conducted by Fond re et al. (1998) about specific tasks related to measurement during practical work sessions in biology, chemistry, and physics. The authors noticed some characteristics of the disciplines and underlined the significance of a decision regarding the quality of measurement values. While this study deals with uncertainties in measuring systems, a broader issue based on the teaching of metrology is not discussed.

As few researches deal with this issue, we lead an exploratory study to investigate the place of measurement education in the first years of university degree of biology in France. Thus, we look at the concepts and methods dedicated to metrology formulated in exercise and practical session documents. We also explore, through interviews, teachers point of views about the role of measurement for research in biology and its position in education.

Research design and methodology:

Firstly, biology and physics course materials (exercise and practical sessions) of first year university degree of biology provided to students are collected then analysed through a grid set up on the work of Fond re and al. (1998) and on the main axes of metrology (Perdijon, 2012). Concepts and methods of measurements are characterised through five rubrics: type of data and measurement; implementation; management; results and values processing; interpretation. Secondly, we interview four biology teachers implied in the analysed biology courses. The interview's guide is constructed to explore the intended purposes dealing with measurement in the teaching sessions as well as their conceptions (as scientist) of the measurement in their research field. Finally, to investigate if our results are reflecting a trend of most university degrees, we are developing a questionnaire that will be addressed to head teachers of biology degrees across France.

Findings:

Our analyse of biology course materials reveals that students carry out some measurements during practical work sessions and analyse quantitative or qualitative data by processing and interpreting them in exercise sessions. However, measurement is not an explicit goal of learning: data are mainly descriptive, measurement implementation paragraphs are mostly informative or descriptive and with rare instances of critical examination. Furthermore, major metrological concepts and methods are notably absent: there is no item dealing with measurement management and decision-making about confidence in values – the

quality of data (reliability, validity) is never questioned –, no item questioning the compliance of the model and items about reflexive feedback on the measurement protocol are rare. The variability (caused by measurement or by biological process) is largely unaddressed.

All the interviewed teachers pinpoint the importance of understanding scales, orders of magnitude, and the fundamental characteristics of certain experimental techniques in their teaching sessions. The mentioned data are mainly quantitative (or countable). The scale diversity seems to be influenced by the biological speciality (animal, plant or cell biology, genetics). Nonetheless, they don't spontaneously address issues of measurement reliability and validity. These observations are consistent with their measurement definition linked to a quantification and a technique of measurement. Despite their unanimous recognition of the importance of measurements in biology research, measurement education is mostly delegated to physics and mathematics lectures without questioning the specificity of measuring biological features.

Conclusions:

These results enlighten our vision of the place of measurement in biology education in the first years of university. They highlight certain deficiencies, mainly about the quality of data. In the near futures, we expect for the presentation to enrich our findings with the analyses of physics courses materials and draw a wider overview of measurement education in French biology degree with the result of our questionnaire. Beyond this exploratory study, a specific measurement education included in those sessions could be design to address this issue in collaboration with the teachers.

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