Research-based innovation in introductory physics course for biotechnology students

Daniele BUONGIORNO, Marisa MICHELINI

University of Udine, Physics Education Research Unit, DMIF (Department of Mathematics, Informatics and Physics), Via delle Scienze 206, 33100, Udine (UD), Italy

Abstract. Teaching introductory physics for biotechnology students requires to revise contents and methods in order to promote the developing of methodological competences through active participation of students. In the framework of the Model of Educational Reconstruction, such research-based innovation started three years ago in Udine University (IT). Structure, choices and research aspects related to the innovation will be here discussed.

1 Introduction

Revision of introductory physics courses for life-science area students at university level is a well-known addressed problem in Physics Education Research.[1-6]. The need is not only to address the relevant topics for the specific field of study, in particular for those courses in which technological applications are prominent, but to build a competence to employ the methodological approach of physics to the biotechnological problems [7,8]. A student-centered approach, in which the active role of students produces operative awareness of the role of physics in solving problems and relative instruments and methods, is relevant as well as taking into account the learning difficulties of students into the learning process to produce effective learning outcomes [9].

To address these main needs, specific research-based intervention modules for innovation in introductory physics course for biotechnology in Udine University (IT) started in the academic year 2015/16 involving - on average - 60 students per year. The content innovation pays attention to the strategies, and in particular to the role of problem-solving activities [10], the contribution of laboratorial activity [11], of ICT in teaching/learning process and the support of Computer-Assisted Instruction (CAI) systems [12]. This work is on 5 different research plans: (a) curricular, understood as a global re-design of contents, instruments and methods; (b) learning modalities and strategies in teaching specific topics (i.e. fluid or optics); (c) role of the laboratorial activity; (d) link between academic research in biotechnology and (e) role of exercises. The institutional role of innovation has been taken into account to give a guarantee of consolidation to the progress achieved in each phase of the experimentation.

Here we describe the adopted strategies, the specific choices and the evolution of the course structure and contents as well as the employed instruments to evaluate and/or to involve students as for example the experimental activities and the on-line self-assessments questionnaires. We also discuss the main achieved results.

2 Design and implementation

The first choice in implementing the innovation was on the contents, after a pre-test on the main traditional topics addressed in physics courses. motion, fluids, waves, acoustic, thermal phenomena, optics and circuits. In the theoretical framework of the Model of Educational Reconstruction [13], Research-Based intervention modules [14] have been designed and implemented, taking into account the above-mentioned goals and aspects, focusing on increase the quality of teaching, avoiding reductionism promoting active involvement of students, both in presence and on the web. Our goal is to build a functional understanding of the addressed contents, in order to allow students in gaining mastery in using physical concepts to critically interpret phenomena in their specific field of study, giving them the opportunity to use methodologies employed in physics in order to derive laws and experimentally validate them.

The very first innovation in introductory physics course for biotechnology students occurred in the academic year 2015/16. At that time, the course consisted in 3 CTS (out of a total of 180 CTS during 3 years). Results produced a recognition of role of physics and now, in the academic year 2017/18, introductory physics for biotechnology is a 4-CTS during the first semester of the first year. The course offers 52 hours of activities, 26 of which are dedicated to lab activities, 20 to teaching and discussing, 6 to exercises and additional 14-20 to tutoring. Every year the sample consisted - on average - of 60 students, selected out of 200 applicants at the beginning of the academic year by means of a selection test with the same criteria at national level.

The role of the laboratory work increased during the three years introducing ICT-based experiments for studying light diffraction phenomena and absorption spectra and conduction of heat with real-time graphs. Experiments have been chosen in a three-years long process in order to represent an interpretative challenge for students that do not have to follow a ready-made procedure but have to interpret and analyze data in order to produce a final report focusing on the specific formative elements.

Students were offered the opportunity to attend several seminars in order to link the academic teaching with advanced research fields in biotechnology as IR spectroscopy, PET, nanotechnologies and nano-structured magnetic materials providing individual written reports.

During the last academic year, a CAI system was designed and offered to students on an on-line platform. For every topic addressed during the course, three categories of exercises were available: multiple-choice questions for self-evaluation (thanks to an interactive interface showing students the right answers and giving them feedback), open exercises with numerical results and open exercises with discussion of the procedure (performed in class with a tutor). Exercises have a role of consolidation, deepening and self-evaluation.

3 Conclusion

The innovation in introductory physics course for biotechnology resulted in an increased formative success from 70% to 85% as concern the last academic year. Written problems for final exams are taken in the international literature to have a standard as a reference. Seminars turned out to be useful, since students were stimulated in searching for applications and reporting them. Exercises proposed to students allow them to work independently showing an high level of commitment asking for doubts, problems and questions. Research carried out offers hints on the following aspects: 1) How to select and address the topics and in particular by the test-in, it emerged that it was possible to lighten mechanics and dynamics topics, but treating it in different ways since some open knots persisted; 2) How laboratorial activities offer a methodological contribution to the described goals; 3) How to engage students in problem solving activities for every specific content; 4) How do students make use of the offered opportunities (seminars, encounters with researchers) to elaborate and deepen the studied topics; 5) how to design a structure for an introductory physics course for biotechnology students in terms of contents, instruments and methods.

References

[1] E. F. Redish, D. Hammer, Reinventing college physics for biologists: explicating an epistemological curriculum, *Am. J. Phys*. **77** (2009) 629-642.

[2] E. Brewe, N. J Pelaez, T. J. Cooke, From Vision to Change: Educational Initiatives and Research at the Intersection of Physics and Biology, *CBE—Life Sciences Education*, **12** (2013) 117–119.

[3] D.C. Meredith, E. Redish, Reinventing physics for life-science majors, *Physics Today* **66** (2013) 28-43.
[4] E.F. Redish, C. Bauer, K.L. Carleton, et al., NEXUS/Physics: An interdisciplinary repurposing of physics for biologists. *Am. J. Phys*. **82** (2014) 368-377.
[5] A.M. Hoskinson, B.A. Couch, B. M. Zwickl, K. Hinko, M.D. Caballero, Bridging Physics and Biology Teaching through Modeling, *American Journal of Physics* **82** (2014) 434-441.
[6] M. Michelini, A. Stefanel, Innovation in Physics Teaching/Learning for the formative success in introductory physics for Bio-Area degrees: the case of fluids, *proc. II WCPE, Sao Paolo* (2018).
[7] M. Michelini, A. Stefanel Teaching Physics to Non Physicist: Physics for Agricultural, Biotech and Environmental Sciences. In *E.Dębowska, T. Greczyło (eds), Key Competences in Physics Teaching and Learning*, University of Wrocław, Wrocław, Poland, ISBN: 978-83-913497-1-7 (2016) 142-149.
[8] M. Michelini, A. Stefanel, Clicker per l'apprendimento attivo della Fisica degli studenti dell'area Bio, *on-line proceedings XXX Convegno Didamatica*, Udine, ISBN:9788898091447 (2016), http://didamatica2016.uniud.it/proceedings/dati/articoli/paper_106.pdf
[9] P.R.L. Heron, P. S. Shaffer, L.C. McDermott, Research as a Guide to Improving Student Learning, In *Building Excellence in Undergraduate STEM Education*, Washington AAAS (2004) 33-38.
[10] D. Maloney, An Overview of Physics Education Research on Problem Solving, *Getting Started in PER, Reviews in PER*: Volume 2, Issue 1, (2011).
[11] AAPT , Goals of the Introductory Physics Laboratory, *Am. J. Phys*. **66** (1998) 483-485.
[12] P. Dunkel, Computer-Assisted Instruction (CAI) and Computer-Assisted Language Learning (CALL): Past Dilemmas and Future Prospects for Audible CALL. *The Modern Language Journal* **71** (1987) 250-260.
[13] R. Duit, H. Gropengießer, U. Kattmann, M. Komorek, I. Parchmann, The Model of Educational Reconstruction - a framework for improving teaching and learning science. In *D. Jorde & J. Dillon (Ed.), Science Education Research and Practice in Europe*, Rotterdam, Sense Publishers (2012) 13-37.
[14] T. Anderson, J. Shattuck, Design-Based Research: A Decade of Progress in Education Research?, *Educational Researcher* **41** (2012) 16-25.