Teaching Laboratory Classes in the Natural Sciences (3)

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3. Encourage Learning: How Can It Be Done?

Overview

1. Pique curiosity by establishing contexts and relationships between theory and practice

Students who drop out of programs in the natural sciences, often cite the obscure relationships between practical experimentation and theoretical concepts as their main reason.[1] The connections between theory and practice (e.g. the kind of connection between a lab class and a lecture) are often difficult for students to grasp. At the same time, some lab classes fall short of their potential to pique the curiosity of students.[2] When teachers introduce additional contexts and current topics, either from everyday life or recent research, this can be very motivating for students. Perhaps you know interesting historical anecdotes you can tell about specific experiments. Contextual knowledge helps students recognise experiments as meaningful.[3]

2. Stepwise transition from detailed instructions to more open experiments

Students new to the university must first acquire basic experimentation skills and competences. Once they master these, it helps their learning not to work exclusively with detailed experiment instructions ("cook book"), but to open the experiments. Since experimentation is not only about practical skills, but also includes designing experiments, developing hypotheses, etc., students need enough opportunities to practise these complex challenges. Such opportunities are crucial in preparing students for careers, as well as for writing their bachelor's and master's theses. In these, students are required to demonstrate independent working skills and to adapt elements of experiments according to research questions and objectives (see interview with Katharina Groß).[4]

3. Encourage analytical thinking through questions

In the lab, students are often "data-driven" [Séré, 635] and focus on the next step of the instructions. Use the opportunity during your lab course to regularly ask your students questions that challenge their ability to think analytically and strategically (in terms of experimentation). The following kinds of questions have proven effective to encourage thinking:

- Questions about observations and preliminary analyses: *What patterns do you recognise? What could they indicate?*
- Questions about result prediction: Formulation of initial hypotheses and reasons for assumptions
- Hypothetical questions; possible examples: *What do you think would happen if you raised the temperature? What would be different if you conducted the experiment at 2000 meters above sea level?*
- Questions about implications: *How does this result affect...?*
- If an experiment yields unexpected results, ask your students think of possible reasons for the deviation.

When students ask you questions, use them as opportunities for (shared) reflection. It is important to offer a mix of support, and to react appropriately to the situation. Possible reactions may include:

- Answer the question.
- Ask the student to answer the question him/herself: It is vital to assure your students that you are not asking the question in order to test or even embarrass them, but to encourage them to reflect and to develop their skills.
- Pass on the questions to the entire class and discuss it together.

4. Enable independent experimentation through procedural competences

In order to conduct experiments more independently, students have to master the procedures, approaches, as well as how to choose them. Students often learn this by "learning by doing" only. However, research has shown that this is not a very effective method, and that students learn more quickly and effectively when teachers explicitly discuss the topic of procedural processes in the lab.[5] Explain why you chose a specific procedural approach to illustrate a phenomenon and decided against other ones. Students appreciate looking "behind the scenes" of choosing experiments.[6]

Tip:

Invite your students to choose one of three different experiments and explain their choice. [7]

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5. Foster an understanding of empirical research in the natural sciences

Some teachers have observed that students do not understand the significance of discussing results and errors when they write their lab reports. This can indicate a lack of understanding of the empirical character of the natural sciences. This, however, is one of the most significant learning potentials of laboratory classes. As a teacher you can address this by asking your students: *"Why do I need a measured value if I have a theoretical value?"* This question provides you with an opportunity to talk to your students about their understanding of data, and to discuss the epistemological uncertainty of empirical work. Try to monitor how your students' understanding of science develops.

6. Learning through feedback

Feedback on student work holds great potential for learning if it includes concrete suggestions for improvement that students are expected to take into consideration in the subsequent assignment (see Teacher Feedback (https://infopool.univie.ac.at/en/home-page/feedback/teacher-feedback/)). In laboratory classes, this primarily applies to experimental work and lab reports. While feedback on practical work is often immediate and provided orally, many teachers give written feedback on written work. Such feedback on lab reports does not have to be very detailed. For example, you can focus on the three most important issues. Students should receive feedback in enough time to be able to implement it in their next report. Peer feedback on a lab report, supported by appropriate teacher instructions, also works well (see Peer Feedback on Written Assignments (https://infopool.univie.ac.at/en/home-page/feedback/teacher-feedback-on-writing-assignments/)). Regardless of class size, regular collective feedback is suitable for laboratory classes if you need to communicate common misconceptions to the entire class.

Continue reading

Laboratory Classes (4): Safety in the Lab (/en/start-page/course-types-disciplines/teaching-laboratory-classes-in-the-natural-sciences/4-lab-safety/)

References

[1] Nilson, Linda B. "Problem Solving in the Sciences." In *Teaching at Its Best: A Research-Based Resource for College Instructors*, 3. Auflage, 199-207. San Francisco: Jossey-Bass, 2010.

[2] Rehfeldt, Daniel. "Erfassung der Lehrqualität naturwissenschaftlicher Experimentalpraktika." In *Studien zum Physik- und Chemielernen*, edited by H. Niedderer, H. Fischler, and E. Sumfleth, Band 246, Berlin: Logos Verlag Berlin, 2017.

[3] You may watch this video to learn more about different examples for teaching laboratory classes:„Laborlehre und praktischer Übungsbetrieb: Wie machen Sie das? (https://infopool.univie.ac.at/videos/laborlehre/#c337068)“ [in German, subtitles forthcoming]

[4] Für ein paar Praxisbeispiele, wie die frage- und entdeckungsorientierten Anteile von Laborpraktika gesteigert werden können, siehe Coppola, B.P. (2011). "Laboratory Instruction: Ensuring an Active Learning Experience." In *McKeachie’s Teaching Tips: Strategies, research and theory for college and university teachers*. , edited by Marilla D. Svinicki, and Wilbert J. McKeachie, 13. Auflage, Belmont, CA: Wadsworth Cengage Learning, 280-289. Coppola baut hier auf Domins klassischer Taxonomie von Laborlehrstilen auf: Domin, Daniel S. „A Review of Laboratory Instruction Styles“. *Journal of Chemical Education* 76, no. 4 (April 1999): 543-547.

[5] Séré, Marie-Geneviève. "Towards Renewed Research Questions from the Outcomes of the European Project *Labwork in Science Education*". *Science Education* 86, no. 5 (2002): 624-644, here: p. 635-638.

[6] Welzel, Manuela, Kerstin Haller, Milena Bandiera, Dorte Hammelev, Panagiotis Koumaras, Hans Niedderer, Albert C. Paulsen, Karine Bécu-Robinault, and Stefan von Aufschnaiter. "Teachers’ objectives for labwork. Research tool and cross country results". *Working paper 6, Labwork in Science Education Project*, European Commission, Project PL 95-2005, 1998.

[7] Séré, "Towards Renewed Research Questions from the Outcomes of the European Project Labwork in Science Education", 635-638 [5].

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