Experimental laboratory exercises where the students plan their own exercises

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Subject, course/other context, study level and number of students: Protein science and enzyme technology, second year, block 3 of the Bachelor's programme in biochemistry, 15 ECTS points, approx. 100 students working together in groups of two of three.

The motivation behind the activity: In general, students express dissatisfaction with exercise instructions. The objective of the activity was therefore to have the students plan the exercise themselves, and to have them think about why and how they perform the individual steps of the lab exercises (as opposed to the traditional step-by-step instructions that provide a detailed plan in advance), so that they would get an idea of how difficult it is to write exercise instructions.

Key learning outcomes, focussing on the way in which the activity is research-based: Enable the students to design, plan and perform experimental experiments on the basis of methodologies described in original, scientific papers, as well as to prepare a protocol and logbook for the experiments carried out.

Description of the activity: The activity takes place in two parts: First, the students are to purify the enzyme fructose 1,6-bisphosphatase from a pig kidney (part 1, four whole days) and, then, describe the enzyme kinetics of the enzyme (part 2, two whole days). The students are given an original paper, on which they are to base the purification procedure. Instead of being given traditional step-by-step instructions, the students are given a guideline containing a collection of the methodologies to be used, however these are only described in general terms (e.g. as in a commercial protein assay kit). There are no checklists indicating how much of the individual solutions the students should mix for the individual experiments, or how much they should dilute the enzyme in order to stay within the measuring range. Before the practical exercise, there is a three-hour theoretical exercise session introducing the students to the purification process and the different methodologies. This also gives the students an idea of how much work they can expect to get done in one day. The students subsequently have to plan the purification procedure in detail, i.e. they have to prepare their own checklists corresponding to the traditional step-by-step instructions. Before starting on the second part of the activity, the students then attend an additional three-hour theoretical exercise session introducing them to enzyme

kinetics and to the use a data-fitting programme, which they will need for data processing. Next, the students have to plan the enzyme kinetics in detail and prepare checklists as in part 1. The students are required to keep a research journal and write a final report in the form of a paper, in which they present and discuss their results. Previously, they were also required to plan and perform one or several experiments of their own design with the purified enzyme, however, unfortunately, this is no longer possible due to time restraints.

Interplay between teaching and exam: The theoretical part (lectures and theoretical exercises) covers a detailed walk-though of enzyme purification as introduction to the experimental exercises. The final report on the exercise is subject to teacher approval and this often entails extensive individual feedback on students' first drafts. The exam includes questions which require that the students are familiar with and understand the exercise, so that they can discuss and provide qualified suggestions for purification of other proteins.

The outcome of the activity for the students: Students generally express dissatisfaction with other course modules that make use of step-by-step instructions, saying that the exercise instructions are difficult to understand. Here, they prepare the instructions themselves and, in the process, they realise how difficult it is to make good instructions. They achieve a deeper understanding of what it is they are doing and why the order of the individual steps in the process is so important. They are generally very enthusiastic about this format, in which they are required to plan the experiments themselves. They learn which details are most important, and they do so, in particular, on the basis of experiments that fail and have to be repeated, usually because they did not plan them properly. Unfortunately, there is not enough time available for the students themselves to prepare the different solutions for use in the exercise. A typical statement in the evaluations is that "it is nice to do an exercise that requires us to do our own thinking".

The outcome for research: Students get a practical understanding, already in their second year, of the experimental way of thinking that underlies the scientific papers they read, and that they eventually have to apply in their Bachelor’s project and their thesis paper.

Strengths and weaknesses of the activity: The enthusiastic students become even more enthusiastic and are keen to repeat experiments until they get good results, which means that they sometimes have to be stopped so they do not exceed the set timeframe. Typically, there will also be a group of students who do not seem particularly enthusiastic and who just want to finish quickly so that they can leave early. These students often just observe the other students and then repeat what they are doing, and it is likely they do not learn as much from having to plan the experiments themselves. An example of a strength of this activity is that the teachers themselves become more enthusiastic about teaching the exercise, partly because of the large degree of variation from group to group, and

partly because they are challenged by the format. However, the challenge can also be a weakness; the activity requires a lot of work due to the close collaboration between teachers and students. Unforeseen situations and the individual protocols can also be a weakness, because they require a far greater effort by the teachers (i.e. internal full-time staff and PhD students). Moreover this teaching format can be difficult to take over for new teachers compared with a teaching format based on using traditional step-by-step instructions. It is a strength that the students are allowed to learn from 'trial-and-error', however, because the exercise must be completed within the specified timeframe, the teacher often has to guide the students too much to ensure that they complete the experiments in time.

Keywords:
Research-based teaching, experiment planning, experimental logbook