Enhanced Learning Through Peer Teaching in the Laboratory

Kellie Fawkes and David Berry (3M 2000)
Chemistry
University of Victoria

Why Change?

A progressive undergraduate teaching laboratory program has a continual evolution of all aspects of the curriculum, and the incorporation of new pedagogical philosophies can be just as important as new scientific theories. Over the last few years, this evolution has focused for us on the transformation of a mainly expository style of laboratory instruction to a format which exposes the students to a more varied learning environment designed to foster higher-order thinking *(1, 2)*. These changes have included the development of some problem-based labs *(3,4)* and an increased emphasis on student-centered learning through peer teaching *(5,6,7)*.

The Course

The course is a weekly, four hour second year inorganic chemistry laboratory which focuses on synthetic preparations followed by physical measurements. The student population is highly diverse ranging from second to fourth year students. The experiments offered are designed to expose the student to a large variety of synthetic techniques and methods of analysis. Some experiments are run independently by each student followed by an exchange of data and results within a team of four students. Other experiments have each student collect a different data set that contributes to a larger project completed by the team. We have included one example in the supplementary material with appropriate teaching notes. This example contains pre-lab questions, experimental procedure, in-lab questions and instructor notes. The final experiment is a problem-based synthesis that gives the students the opportunity to apply their skills in developing their own experimental procedure *(4)*.

Components of the Course

The laboratory course has four major components: pre-lab exercises, experimental work, in-lab assignments, and written reports. Each of these has different goals and has therefore been changed in different ways to foster a higher level of learning.

Pre-Lab Assignments

These assignments typically consist of six to twelve short-answer questions for the students to complete prior to attending the lab. The focus tends to be on the more mechanical aspects of the procedure and the basic chemistry of the experiment, requiring the students to read the manual and be prepared to begin the experiment when they come to class.

Many options were considered as alternatives to this format including a short in-class quiz, written or oral, given at the beginning of the lab to assess student preparedness. These alternatives did not seem to offer increased learning for the loss of in-class lab time, so a modification of the pre-lab assignments was adopted instead. This retained the expectation of the students to complete the same questions before the lab began but set aside approximately 15-20 minutes of lab time to allow discussion of these questions. The instructor coordinates the review of the pre-lab questions but allows the students to contribute the answers and to discuss errors and misunderstandings as a group, working through to the correct solution. Peer learning has increased the level of understanding and the students have the opportunity to see many different approaches to solving the same problem. The active instructor aims to keep everyone involved in the discussion and to provide stimulation when the class gets stuck on a problem or needs a

larger perspective to approach the question. This is also an excellent opportunity for the instructor to stress some key points and aims of the questions and to tie this information to the overall learning experience. The students no longer see the goal of the pre-lab questions as mark-oriented but now learning-oriented with an immediate result that can be applied during the lab period and later in writing the report.

Experimental Work

The experimental work stresses psychomotor skill development and thus demands a large time investment. By structuring the work to be done in groups of four students we provide a peer-based learning experience which allows an expansion of the experimental work as not every student need be required to perform the same measurements. The time saved can then be used to allow for more discussion of the experiment as well as the introduction of more techniques. Alternatively, we can include multi-faceted experiments with the group dividing the labor and organizing themselves to complete one large project. Group learning requires the development of interpersonal and leadership skills along with the ability to manage time while actively participating in the group *(8)*.

In-Lab Assignments

Whenever the experimental procedure leaves the students with 30 minutes or more of unproductive time, a set of questions is given for the students to work on. These questions are designed to keep them thinking about the experiment and to challenge them at a higher level than the pre-lab questions, hopefully stimulating some discussion points. This has evolved into an in-class assignment which provides one copy of the questions to each group to be completed together. This format allows for higher order questions that might have been out of reach for many individuals working alone and is meant more to stimulate discussion than to test current knowledge. The instructor's role is no longer to invigilate an exam but to facilitate learning and to help the students to understand the material before the end of the period. They can then apply what they have learned immediately and this understanding will often show up in the discussion portion of the lab report.

Reports

Since the implementation of the group work, each student is still required to submit an independent report but must now also discuss their results in relation to those of other members of their team. Although this does require more work from the student to analyze the data and to discuss the implications more thoroughly, it is invaluable in providing a sense of perspective. Individual results can now be compared to an average and the variety of results is of more interest than the dualism of being either "right" or "wrong".

In addition to the reports being graded by the instructor, one report each term is also evaluated by two peers. Each reviewer is expected to provide qualitative constructive criticism on two anonymous reports randomly selected from within their own class, but not from their own group, and, in exchange, has two copies of their own report reviewed by two other students. The quality of the reviews is assessed by the instructor before being returned to the original author of the report. This peer-evaluation exercise is worth very few marks to each student but is quite eagerly performed. It gives them the chance to see how others have presented the same material and they readily acknowledge creative ideas as well as suggest changes to improve the presentation.

Evaluation of Changes

Feedback is very positive on the subject of group learning. The students feel they are actively participating in an open and cooperative learning environment and that the stress level of the laboratory has decreased. These personal interactions within the classroom have also led to more cooperation outside of class time. The instructors have seen the immediate effect of increased student participation and higher-level discussion of the experimental material. The changes have also resulted in increased

instructor confidence of the grades being assigned to the students, as it is very clear through discussion who has prepared and understood the experiment.

References

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