ASSOCIATION OF ATLANTIC UNIVERSITIES
ASSOCIATION DES UNIVERSITÉS DE L'ATLANTIQUE

Proceedings of the 2017 Atlantic Universities' Teaching Showcase

Volume 21 | Pages 53–59 | https://ojs.library.dal.ca/auts/index

# PREPARING STUDENTS FOR MEANINGFUL LABORATORY EXPERIENCES

Kelly L. Resmer

*Association of Atlantic Universities/*
*Association des universités de l'atlantque*
*Editor-in-Chief: Donovan Plumb*
*www.atlanticuniversities.ca*

*Volume 21 | Pages 53–59*

# PREPARING STUDENTS FOR MEANINGFUL LABORATORY EXPERIENCES

**Kelly L. Resmer**
Department of Chemistry and Physics
Mount Saint Vincent University

**Abstract**

*The chemistry laboratory provides a unique learning opportunity for students. In the lab, students experiment with the concepts learned in class. To prepare for experiments, students are asked to complete short assignments. These "pre-labs" provide relevant background information and the opportunity to practice calculations so that students can gain a deeper understanding of the material. Pre-labs help build a framework for students on which to base their laboratory learning experiences and serve to lessen the stress of being in a lab environment. Most recently, I have used on-line quizzes that are marked instantly. Students receive immediate feedback to determine if they understand the material, calculations, and techniques. Greater learning gains were observed after treating pre-labs as formative assessments. I have also recorded videos demonstrating lab equipment, sample calculations, and reviewing class and lab theory. Students say these videos are an excellent way to learn since they can watch the video at their own pace. After introducing these quizzes and videos I noticed that students were better prepared, more efficient, and they asked more relevant and meaningful questions. Overall, there is a noticeable improvement to students' understanding of the material, increased confidence in the lab, and better engagement with their peers and the instructor.*

**Keywords**

*laboratory instruction; pre-lab activities; hands-on experiments; student engagement*

Association of Atlantic Universities/
Association des universités de l'atlantque
Volume 21 | Pages 53–59

## Introduction

Laboratory work provides students with unique opportunities to use their knowledge and skills in unfamiliar situations. Completing experiments develops practical skills such as using laboratory equipment, but also transferable skills like teamwork (Hofstein & Lunetta, 2003; Reid & Shah, 2007). For meaningful learning to occur students must have relevant background knowledge and cognitive ability to understand and carry out the experiment (Mayer, 2002). If students just attempt to memorize the material and not engage with the new information the learning will be meaningless (Ausubel, 1968). Ausubel's (1968) three conditions for meaningful learning are: 1) the student must have relevant prior knowledge; 2) the new material must be presented in a meaningful way; and 3) the student must choose to actively incorporate new knowledge with their prior learning (Bretz, 2001). To integrate the new material students must be motivated to learn and make connections from their existing knowledge to the new material. A lack of motivation can be difficult to overcome if lab material is not presented in an engaging way that provides a framework upon which students may build their knowledge of laboratory procedures.

Stress and anxiety can present another barrier to meaningful learning and motivation. Kurbanoglu and Akin (2010) surveyed first-year chemistry students on their laboratory anxiety, attitudes, and self-efficacy beliefs. Kurbanoglu and Akin (2010) reported that lab anxiety has a negative effect on the students' self-efficacy. When students are anxious, their belief in their ability to perform a given task successfully is negatively affected. The report recommends that reducing student lab anxiety will improve learning and enhance self-efficacy (Kurbanoglu & Akin, 2010). Miller and Lang (2016) report that lab anxiety is a complex issue; the lab has social dynamics, intellectual components, and physical barriers that all must be overcome within the lab's time constraints. Incorporating elements of Universal Design for Learning (UDL) can help minimize stress and anxiety.

Universal Design for Learning is a teaching and learning framework that addresses the recognition, strategic and affective domains of the brain (CAST, 2018). UDL has three guiding principles; students should be provided with multiple means of representation, action and expression, and engagement (CAST, 2018). The first UDL principle is that material should be presented using multiple methods so that students can have options for acquiring the information (Hall, Meyer, & Rose, 2012). Presenting lab experiments with videos, written directions, and in-class lecture allows students to engage with the material in a manner that best supports their learning. Incorporating UDL can help foster an equitable and inclusive learning environment.

Proper preparation before the lab experiment can promote meaningful learning and minimize lab anxiety so students can develop and demonstrate the unique skills of laboratory work.

The following methods have demonstrated efficacy in preparing students for the undergraduate chemistry labs.

## Engaging students

Students need appropriate prior knowledge of theories, definitions, and vocabulary before coming to the lab to help link class theory to lab material. Students need help making connections and organizing their thinking. Traditionally, at the beginning of the lab students will present answers to pre-lab questions on paper. The question set is graded and handed back to the students the following week. This preparatory method provides no timely feedback to students. Quizzes completed at the beginning of the lab do offer instant feedback if answers are marked in the lab, but this leads to student stress and takes up lab time. Alternatively, a pre-lab quiz completed online through the course management software provides timely feedback. I include questions on lab terminology, theory, and calculations. Often these quizzes can be programmed so that each student receives a calculation with different numbers so the answers are unique. With third-year labs I treat pre-lab assignments and quizzes as formative assessments and students will get marks for an honest attempt while receiving answers directly upon completion. The goal is to obtain honest responses in order to determine what material students generally understand, as well as where further clarification is needed. I can then tailor my pre-lab lecture to the responses to students' knowledge. If there is a concept that many students did not understand, I will cover it in greater detail during the pre-lab talk. This approach has led to more meaningful interactions in the lab, and students come to class with deeper, more focused questions.

Engaging students in lectures about lab safety and policy can be very difficult. This material can be boring and repetitive, but it is important to discuss. Instead of a traditional lecture explaining all the lab safety policies and procedures, I introduce the material in a Kahoot quiz (kahoot.com). I divide the lab class into teams of four and allow students to work together to answer multiple choice lab safety questions. The competitive nature of the Kahoot quiz engages students. Incorrect answers are revealed immediately and follow-up discussion ensures that everyone understands the safety policies and procedures of the lab. Proper pre-lab preparation also involves the necessary knowledge of working safely with chemicals. Previously, important lab safety documents like safety data sheets (SDS) were available for students to read in the lab on paper. Students would sort through a binder full of paper to find the relevant SDS. As a result, it was unlikely that students actually read these sheets. Now, all of our SDS pages are available online. Links to the database (SharePoint) containing the SDS files are provided through the course management software (Moodle). Moodle allows instructors to see which students have clicked on the files. If a student has not viewed the file,

grades for their pre-lab assignment will be deducted. Incorporating safety questions into pre-lab assignments and quizzes are a good way to ensure that safety procedures are understood. Students report, and instructor observations confirm, that students did not read the SDS when they were on paper in a binder in the lab. Now that SDS are easily accessed on-line students read the SDS before coming to the lab.

In their first-year, chemistry students arrive with a broad range of prior knowledge and training. Some students are skilled at problem solving or lab skills, while others may have little to no lab training. Videos have been a valuable tool to prepare students for the lab. If there is a challenging calculation to be done in the lab, I will prepare a video of a sample calculation. These are the same sample calculations that are worked out in the lab manuals. In the videos I narrate my thought process, describing how I approach the problem. I use Camtasia studio software to record and edit videos, as well as Screencast-O-Matic (free software), and upload the mp4 files to Vimeo or YouTube. Videos are provided with closed captioning or a written transcript. These videos have had the most positive impact on student learning; I have observed a significant improvement in student understanding. Students are able to carry out the calculations needed to be done in the lab. When these calculations were only provided in written format I noticed students had greater difficulty completing the same calculations. Students report to me by email and in-person that they enjoy the videos since they can re-watch them as many times as they like, and they can pause and research key words. This format is also efficient since I do not spend time in pre-lab lectures covering pre-requisite material that should be known from previous courses. With help from MSVU's digital media zone, I have made a few lab equipment videos, such as how to use a burette and setting up a distillation apparatus. I demonstrate the glassware and equipment needed and show how to set up and use the apparatus. These videos are filmed in the lab so that students can see the exact equipment they will be working with in a familiar setting. Students report feeling better prepared for the lab environment after viewing the equipment videos. This familiarization with equipment helps minimize lab anxiety by increasing students' self-efficacy. The use of videos is also well supported in published research as effective preparation for the experiment (Chaytor, Al Mughalaq, & Butler, 2017) and can lead to increased student performance in the lab (Stieff, Werner, Fink, Meador, 2018).

Student stress also comes from assessments. Unclear expectations and feelings of unfairness in grading can contribute to this stress. I now use grading rubrics for formal lab reports. I have created grading rubrics online using course management software (Moodle). The grading rubric provides students with the evaluation criteria, quality definitions, and a scoring strategy (Reddy & Andrade, 2010). The levels of performance are clearly defined with descriptions of what should be

demonstrated at each grade level. Students can view the rubrics ahead of time before submitting their report to reflect on their assignment and assess their work before handing it in. Expectations are clear and the process is transparent and consistent. Grading rubrics represent a large initial investment in time but the rewards are great. Rubrics allow instructors to think about what they value in their assessments, while grading is quick and objective. Students likewise benefit from the clear expectations provided at the outset and the feedback they receive on their assignments.

## UDL in the lab

UDL encourages using multiple means of representation so students can choose what method works best for their learning. In the lab, material is presented in in multiple modes, such as using video as described previously, written instruction in a lab manual, and in-lab demonstrations. Incorporating UDL benefits instructors and students. When students have individual accommodations for disabilities, the accommodations are often already addressed by incorporating aspects of UDL, saving time for the instructor by not having to prepare additional material. With UDL, all students have access to these additional materials and have the option of choosing what materials to use. I have only presented one principle of the UDL framework by incorporating multiple means of representation. There are three principles and nine UDL guidelines (CAST, 2018). Developing materials, resources, and assessments with UDL framework remains an area of future work to further support student learning.

## Conclusion

Minor changes to pre-lab instruction can enhance student preparation. When students are motivated to learn new material, they can deepen their lab learning and strengthen lab skills. For effective lab learning, students need to understand thoroughly the principles of the experiment before completing the lab. By providing preparatory materials to ensure appropriate knowledge for procedures and experiments for the lab environment, and facilitating cognitive thought processes for working out problems in sample videos, students can have a more meaningful lab experience. Concepts become relatable to students' existing knowledge, allowing for meaningful connections with material. Students can receive timely feedback on their understanding using prelab quizzes online. Treating prelab preparation as formative assessments can decrease anxiety and gives authentic feedback for the students. Following the report by Kurbanoglu and Akin (2010), to increase students' self-efficacy, lab anxiety should be decreased. Clear grade expectations with detailed rubrics, incorporating UDL, and having videos showing a familiar lab environment and

equipment are all effective ways to reduced lab anxiety and stress. Focusing on effective methods for student pre-laboratory preparation can lead to more meaningful learning.

## Acknowledgments

I would like to thank faculty in the Department of Chemistry and Physics for their helpful advice and support as I introduced new pre-lab activities in labs associated with their courses. Thanks also to members of the Mount's Teaching and Learning Centre and Online Learning for their advice, discussions and informative workshops, and the Mount's Digital Media Zone for filming and editing lab equipment videos.

## References

Ausubel, D. P. (1968). *Educational psychology: A cognitive view.* New York, NY: Holt, Rinehart, and Winston.

Bretz, S. L. (2001). Novak's theory of education: Human constructivism and meaningful learning. *Journal of Chemical Education, 78,* 1107. doi: 10.1021/ed078p1107.6

CAST (2018). *Universal Design for Learning Guidelines version 2.2.* Retrieved from http://udlguidelines.cast.org

Chaytor, J.L., Al Mughalaq, M., & Butler, H. (2017) Development and use of online prelaboratory activities in organic chemistry to improve students' laboratory experience. *Journal of Chemical Education, 94,* 859–866. doi: 10.1021/acs.jchemed.6b00850

Hall, T. E., Meyer, A., & Rose, D. H. (2012). *Universal Design for Learning in the classroom: Practical applications.* New York, NY: Guilford.

Hofstein, A., & Lunetta, V.N. (2003). The laboratory in science education: Foundations for the twenty-first century. *Science Education, 8,* 28–54. doi: 10.1002/sce.10106

Kurbanoglu, N.I. & Akin, A. (2010). The relationships between university students' chemistry laboratory anxiety, attitudes, and self-efficacy beliefs. *Australian Journal of Teacher Education, 35,* 48–59. doi: 10.14221/ajte.2010v35n8.4

Mayer, R.E. (2002). Rote versus meaningful learning. *Theory Into Practice, 41,* 226–232. doi: 10.1207/s15430421tip4104_4

Miller, D.K. & Lang, P.L. (2016). Using the Universal Design for Learning approach in science laboratories to minimize student stress. *Journal of Chemical Education, 93,* 1823–1828. doi: 10.1021/acs.jchemed.6b00108

Reddy, Y.M. Andrade, H. (2010). A review of rubric use in higher education. *Assessment &*

*Evaluation in Higher Education, 35,* 435–448. doi: 10.1080/02602930902862859

Reid, N., & Shah, I. (2007). The role of laboratory work in university chemistry. *Chemistry Education Research and Practice, 8,* 172–185. doi: 10.1039/B5RP90026C

Stieff, M., Werner, S.M., Fink, B., Meador, D. (2018) Online prelaboratory videos improve student performance in the general chemistry laboratory. *Journal of Chemical Education, 95,* 1260–1266. doi: 10.1021/acs.jchemed.8b00109

## Author

**Kelly Resmer.** Kelly is a laboratory instructor in the Department of Chemistry and Physics at Mount Saint Vincent University, Halifax NS. She teaches a range of chemistry labs from first-year general chemistry to third-year biochemistry. Kelly.resmer@msvu.ca