Editorial – Welcome to Volume 23, Issue 2

Special issue on assessing laboratory learning

Welcome to this special issue of IJISME in which we explore different ways to assess laboratory learning. Laboratories (and other practical activities, such as field trips) have a special role in science education because they allow students to learn, apply and connect different types of knowledge (factual, conceptual, procedural and practical) and provide both sensory and social experiences (Abraham, 2011; Abrahams, Reiss, & Sharpe, 2013; Bruck & Towns, 2013; Kirschner & Meester, 1988; Lazarowitz & Tamir, 1993; Reid & Shah, 2007). In practice, however, many laboratory programs – at both tertiary and secondary level – fail to live up to their educational potential (George et al., 2009; Hilosky, Sutman, & Schmuckler, 1998; Hofstein & Lunetta, 1982, 2004; Kirschner & Meester, 1988). Inadequate assessment methods have been identified as a major factor in this failure.

Recently, the landscape of laboratory learning in Australia and elsewhere has begun to change. At many institutions, conventional practical programs, too often characterised by repetitive, recipe-style exercises with poorly defined learning outcomes, are being re-worked into more engaging activities in line with pedagogical evidence. Often this involves investigative approaches in the form of guided-inquiry experiments (Gliddon & Rosengren, 2012; Gray et al., 2015; POGIL project, 2014; Pullen, Yates, & Dicinoski, 2014; Rayner, Charlton-Robba, Thompson, & Hughes, 2013; Suits, 2004; Walker, Sampson, & Zimmerman, 2011; Weaver, Russell, & Wink, 2008), problem- and case-based learning (Flynn & Biggs, 2012; Gallet, 1998; Grunwald & Hartman, 2010; Kelly & Finlayson, 2007; McDonnell, O'Connor, & Seery, 2007; Smith, 2012) or undergraduate research projects (Belanger, 2009; Dillner, Ferrante, Fitzgerald, & Schroeder, 2011; Iimoto & Frederick, 2011; Lexis & Julien, 2014). Alternatively, it has been shown that even small modifications to conventional practical exercises can make them more intellectually stimulating and more effective for achieving desired learning outcomes (Abbott, Saul, Parker, & Beichner, 2000; Johnstone & Al-Shuaili, 2001; McGarvey, 2004).

The question of how to assess learning in these practical formats has received less attention, even though assessment has a critical role in signalling to students where they should direct their efforts. Moreover, the learning goals typically include attributes such as problem-solving and critical thinking, which are more difficult to assess than conceptual knowledge or narrowly defined manipulative skills. Crucially, there is strong evidence that practical work requires a unique set of skills that cannot be adequately assessed by laboratory reports and other written formats (Abrahams et al., 2013; Gott & Duggan, 2002; Tamir, 1991). Performance-based and continuous assessment methods have been explored as alternatives (Gron, Bradley, McKenzie, Shinn, & Teague, 2013; Hunt, Koenders, & Gynnild, 2012).

The authors in this special issue have focussed on formative assessment innovations designed to guide and motivate students in their laboratory or fieldwork. The contributions span a range of disciplines, including physics, biology, ecology and chemistry, and feature inquiry-type activities as well as adaptations of conventional experiments. Video and other forms of technology have been explored as means to enhance the learning experience and expand the range of available assessment options.

Bourne, Dave and Kench describe the implementation of a remote MRI system. The technology they use allows students the benefit of genuine experimentation with equipment that is too fragile, dangerous and expensive to allow hands-on practicals. Students are assessed on their technical understanding of the experiments they conducted, but also on their ability to relate their results to the application of MRI in clinical settings. In addition, because this is real equipment and not a simulation, the practical encourages students to explore beyond the set experiments and to learn about measurement variation due to noise and drift of magnetic field. This paper provides valuable insight into using advanced technology in a way that is accessible to remote learners.

Tulloch and Spiller report on student teams producing an explanatory video as a small assessment item to improve microscopy skills for biology. Producing the videos increased competence with the microscope and also enhanced student learning through co-operation. Students were able to increase their marks by reviewing their own videos and identifying mistakes, which leads to better retention of key concepts as well as the development of critical thinking skills. This type of assessment item is easily implemented using new, accessible technology and can contribute to learning practical laboratory skills.

A completely different use of video is detailed by Devine, Gormley and Doyle, who used a wearable camera to produce an interactive video of a laboratory technique from the point of view of the experimenter. In a form of flipped laboratory, watching the video before class improved student preparation for their practical session. Inclusion of a multiple choice question during the video increased engagement, a technique that could be used for the assessment of laboratory skills in the future. Although only a pilot study, this process was shown to be relatively simple and reduces the cognitive load for students once they are in the laboratory using complex equipment.

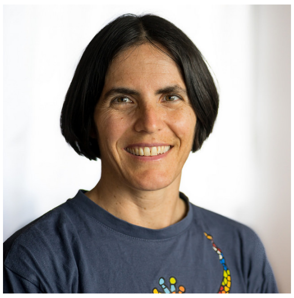
For ecology students, the natural environment is their laboratory. Kuchel, Wilson and Ellis have introduced a field trip for a very large ecology class. They detail how this works logistically and how the seamless integration of assessment tasks into the field trip activities enhances both learning and the student experience. At the core of the field day is an innovative ‘photo hunt’ assessment, in which student teams creatively find and document examples of species and ecological interactions. Fieldwork in a complex natural environment is vital for deep understanding of ecology and this paper shows that it can be achieved with over 500 students.

Kwan reports the introduction of very short (one page limit) lab reports for service physics laboratories, combined with an inquiry learning approach. This strategy did not require any change to a traditional laboratory manual. Instead, students were encouraged to use the manual as a starting point and investigate on their own when they came across an aspect that they did not understand. After collecting data, the students had to choose an argument for their report and provide data to support it in a suitable format but within the one page limit. The combination of open inquiry with feedback on writing improved student engagement and learning outcomes.

As another alternative to traditional lab reports, Lim describes the development and refinement of a self- and peer-assessment exercise. Based on a kitchen chemistry experiment that students perform at home, students receive their marks for the consistency of their self evaluation with peer evaluations of their report rather than for their report itself. Following this exercise, self evaluations are used in the following four (staff marked) laboratory reports. Lim reports an improvement in metacognitive self-evaluation skills as well as improvement in technical writing skills through this exercise.

Finally, Burgess, Yeung and Sharma report on the implementation of an introductory laboratory session for foundation chemistry students with no prior lab experience. The practical procedure was refined using the ASELL methodology (ASELL Project, 2015). In this study, the authors tested experimental competence and conceptual understanding using a formative oral assessment, which was conducted in the form of a dialogue between academic staff and student that encouraged students to critically self-assess their own level of proficiency. Evaluation using the ASELL Student Learning Experience survey showed highly positive student feedback.

We hope that you enjoy reading this special issue and that you may be inspired to modify your own laboratory assessment as a result. We thank our contributors and reviewers for their efforts.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References

Abbott, D. S., Saul, J. M., Parker, G. W., & Beichner, R. J. (2000). Can one lab make a difference? *American Journal of Physics, 68*(S1), S60-S61. doi:10.1119/1.19521

Abraham, M. R. (2011). What can be learned from laboratory activities? Revisiting 32 years of research. *Journal of Chemical Education, 88*, 1020-1025. doi:10.1021/ed100774d

Abrahams, I., Reiss, M. J., & Sharpe, R. M. (2013). The assessment of practical work in school science. *Studies in Science Education, 49*(2), 209-251. doi:10.1080/03057267.2013.858496

ASELL Project. (2015). Advancing Science By Enhancing Learning in the Laboratory. Retrieved from www.asell.org

Belanger, K. D. (2009). Using affinity chromatography to investigate novel protein-protein interactions in an undergraduate cell and molecular biology lab course. *CBE - Life Sciences Education, 8*(3), 214-225. doi:10.1187/cbe.09–03–0019

Bruck, A. D., & Towns, M. (2013). Development, implementation, and analysis of a national survey of faculty goals for undergraduate chemistry laboratory. *Journal of Chemical Education, 90*(6), 685-693. doi:10.1021/ed300371n

Dillner, D. K., Ferrante, R. F., Fitzgerald, J. P., & Schroeder, M. J. (2011). Integrated laboratories: Laying the foundation for undergraduate research experiences. *Journal of Chemical Education, 88*(12), 1623-1629. doi:10.1021/ed101180f

Flynn, A. B., & Biggs, R. (2012). The development and implementation of a problem-based learning format in a fourth-year undergraduate synthetic organic and medicinal chemistry laboratory course. *Journal of Chemical Education, 89*, 52-57. doi:10.1021/ed101041n

Gallet, C. (1998). Problem-solving teaching in the chemistry laboratory: Leaving the cooks. *Journal of Chemical Education, 75*(1), 72. doi:10.1021/ed075p72

George, A. V., Read, J. R., Barrie, S. C., Bucat, R. B., Buntine, M. A., Crisp, G. T., . . . Kable, S. H. (2009). What makes a good laboratory learning exercise? Student feedback from the ACELL project. In M. Gupta-Bhowon, S. Jhaumeer-Laulloo, H. Li Kam Wah, & P. Ramasami (Eds.), *Chemistry Education in the ICT Age* (pp. 363-376). Dordrecht: Springer.

Gliddon, C. M., & Rosengren, R. J. (2012). A laboratory course for teaching laboratory techniques, experimental design, statistical analysis, and peer review process to undergraduate science students. *Biochemistry and Molecular Biology Education, 40*(6), 364-371. doi:10.1002/bmb.20645

Gott, R., & Duggan, S. (2002). Problems with the assessment of performance in practical science: Which way now? *Cambridge Journal of Education, 32*(2), 183-201. doi:10.1080/03057640220147540

Gray, C., Price, C. W., Lee, C. T., Dewald, A. H., Cline, M. A., McAnany, C. E., . . . Mura, C. (2015). Known structure, unknown function: An inquiry-based undergraduate biochemistry laboratory course. *Biochemistry and Molecular Biology Education, 43*(4), 245-262. doi:10.1002/bmb.20873

Gron, L. U., Bradley, S. B., McKenzie, J. R., Shinn, S. E., & Teague, M. W. (2013). How to recognize success and failure: Practical assessment of an evolving, first-semester laboratory program using simple, outcome-based tools. *Journal of Chemical Education, 90*(6), 694-699. doi:10.1021/ed200523w

Grunwald, S., & Hartman, A. (2010). A case-based approach improves science students' experimental variable identification skills. *Journal of College Science Teaching, 39*(3), 28-33.

Hilosky, A., Sutman, F., & Schmuckler, J. (1998). Is laboratory based instruction in beginning college-level chemistry worth the effort and expense? *Journal of Chemical Education, 75*(1), 100. doi:10.1021/ed075p100

Hofstein, A., & Lunetta, V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research, 52*(2), 201-217. doi:10.3102/00346543052002201

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: foundations for the twenty-first century. *Science Education, 88*, 28-54. doi:10.1002/sce.10106

Hunt, L., Koenders, A., & Gynnild, V. (2012). Assessing practical laboratory skills in undergraduate molecular biology courses. *Assessment & Evaluation in Higher Education, 37*(7), 861-874. doi:10.1080/02602938.2011.576313

Iimoto, D. S., & Frederick, K. A. (2011). Incorporating student-designed research projects in the chemistry curriculum. *Journal of Chemical Education, 88*(8), 1069-1073. doi:10.1021/ed1011103

Johnstone, A. H., & Al-Shuaili, A. (2001). Learning in the laboratory: some thoughts from the literature. *Univ. Chem. Educ., 5*, 42.

Kelly, O., & Finlayson, O. E. (2007). Providing solutions through problem-based learning for the undergraduate 1st year chemistry laboratory. *Chemistry Education Research and Practice, 8*(3), 347-361. doi:10.1039/B7RP90009K

Kirschner, P. A., & Meester, M. A. M. (1988). The laboratory in higher science education: Problems, promises and objectives *Higher Education, 17*, 81-98.

Lazarowitz, R., & Tamir, P. (1993). Research on using laboratory instruction in science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 94-128). New York: Macmillan Publishing.

Lexis, L. A., & Julien, B. L. (2014). A model of investigative project work to teach discipline-specific research skills to students studying advanced human physiology. *International Journal of Innovation in Science and Mathematics Education, 22*(4), 15-32.

McDonnell, C., O'Connor, C., & Seery, M. K. (2007). Developing practical chemistry skills by means of student-driven problem based learning mini-projects. *Chemistry Education Research and Practice, 8*(2), 130-139. doi:10.1039/B6RP90026G

McGarvey, D. J. (2004). Experimenting with undergraduate practicals. *University Chemistry Education, 8*, 58-65.

POGIL project. (2014). POGIL - Process-oriented guided inquiry learning. Retrieved from https://pogil.org/

Pullen, R., Yates, B. F., & Dicinoski, G. W. (2014). A preliminary study: An evaluation and redevelopment of current first year laboratory practices. *International Journal of Innovation in Science and Mathematics Education, 22*(7), 23-34.

Rayner, G., Charlton-Robba, K., Thompson, C. D., & Hughes, T. (2013). Interdisciplinary collaboration to integrate inquiry-oriented learning in undergraduate science practicals. *International Journal of Innovation in Science and Mathematics Education, 21*(5), 1-11.

Reid, N., & Shah, I. (2007). The role of laboratory work in university chemistry. *Chemistry Education Research and Practice, 8*(2), 172-185. doi:10.1039/b5rp90026c

Smith, C. J. (2012). Improving the school-to-university transition: using a problem-based approach to teach practical skills whilst simultaneously developing students' independent study skills. *Chemistry Education Research and Practice, 13*(4), 490-499. doi:10.1039/C2RP20096A

Suits, J. P. (2004). Assessing investigative skill development in inquiry-based and traditional college science laboratory courses. *School Science and Mathematics, 104*(6), 248. doi:10.1111/j.1949-8594.2004.tb17996.x

Tamir, P. (1991). Evaluation of student laboratory work and its role in developing policy. In E. Hegarty-Hazel (Ed.), *The Student Laboratory and the Science Curriculum* (pp. 242-266). London: Routledge.

Walker, J. P., Sampson, V., & Zimmerman, C. O. (2011). Argument-driven inquiry: An introduction to a new instructional model for use in undergraduate chemistry labs. *Journal of Chemical Education, 88*(8), 1048-1056. doi:10.1021/ed100622h

Weaver, G. C., Russell, C. B., & Wink, D. J. (2008). Inquiry-based and research-based laboratory pedagogies in undergraduate science. *Nature Chemical Biology, 4*(10), 577-580. doi:10.1038/nchembio1008-577