Laboratory Education in New Zealand

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Laboratory work is one of the main forms of teaching used in chemistry, physics, biology and medicine. Studies carried out in the 1970s and 1980s showed that students did not enjoy this type of work, which is hardly surprising when one considers the effort (workload, commitment) and risks (chemical burns, poisoning, *etc*.) associated with it.[1] Since then, safety technology has been improved to a point where laboratory work is safe and, in principle, enjoyable. However, the technology of improving laboratory conditions came with significant increase in costs and effort to equip and maintain practical work areas, and as a result, raised questions regarding its necessity and viability. The NZ tertiary education budget is above average for OECD countries at 1.7% compared to 1.4% of GDP (Ireland 1.3 %; Finland and Sweden 1.7 %; Australia 1.5 %) specifically to address continuing skills shortages.[2] The GDP of New Zealand is approximately three quarters of that of other OECD countries, *e.g.* Finland and Ireland, and thus the actual amount of funding available for tertiary education is rather low. Furthermore, the market-driven nature of NZ universities and educational institutions places limitations on the willingness of financers and managers to approve comparatively costly forms of education.[3]

Doubts about education in laboratory environments are not just limited to managers and financiers; teachers, lecturers and students have discovered new technologies that can be applied at a fraction of the costs and effort of laboratory education.[4] The discussion about laboratories and other educational techniques is very opinionated, with many scientists arguing heatedly either in favour,[5] or against laboratory education.[6] Recently, the online journal *Chemistry Education Research and Practice* dedicated a special issue in 2007 to *Experiments and the Laboratory in Chemistry Education*,[7] and several of the articles discuss the history, development, and current standard in laboratory education with a focus on technique and procedures.

One question is often ignored in this context: What do *students* think about laboratory education? In 2006 Polles wrote a PhD thesis investigating student perspectives on chemistry teaching laboratories.[8] He found that students' experiences were strongly dependent on their learning environment and the stance of their teachers, lecturers, demonstrators, and technicians. This dependence raised questions for Polles about the validity of assessing student opinion. Many academics feel that students tend to give overly positive replies that do not adequately reflect their true opinions regarding different forms of education.[8]

Presented here are the results of a survey using independent indicators. Students were asked to comment on how a set of strategic aims formulated by Victoria University staff and management are realised in laboratory education (For the questions, see Appendix 1). The outcome was a good spread of results with the aims used as indicators appearing to be largely unconnected, meaning that the responses presented are statistically valid, thus alleviating the concerns academics usually have towards the collection of student opinion. The results are presented here to inform academics and researchers about the views of students regarding laboratory education and the effectiveness of this form of teaching of chemistry.

An Investigation of Students' Opinions Regarding Chemistry Laboratory Education

Based upon statements from Victoria University of Wellington's strategic plan, and conversations with the Dean of Science, lecturers in chemistry, and the School Head, a list of the seven most important joint strategic goals for the University and the School was collated. The goals are directly linked to generic, course-independent attributes, which a chemistry student at Victoria University should have or attain during study. The list was limited to seven items based on the importance attributed to the individual goals in the discussions. Between the selected seven items (and other items not included in this study) a perceivable step in importance was noticed. According to University and School guidelines, the goals assessed in this study should be realized in the teaching curriculum as provided, *e.g.* in the university calendar, course outlines, and reports.

The seven attributes thought to be the most important (in no particular order) are:

i. Confidence,
ii. Interest,
iii. Linking theory with observation,
iv. Critical thinking,
v. Scientific methods like analysis, observation and the deductions on observations,
vi. Leadership skills, and
vii. Practical skills

A questionnaire was formulated and distributed in chemistry lectures and laboratory classes to students at all levels (see Appendix 1). Ethical standards were strictly obeyed in the collection and handling of the questionnaire. Answers to the questionnaire were categorical to avoid confusion, with five categories given – the positive always being on the left-hand and the negative always being on the right hand side. Students were told that they could choose two categories to express that their answer lay between the categories given. Thus a total of nine categorical answers were possible for each question. For the evaluation of the answers, the five main and four intermediate categories were translated into a 9-point scale of numbers, ***5*** standing for most positive and ***1*** for most negative possible. After compilation of statistical data (calculation of means, errors, chi-tests, *etc*.) and construction of box plots, the numbers were transformed back into categories for interpretation of the results so calculated.

Return Rate and Survey Statistics

One of the issues facing any survey is whether it is representative. The population selected for the survey was all enrolled chemistry students. No sampling was undertaken, so representativeness is not an issue for this study. The survey was carried out close to the end of a trimester, a time when students are pre-occupied with exams, assignments and presentations; attendance levels in classes and response rates to questionnaires can be low. This was weighed against the higher level of experience that the students have accumulated by the stage of the course when the survey was undetaken. As experience of laboratory teaching is important for the purposes of this study, a lower response rate was accepted as a risk and, as expected, attendance levels had dropped (Table 1). However, even an attendance of 77.8 %, as at the 100-level (1st year students) is respectable. Thus the return rate of 72.8 % means that 56.6 % of all 100-level students enrolled in chemistry participated in this study. The values for 200-level students and 300-level students are even better: 86.1 % and 75.0 %, respectively. This means that a total of 65.6 % of all undergraduate students enrolled in chemistry at Victoria University participated in the study. A detailed examination of the survey statistics (statistical data and histograms comparing the distribution of results) is available upon request.

Table 1. Return rate

Level	No. Enrol	Distrubut-ed Surveys No. (%)	Returned Surveys No. (%)	Return Rate (%)
100	189	147 (77.8)	107 (72.8)	56.6
200	72	67 (93.1)	62 (92.5)	86.1
300	24	22 (91.7)	18 (81.8)	75.0

Opinions Regarding the Realization of Strategic Aims

Results in terms of the strategic aims are diverse (Fig. 1).[9] Aims for confidence, interest, linking theory with observation, and scientific method have been achieved well, with replies being between neutral and positive. Critical thinking is not realized as well as the other aims: opinion tending more towards a neutral position. It is likely that the relatively narrow knowledge base of the undergraduate student does not allow them sufficient opportunity to train themselves in the evaluation and discussion of concepts. Pending findings among postgraduate students, this might be an issue that should be discussed amongst, and remedied by, the academic staff and students. Leadership was the only strategic aim not fully realized in chemistry laboratories. The undergraduate laboratories leave little room for the students to take leadership roles. Owing to safety considerations, instructions, guidelines and requirements are precise and strict, especially for 100-level students, allowing little room for taking leading roles. Only at 300-level do students start to embark on self-guided, independent research and start to get involved in leading functions (outreach programs, providing guidance for first year students, chairing discussions, *etc*.). One other strategic aim is prominent – practical skills, which owing to the nature of laboratory courses is not surprising. Opinions regarding the acquisition of these skills are positive to very positive; the median lies above the positive category with a value around 4 (indicating a high degree of approval; the maximum value possible is 5).

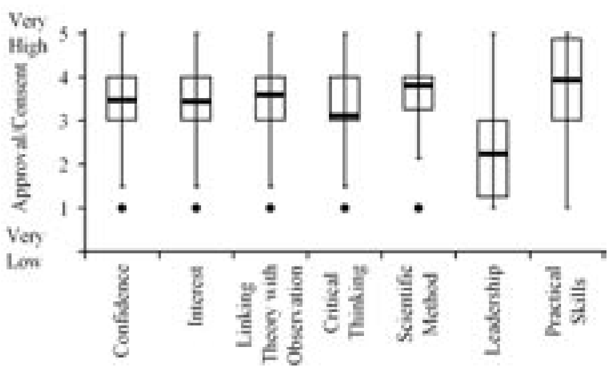

Fig. 1. Box plot showing the spread of opinions of 100-level students regarding laboratory education assessed by independent indicators. Key: Thick horizontal line – median; box – 2nd & 3rd quartile (middle 50 % of opinions); whiskers: spread between 1st & 4th quartile; dots outliers.

Several researchers have investigated the relation between laboratory work, lectures, and other teaching techniques.[4] DiBase and Polles both came to the conclusion that a good alignment between the different forms of teaching needs to be achieved for maximum effectiveness.[8,10] DiBase and Deters have both suggested strategies for how this may be achieved.[10,11] The effectiveness of the link between the different teaching techniques, lectures and laboratories at Victoria University was represented in the ranking of the corresponding question (see Fig. 1) and in the free-form part of the questionnaires, where 31.3 % of the students stated that laboratories helped them understand concepts. Further positive points mentioned by approximately a quarter of the students were visual learning (22.9 %) and the acquisition of practical skills (27.7 %). The only negative remarks were comments on the high workload and the time required were stated by a significant number of students (28.2 %). In general only 33.2 % of all participating students used the free-form questions.

The raw data have been submitted to Chi-square tests to see if group (other than level) specific trends would be noticeable by correlation of the replies to demographic data collected at the beginning of the survey. The result was overwhelmingly negative, with the error in the Chi-square test being unacceptably high (22 %). This means that no statistical significance for differences between any of the demographical groups has been observed.

The spread of results includes negative as well as positive opinion. Nonetheless, the overall trend is quite positive, with student opinion being quite favourable towards laboratory education.

The Development of Opinion through the Levels

Student opinions, regarding the alignment between laboratory education and strategic aims, improve as students advance through their undergraduate career. While there is a noticeable improvement in opinion between 100- and 200-level (Fig 2), the opinions expressed by 300-level students are very positive (Fig. 3). Generally the spread of opinions becomes narrower over the years, which could indicate that the students' perception and understanding of the strategic aims become clearer and more refined. If this is the case, the results concerning leadership and critical thinking might be due to a lack of student understanding of these concepts. Victoria University has a policy of research-led teaching in line with good teaching practice as formulated by Vallarino, Polo, and Esperdy.[12] At 300-level the students become involved in independent three-week research projects. Here almost all opinion is in the range between positive and very positive. Only the opinions regarding the realisation of critical thinking and leadership in laboratory education remain lower than the rest, but even they are improved, with critical thinking tending towards a positive rating and the opinions regarding leadership being expressed relatively evenly around the neutral mark.

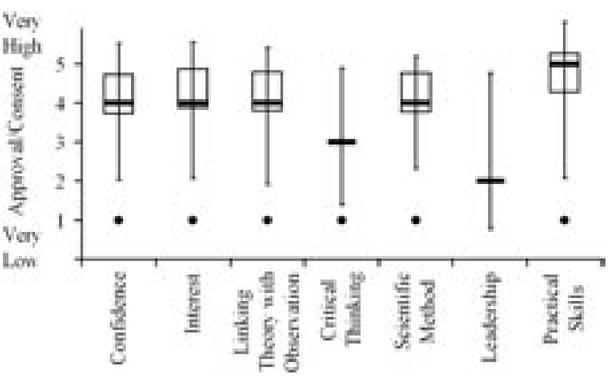

Fig. 2. Box plot showing spread of opinions of 200-level students regarding laboratory education assessed by independent indicators. (Key as for Fig. 1)

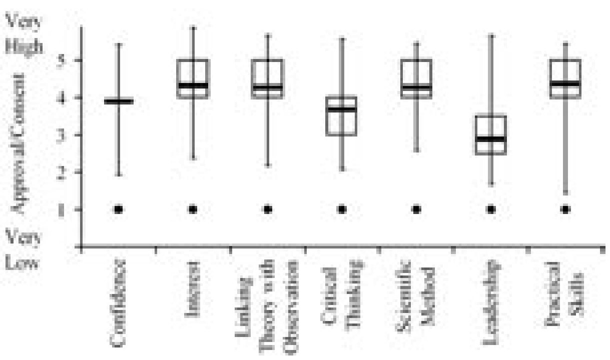

Fig. 3. Box plot showing spread of opinions of 300-level students regarding laboratory education assessed by independent indicators. (Key as for Fig. 1)

Seeing the improvement in opinion as the student advances through the levels leaves one question to be answered: Did student opinion improve or did the students with negative and neutral opinions move to other subject areas? A short follow-up survey of a sample of students indicated that over 95 % of the students' opinions improved as they progressed through the levels. This follow-up study included students moving to other subject areas; of the seventy-two 200-level students surveyed initially 52 (72.2 %) were included and replied to the follow-up study. Of these 52 students 38 were still pursuing a chemistry degree at Victoria University. The students commented that this improvement in opinion is due to better linkages between lectures and laboratories at 300-level than at the lower levels.

Laboratory Education Is Indispensable

Chemistry students appear to value highly laboratory education. As they progress through the levels, the linkages between lecture and laboratory materials increases and the appreciation of students for laboratory education grows as well. Several strategic aims, especially those regarding confidence, interest, linking theory with observation, scientific method and practical skills have been achieved quite well, with replies ranging between neutral and positive. Critical thinking and leadership are not realised well and laboratory personnel and academics should consider how to improve laboratory education in this regard.[5] Lectures and other forms of teaching and learning usually achieve better results in regards to critical thinking, but fall short in terms of inspiring confidence, interest, and linking theory with observation. In light of the achievements of laboratory education, and the way it complements other forms of education, it remains important to keep it despite the (sometimes) high costs involved. Student opinion certainly appears to places a value on it, and teachers and academics are wise to consider the opinions of their students.

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Appendix 1. Questions from the survey

1. Please circle the most appropriate answer(s) for each question below

a) Are you currently enrolled in a chemistry *laboratory course*? Yes No

b) Are you currently enrolled in a chemistry lecture course? Yes No

c) How many university chemistry *lab courses* have you completed before this course?

0 1 2 3 4 or more

d) Are you currently taking part in chemistry *lab research project*? Yes No

e) What is your gender? Female Male

f) Your residency status?
NZ Citizen/Resident International Student

g) What is your current status at VUW?
__1st year undergraduate; __ 2nd year undergraduate;
__ 3rd year undergraduate; __ 4th year undergraduate;
__ postgraduate (MSc); __ postgraduate (PhD)

In response to each statement below, please circle the option(s) that most closely represent your views. Circle two responses to indicate an answer in between categories:

2. For me, to learn to understand and do chemistry well, *laboratory courses* are:

Absolutely necessary	Necessary	Very helpful, but not necessary	Somewhat helpful, but not necessary	Absolutely unnecessary

3. Considering the time and effort I have invested in chemistry *laboratory course(s)* overall, I would describe the value of what I have learned as

Very high	More than adequate	Adequate	Less than adequate	Very low

4. The contribution of *laboratory courses* to my achievements and progress in chemistry, is

Very high	More than adequate	Adequate	Less than adequate	Very low

5. *Laboratory work* has advanced my understanding of key concepts in chemistry:

A great deal	Quite a lot	Somewhat	Not much	Not at all

Chemistry *laboratory courses* are designed and taught to help you achieve specific learning outcomes. Please rate how well they have achieved those outcomes by circling the response that most closely represents your views:

6. *Laboratory work* has improved my confidence in performing well in chemistry

A great deal	Quite a lot	Somewhat	Not much	Not at all

7. *Laboratory work* has stimulated my interest in learning/doing more chemistry

A great deal	Quite a lot	Somewhat	Not much	Not at all

8. *Laboratory work* has helped me to link theory with observation

A great deal	Quite a lot	Somewhat	Not much	Not at all

9. *Laboratory work* has developed my ability to think critically

A great deal	Quite a lot	Somewhat	Not much	Not at all

10. *Laboratory work* has introduced me to scientific methods like analysis, observation and the deduction of results based on observations

A great deal	Quite a lot	Somewhat	Not much	Not at all

11. *Laboratory work* has helped me develop leadership skills

A great deal	Quite a lot	Somewhat	Not much	Not at all

12. *Laboratory work* has taught me valuable practical skills

A great deal	Quite a lot	Somewhat	Not much	Not at all

13. Please share 3-4 specific comments on the ways chemistry *Laboratory work* has helped you learn.
14. Please share 3-4 specific comments on the ways chemistry *Laboratory work* has hindered or interfered with your learning.
15. Please share 3-4 specific, practical suggestions for improving chemistry *laboratory courses*.
16. Other comments?