EVIDENCING LEARNING STANDARDS IN SCIENCE: GRADUATE PERCEPTIONS OF GAINING KNOWLEDGE AND SKILLS AT TWO RESEARCH-INTENSIVE UNIVERSITIES

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ABSTRACT
There is a move in higher education institutions in Australia, and internationally, towards the statement of learning outcomes to focus curriculum and allow for accountability of degree programs. Whilst Australian institutions have listed broad, university-wide graduate attributes/capabilities/qualities, science-specific learning outcomes and standards have only more recently been discussed and identified at the national level. The challenge of evaluating program level, science-specific learning outcomes, such as teamwork, communication, writing and quantitative skills along with scientific content knowledge, has emerged. This paper is reporting on a cross-institutional study, which aimed to evaluate student perceptions of learning outcomes gained during undergraduate studies in Biomedical Science at two research-intensive Australian universities using the Science Student Skills Inventory. The results indicate that students gained content knowledge along with writing, communication and team-work skills at equal levels with no statistically significant differences across the two university cohorts. The exception was student's low perception of building quantitative skills, which differed significantly across the cohorts. The findings suggest that quantitative skills are an area needing further attention. Implications for evaluating program-level learning outcomes framed within the quality assurance versus quality enhancement national policy debate are discussed, along with directions for further research.

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SCIENCE CURRICULUM IN HIGHER EDUCATION
There is a move in higher education institutions in Australia, and internationally, towards the statement of learning outcomes to improve curriculum and accountability for degree programs. The dynamic nature of modern science requires responsive and equally dynamic curricular models to ensure that science graduates are prepared for the needs of the larger world of science. However, evidence suggests that science programs have typically remained static, emphasising content at the expense of students learning skills needed to apply content knowledge (American Association for the Advancement of Science [AAAS], 1989; Bransford, Brown, Cocking, & National Research Council Committee on Developments in the Science of Learning, 1999; NRC, 2003; Wieman, 2007; Wood, 2009). Large research intensive universities are often the most resistant to educational change even in the face of educational research that highlights the overwhelming benefits of curricular reforms (Wieman, Perkins, & Gilbert, 2010; Anderson Banerjee, Drennan, Elgin, Handlsman, Hatfull, Losick, O'dowd, Olivera, Strobel, Walker, & Warner, 2011).

LEARNING OUTCOMES IN SCIENCE
The Australian Government (through the Australian Learning and Teaching Council and Department of Education, Employment and Workplace Relations) has funded two projects that stand to influence how skills and knowledge are considered, implemented and evaluated in Science degree programs. These include the *Learning and Teaching Academic Standards* (LTAS) and the *Quantitative Skills (QS) in Science* projects. The *LTAS* project has identified a set of threshold learning outcomes that can be applied to students graduating from an Australian University Bachelor Science program. To date, the project has consulted broadly and has generated a statement of threshold learning outcomes categorised into four areas. Implicit in the statements are several skills including teamwork, oral and written communication, and quantitative skills (QS) (http://www.altc.edu.au/standards/disciplines/science). The *QS in Science* project aims to identify innovative curriculum models, which reflect the interdisciplinary and quantitative nature of modern science with the intention of sharing effective practices in building QS into undergraduate science curricula (www.qsinscience.com.au). As new approaches are implemented to achieve the desired learning

outcomes like QS, teamwork skills and communication skills, the challenge of evaluating the effectiveness of these efforts is emerging. Indeed, the *LTAS* project report for Science suggests several areas for further research and scholarship, including 'ideas for assessment', 'example of teaching materials' and 'curriculum implementation from a student perspective' (http://www.altc.edu.au/system/files/LTAS_Science_June_2011_Newsletter.pdf). Indeed, the changing policy landscape in Australia will require evidence of learning standards at a generic and discipline level (http://www.deewr.gov.au/HigherEducation/Policy/teqsa/Documents/Teaching_Learning_Discussion_Paper.pdf).

STUDENT PERCEPTIONS OF THEIR LEARNING OUTCOMES

Student surveys can provide quick, low-cost and meaningful information about the acquisition of knowledge and skills which can be used to inform curriculum development. However, there are some limitations of student surveys. A recent study conducted by Bowman (2011) in the USA with over 1000 students found little correlation between student's self-reported perceptions of their learning gains to their actual learning gains. Although this study highlights the limitations of using surveys as a direct measure of student learning gains, it does not suggest that student survey data should be disregarded, as student's graduate holding perceptions, attitudes and beliefs which they believe to be true (Bowman, 2011). In efforts to determine the effectiveness of curriculum reform, multiple sources of data, self-reporting and performance-based, would seem preferable in measuring what students can do and what they think they can do (Harris, Driscoll, Lewis, Matthews, Russell, & Cumming, 2010).

RESEARCH DESIGN

The current study evolved from a desire to obtain data from graduating students that can inform on-going curriculum development at the program level while also being useful to the accountability agenda. The study of two Biomedical Science programs at two universities aims to explore the following questions:

1. What skills and knowledge do students believe they gained from their undergraduate studies?
2. What skills do graduating students believe they will be using in their future professions?
3. How do student responses compare across the two Australian institutions?

Context is crucial in educational research when drawing conclusions and making wider generalisations (Gibbs, 2010). As such, a description of the educational context is provided. Both universities are large, research-intensive institutions in Australia, with over 40,000 students drawn from more than 100 countries across both undergraduate and post-graduate programs. Both universities are in the Group of Eight (Go8) coalition of leading Australian universities in terms of research income.

At the University of Queensland (UQ), the Bachelor of Biomedical Sciences was introduced in 2008 with a structured science curriculum consisting of 14 required core courses including a requirement to complete an undergraduate research project course, a research project-based 3rd year capstone course, and a compulsory honours 4th year. The program sits within the Faculty of Science, which is separate from the Faculty of Health Sciences, and has a focus on training future biomedical science researchers. Information of the degree program is available at http://www.uq.edu.au/study/science/studyplanners/index.html?page=91218. Applicants are required to have completed high school level English and Mathematics (study of functions, sequences and series, an introduction to calculus, and probability and statistics), along with either Chemistry or Physics. The objectives of the UQ program are not explicitly stated online but were established when the program was developed and are introduced to students during orientation week. They include statements about (1) gaining broad knowledge in biomedical science and (2) in-depth scientific content knowledge in one specialised field, (3) building scientific research skills including quantitative skills, written and oral communication and teamwork, and (4) awareness of bioethical issues.

Like UQ, the Monash Bachelor of Biomedical Science is a separate integrated program of 14 core courses incorporating a research experience in the final 3rd year capstone course. The Monash program, housed within the Faculty of Nursing, Medicine and Health, has been running since 1999 with information on the program structure at http://www.monash.edu.au/pubs/handbooks/courses/2230.html. Applicants are required to have completed high school level English and Chemistry, along with either Mathematics or Physics. Monash explicitly states 10 learning objectives of the program online. These including (1) gaining biomedical knowledge base, (2) written and oral communication skills and analytic procedures, (3) preparation for career in health care and related industries and (4) further vocational or postgraduate studies, (5) complete a flexible program (6) having received training relevant to health care industries (7) where by students can relate biomedical science to other areas of learning, (8) gained skills in information technology and (9) exposure to advances in biomedical research, and (10) appreciate bioethical issues. Whilst the structure of the two curricular are similar in terms of numbers of core courses, the Monash program has a broader focus in the health care professions while the UQ focus is on preparing future biomedical researchers.

DATA COLLECTION

The study employed the Science Student Skills Inventory (SSSI), a survey developed in 2008 from a study at UQ (Matthews, 2010) that was originally modelled on the Student Assessment of Learning Gains (Seymour, Wiese, Hunter, & Daffinrud, 2000). The SSSI collects information on graduating science students' perceptions of their learning outcomes, demographic data, disciplinary identities in science and mathematics, and post-graduation plans. As part of the survey, students were asked to rate the extent to which their studies in the science degree program had contributed to the development of five specific areas (teamwork skills, QS, communication skills, writing skills and content knowledge) across four indicators (importance, confidence, improvement and inclusion in the curriculum).

Data were collected from Bachelor of Biomedical Science students from UQ and Monash. The survey was administered online via SurveyMonkey in semester 2 of 2010 of the 3rd year, prior to entry into honours. Students were emailed a survey link along with the study information sheet. At UQ, an incentive of a $20 voucher was offered for completion of three evaluation items, of which this was one. At Monash, the incentive was inclusion in a draw to win one of three vouchers valued at $50. The use of an incentive to encourage students to complete online surveys is common practice (Berk, 2006) and was not viewed by the authors as a factor causing bias in student responses.

The study was approved through the human ethics committee at both UQ (approval no 2010000571) and Monash (approval no CF10/2804 2010001446).

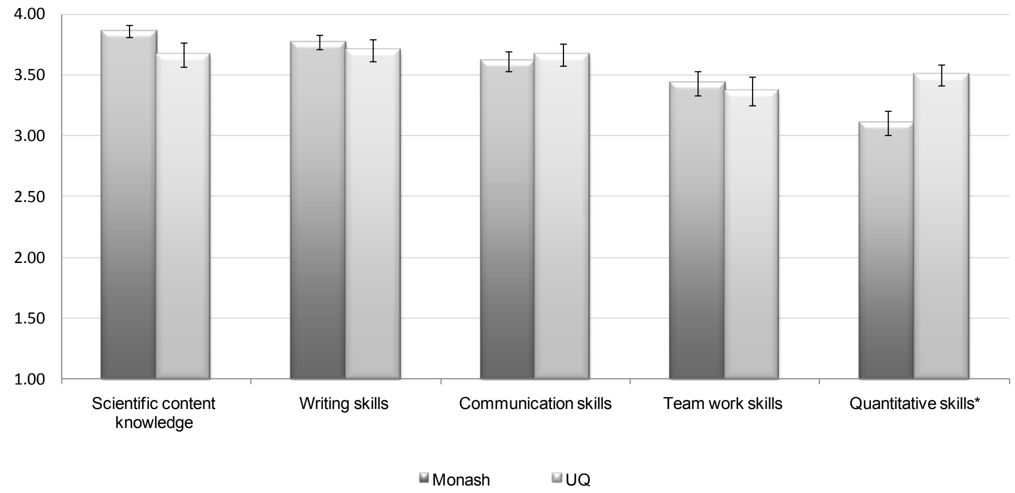
STUDY PARTICIPANTS

Final year Bachelor of Biomedical Science degree students were identified at each university via enrolment in the 3rd year compulsory capstone courses. At UQ, 50 students were identified with 33 completing the survey (66% response rate). At Monash, 155 students were identified with 62 completing the survey for a 40% response rate. The demographic characteristics of the respondents from the two university cohorts in terms of gender and age were also collected.

RESULTS

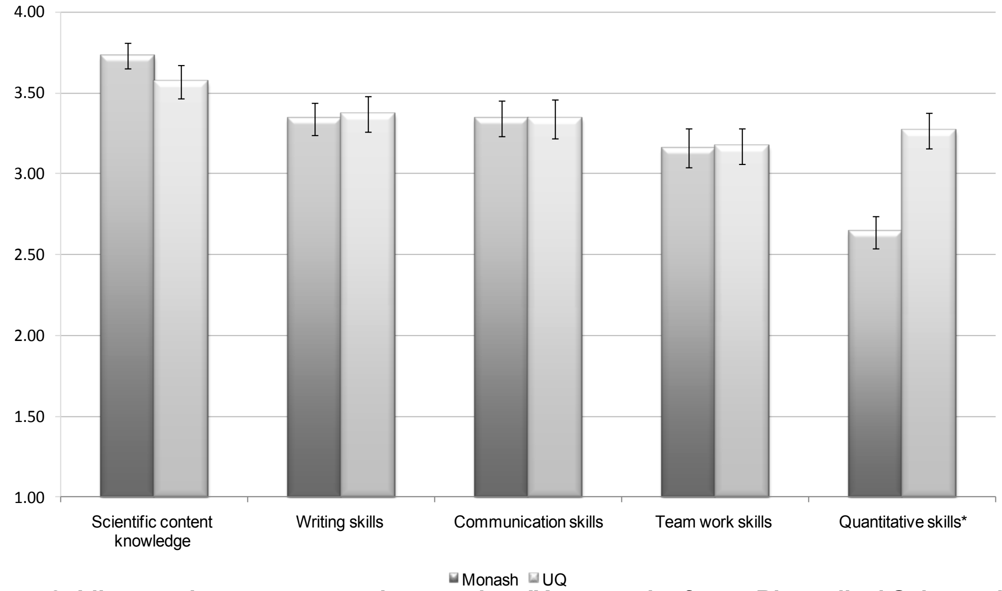
All statistical analysis was completed using Stata version 11. Missing data were not an issue as the survey was administered online using a function that required students to answer the question before being able to submit the survey although respondents who partially completed the survey were deleted for the purpose of analysis, leaving 75 cases. Each participant was asked to consent for their data to be used in the study; one student declined consent (from Monash) and was removed from the survey analysis, leaving 74 cases. Demographic data were examined separately for Monash (n=44) and UQ (n=30) using two-tailed t-tests to assess differences in means to a 0.01 threshold for statistical significance. Examination of difference by gender and age revealed no statistical differences across the two university cohorts, suggesting similarities amongst the two cohorts, reducing the influence of age and gender as confounding variables.

Figures 1-4 display the results by item across the importance, inclusion, improvement and confidence indicators for five specific areas, displaying mean and standard error, on a 4-point Likert scale with “1” being the lowest level of agreement and “4’ being the highest. The findings reveal little difference across how the two university cohorts responded with the exception of QS. Examining differences to a 0.01 threshold, QS across the importance, inclusion and improvement indicators are the only statistically significant differences with UQ students indicating higher levels across the three indicators. The QS confidence indicator showed no statistical significant difference across the two cohorts.



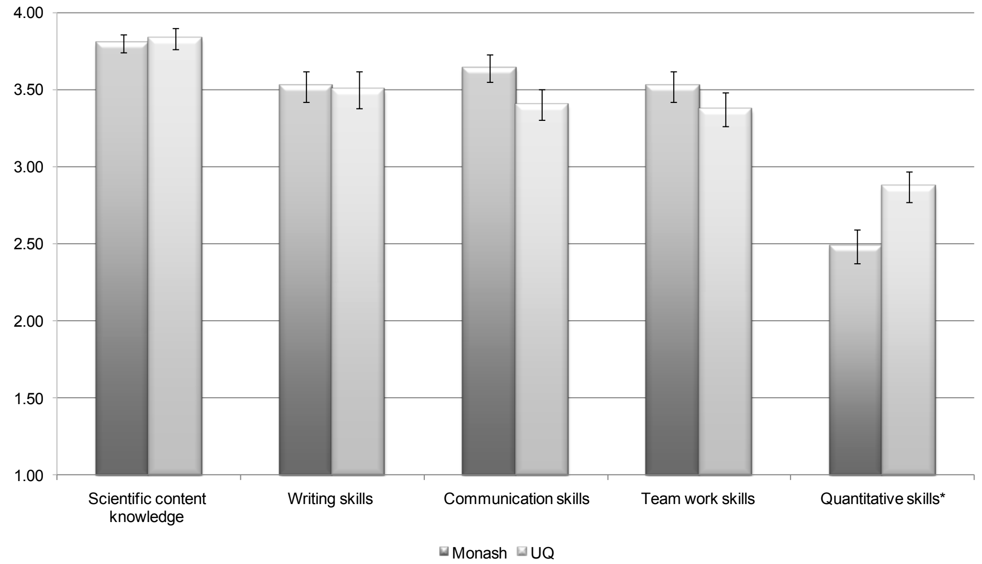
* Statistically significant to ≤ 0.01

Figure 1: Likert scale responses to the question, "How IMPORTANT is it to have activities that develop the following in the Biomedical Science degree program?"



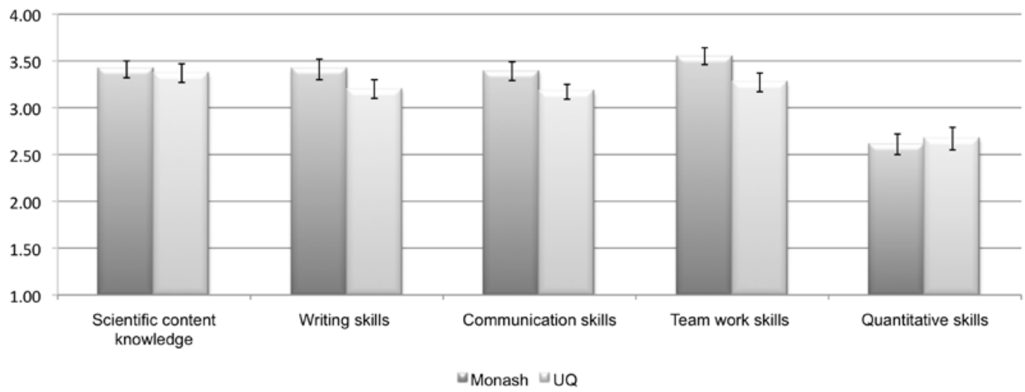
*Statistically significant to ≤ 0.01

Figure 2: Likert scale responses to the question, "As a result of your Biomedical Science degree program, please indicate the level of IMPROVEMENT you made in the following?"



*Statistically significant to ≤ 0.01

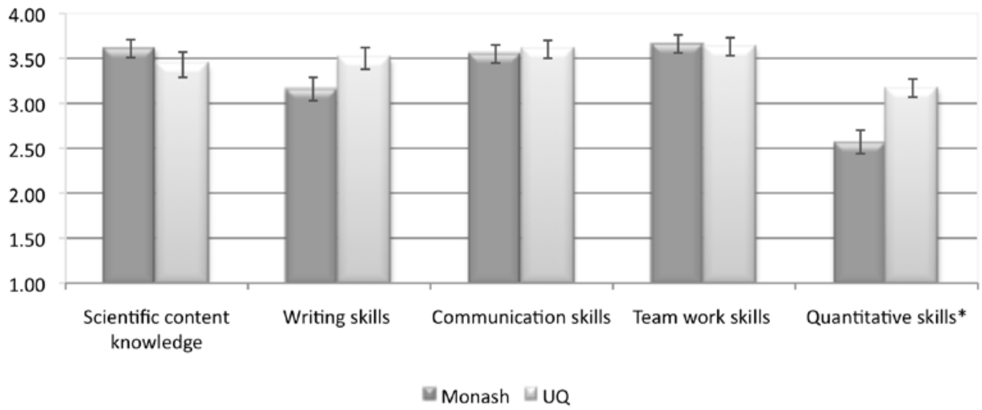
Figure 3: Likert scale responses to the question, "To what extent were activities to develop the following INCLUDED in your Biomedical Science degree program?"



* Statistically significant to < 0.01

Figure 4: Likert scale responses to the question, "To what extent do you feel CONFIDENT in the following as a result of your Biomedical Science degree program?"

Finally, respondents were asked to indicate how much they believed they would be using their skills and content knowledge in five years time. Figure 5 displays the results, again revealing no statistically significant differences across the two university cohorts with the exception of QS.



* Statistically significant to < 0.01

Figure 5: Likert scale responses to the question, "Five years after you graduate from your Biomedical Science undergraduate degree program, how much do you think you will be using your...?"

DISCUSSION

The study was designed to explore biomedical science students' perceptions of their learning outcomes and to benchmark these beliefs across two university cohorts. This initial study was conducted as a starting point to gather evaluation data at a program level that may be used to inform curricular decisions around learning outcomes. Comparisons across the five areas (content knowledge, writing, communication, teamwork and QS) on the four indicators (importance, inclusion, improvement and confidence) along with the perception of use in five years revealed students value content knowledge and skill acquisition. Whilst many claims have been made that current science curricula are content-driven and focused (AAAS, 1989; Bransford et al., 1999; NRC, 2003; Wieman, 2007; Wood, 2009), this data appears to be evidence of the contrary. In the case of these two universities the data indicates that from the perspective of graduating Biomedical Science students, skills acquired are just as important as the knowledge acquired and that they have opportunities within the degree program to gain content knowledge and build skills.

Across both universities, students reported lower perceptions across all the indicators (importance, inclusion, improvement and confidence) for QS. The data supports numerous reports which have highlighted the deficiency in science student's QS (NRC, 2003; Bialek & Bostein, 2004; AAAS, 2010; AAMC Report, 2009). However, the data does show differences amongst UQ and Monash, which should be interpreted in light of the stated learning outcomes for the two programs. At UQ, building QS in science was a major focus on a recent curriculum review and QS was seen as essential for students in the Biomedical Sciences program with specific curricular innovations established to build

QS (Matthews, Adams, & Goos, 2009; 2010). This is in contrast to Monash, where curricular reforms have not focused on QS. However, UQ students reporting of increased importance, inclusion in the curriculum and improvement did not result in increased confidence. It appears the changes to the curriculum were apparent to students but did not lead to increased confidence when compared to Monash students. This anomaly highlights the complexity of building QS in undergraduate science programs. The low rating of QS at both institutions is a concern deserving sector wide attention to develop effective approaches to developing QS in Biomedical Science, particularly given the statements of learning outcomes from the LTAS project, where QS underpin many of the outcomes.

The study reveals the perceptions of graduating biomedical science students, and makes no claims of a correlation to actual student learning outcomes. Indeed, research by Bowman et al (2011) shows that students' perceptions are not necessarily predictors of their actual learning outcomes, although this does not diminish the value of understanding what students think. This study provides Biomedical Science-specific evidence of student perceptions that has been used to inform on-going curricular reform efforts at both institutions.

The importance of gathering meaningful, discipline-specific data at the program level cannot be under-estimated. Programs that lack external accreditation as a driving force for the articulation and evidencing of learning outcomes will need to look to national professional discipline bodies for debates and consensus about graduate skills and standards. In the Biomedical Sciences, the Australian Academy of Science's National Committee for the Biomedical Sciences and the recently formed Collaborative University Biomedical Education Network (CUBENET) are well positioned to play a major role alongside the newly formed TESQA (the Tertiary Education and Standards Quality Agency). Biomedical Sciences currently have no practices, procedures or examples in place to demonstrate how program-level, discipline-specific data can be used to satisfy quality assurance or quality enhancement purposes.

CONCLUSION

The sector will continue to move towards stated program-level learning outcomes and assessment of outcomes, as such applied research is needed to guide the process in the sciences. Given the changing national policy landscape, the need is urgent. Ideally, evidence will come from multiple sources with student performance and perception data as an important source, as they are the intended beneficiaries of curriculum reform efforts (Levin, 2000). Further research areas aimed at the program-level that could benefit the sector include: How do perceived learning outcomes compare to actual learning outcomes? How can curriculum be developed that allows for the alignment of perceived and actual student learning outcomes?

Ultimately, our goal for program-level evaluation should be to gather meaningful evidence that informs on-going curricular reform (quality enhancement), and satisfies accountability requirements (quality assurance), with the aim to graduate students who know what they know, and know what they don't know.

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