The Science Students Skills Inventory: Capturing Graduate Perceptions of Their Learning Outcomes

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Abstract

Within the context of changing government policies demanding accountability and a desire for science curricular leaders to draw on evidence to inform on-going curricular reform efforts, we report on an Australian cross-institutional benchmarking study of graduates' perception of their learning gains across the whole of their degree program. The study utilises a purpose-built instrument, the Science Students Skills Inventory (SSSI), which we suggest is one tool for evidencing the obtainment of the recently articulated national Learning Threshold Outcomes in Science. The results indicate that students gained content knowledge along with writing, oral 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 benefits, limitations and scope of the SSSI as one tool for evidencing learning outcomes are discussed. Implications are presented for evaluating program-level learning outcomes framed within the quality assurance versus quality enhancement national policy debate, along with directions for further research.

Introduction

The Australian higher education sector is facing increasing demands from government policy-makers to articulate the value of an undergraduate degree qualification. The Australian Qualifications Framework (AQF) has adopted a taxonomic approach to enable consistency and clarity about differences and relationships between qualification types in the tertiary education sector. The AQF levels are defined by criteria expressed as learning outcomes and serve to identify the complexity and depth of achievement graduates are required to demonstrate. Universities are required to express the learning outcomes for the degree programs they offer and to provide evidence of student achievement for those stated learning outcomes. Essentially three questions are beginning asked: *what are students learning from your degree program?; how do you know?*; and *how are your learning outcomes aligned with national and international quality standards?* These new government policies are shifting the focus towards the 'whole experience' of the entire undergraduate curriculum. Along with policy implications for accountability, science undergraduate education has seen a reform movement calling for actions to shift from content-heavy curricular approaches to more evidence-based practices, which enhance student engagement, and learning. The question arises, how can the Australian science higher education community gather evidence of student learning that satisfies accountability requirements at the national level *and* offers meaningful data to enhance curriculum at the local level?

Within the context of changing government policies demanding accountability, and a desire for science curricular leaders to draw on evidence to inform on-going curricular reform efforts, we report on an Australian cross-institutional benchmarking study of graduates' perception of their learning gains across the whole of their degree program. The study utilises a purpose-built instrument, the Science Students Skills Inventory (SSSI) and expands on work presented at the Australian Conference on Science and Mathematics Education (ASCME) and published in the conference proceedings (Matthews and Hodgson, 2011). Focusing on quality enhancement and policy issues emerging in Australia, this paper elaborates on the development of the SSSI and its use as a tool for evidencing science specific learning outcomes at the level of the degree program. The conference paper highlighted the outcomes from the study and only hinted at the policy implications with little discussion of the survey instrument. The aims of the paper are to

- link the statements of the science learning outcomes generated from the national *Learning and Teaching Academic Standards* project with the SSSI as one tool for evidencing these outcomes;
- interpret and discuss data collected via the SSSI from two universities; and
- to publish the SSSI as a means to further research and debate at the 'whole experience' level of the undergraduate science curriculum.

Science undergraduate education

The desire to enhance science undergraduate education extends beyond government accountability policies. The larger issue of attracting, engaging and preparing future scientists, a quality enhancement issue, is of concern for universities and science academic staff. Indeed, science curricular reform efforts have been generously funded by government organisations, such as the National Science Foundation in the United States, and the Higher Education Academy in the United Kingdom. However, much of the project-based efforts have proven ineffective in creating persistent change at the classroom level or in creating a research-base for science higher education (Dancy & Henderson, 2008; Grove, 2012). In Australia, project based government funding has also had little up-take or impact beyond the project team (Gannaway & Hinton, 2011). The new government policies shifting towards a whole of program focus provide opportunities that may to lead to persistent change. Briefly, a reminder of the larger global landscape driving reform efforts is presented followed by a specific discussion of the Australian context.

Considering the changing nature of science and the static nature of science education

The dynamic nature of modern science requires responsive and equally dynamic curricular models to ensure that science graduates are well prepared for the needs of the modern workforce and larger world of science. Evidence, however, suggests that science programs have typically remained static, emphasising the learning of content at the expense of learning the skills which are require to apply that content knowledge (American Association for the Advancement of Science [AAAS], 1989; Bransford, Brown & Cocking 1999; National Research Council [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 in the context of science (Wieman, Perkins & Gilbert, 2010; Anderson, Banerjee, Drennan, Elgin, Handelsman, Hatfull, Losick, O'dowd, Olivera, Strobel, Walker & Warner, 2011).

Considering societal need for more science graduates and student disillusionment with science education

The changing nature of society has given rise to calls for more science and mathematics graduates globally. The trends of science and mathematics enrolments in Australia, the USA and UK run counter to the 'calls' for more students in this area (Ainley, Kos & Nicholar, 2008). Research into undergraduate science education paints a picture of a curriculum that is content-driven with didactic lectures and recipe based laboratory classes that are disconnected from (1) the actuality of being a scientist and (2) the daily lives, experiences and motivations of students (Seymour & Hewitt, 1997; Tobais, 1990 & 1992; NRC, 2003; Rice, Thomas & O'Toole, 2009; Smith & Cooke, 2011). A plethora of funding with limited success has been dedicated to reversing the declining enrolments in science and improving the science undergraduate experience.

Curriculum and learning outcomes

The current situation in Australia of changing government policies has sparked debate and activity around the whole of the science undergraduate curriculum nationally. The Australian Government in 2010-11 (through the Australian Learning and Teaching Council and Department of Education, Employment and Workplace Relations) funded the *Learning and Teaching Academic Standards* (*LTAS*) project in which disciplinary leaders across the sector were consulted to identify a set of threshold learning outcomes that could be applied to students graduating from any Australian University Bachelors program. In 2011, the project generated a statement of threshold learning outcomes for students graduating with a qualification in science. Following an extensive consultation period with science academics across the sector, the Science Threshold Learning Outcomes were endorsed by the Australian Council of the Deans of Science, and thus reflect the learning valued by the scientific community. The *LTAS* project had a limited scope, simply stating discipline specific learning outcomes that resulted from a community consensus, a critical initial step in gaining national focus for the science sector.

> *The Science Threshold Learning Outcomes provide a foundation for articulating and developing the higher education science curriculum, and for improving learning and teaching in science at the university level.* (Yates, Jones & Kelder, 2011; p.16)

The statements, see Supplementary Material 1, place an emphasis on disciplinary content knowledge and applying that knowledge. Implicitly there are several skills underpinning the statements including teamwork, oral communication, written communication, and quantitative skills (QS). A major challenge for the sector now is assessing and evidencing the achievement of these learning outcomes in science graduates, not only for national accountability purposes but also for curricular enhancement within institutions (Yates & Jones, 2011). The SSSI was conceptualised and developed before the *LTAS* project. However, the Science Threshold Learning Outcomes are clearly underpinned by the same skills as those explored in the SSSI, thus the SSSI offers one tool for evidencing learning outcomes.

The precedent of surveys as tools for accountability

Student surveys can provide quick, low-cost and meaningful information about student acquisition of knowledge and skills which can be used to inform curriculum development. Surveys of students' experiences and learning in the Higher Education sector have become important sources of data for governments seeking measures of institutional success and political accountability. In the USA and UK national student surveys (Kuh, 2001; Surridge,

2008) have been administered for a number of years. In Australia, the Course Experience Questionnaire (CEQ) has been widely used to gather data from recently graduated university students. The CEQ explores generic skills at the level of the institution for the purposes of comparison between institutions as a means of political accountability. The results are aggregated to degree program level as survey items are sufficiently generic without discipline specific jargon. The terminology used includes: analytic skills; problem-solving skills; communication skills; application of skills to unfamiliar problems; collaboration skills; and self-regulation skills (Ramsden, 1991). However, if the results of institutional surveys are going to be effectively used to inform changes to teaching practices it would be better to survey students at the discipline level, rather than the institutional level (Entwistle, 1989; Gibbs, 2006; Trowler and Cooper, 2002). There is a tension between national level accountability data for satisfying governmental requirements and the data required to inform on-going curricular enhancements at the local level. Whilst the CEQ offers precedent in the higher education sphere for surveying students at the whole of program level, the non-discipline specific nature of the survey and the reporting of results seem to have hindered its usefulness as a mechanism for enhancing curricular reform efforts in the sciences at the local level.

The Science Students Skills Inventory (SSSI)

To more genuinely explore the perceptions of graduating science students, a new survey has been developed which explores the learning outcomes valued by the scientific community and those teaching science at the university level in Australia. The SSSI builds on the whole of program notion with the added benefit of being tailored to the discipline. The SSSI prioritizes learning outcomes and skills in science, and is designed to offer meaningful data that could be used to enhance teaching and learning at the level of the degree program. Modelled on the Student Assessment of Learning Gains (Seymour Wiese, Hunter & Daffinrud, 2000), the SSSI was developed at the University of Queensland (UQ) to specifically investigate and capture graduating science students' reflections on their learning. Following a search of the literature, no suitable existing survey could be identified for direct use.

The SSSI collects information on graduating science students' perceptions of their learning outcomes. Students are asked to rate the extent to which their studies in the science degree program contributed to the development of five specific areas (teamwork skills, QS, oral communication skills, writing skills and content knowledge) across four indicators (importance, confidence, improvement and inclusion in the curriculum). Multiple indicators were added to offer deeper insight than a single indicator and to better represent the range of student perceptions possible relating to attitudes (importance), beliefs (confidence, self-improvement) and visibility in the curricula (inclusion). Respondents were asked to select from four-point Likert scales, based on validated scales from Berk (2006) and Vagias (2006). The scale does not include a neutral point, which prompts respondents to make a definitive choice and four points were selected given that evidence suggests four, six or eight point scales does not influence the results (Kember & Ginns, 2012). All points on the scale were labelled with words, which builds on prior research suggesting clearly articulated words instead of numeric points significantly improves reliability (Weng, 2004), which is common practice in social sciences research to convert word scales (categorical) to numeric (continuous) points for the sake of statistical analysis. Indeed, many institutional unit evaluations convert text-based scales to numeric points, reporting mean values which

suggests this is a common practice in institutional research and evaluation of teaching effectiveness.
The full SSSI is presented in Supplementary Material 2 including some advice on how the survey can be adapted. The five specific areas were initially selected based on statements of university level graduate attributes and science specific outcomes articulated during a 2007 review of the science curriculum. Consultations were then held with teaching staff from the science degree programs to ascertain the qualities deemed important for modern scientists. These were used to draft the survey items. The Science Threshold Learning Outcomes were not available in 2007 or 2008 when the SSSI was created and piloted. The survey was then validated using think aloud protocols with undergraduate science students and revised accordingly to ensure the terminology was recognised and understood by students. The SSSI was piloted at UQ with the graduating Bachelor of Science (BSc) cohort in 2008.

Given the principles of utilization-focussed evaluation, the validity of the survey was grounded in the usefulness of the results to science academics (Patton, 2008). Evidence of the usefulness of the SSSI is its continued use at UQ, running each year since 2008 in the BSc and Bachelor of Biomedical Sciences (BBiomed) degree programs. In 2010, the SSSI was deployed in the BBiomed at Monash and in 2011 the benchmarking continued with the SSSI also administered in the BSc to inform up-coming BSc program reviews and to gather trend data. Results from the SSSI have been both presented and published (Matthews, 2011), although this paper is the first time the SSSI instrument has been published such that others can debate its merits, and adapt it for use.

Research design

The current study was designed to gather data from graduating students to inform on-going curriculum development at the program level while also being useful to the accountability agenda. Using the SSSI across two BBiomed programs at two universities, the benchmarking analysis explored the following broad questions:

1. What skills and knowledge do students believe they gained from their undergraduate studies?
2. How do student responses compare across the two Australian institutions?

While this paper draws on the same data presented at the ACSME, the paper is extended to include survey design, the survey instrument itself and an in-depth discussion of policy implications for science faculties.

The clarification of some commonly used terms in this paper is warranted. Students earn a qualification when they graduate, for example a Bachelor of Science or BSc, and we refer to this as a *degree program* or the *degree program level*. Similarly, when we use the term curriculum we are referring to curriculum at the degree program level. To earn a BSc, students complete a designated number of subjects/courses/classes, which we refer to as *units* for the purposes of this paper.

Educational context

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 UQ, the BBiomed was introduced in 2008 with a structured science curriculum consisting of 14 required core units including a requirement to complete an undergraduate research project unit, a research project-based 3rd year capstone unit, 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 on the degree program is available at http://www.uq.edu.au/study/science/studyplanners/index.html?page=91218. Applicants to the program 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 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 BBiomed is a separate integrated program of 14 core units incorporating a research experience in the final 3rd year capstone unit. 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 to the program 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 curricula are similar in terms of numbers of core units, 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 SSSI to collect data from BBiomed 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).

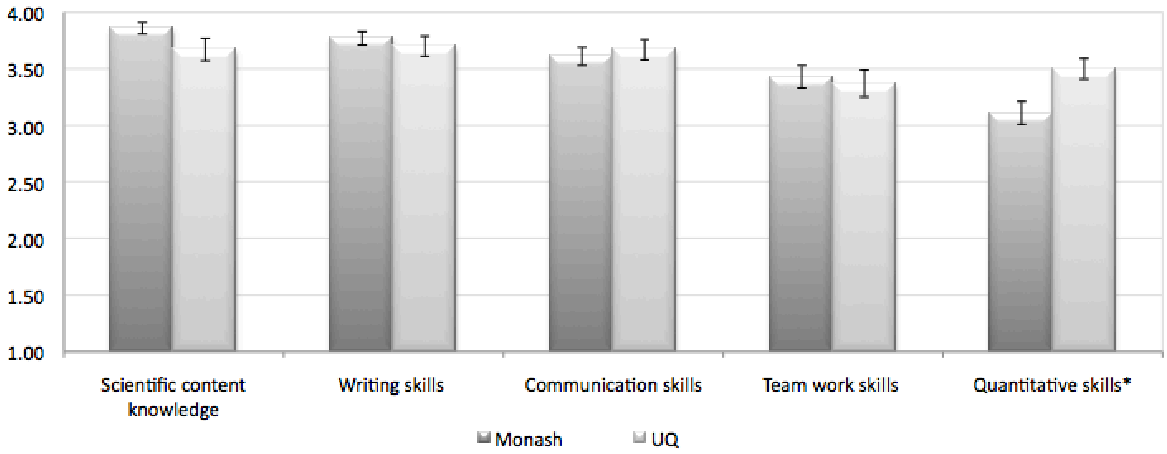
Study Participants

Final year BBiomed degree students were identified at each university via enrolment in the 3rd year compulsory capstone units. 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 giving 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

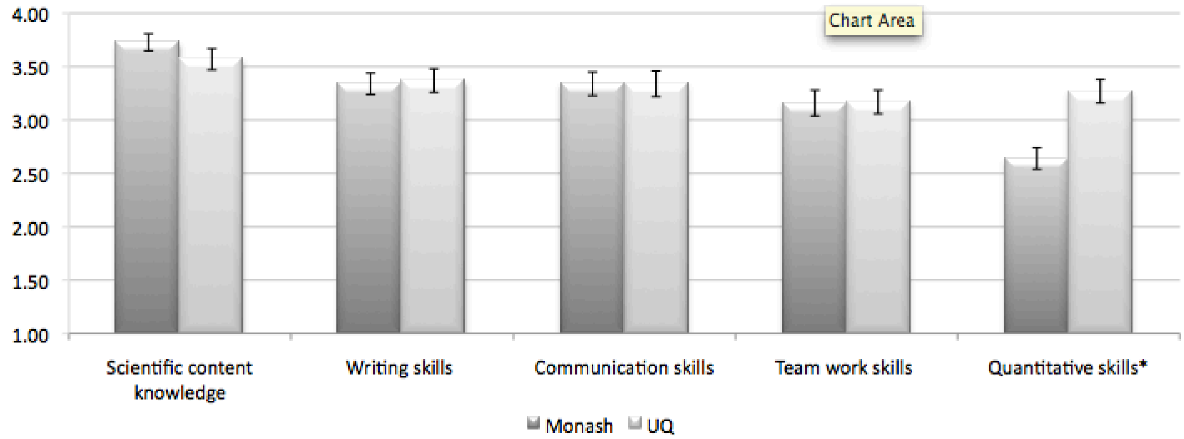
All statistical analysis was completed using Stata version 11. Missing data was not an issue as the survey was administered online using a function that required students to answer the question before being able to submit the survey and allows for only one response per survey link (avoiding issues associated with duplication of respondents). There were 75 surveys completed. 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.

Graphs 1-4, (from Matthews and Hodgson, 2011) display the results by item for the five specific skills areas across the indicators of importance, inclusion, improvement and confidence rated by students. Results are displayed using the mean and standard error, on a 4-point Likert scale with "1" being the lowest level of agreement and "4" being the highest that were quantified from standard Likert survey prompts (Berk, 2006). Refer to Supplementary Material 2 for precise wording. The findings reveal little difference across how the two university cohorts responded with one exception. 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.



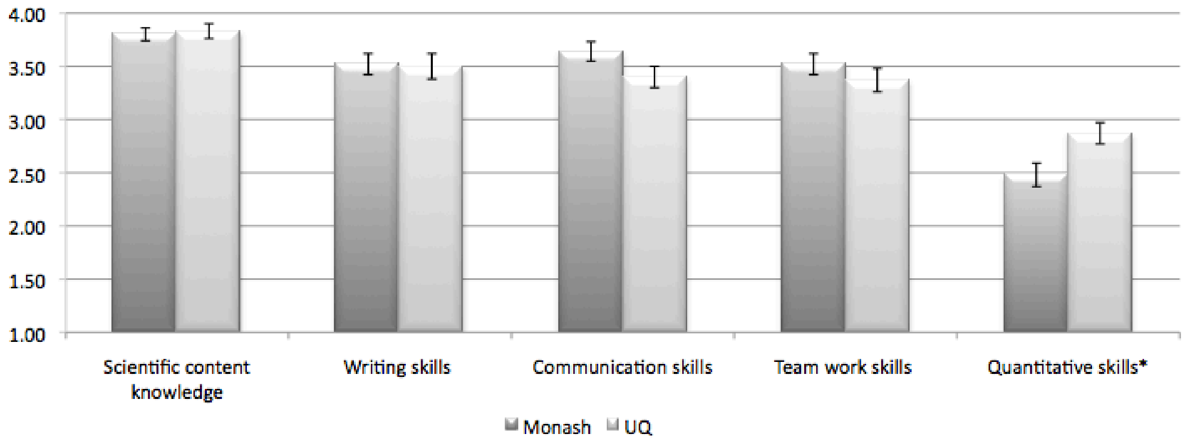
Graph 1: How IMPORTANT is it to have activities that develop the following included in the biomedical science degree program?

* Statistically significant difference to $\leq$ 0.01



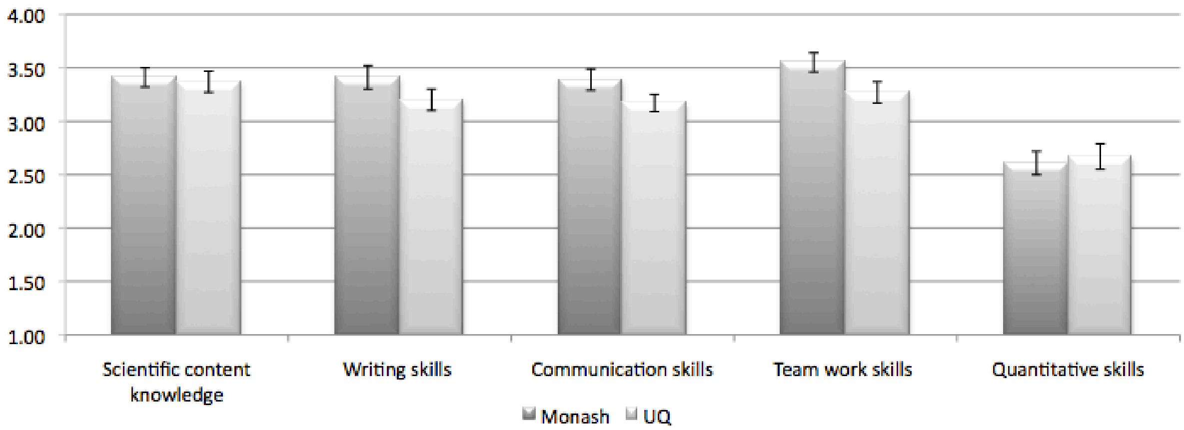
Graph 2: As a result of your overall biomedical science degree program, please indicate the level of IMPROVEMENT you made in the following?

* Statistically significant difference to ≤ 0.01



Graph 3: To what extent were activities to develop the following INCLUDED in your biomedical science degree program?

* Statistically significant difference to ≤ 0.01



Graph 4: To what extent do you feel CONFIDENT in the following as a result of your biomedical science degree program? (4-point scale)

* Statistically significant difference to ≤ 0.01

Discussion

Interpreting the SSSI results

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 skills areas (content knowledge, writing, communication, teamwork and QS) on the four indicators (importance, inclusion, improvement and confidence) reveal students value content knowledge and skill acquisition with the exception of QS. 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 further demonstrates that students have opportunities within the degree programs to gain content knowledge and build skills.

Across both universities, students reported lower perceptions for QS across all the indicators of importance, inclusion, improvement and confidence. The data supports numerous reports that have highlighted the deficiency in science student's QS (NRC, 2003; Bialek & Botstein, 2004; AAAS, 2010; AAMC Report, 2009). However, the data does show differences between the two universities, 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 of a recent curriculum review where QS was seen as an essential skill for students in the Biomedical Sciences program and specific curricular innovations were established to build this skill (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 in this skill area. 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 data from this cross-institutional study, while limited, clearly points towards an issue with graduates' notions of gaining QS. Further research employing qualitative methodologies would enhance our understanding of how students experience QS. Extended use of the SSSI across more universities will also help determine the extent of the QS issue.

Limitations of surveys

The SSSI, like the CEQ, has the inherent limitation of any survey in that it relies on students self-reporting of learning and is thus not evidence of 'actual' learning. There is the notion that self-reporting provides subjective indicators while accountability requires objective measures of learning, such as the Collegiate Learning Assessment (CLA) or equivalent. Studies have suggested that self-reported learning gains do not correlate to learning gains as measured by CLA type assessment tasks (Bowman, 2011). Other studies suggest that self-reporting gains offer insight to improve curricular reform efforts at the local level and are cost-effective (Douglass, Thompson & Zhao, 2011). These studies highlight the divide between gathering evidence of student learning as an accountability exercise and gathering evidence that can be meaningfully used to inform curricular reform efforts within institutions at the local disciplinary level. This limited body of research, largely out of the United States driven by government policy changes in the last decade, comes to agreement on two points. First, more research is needed in this area. Second, the type of institution (small, liberal arts college versus a large research-intensive university) is a variable that warrants consideration when interpreting and comparing learning outcome results.

Making a case for the SSSI

However, it is not the intention of this paper to debate the merits of either surveys or tests being the panacea for measuring learning outcomes. Nor is it the intention to debate the realities of objective measurements for student learning across a degree program, although we contend both are important debates that could benefit the Australian higher education sector as we move towards increased accountability. While acknowledging the limited nature of this research, the study offers a contribution to research within the Australian context and within the science context. The methodology utilities a survey design relying on student reporting as an indicator of student's perceptions of their learning gains with no claims to measuring 'actual' learning. Pike (2011) suggests that 'too many studies have failed to consider how self-report data are to be interpreted and used', and goes on to support the use of self-reports for scholarly research. The approach endorsed by the Student Experience in Research Universities (SERU) Consortium suggests that self-reporting surveys are more sensible financially and more valid than performance measures such as the CLA (Douglass et al, 2011). The SSSI was developed within a framework of utilization-focused evaluation whereby the end-user of the data is central to the design and reporting procedures (Patton, 2008). Hence, the SSSI tends towards the quality enhancement side of the accountability-enhancement spectrum; although, we argue there is scope to feed into accountability reporting as one indicator. 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.

Benefits and scope of the SSSI

The study reveals the perceptions of graduating biomedical science students and makes no claims of a correlation to actual student learning outcomes. This study provides specific evidence of Biomedical Science student's perceptions for the purpose of informing on-going curricular reform at both institutions.

Gathering meaningful, useable data

The response rates obtained from our surveys highlight the benefits of questionnaires that survey students within the context of the discipline. Students appear to be far more willing to respond to such surveys when compared to generic questionnaires such as the CEQ. Instruments, like the SSSI, can be administered via final year compulsory capstone units when students are still enrolled and views and experiences of their studies are fresh. Importantly, academics can articulate the value placed on their perspectives and explain how the data could be used by the institution to inform curricular change. While instruments like the SSSI will benefit from psychometric testing, this on its own is not the panacea. The principles of gathering meaningful data for those who will use it should be factored into the validity process. This important consideration is supported by Pike (2011) in his study that used Holland's person-environment fit theory. This falls within the principles of the utilisation-focused evaluation used in the present study (Patton, 2008).

Meaningful data at the disciplinary level

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. 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. 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).

Meaningful data to drive improvements

The SSSI data presented in this paper has offered some insights into the achievement of learning outcomes, even with the limitations of only drawing on a single data source (student self-reporting of perceptions) from two universities in a single year. A quick analysis of the results highlights the issue with QS that parallels that already identified in the United States and the UK. Indeed the SSSI findings offer corroborative evidence from the perspective of students for the recent Australian report on the declining state of quantitative disciplines (Brown, 2009).

Further research

Acknowledging the focus on the whole of program experience in the sciences, an area in which there is little literature on which to build, raises further research questions such as: 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? As more program level science specific data is collected, research exploring how this data is linked meaningfully to curricula reforms at the local level would be beneficial both for practice and for developing a theoretical underpinning for change in science higher education.

Conclusion

Within the broader context of government accountability for program level learning outcomes and local efforts to use evidence to inform curricula reviews, this paper purported three intentions, i) to report data from a cross-institutional study of graduates using a purpose-built instrument, the SSSI, ii) to connect the SSSI to the broader national statements for science graduates in Australia and iii) to publish the SSSI to enable further research and debate at the level of undergraduate science curricula. We acknowledge the limitations of surveys and do not claim the SSSI to be the panacea for evidencing outcomes or driving reform agendas. Instead, we offer a model whereby disciplinary values are integrated into accountability and quality enhancement processes. We argue that, for data to be utilised for curricular reform, the data must be collected, interpreted and reported in a manner that is not only understood, but also meaningful and useful to science academics, the people who actually teach and create the science curriculum. Forth coming publications will explore the notion of the science curriculum, and the complexity that a series of units endow when institutions attempt to document, frame and link these units within a coherent system. This study demonstrates that data at the level of the science degree program, collected from students, in a financially feasible manner, can produce valuable insights on learning outcomes that can be useful in curricular reform efforts. Indeed, dissemination of the preliminary results at the ACSME has led to requests from other higher education institutions to implement the SSSI, highlighting the relevance of this discipline specific survey.

The science higher education sector should be working to gather meaningful data that can be used to inform on-going curricular reform (quality enhancement), and to satisfy accountability requirements. Ultimately, the goal we should be working towards is to promote optimal learning opportunities that prepare graduates who can genuinely self-assess their own learning such that their perceptions and performance are aligned.

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Appendix 1

Threshold learning outcomes for science (Yates, Jones & Kelder, 2011, p.13) (http://www.olt.gov.au/resources?text=LTAS accessed 26 March 2012)

	Upon completion of a bachelor degree in science, graduates will:
Understanding science	1. Demonstrate a coherent understanding of science by: 1.1 articulating the methods of science and explaining why current scientific knowledge is both contestable and testable by further inquiry 1.2 explaining the role and relevance of science in society.
Scientific knowledge	2. Exhibit depth and breadth of scientific knowledge by: 2.1 demonstrating well-developed knowledge in at least one disciplinary area 2.2 demonstrating knowledge in at least one other disciplinary area.
Inquiry and problem solving	3. Critically analyse and solve scientific problems by: 3.1 gathering, synthesising and critically evaluating information from a range of source 3.2 designing and planning an investigation 3.3 selecting and applying practical and/or theoretical techniques or tools in order to conduct an investigation 3.4 collecting, accurately recording, interpreting and drawing conclusions from scientific data.
Communication	4. Be effective communicators of science by: 4.1 communicating scientific results, information, or arguments, to a range of audiences, for a range of purposes, and using a variety of modes.
Personal and professional responsibility	5. Be accountable for their own learning and scientific work by: 5.1 being independent and self-directed learners 5.2 working effectively, responsibly and safely in an individual or team context 5.3 demonstrating knowledge of the regulatory frameworks relevant to their disciplinary area and personally practising ethical conduct.

1. Study Information & Consent

Welcome to the Science Student Skills Inventory

Feedback from students is an essential part of how we improve the science program. Your perspective is particularly important because as an upper level science student you have fully experienced the current curriculum. The opinions you provide will be used to enhance the undergraduate science curriculum by understanding how it is impacting on students.

Instructions for institutions when setting up survey:

If applicable: include information on 'incentives' here

Instructions for institutions when setting up survey:

INCLUDE ETHICS Study Information HERE

***1. Consent: I have read the information provided above about the research, and give my consent to participate in this study based on the understanding that:**-

1. I am aware of the general purpose, methods and demands of the study, and

2. My participation in this study is voluntary and I am free to withdraw from the study or refuse to take part at any time, without any negative consequences, and

3. All information that I provide or that which is accessed from university records will be kept confidential and will not be identifiable.

- ◯ Yes
- ◯ No

2. Demographic Info

Instructions for institutions when setting up survey:

Demographic information can be collected based institutional prefers for analysing the data. For example, information can be collected on gender, age, major/field of study, post-graduation plans (post-graduate studies in research, medicine or enter the workforce, etc), participation in undergraduate research or other "selective" extra-curricular activities.

3. Skills Inventory in Science Degree Program

Instructions for institutions when setting up survey:

Institutions might vary the 'learning outcomes' although care should be taken (1) to ensure students understand the terminology used, and (2) to avoid listing too many 'learning outcomes' or options for 'class contact' or 'assessment' options.

SSSI: Science Student Skills Inventory

NOTE: The same 'learning outcomes' should be used in this section and the section below. Do not change the terminology, although changing the order in which they appear is acceptable.

***2. Throughout your entire Science degree program, which types of class contact required you to utilise the following:**
(choose all that apply)

	Lectures	Practicals	Tutorials	N/A
Communication skills (oral scientific presentations)	☐	☐	☐	☐
Ethical thinking (ethical responsibilities and approaches)	☐	☐	☐	☐
Writing skills (scientific writing)	☐	☐	☐	☐
Team work skills (working with others to accomplish a shared task)	☐	☐	☐	☐
Scientific content knowledge in your field(s) of study	☐	☐	☐	☐
Quantitative skills (mathematical & statistical reasoning)	☐	☐	☐	☐

***3. Throughout your entire Science degree program, which assessment tasks required you to utilise the following:**
(choose all that apply)

	Practical reports	Laboratory assignments	Quizzes	Posters	Literature reviews	Exams	N/A
Communication skills (oral scientific presentations)	☐	☐	☐	☐	☐	☐	☐
Writing skills (scientific writing)	☐	☐	☐	☐	☐	☐	☐
Quantitative skills (mathematical & statistical reasoning)	☐	☐	☐	☐	☐	☐	☐
Scientific content knowledge in your field(s) of study	☐	☐	☐	☐	☐	☐	☐
Team work skills (working with others to accomplish a shared task)	☐	☐	☐	☐	☐	☐	☐
Ethical thinking (ethical responsibilities and approaches)	☐	☐	☐	☐	☐	☐	☐

4. Skills Perceptions in Science Degree Program

Instructions for institutions when setting up survey:

If you alter the Likert scale, do so with caution and seek advise from a survey designer. Remember to use the same 'learning outcomes' as used in the above section.

Recall: If you are benchmarking with another institution, it is advisable to utilise the same terminology for overlapping 'learning outcomes' and utilise the same Likert scale.

***4. As a result of your overall Science degree program, please indicate the level of IMPROVEMENT you made in the following?**

	No improvement	Little improvement	Moderate improvement	A great deal of improvement
Writing skills (scientific writing)	○	○	○	○
Team work skills (working with others to accomplish a shared task)	○	○	○	○
Ethical thinking (ethical responsibilities and approaches)	○	○	○	○
Scientific content knowledge in your field(s) of study	○	○	○	○
Communication skills (oral scientific presentations)	○	○	○	○
Quantitative skills (mathematical & statistical reasoning)	○	○	○	○

***5. How IMPORTANT is it to have activities that develop the following included in the Science degree program?**

	Not at all important	Not very important	Important	Very important
Ethical thinking (ethical responsibilities and approaches)	○	○	○	○
Team work skills (working with others to accomplish a shared task)	○	○	○	○
Quantitative skills (mathematical & statistical reasoning)	○	○	○	○
Scientific content knowledge in your field(s) of study	○	○	○	○
Communication skills (oral scientific presentations)	○	○	○	○
Writing skills (scientific writing)	○	○	○	○

***6. To what extent were activities to develop the following INCLUDED in your Science degree program?**

	Not included at all	Included a little	Included a moderate amount	Included a lot
Quantitative skills (mathematical & statistical reasoning)	○	○	○	○
Scientific content knowledge in your field(s) of study	○	○	○	○
Writing skills (scientific writing)	○	○	○	○
Communication skills (oral scientific presentations)	○	○	○	○
Team work skills (working with others to accomplish a shared task)	○	○	○	○
Ethical thinking (ethical responsibilities and approaches)	○	○	○	○

***7. To what extent do you feel CONFIDENT in the following as a result of your Science degree program?**

	Not at all confident	A little confident	Moderately confident	Very confident
Scientific content knowledge in your field(s) of study	○	○	○	○
Team work skills (working with others to accomplish a shared task)	○	○	○	○
Quantitative skills (mathematical & statistical reasoning)	○	○	○	○
Writing skills (scientific writing)	○	○	○	○
Communication skills (oral scientific presentations)	○	○	○	○
Ethical thinking (ethical responsibilities and approaches)	○	○	○	○

5. Institutional specific questions

Instructions for institutions when setting up survey:

Institutions can include some local questions here. The example below is from an institution where quantitative skills was a particular focus in there program review cycle so they elected to dig deeper into that 'learning outcome'.

Advise: Avoid adding too many questions here, as the length of the survey could impact on student completion, lowering the response rate. Consult with a survey designer when drafting new questions.

***8. Please think now about the courses you took as part of your Science degree program that made you utilise quantitative skills.**

HINT: For a list of courses you completed in your science degree program, log on to mySI-net and view your study report.

List the 1st year course(s) that required you to utilise quantitative skills

List the 2nd year course(s) that required you to utilise quantitative skills

List the 3rd year course(s) that required you to utilise quantitative skills

6. Incentive Information

Instructions for institutions when setting up survey:

Offering an incentive to (1) encourage survey completion, and (2) thank students for taking the time to complete the survey, is a common practice. However, the use of incentives is a decision left to the institution. Below is a an example of how information on incentives can be collected.

9. This survey is entirely confidential. If you choose to enter your university student email address below, your confidentiality will be maintained. Your email address allows us to contact you if agree to any of the statements below and will not be used or stored for any other purpose. This survey is focusing on science students as a group, not as individuals.

	Yes	No
I would like a summary of the results from this survey emailed to me.	◯	◯
I would like to be considered for 'incentive'. (depends on local context)	◯	◯

Enter your university email address

Thanks for completing the Science Student Skills Inventory

Please click the SUBMIT button below to complete the survey and submit your responses.