Toward curriculum convergence for graduate learning outcomes: Academic intentions and student experiences

Running Title: Curriculum convergence for graduate learning outcomes

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Abstract

Graduate learning outcomes in undergraduate science degrees increasingly are focussed on the development of transferrable skillsets. Research into, and comparisons of, the perceptions of students and academic staff on such learning outcomes has rarely been explored in science. This study used a quantitative survey to explore the perceptions of 640 undergraduate science students and 70 academics teaching into a Bachelor of Science degree program on the importance, the extent to which outcomes were included and assessed, the improvement and likely future use of science graduate learning outcomes. Analysis of findings shed light on potential pathways toward curriculum convergence by arguing the need for shared perspectives of academics and students on graduate learning outcomes and drawing on the *planned-enacted-experienced* curriculum model. Moving toward coherent curriculum planning that draws on both student and academic perspectives to achieve graduate learning outcomes is the key contribution of this study. Resulting recommendations include: the need to consider the development of each complex graduate learning outcome as distinct from other outcomes in both curricular and pedagogical approach, and the need for a programmatic framework for assessment practices to facilitate the constructive alignment of assessment with learning outcomes.

Keywords

Graduate learning outcomes, curriculum development, curriculum convergence, undergraduate science, student perceptions, academic perceptions

Introduction

There is an international impetus to introduce a degree of accountability and to promote graduate employability in higher education institutions. Graduates increasingly are expected to be proficient in a range of skills that are widely applicable and transferrable, and beyond discipline-oriented content knowledge. These changing expectations have been met with the introduction of graduate learning outcome statements at universities across continents. The articulation of graduate learning outcomes for degree programs represents a 'set of intentions' that ideally guide academics in curriculum design, development, and reform activities (Oliver 2011). Placing those outcomes and intentions within a curriculum in a meaningful way presents many challenges, particularly in more generalist degree programs. Such programs, including the Bachelor of Science (BSc), typically have few core compulsory units, a huge variety of subject choices, little pre-defined structure, and no external accrediting body (Fraser and Thomas 2013) – all of which make coherent curriculum planning and the development of a prescribed set of broad skills difficult.

In the Australian undergraduate BSc the need for a transferrable skillset is reflected by the development of a set of 'Science Threshold Learning Outcomes' which are defined as "nationally agreed upon descriptions of what a science graduate should know and be able to do" within which the development of learning objectives may occur (Australian Council of Deans of Science 2013). These science-specific undergraduate learning outcomes are underpinned by discipline-specific knowledge (e.g. content) and transferrable skills (e.g. communication, teamwork, and quantitative skills) (Jones, Yates, and Kelder 2011). They arose from a national project in Australia, the *Learning and Teaching Academic Standards* (LTAS) project, focused on engaging academic communities to define and set national level, discipline-specific learning outcomes referred to as 'Threshold Learning Outcomes' (Ewan, 2010). The science-specific statements were underpinned by teamwork skills, oral communication, written scientific communication, quantitative skills, ethical thinking skills, and the acquisition of scientific content knowledge. For the purposes of this study, the terminology of graduate learning outcomes will be employed, which refers to broader outcomes of learning expected of students who graduate from an undergraduate degree program. The majority of research into graduate learning outcomes in undergraduate science has focused on either student or academic perceptions in isolation (e.g. Varsavsky, Matthews, and Hodgson 2013, Herok, Chuck, and Millar 2013, Mercer-Mapstone and Matthews 2015); employer perspectives (e.g. Schull et al. 2012); the development of outcomes in unit-specific contexts (e.g. Lluka and Chunduri 2015, Windsor et al. 2014); or on a single, specific outcome (e.g. Moni et al. 2007, Hager et al. 2003, Mercer-Mapstone and Kuchel 2015). There are relatively few published articles focussing on the comparison of academic and student perceptions explicitly. One such paper, however, asked students and academics to rank the importance of 20 broad skills (including, for example, finding information, organising ideas, and time management) in biology, chemistry and environmental management degree programs at an Australian university (Leggett et al. 2004). Leggett et al. (2004) conducted a mixed methods survey of first, second, and third year students and academic staff. This survey asked students to rate the importance of 20 generic skills (a list of which had been generated by staff) and to list five additional skills that were not on the list that they perceived to be important as well. Results showed that the alignment between student and staff perceptions of skill importance increased by student year level; that is, the gap between student and staff perceptions closed as students progressed through their studies. In general, academics saw different skills as being important than did students. Perceptions of importance have been shown to be associated with students' motivation toward learning (Lattuca & Stark 2009) however research suggests students often repeat rhetoric advocated by teachers (Schoenfeld 1989). As such it is valuable to combine perceptions of importance with the exploration of other indicators to provide a more representative and holistic picture of a curriculum.

Graduate learning outcomes are linked inextricably to the degree program curriculum. In higher education, however, academic teaching staff rarely engage in depth with the education and curriculum research and theory. This means that academics often perceive 'curriculum' to be one and the same as the syllabus – the discipline-specific knowledge in a unit of study that delivers that knowledge (Fraser and Bosanquet 2006, Lattuca and Stark 2009). Having a clearly defined curriculum model with which academics can engage is an important step toward coherent curriculum planning to achieve graduate learning outcomes. Research into graduate learning outcomes would benefit from more explicit use of curriculum models that encompasses the experiences of both academics and students.

Academics as both the planners and enactors (educators) are essential in curriculum development. Students are also essential stakeholders in curriculum development and reform activities. Student voice research is substantially focused on exploring what students think about pedagogical approaches, curricular reform, and general attitudes to learning. The rationale is that students are the intended beneficiaries of educational systems and should therefore be consulted at the very least, with others arguing for greater student involvement in curricular design and development (Cook-Sather 2002, Jenkins 2006, Levin 2000). The *planned-enacted-experienced* curriculum model (Erickson and Shultz 1992) positions students in relation to the educational intentions of educators, and has been utilised in various higher education studies (Aulls 2004, Cook-Sather 2006, Hawthorne 1998, Lerch 2004, Lyon 2004, Zidon 1996). The model has been represented visually as a nested diagram, as conceptualised in Figure 1 (Matthews et al. 2013). The *planned* curriculum refers to curricular goals or learning outcomes, which are *enacted* by educators who make decisions on content, pedagogies and assessment. Students are the beneficiaries of teachers' actions and activities as they *experience* the curriculum and ideally achieve the intended learning outcomes. For this study, the model provides a lens to view curriculum at multiple levels, from individual units to whole degree programs. Students and educators would, ideally, share similar views on the goals and outcomes. This would indicate two important levels of alignment and translation of plans into practice. Firstly, that the curriculum that was planned from an academic standpoint was enacted by educators in a manner that had a high degree of alignment; that is, that concepts, factors, or outcomes of the planned curriculum are not lost in translation through the enactment of those curricular intentions. Secondly, students experience this enacted curriculum in a way that aligns with both how academics perceive it to be enacted and ultimately, with the original curricular plan and intentions. This curriculum convergence is an important facet of ensuring that students benefit to the full extent of the 'behind the scenes' planning that is dedicated to curriculum design.

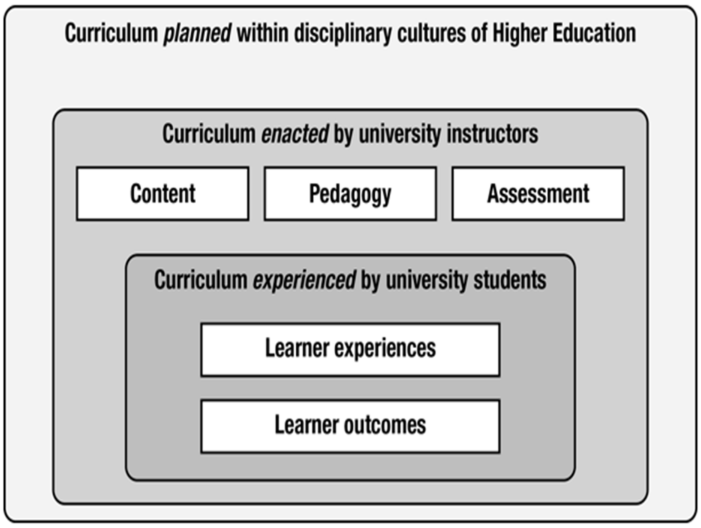

Figure 1. The *planned-enacted-experienced* curriculum model adapted for application to higher education by Matthews et al. (2013), originally from Erickson and Shultz (1992).

Purpose

This study focussed on curriculum convergence by exploring the views of science students and academics to gauge the extent to which they hold similar beliefs about stated graduate learning outcomes. The research question addressed in this study is: *how do the perceptions of students' experiences of graduate learning outcomes converge with academics' plans for the curriculum*? Ideally, as outlined above, these perceptions will converge. In cases where that is not the case, this research will indicate a way forward in curriculum development.

Theoretical Framework

The framework of progressive development of complex learning outcomes from Knight (2001) was used to interpret the process through which learning outcomes might be integrated into the *planned-enacted-experienced* curriculum model. Graduate learning outcomes encompass a range of complex skills and competencies, and it follows that learning and mastery of such skills is also complex. It can be argued that the curriculum through which complex learning outcomes are taught should support the progressive development of skills as a result of coherent curriculum planning (Mercer-Mapstone and Matthews 2015). Key to this skill development is the idea that "learning encounters need to be planned to suffuse the program" (Knight 2001, 10) with multiple and consistent opportunities for practice. For this to occur, these opportunities must be planned and enacted to the extent that they are equally visible to both academics (as the enactors) and students (as the beneficiaries). This framework of progressive development of complex learning outcomes has been applied in previous studies on student perceptions (e.g. Mercer-Mapstone and Matthews 2015) and is now extended to interpret the comparison of academic and student perceptions in this study. Within this theoretical framework, results showing no statistically significant differences would demonstrate curriculum convergence whereby students *experienced* the *planned* curriculum as it was intended by academics.

Methods

Context

This study was situated within an Australian research-intensive university ranked in the top 100 universities worldwide (for example, Times Higher Education World University Rankings, Quacquarelli Symonds World University Rankings). The BSc degree program comprises three years of undergraduate study with an optional fourth year for Honours, and consistently attracts applicants straight from high school.

Data collection

A quantitative study design was used, drawing on the Science Students Skills Inventory (SSSI). The SSSI is a survey tool that explores how an entire science degree program contributes to the development of the knowledge and skills that underpin expected graduate learning outcomes (Matthews and Hodgson 2012) and has been used in previous studies (Varsavsky, Matthews, and Hodgson 2013, Hodgson, Varsavsky, and Matthews 2013, Mercer-Mapstone and Matthews 2015). These outcomes include teamwork skills, oral communication, written scientific communication, quantitative skills, ethical thinking skills, and the acquisition of scientific content knowledge, which underpin the national statement for science threshold learning outcomes (Jones, Yates, and Kelder 2011).

The survey consisted of questions which asked students to rate, on a four-point alpha-numeric scale, each learning outcome across indicators as shown in Table 1. These five indicators used to explore each outcome were the '*importance'* of being taught in the program, the extent to which each outcome was '*included'* in the curriculum, being '*assessed'* in the curriculum, '*improvement'* as a result of the degree program, and perceptions of '*future use*' of the outcome. These questions addressed students' experiences up to and including the part of their degree they had completed at the time the survey was administered. The SSSI also was modified slightly for academic use for this study (questions shown in Table 1). The demographic information sought from students included gender, age, and plans students had for after graduation (employment, postgraduate studies – research or other, or no plans yet).

Table 1. SSSI quantitative survey questions and alpha-numeric scale responses for each indicator

Indicator	Academic/ student survey	Survey Question	Alpha-Numeric Scale
Importance	Student	How IMPORTANT is it to have activities that develop [graduate learning outcome] included in the Science degree program?	1 – Not at all, 2, 3, 4 – Very
	Academic	How IMPORTANT is it to have activities that develop [graduate learning outcome] included in the Science degree program?	As above
Assessed	Student	Throughout your entire Science degree program, how often were [graduate learning outcome] ASSESSED?	1 – Not at all, 2, 3, 4 – A lot
	Academic	Thinking about what you know of the BSc as a whole, how often are [graduate learning outcome] ASSESSED?	As above
Included	Student	To what extent were activities to develop [graduate learning outcome] INCLUDED in your Science degree program?	1 – Not at all, 2, 3, 4 – A lot
	Academic	Thinking about what you know of the BSc as a whole, to what extent are activities to develop [graduate learning outcome] INCLUDED in the Science degree program?	As above
Improvement	Student	As a result of your overall Science degree program, please indicate the level of IMPROVEMENT you made in [graduate learning outcome]?	1 – Not at all, 2, 3, 4 – A lot
	Academic	Thinking about what you know of the BSc as a whole, please indicate the level of IMPROVEMENT you believe students do make in [graduate learning outcome]?	As above
Future Use	Student	Five years after you graduate from your Science undergraduate degree program, how much do you think you will be using your [graduate learning outcome]?	1 – Not at all, 2, 3, 4 – A lot
	Academic	Five years after graduation from the Science undergraduate degree program, how much do you think students will be using their [graduate learning outcome]?	As above

Participants: Students

The survey was administered online to all Bachelor of Science single-degree students (n = 2566) across first (n = 1223), second (n = 773), and third (n = 570) years. In total, 640 students responded to the online survey for a response rate of 25%, comprised of 44% first-year students (response rate = 23%), 33% second-year students (response rate = 27%), and

23% third-year students response rate = 25%); 58% female; and 70% in the 17—20 age bracket. Respondents had differing plans following graduation with 19% planning to seek employment, 69% planning to do postgraduate study, and 12% unsure. Table 2 shows the proportions by broad discipline determined by student's major.

Participants: Academics

The survey was administered online to all academics teaching into the BSc degree program. The mode of dissemination for this survey was to ask administration staff in each school to send the survey to academics via email. As such the total number of academics to which the survey was administered is unknown. In total, 102 academics responded to the online survey; however, 32 responses were removed because of incomplete answers. As the survey was administered confidentially there is no reason readily available to explain this relatively large number of non-completes. The overall academic response rate was 70. Demographic data were not collected from academics so as to maintain staff anonymity. Table 2 shows the proportions by broad discipline determined by academic's department.

Table 2. Survey respondent proportions by broad discipline

	Staff		**Students**	
Category	*n*	%	*n*	%
Biosciences	29	41	423	67
Physical Sciences	37	53	181	29
Psychological Sciences	4	6	27	4

Note: Biosciences include biomedicine, biology, and environment sciences. Physical sciences include chemistry, computer sciences, mathematics and physics. Nine students did not indicate a major.

Statistical Analysis

Descriptive statistics for each indicator were examined for all skills. 'Percentage agreement' was calculated based on the two highest points of a four-point scale for all indicators. Prior to statistical analysis, checks of normality were conducted using absolute values of skewness and kurtosis (instead of calculating statistics due to the large sample size and small standard error values), as well as stem and leaf plots and frequency histograms, for each graduate learning outcome. On visual inspection of histograms, and stem and leaf plots, the data appeared significantly non-normal. The assumption of homogeneity of variance was also violated on several variables, as determined by Levene's statistic, and sample sizes were uneven. Furthermore, data were re-analysed for normality following a natural-log transformation, which was unsuccessful in correcting the distributions. The initial examination of the data found the dataset to be not normally distributed, which meant that parametric statistical tests were not appropriate. Therefore, appropriate nonparametric tests were used in the following analyses. Specifically, the Mann-Whitney U Test to test differences in nonparametric data sets with one population having larger values than the other.

Results

Table 3 displays descriptive statistics for the five indicators for each of six graduate learning outcomes. Details of the statistical analysis are presented separately for each graduate learning outcome across the five indicators.

Table 3. Summary statistics including mean (M), standard deviation (SD), and percent agreement (% Agree) for student and academic perceptions of all graduate learning outcomes across all indicators.

		Importance		Included		Assessed		Improvement		Future Use	
		M (SD)	% Agree	M (SD)	% Agree	M (SD)	% Agree	M (SD)	% Agree	M (SD)	% Agree
Scientific Content Knowledge	Academics	3.74 (.44)	100.0	3.64 (.59)	94.3	3.54 (.65)	91.5	3.53 (.58)	95.7	2.77 (.62)	70.0
	Students	3.74 (.46)	98.9	3.72 (.54)	96.6	3.75 (.50)	97.3	3.59 (.66)	92.8	3.37 (.75)	91.1
Oral Communication Skills	Academics	3.27 (.54)	95.7	2.53 (.65)	47.1	2.40 (.67)	38.6	2.79 (.61)	71.5	3.37 (.64)	91.4
	Students	3.26 (.68)	88.9	2.59 (.83)	54.0	2.50 (.84)	46.1	2.52 (.90)	51.4	3.31 (.82)	82.6
Writing Skills	Academics	3.61 (.52)	98.6	2.70 (.75)	61.5	2.64 (.76)	62.9	2.76 (.60)	70.0	3.44 (.63)	92.9
	Students	3.47 (.61)	94.6	3.18 (.79)	80.5	3.19 (.78)	80.8	2.95 (.86)	70.6	3.00 (.87)	70.7
Quantitative Skills	Academics	3.64 (.57)	95.9	2.93 (.69)	72.9	2.80 (.69)	64.3	2.94 (.66)	75.7	3.03 .70	70.0
	Students	3.44 (.60)	94.7	3.22 (.71)	84.6	3.20 (.75)	81.4	3.03 (.79)	76.8	2.98 (.86)	71.6
Teamwork Skills	Academics	2.83 (.59)	75.7	2.56 (.65)	55.7	2.26 (.61)	31.4	2.59 (.53)	60.0	3.41 (.55)	97.1
	Students	3.24 (.70)	87.0	2.89 (.78)	70.1	2.70 (.81)	59.1	2.67 (.83)	59.9	3.47 (.69)	90.2
Ethical Thinking Skills	Academics	2.83 (.72)	70.0	1.99 (.67)	15.8	1.74 (.67)	10.0	2.20 (.81)	32.8	2.40 (.84)	37.2
	Students	3.22 (.72)	86.9	2.42 (.88)	40.8	2.31 (.76)	32.9	2.48 (1.35)	49.5	3.07 (.90)	74.1

Scientific content knowledge

Students' and academics' perceptions converged on three of the five indicators for scientific content knowledge with students reporting higher levels of future use and assessment of content knowledge than academics. Table 3 shows high levels of agreement were found between both groups with the exception of academics' views on the future use of scientific content knowledge.

Importance: There was no significant difference between students and academics in their perceptions of the importance of scientific content knowledge, $p = .788$.
Included: There was no significant difference between students and academics in their perceptions of inclusion of scientific content knowledge, $p = .207$.
Assessed: A significant difference was identified between academics and students in their perceptions of the assessment of scientific content knowledge, $U = 18413.00$, $z = 3.42$, $p = .001$, such that students reported more assessment of scientific content knowledge than do academics.
Improvement: There was no significant difference between students and academics in their perceptions of improvement in scientific content knowledge, $p = .226$.
Future Use: A significant difference was identified between students and academics in their perceptions of the expected future use of scientific content knowledge, $U = 10421.50$, $z = 8.196$, $p < .001$, such that students expect to use their scientific content knowledge more often five years after graduation than do academics.

Oral communication skills

Students' and academics' perceptions converged on four of the five indicators with students reporting higher levels of assessment of oral communication than academics. Table 3 shows students and academics both cited low levels of inclusion in the curriculum, assessment and sense of improvement when compared to indicators of importance and use of oral communication in the future.

Importance: There was no significant difference between academics and students in their perceptions of the importance of communication skills, $p = .581$.
Included: There was no significant difference between academics and students in their ratings of the inclusion of communication skills, $U = 19606.50$, $z = 1.84$, $p = .065$.
Assessed: A significant difference was identified between students and academics in their perceptions of how often communication skills are assessed, $U = 19220.00$, $z = 2.11$, $p = .035$, such that students reported more assessment of communication skills than did academics.
Improvement: There was no significant difference between academics and students in their ratings of improvement in communication skills, $U = 19563.00$, $z = 1.85$, $p = .064$.

Future Use: There was no significant difference between students and academics in the perceived use of communication skills five years after graduation, $p = .884$.

Scientific writing skills

Students' and academics' perceptions converged on only one indicator – that scientific writing skills were an important graduate learning outcome to be developed in a science degree program. Consistently low levels of agreement across the indicators were found, as shown in Table 3, particularly for academics who identified the importance of the skill and future use compared to inclusion and being assessed in the curriculum.

Importance: There was no significant difference between academic and student perceptions of the importance of writing skills, $p = .206$.
Included: A significant difference was identified between academics and students in their perceptions of the inclusion of writing skills, $U = 13804.50$, $z = 5.71$, $p < .001$, such that students report more inclusion of writing skills than do academics.
Assessed: A significant difference was identified between academics and students in their perceptions of assessment of writing skills, $U = 12864.00$, $z = 6.32$, $p < .001$, such that students report more assessment of writing skills than do academics.
Improvement: A significant difference was identified between academics and students in their perceptions of improvement in writing skills, $U = 18029.50$, $z = 2.86$, $p = .004$, such that students report more improvement in writing skills than do academics.
Future Use: A significant difference was identified between academics and students in their perceptions of expected future use of writing skills, $U = 15962.50$, $z = 4.19$, $p < .001$, such that academics expect more use of writing skills five years after graduation than do students.

Quantitative skills

Students' and academics' perceptions of quantitative skills converged on only two indicators – student improvement in quantitative skills and the likelihood that students will use quantitative skills five years after graduation. Consistently high levels of agreement across the indicators were not found, although students' views of quantitative skills were more consistently high than academics as shown in Table 3.

Importance: A significant difference was identified between students and academics in their perceptions of the importance of quantitative skills, $U = 18343.00$, $z = 2.82$, $p < .005$, such that academics perceive quantitative skills to be more important than do students.
Included: A significant difference was identified between students and academics in their perceptions of the inclusion of quantitative skills, $U = 17405.00$, $z = 3.36$, $p < .001$, such that students report quantitative skills are more often included than do academics.
Assessed: A significant difference was identified between students and academics in their perceptions of the assessment of quantitative skills, $U = 16209.50$, $z = 4.09$, $p < .001$, such that students report more assessment of quantitative skills than do academics.
Improvement: There was no significant difference between academics and students in their perceptions of improvement in quantitative skills, $p = .235$.
Future Use: There was no significant difference between academics and students in their perceptions of how much students would use quantitative skills five years after graduation, $p = .666$.

Teamwork skills

Students' and academics' perceptions converged on only two of the indicators for teamwork skills with students reporting higher levels of inclusion in the curriculum, being assessed and beliefs that teamwork skills are important. Table 3 shows a lack of consistent, high level agreement across all the indicators for both students and academics.

Importance: A significant difference was identified between academics and students in their perceptions of the importance of teamwork skills, $U = 14398.50$, $z = 5.42$, $p < .001$, such students perceive teamwork skills to be more important than do academics.
Included: A significant difference was identified between academics and students in their perceptions of the inclusion of teamwork skills, $U = 15786.50$, $z = 4.42$, $p < .001$, such that students report more inclusion of teamwork skills than do academics.
Assessed: A significant difference was identified between students and academics in their perceptions of the assessment of teamwork skills, $U = 14453.00$, $z = 5.24$, $p < .001$, such that students report more assessment of teamwork skills than do academics.
Improvement: There was no significant difference between student and academic perceptions of improvement in teamwork skills, $p = .121$.

Future Use: There was no significant difference between student and academic perceptions of expected future use of teamwork skills five years after graduation, $p = .106$.

Ethical thinking skills

Students' and academics' perceptions did not converge on any of the indicators for ethical thinking skills. Table 3 displays overall low levels of agreement across indicators for ethical thinking skills for both students and academics.

Importance: A significant difference was identified between students and academics in their perceptions of the importance of ethical thinking skills, $U = 15150.00$, $z = 4.92$, $p < .001$, such that students report ethical thinking skills to be more important than do academics.
Included: A significant difference was identified between academics and students in their perceptions of the inclusion of ethical thinking skills, $U = 14142.00$, $z = 5.57$, $p < .001$, such that students report more inclusion of ethical thinking skills than do academics.
Assessed: A significant difference was identified between students and academics in their perceptions of assessment of ethical thinking skills, $U = 12291.50$, $z = 6.88$, $p < .001$, such that students report more assessment of ethical thinking skills than do academics.
Improvement: A significant difference was identified between students and academics in their perceptions of improvements in ethical thinking skills, $U = 16797.00$, $z = 3.66$, $p < 001$, such that students report more improvement in ethical thinking skills than do academics.
Future Use: There was a significant difference between students' and academics in their perceptions of expected future use of ethical thinking skills, $U = 12400.00$, $z = 6.50$, $p < .001$, such that students expect to use ethical thinking more often five years after graduation than do academics.

Discussion

This study is situated in the *planned-enacted-experienced* curriculum model (Figure 1; Erickson and Schulz 1992) with results interpreted through the lens of the adapted framework for the progressive development of complex learning outcomes (Knight 2001, Mercer-Mapstone and Matthews 2015) to illuminate convergence between 'what academics plan' and 'what students experience' in regards to broader graduate learning outcomes. Ideal results would reveal curriculum convergence between the *planned* and *enacted* curriculum of academics' and the students' *experience* of that curriculum with both reporting high levels of agreement consistent across all indicators for each graduate learning outcome. Overall, the results demonstrate that curriculum convergence was rare. Curriculum convergence between students and academics with high levels of agreement across indicators was only visible for the acquisition of scientific content knowledge.

These results are perhaps unsurprising considering that graduate learning outcomes for whole of program curriculum development are a recent phenomenon and the flexible nature of generalist degree programs complicates notions of progressive development (Fraser and Thomas 2013). Furthermore, academics' conceptions of curriculum are typically focused on unit-level activities (Fraser and Bosanquet 2006) and graduate learning outcomes are largely invisible to science students with the exception of content knowledge (Varsavsky, Matthews, and Hodgson 2013). Yorke and Knight (2006) stated that the presence of gaps and discontinuities in the expectations for, and provision of, transferrable skills are most likely to occur where students have a broad range of course choices – as is the case for generalist degrees such as the BSc.

The divergence between students and academics is striking for several of the graduate learning outcomes. There was no convergence on ethical thinking with low levels of agreement from both students and academics. Students reported higher perceptions than academics across all indicators. This result reveals a fundamental tension between students and academics in the teaching and learning of ethical thinking in the degree program. There is a clear need to further investigate the complexities of this graduate learning outcome from the perspective of both students and academics. Perhaps the students in this study are more ethical than their teachers, or the academics avoid teaching ethical thinking because it is a difficult task. Ethical attitudes and beliefs are influenced by disciplinary context and have been conceptualised as a developmental process linked to critical thinking (Clarkeburn, Downie, Gray, & Matthews, 2003). Explicitly teaching ethics within the context of the discipline, linked to critical thinking across the degree program has been recommended (Healey, 2014).

Where convergence is not occurring, the results offer a clear focus for curriculum development. Beyond the "gaps" identified, an examination of the patterns in the results between students and academics provides direction for further research and curriculum development more broadly.

Graduate learning outcomes are distinctive

Each of the six learning outcomes (quantitative skills, ethical thinking, written and oral communication, disciplinary knowledge, and teamwork) explored has a distinct trend across the five indicators (importance, included, assessed, improvement, and future use) with varying levels of convergence between student and academic perceptions. This indicates that where gaps in perceptions, and particularly low agreements, arise there is not likely to be a 'one size fits all' explanation or solution. It is more likely that the development of each learning outcome will benefit most from being considered individually and there may be a specific curriculum development model that is most suitable for each skillset. Knight's (2001) notion of progressive curriculum development, which argues that such outcomes should be systematically incorporated across the whole degree program and scaffolded appropriately, provides a broad model. What progressive development looks like, however, will differ for each learning outcome with each requiring thoughtful consideration of the context, student cohorts, and academics' beliefs. For example, the pedagogical approach of explicit instruction has been shown to be particularly successful in teaching transferrable communication skills in science degrees (e.g. Moni et al. 2007, Mercer-Mapstone and Kuchel 2015). In contrast, the development of quantitative skills in science curricula is dependent on prior mathematical knowledge of students (Matthews, Adams, and Goos 2009) and hence prerequisites for entry into the science degree program (Belward et al. 2011).

Programmatic assessment frameworks for graduate learning outcomes

The results of this study indicate that there was no convergence between academics and students on assessment, with students reporting consistently higher levels of assessment, across all six of the graduate learning outcomes. This suggests that students are more assessed than academics realise and that the assessment of these learning outcomes is not occurring in a structured or visible manner. This lack of convergence on assessment is disconcerting. Assessment is integral to the quality of learning outcomes and critical to student learning and retention (Biggs and Tang 2011, Morgan et al. 2007, Crooks 1988). One explanation for the lower academic perceptions is that academics experience a smaller sample of assessment tasks than students. Students experience a series of parallel units of study progressing from year to year, while academics experience the modules or unit of studies they teach as isolated experiences with little collective planning of the curriculum (Barnett and Coate 2007; Lattuca and Stark 2009).

The risks in academics' unawareness of when, where, and how often students are being assessed are twofold. First, over-assessment becomes an issue because students tend to adopt instrumental and shallow approaches to learning when overwhelmed with multiple assessment tasks (Biggs and Tang 2011), which is often the case in science programs (Jessop and Maleckar 2014). Second, uncoordinated patterns of assessment in degree programs can inhibit students' development of graduate learning outcomes. Students will not necessarily make the connections across different assessment tasks even when there are numerous assessment opportunities to build a specific graduate learning outcome across the degree program (Boud, Lawson, and Thompson 2014). This is important given that coordinating assessment tasks and grading criteria across units of study has been found to enhance students' awareness of their own learning (Boud, Lawson, and Thompson 2014). A coherent approach to curriculum planning in assessment practices would facilitate the development of complex learning outcomes in a structured and progressive manner (Knight 2001), which could address over-assessment and open up resources for deeper student learning and engagement given fewer assessment tasks. As discussed previously, however, this approach would need to take into consideration the nuanced differences required to teach and learn each individual graduate skillset.

Strengths, limitations and further research

These results of this study provide a much needed comparison of two perspectives on curricula that are under-represented in the literature. This comparison provides valuable insight into where limited resources in the higher education sector might best be allocated to ensure students and academics gain most benefit from being actively engaged with the science curriculum. However, care should be taken when generalising or extrapolating the results of this study to a broader context for two key reasons. First is the fact that the academics may view the curriculum in a significantly different way to students – with a subject-specific perspective rather than that of the broad curriculum. Second, the sample size of students is large; however, data were collected from a single institution without longitudinal data to explain trends.

Future focus for practice and research in curriculum development for graduate learning outcomes would usefully be on convergence between stakeholders to develop a shared understanding of curricular goals. Further research into which pedagogical and curricular approaches best fit each graduate skillset would greatly facilitate the progressive development of these complex learning outcomes in future curriculum development. Studies at the level of degree programs exploring specific science graduate learning outcomes are rare but emerging (e.g. Matthews, Hodgson, and Varsavsky, 2013, Mercer-Mapstone and Matthews 2015). Such studies would benefit the sector, particularly where links are explored between graduate learning outcomes and specific models or framework for curriculum development. The influence of individual student characteristics and how the learning environment shapes these complex learning outcomes is another important avenue for further research.

Conclusion

This study paints a picture of how students and academics perceive the development of graduate learning outcomes at a research-intensive Australian university. Overall, curriculum convergence – agreement between the *planned* and *enacted* curriculum of academics' and the students' *experience* of that curriculum – was rare. Examination of the trends across learning outcomes and indicators provided insight into areas for curriculum development and further research. Two predominant recommendations resulted from this analysis. The first is the need to view each learning outcome as distinct – indicating the need for potentially different pedagogical and curricular approaches to the progressive development of each graduate skillset. The second is the need for a programmatic assessment framework to be developed for the BSc at the degree program level. This recommendation arose from the findings that indicated that students' and academics' perceptions of assessment did not converge for any of the six graduate learning outcomes explored in this study. A more coherent approach to assessment could facilitate the development of such complex learning outcomes in a structured and progressive manner.

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