International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

A comparative study on student perceptions of their learning outcomes in undergraduate science degree programmes with differing curriculum models

Kelly E. Matthews, Jennifer Firn, Susanne Schmidt & Karen Whelan

To cite this article: Kelly E. Matthews, Jennifer Firn, Susanne Schmidt & Karen Whelan (2017): A comparative study on student perceptions of their learning outcomes in undergraduate science degree programmes with differing curriculum models, International Journal of Science Education, DOI: 10.1080/09500693.2017.1304672

To link to this article: http://dx.doi.org/10.1080/09500693.2017.1304672

Published online: 24 Mar 2017.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2017
http://dx.doi.org/10.1080/09500693.2017.1304672

A comparative study on student perceptions of their learning outcomes in undergraduate science degree programmes with differing curriculum models

Kelly E. Matthews[a], Jennifer Firn[b], Susanne Schmidt[c] and Karen Whelan[d]

[a]Institute for Teaching and Learning Innovation, The University of Queensland, Brisbane, Australia; [b]School of Earth, Environmental and Biological Sciences, Queensland University of Technology (QUT), Brisbane, Australia; [c]School of Agriculture and Food Sciences, The University of Queensland, Brisbane, Australia; [d]Science and Engineering Faculty, Queensland University of Technology (QUT), Brisbane, Australia

ABSTRACT

This study investigated students' perceptions of their graduate learning outcomes including content knowledge, communication, writing, teamwork, quantitative skills, and ethical thinking in two Australian universities. One university has a traditional discipline-orientated curriculum and the other, an interdisciplinary curriculum in the entry semester of first year. The Science Students Skills Inventory asked students ($n = 613$) in first and final years to rate their perceptions of the importance of developing graduate learning outcomes within the programme; how much they improved their graduate learning outcomes throughout their undergraduate science programme; how much they saw learning outcomes included in the programme; and how confident they were about their learning outcomes. A framework of progressive curriculum development was adopted to interpret results. Students in the discipline-oriented degree programme reported higher perceptions of scientific content knowledge and ethical thinking while students from the interdisciplinary curriculum indicated higher perceptions of oral communication and teamwork. Implications for curriculum development include ensuring progressive development from first to third years, a need for enhanced focus on scientific ethics, and career opportunities from first year onwards.

ARTICLE HISTORY
Received 8 December 2016
Accepted 7 March 2017

KEYWORDS
Learning gains; science skills; undergraduate science; student perceptions; interdisciplinary science; curriculum development

Introduction

Australian universities, like institutions elsewhere, have undergone a shift towards the development of explicit 'graduate attributes or graduate learning outcomes' (Barrie, 2006). This shift was reflected in the sciences with a nationally agreed-upon set of 'Threshold Learning Outcomes for Science' (referred to here as 'graduate learning outcomes') expected of all university graduates in science (Jones, Yates, & Kelder, 2011). These statements represent a 'set of intentions' that ideally guide academics in curriculum development and reform activities (Oliver, 2013). Placing these outcomes within a curriculum in a meaningful way presents many challenges, particularly in more generalist

CONTACT Kelly E. Matthews k.matthews1@uq.edu.au

degree programmes such as the Bachelor of Science (BSc). Generalist degree programmes typically have fewer core compulsory units, numerous subject choices, no accrediting body, and minimal structure (Fraser & Thomas, 2013).

Research on the efficacy of embedding graduate learning outcomes in undergraduate science degrees has centred on student or academic perceptions (e.g. Mercer-Mapstone & Matthews, 2017; Varsavsky, Matthews, & Hodgson, 2014); employer perceptions (e.g. Schull, Morton, Coleman, & Mills, 2012); student compared to academic perceptions (Matthews & Mercer-Mapstone, 2016); single-degree compared to dual-degree students (Dvorakova & Matthews, 2016) or on specific outcomes (e.g. Matthews, Adams, & Goos, 2015). Cross-institutional studies are rare, with the notable exception of Varsavsky et al. (2014), that draw on graduating science students from two research-intensive Australian universities. They used the Science Students Skills Inventory (Matthews & Hodgson, 2012) to capture students' views about their attainment of some of their graduate learning outcomes (e.g. scientific content knowledge, quantitative skills, ethical thinking). Results indicated that students' perceptions of the importance of all of the graduate learning outcomes was higher than their perceptions of whether they developed them during their science degree programme with the exception of scientific content knowledge.

This study builds on the Varsavsky et al. (2014) study – who argued for further research that explored students' perceptions across more varied educational contexts – by investigating science students' perceptions of their graduate learning outcomes across two universities with two differing curricular models: one traditional, discipline-oriented approach (*University A*) and the other with an interdisciplinary entry semester that leads to a more traditional curriculum structure (*University B*). Understanding science students' perceptions about how the curriculum influences their development of graduate learning outcomes is vital for both practice and research, especially given that students are the intended beneficiaries of curricular reform efforts (Matthews, 2014).

Purpose of study

This study investigates students' perceptions of some of their graduate learning outcomes from two Australian universities that are both guided by the national science graduate learning outcomes. Perceptions were captured from students in both first and third (final) years. Given the interdisciplinary curricular context was specific to first year in *University B*, exploring first-year perceptions offers insight into the lasting effects of the curriculum on broader development of graduate learning outcomes. The research questions guiding this study are:

(1) How do students perceive the development of their science graduate learning outcomes?
(2) How do student perceptions change depending on different cohorts and university curricula?
(3) How do these perceptions differ between first- and final-year students within the same universities?

Methods

The study context

University A is an Australian research-intensive university ranked in the top 100 worldwide (e.g. Times Higher Education World University Rankings, Quacquarelli Symonds World University Rankings). The BSc degree programme underwent an extensive curriculum review in 2006 and again in 2015. The national science graduate learning outcomes were adopted and used to frame curriculum development in the latter review with a strong focus on quantitative skills in the former review (McManus & Matthews, 2015). *University A* enrols approximately 1200 new BSc students annually. The formal (assessed) curriculum comprises discipline-oriented units of study (e.g. chemistry, biology, mathematics, physics) that progress in difficulty, depth, and specificity as students move from lower to upper level units. It includes a traditional assessment regime with highly weighted final examinations that tend towards multiple-choice questions, particularly in large first-year units. Students must complete a compulsory first-year statistics unit and the requirements for a given major (field of study) including a compulsory final-year unit specific to the major.

University B is an Australian University ranked in the top 300 worldwide, and ranked 18 of universities globally that are 50 years and younger (e.g. Quacquarelli Symonds 50 under 50 World University Rankings). *University B* enrols approximately 600 new BSc students annually. The BSc degree programme underwent extensive curriculum renewal in 2012 framed around the national science graduate learning outcomes. The outcome of the 2012 review was the development of a first semester, first-year interdisciplinary curriculum comprised of four units of study framed around wicked problems (e.g. food security, space – the new frontier, and climate change). The intent was to maximise inquiry-based, collaborative learning opportunities. Students in the first year were assessed through a range of authentic tasks including oral poster presentations and written literature reviews. After this first semester, students then choose among five majors that are disciplinary-oriented (chemistry, biology, physics, earth sciences, and environmental sciences) that contribute towards a compulsory final-year unit of study.

Theoretical framework for curriculum development

We apply the adaptation of Knight's argument (2001), as articulated by Mercer-Mapstone and Matthews (2017), that the curriculum through which complex learning outcomes are taught should support the progressive development of skills over time as a result of coherent planning. According to Knight (2001, p. 10), 'learning encounters need to be planned to suffuse the programme' to allow students multiple, coherent yet progressive opportunities to practise and master skill development across the degree programme. We draw on Knight's (2001) framework as follows:

> An ideal curriculum under the framework of progressive development of complex learning outcomes would show that student perceptions of learning were high at each year level reflecting a status in which the expectations of students were met with teaching and learning activities appropriate to their stage of skills development. (Mercer-Mapstone & Matthews, 2017, p. 4)

Thus, students' levels of perception of their graduate learning outcomes would be high across all indicators. Similar to the way that Mapstone-Mercer and Matthews (2017) interpreted this framework, these graduate learning outcomes should be visible to students in both first and final years such that no statistically significant differences should be evident between them given that students were asked to reflect on their current experiences, rather than in hindsight.

Data collection instrument

The Science Student Skills Inventory (SSSI) is a survey specific to science and explores how the whole science degree programme contributes to the development of several science graduate outcomes. The SSSI has been published previously, including information on its validity and reliability (Matthews & Hodgson, 2012), and has been used in multiple studies (Matthews, Hodgson, & Varsavsky, 2013; Mercer-Mapstone & Matthews, 2017; Varsavsky et al., 2014). The survey elicited students' perceptions of their own graduate learning outcomes and the role of those six outcomes in the science programme, on a four-point scale, across five indicators (importance, inclusion, assessment, improvement, and confidence). For example, respondents were asked, 'to what extent were activities to develop the following *assessed* in your science program?' Then, six graduate outcomes were listed: *scientific content knowledge* in your field(s) of study; *communication skills* (oral scientific presentations); *writing skills* (scientific writing), *teamwork skills* (working with others to achieve a shared task); *quantitative skills* (mathematical and statistical reasoning); and *ethical thinking* (ethical responsibilities and approaches). The exact wording for survey prompts is displayed in Table 1. The demographic information sought from students included gender, age, and graduation plans (employment, postgraduate studies – research, postgraduate studies – professional, other, or no plans yet), as outlined in Table 2.

Table 1. Structure of survey questions, with measures of perception and categories used for analyses to explore six graduate learning outcomes.

	1 (low)	2 (low)	3 (high)	4 (high)
How IMPORTANT is it to have activities that develop the following included in the Science degree course?	Not at all important	Not very important	Important	Very important
To what extent were activities to develop the following INCLUDED in your Science degree course?	Not included at all	Included a little	Included a moderate amount	Included a lot
Throughout your entire Science degree course, how often were the following assessed?	Not at all	A little	Quite a bit	A lot
As a result of your overall Science degree course, please indicate the level of IMPROVEMENT you made in the following?	No improvement	Little improvement	Moderate improvement	A great deal of improvement
To what extent do you feel CONFIDENT in the following as a result of your Science degree course?	Not at all confident	A little confident	Moderately confident	Very confident

Table 2. Demographic variables and categories used for analysis.

Variable	Categories				
Sex	Female	Male			
University	Uni A	Uni B			
Graduate plans	Paid work	Postgraduate (professional)	Postgraduate (research)	No set plans	Other
Year level	First year	Third year			

Data collection and participants

First- (*n* = *1077 at University A; n* = *559 at University B*) and final- (*n* = *667 at University A; n* = *264 at University B*) year science students from the BSc were invited to complete the SSSI online. The overall response rate was 23.88% *(n* = *613)* with 28.38% for *University A* and 14.34% at *University B*. The majority of the sample was from *University A* (*n* = 495, 80%) which corresponds with a twofold enrolment at *University A* relative to *University B*. At *University A*, 60.8% (*n* = 301) were female respondents with 191 (38.6%) male respondents with 0.6% (*n* = 3) not indicating a gender with 147 female first-year respondents and 154 female final-year respondents. At *University B,* 58.5% (*n* = 69) were female respondents with 49 (38.6%) male respondents with 41 female first-year respondents and 28 female final-year respondents.

First-year students comprised 51.9% of the sample (*n* = 318) with 370 (60.4%) female respondents (*n* = *301 at University A; n* = *at University B*), which corresponds to more females in the BSc than males at both institutions.

Data analysis

Analysis followed the approach used by Varsavsky et al. (2014). This involved examining descriptive statistics for each indicator of importance, inclusion, assessment, improvement, and confidence across each learning outcome (as shown in Table 1), which were also compared between first- and third-year cohorts and universities. Students' plans after graduation were categorised according to students' intentions across five categories. Students intending to enter the work force following graduation, whether in a science- or non-science-related area, were categorised as 'paid work'. Those indicating a preference for continued study in education, medicine, or other health discipline were categorised as having 'professional' postgraduate plans. Similarly, students planning to pursue postgraduate research degrees were classified as having 'research' postgraduate plans. Students indicating that they had no fixed intentions to work or study were categorised as 'no set plans', while those who indicated fixed intentions for activities other than work or postgraduate study (e.g. travelling, another unspecified undergraduate degree) were categorised into 'other'. Table 2 provides a summary of categories used in the analyses. The sample was also categorised according to whether students were completing first-year subjects, categorised as 'first years' or third-year subjects categorised as 'third years'.

A series of independent samples *t*-tests and one-way analyses of variance (ANOVAs) were used to determine differences in student perceptions of each graduate learning outcome across gender, university, graduate plans, and year level, as done in Varsavsky et al. (2014). Where Levene's test of homogeneity of variance was significant, more conservative *p* values are reported (using Welch's *F* and with equal variances not assumed).

Follow-up independent *t*-tests of differences between graduate plans used a Bonferroni correction to control for multiple comparisons. An alpha level of .05 for statistical significance was used for all analyses. Data were analysed using IBM SPSS Version 22.

Findings

Perceptions of graduate learning outcomes overall

Table 3 displays perceptions of each indicator (assessment, importance, inclusion, improvement, confidence) for each of the six learning outcomes showing the mean (standard deviation) and number (percentage) of students rating 'high' (top two Likert items added together).

Scientific content knowledge

Perceptions of scientific content knowledge (Table 4, Figure 1) did not differ significantly depending on gender or year level, but differed significantly between universities and graduate plans.

University A and *University B* differed significantly across student perceptions of four of the five indicators measured in scientific content knowledge such that *University A* (discipline-oriented curriculum) student's ratings were higher than *University B* (interdisciplinary entry curriculum) students' ratings of inclusion, assessment, improvement, and confidence ($p \leq .01$ for each, respectively).

Students' ratings of scientific content knowledge also differed with graduate plans in terms of inclusion, assessment, and confidence. Students with plans for further 'professional postgraduate' reported more inclusion of scientific content knowledge than 'no set plans' students ($p = .003$). Students with 'professional postgraduate' plans reported more frequent assessment of scientific content knowledge than 'research postgraduate students' ($p = .043$) and students with 'no current plans' ($p < .001$). Students planning to enter 'paid work' (e.g. employment) upon graduation reported lower confidence in scientific content knowledge than 'professional postgraduate' students ($p = .009$). Students with plans for further 'professional postgraduate' study reported more confidence in scientific content knowledge than students with no 'set plans' ($p < .001$). Similarly, students with 'research postgraduate' plans reported higher confidence in scientific content knowledge skills than students with 'no set plans' ($p < .001$).

Table 3. Perceptions of assessment, importance, inclusion, improvement, and confidence for each of the six skills: mean (standard deviation) and number (percentage) of students rating 'high'.

	Scientific content knowledge	Oral communication	Writing	Teamwork	Quantitative	Ethical thinking
Importance	3.77 (±.45)	3.35 (±.66)	3.58 (±.53)	3.34 (±.64)	3.47 (±.57)	3.28 (±.70)
High	605 (98.7%)	557 (90.9%)	603 (98.4%)	557 (90.9%)	591 (96.4%)	534 (87.1%)
Inclusion	3.68 (±.54)	2.63 (±.84)	3.21 (±.75)	3.07 (±.75)	3.20 (±.68)	2.44 (±.77)
High	593 (96.7%)	346 (56.4%)	504 (82.2%)	477 (77.8%)	527 (86.0%)	257 (41.9%)
Assessment	3.71 (±.54)	2.48 (±.86)	3.23 (±.71)	2.85 (±.80)	3.14 (±.71)	2.29 (±.75)
High	592 (96.6%)	295 (48.1%)	521 (85.0%)	407 (66.4%)	506 (82.5%)	196 (32.0%)
Improvement	3.56 (±.65)	2.56 (±.86)	3.03 (±.80)	2.80 (±.80)	2.96 (±.78)	2.55 (±.85)
High	576 (94.0%)	331 (54.0%)	463 (75.5%)	407 (66.4%)	457 (74.6%)	316 (51.5%)
Confidence	3.22 (±.64)	2.77 (±.83)	3.04 (±.71)	3.08 (±.72)	2.89 (±.77)	2.83 (±.81)
High	553 (90.2%)	404 (65.9%)	496 (80.9%)	503 (82.1%)	449 (73.2%)	422 (68.8%)

Table 4. Differences in perception of *scientific content knowledge* by socio-demographic and academic factors.

	Importance		Inclusion		Assessment		Improvement		Confidence	
Variables	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*
Sex		.47		.38		.29		.63		.07
Male	3.75 (±.48)		3.66 (±.56)		3.68 (±.57)		3.54 (±.70)		3.28 (±.68)	
Female	3.78 (±.43)		3.70 (±.53)		3.73 (±.52)		3.57 (±.62)		3.18 (±.62)	
University		.63		**<.01**		**<.01**		**<.01**		**.01**
Uni A	3.77 (±.46)		3.74 (±.49)		3.79 (±.45)		3.60 (±.63)		3.26 (±.64)	
Uni B	3.79 (±.41)		3.44 (±.65)		3.39 (±.75)		3.37 (±.69)		3.08 (±.66)	
Graduate plans		.22		**.01**		**<.01**		.06		**<.01**
Paid work	3.77 (±.45)		3.65 (±.52)		3.69 (±.55)		3.55 (±.58)		3.15 (±.58)	
Professional	3.78 (±.45)		3.78 (±.47)		3.83 (±.42)		3.61 (±.71)		3.35 (±.65)	
Research	3.86 (±.42)		3.70 (±.54)		3.63 (±.63)		3.66 (±.60)		3.37 (±.71)	
No set plans	3.69 (±.49)		3.54 (±.68)		3.54 (±.63)		3.42 (±.66)		2.97 (±.64)	
Other	3.80 (±.41)		3.53 (±.52)		3.53 (±.64)		3.33 (±.62)		3.13 (±.52)	
Year Level										
Uni A		.714		.450		.221		<**.001**		.635
First year	3.77 (±.45)		3.72 (±.49)		3.76 (±.45)		3.49 (±.70)		3.24 (±.62)	
Third year	3.76 (±.47)		3.76 (±.49)		3.81 (±.45)		3.71 (±.53)		3.27 (±.66)	
Uni B		.070		**.034**		**<.001**		**.001**		**.015**
First year	3.73 (±.45)		3.34 (±.68)		3.20 (±.79)		3.20 (±.71)		2.96 (±.62)	
Third year	3.87 (±.34)		3.60 (±.58)		3.68 (±.59)		3.64 (±.57)		3.26 (±.68)	

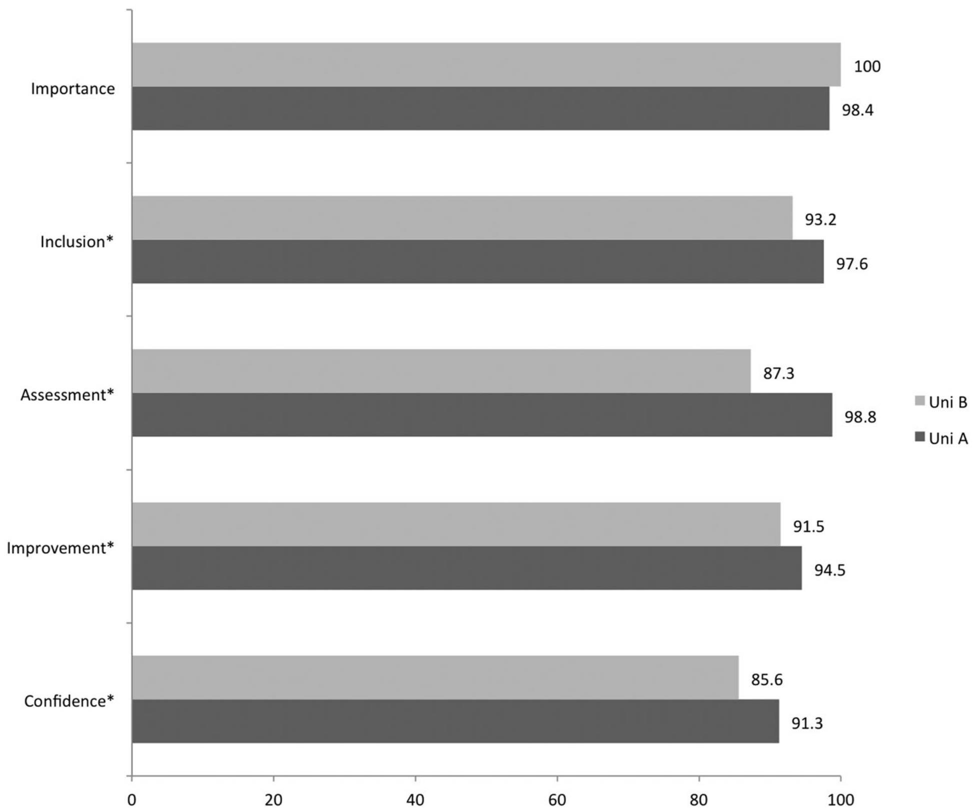

Figure 1. Per cent for high level of agreement for scientific content knowledge by university (*statistically significant difference between universities).

Oral scientific communication skills

Perceptions of oral communication skills varied statistically across all demographic factors (Table 5 and Figure 2).

University B students' ratings were higher than *University A* students' ratings of inclusion ($p < .001$), assessment ($p < .001$), improvement ($p = .001$), and confidence in communication skills ($p = .035$).

Students with 'no set plans' perceived oral communication as less important than students with plans for 'paid work' ($p = .001$), 'professional postgraduate' ($p = .003$), or 'research postgraduate' ($p = .060$) studies. 'Paid work' students perceived that oral communication skills were more frequently included in their degree compared to students intending further 'professional study' ($p = .002$). 'Paid work' students reported greater improvement in oral communication skills than either 'professional' ($p = .001$) or 'no set plans' students ($p = .027$). Students planning further 'research' reported greater improvement in oral communication skills than students with plans for 'professional study' ($p = .034$). Finally, students with 'no set plans' reported lower confidence in their oral communication skills than paid work ($p < .001$), professional ($p < .001$) or research students ($p = .001$).

Perceptions of oral communication skills differed by year level across all five indicators.

Scientific writing skills

Perceptions of scientific writing skills (Table 6 and Figure 3) differed by gender, graduate plans, and year level, but not by university.

Perceptions of confidence in writing skills differed by graduate plans. Students with no 'set plan' reported lower confidence in their writing skills than students planning to do 'research' ($p = .041$).

Across all five indicators, third-year students gave higher ratings than first-year students.

Table 5. Differences in perception of *oral communication skills* by socio-demographic and academic factors.

	Importance		Inclusion		Assessment		Improvement		Confidence	
Variables	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*
Sex		**.037**		.85		.16		.33		**.033**
Male	3.28 (±.69)		2.64 (±.81)		2.43 (±.82)		2.52 (±.85)		2.85 (±.83)	
Female	3.39 (±.63)		2.62 (±.86)		2.52 (±.88)		2.59 (±.87)		2.71 (±.82)	
University		.44		**<.001**		**<.001**		**.001**		**.035**
Uni A	3.36 (±.66)		2.55 (±.83)		2.39 (±.86)		2.51 (±.88)		2.74 (±.84)	
Uni B	3.31 (±.63)		2.96 (±.78)		2.86 (±.75)		2.77 (±.73)		2.91 (±.77)	
Graduate plans		**<.01**		**<.01**		**.054**		**<.01**		**<.01**
Paid work	3.41 (±.60)		2.79 (±.83)		2.61 (±.84)		2.74 (±.83)		2.83 (±.82)	
Professional	3.39 (±.67)		2.49 (±.84)		2.38 (±.88)		2.42 (±.88)		2.83 (±.81)	
Research	3.38 (±.63)		2.78 (±.79)		2.57 (±.77)		2.75 (±.84)		2.89 (±.87)	
No set plans	3.10 (±.69)		2.53 (±.83)		2.41 (±.92)		2.43 (±.82)		2.42 (±.76)	
Other	3.20 (±.68)		2.40 (±.74)		2.33 (±.72)		2.13 (±.83)		2.53 (±.74)	
Year Level										
Uni A		**<.001**		**<.001**		**<.001**		**<.001**		**<.001**
First year	3.25 (±.70)		2.28 (±.85)		2.08 (±.88)		2.27 (±.90)		2.60 (±.88)	
Third year	3.46 (±.60)		2.82 (±.72)		2.70 (±.72)		2.75 (±.79)		2.87 (±.77)	
Uni B		.846		.629		.685		.337		.121
First year	3.30 (±.66)		2.99 (±.71)		2.89 (±.73)		2.72 (±.66)		2.82 (±.82)	
Third year	3.32 (±.59)		2.91 (±.88)		2.83 (±.79)		2.85 (±.83)		3.04 (±.69)	

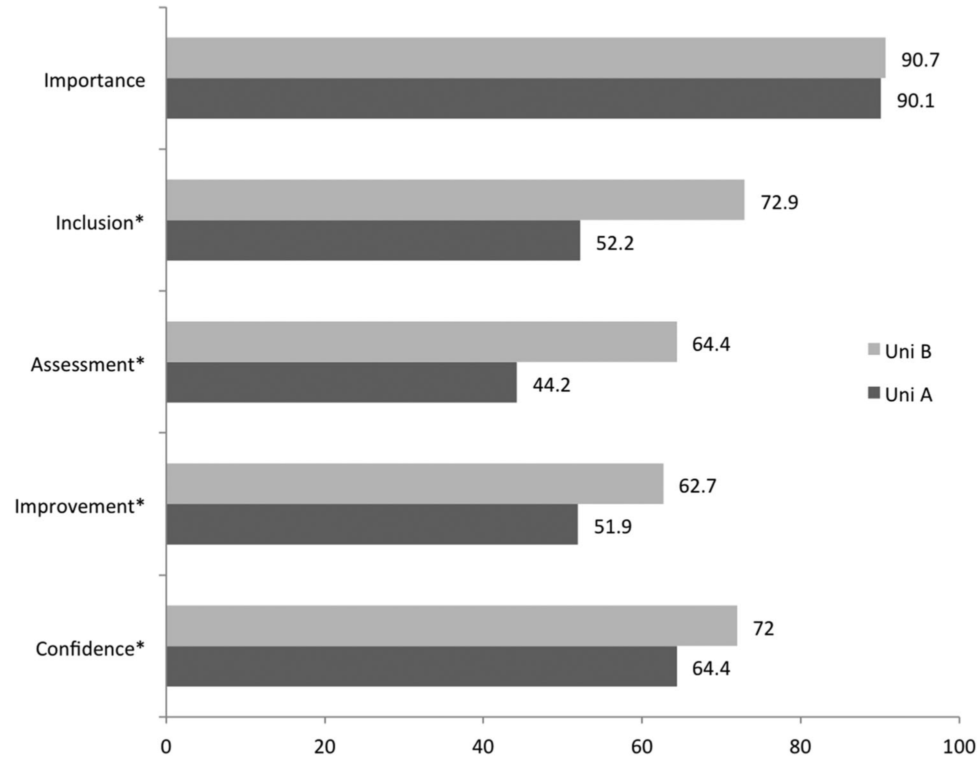

Figure 2. Per cent for high level of agreement for oral science communication skills by university (*statistically significant difference between universities).

Table 6. Differences in perception of *writing skills* by socio-demographic and academic factors.

Variables	Importance		Inclusion		Assessment		Improvement		Confidence	
	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*
Sex		**.019**		.06		.067		.43		.16
Male	3.52 (±.55)		3.13 (±.77)		3.17 (±.70)		3.00 (±.82)		3.09 (±.71)	
Female	3.62 (±.51)		3.25 (±.74)		3.28 (±.71)		3.05 (±.79)		3.01 (±.72)	
University		.52		.52		.46		.93		.24
Uni A	3.58 (±.53)		3.21 (±.74)		3.22 (±.70)		3.03 (±.80)		3.02 (±.71)	
Uni B	3.61 (±.51)		3.20 (±.81)		3.28 (±.73)		3.03 (±.80)		3.11 (±.74)	
Graduate plans		.25		.11		.17		.08		**.01**
Paid work	3.58 (±.52)		3.24 (±.76)		3.31 (±.74)		3.08 (±.74)		2.98 (±.68)	
Professional	3.59 (±.53)		3.26 (±.73)		3.23 (±.66)		3.03 (±.87)		3.12 (±.74)	
Research	3.67 (±.53)		3.18 (±.84)		3.20 (±.78)		3.14 (±.80)		3.21 (±.72)	
No set plans	3.52 (±.52)		3.03 (±.69)		3.09 (±.68)		2.85 (±.71)		2.90 (±.72)	
Other	3.40 (±.51)		3.13 (±.83)		3.33 (±.72)		2.80 (±.94)		2.80 (±.56)	
Year Level										
Uni A		**.006**		**<.001**		**<.001**		**<.001**		**.016**
First year	3.51 (±.55)		3.04 (±.70)		3.02 (±.67)		2.78 (±.78)		2.95 (±.71)	
Third year	3.64 (±.51)		3.37 (±.74)		3.42 (±.68)		3.27 (±.75)		3.10 (±.71)	
Uni B		.391		.136		.076		**.046**		.332
First year	3.58 (±.50)		3.11 (±.77)		3.18 (±.72)		2.92 (±.75)		3.06 (±.67)	
Third year	3.66 (±.52)		3.34 (±.87)		3.43 (±.72)		3.21 (±.83)		3.19 (±.83)	

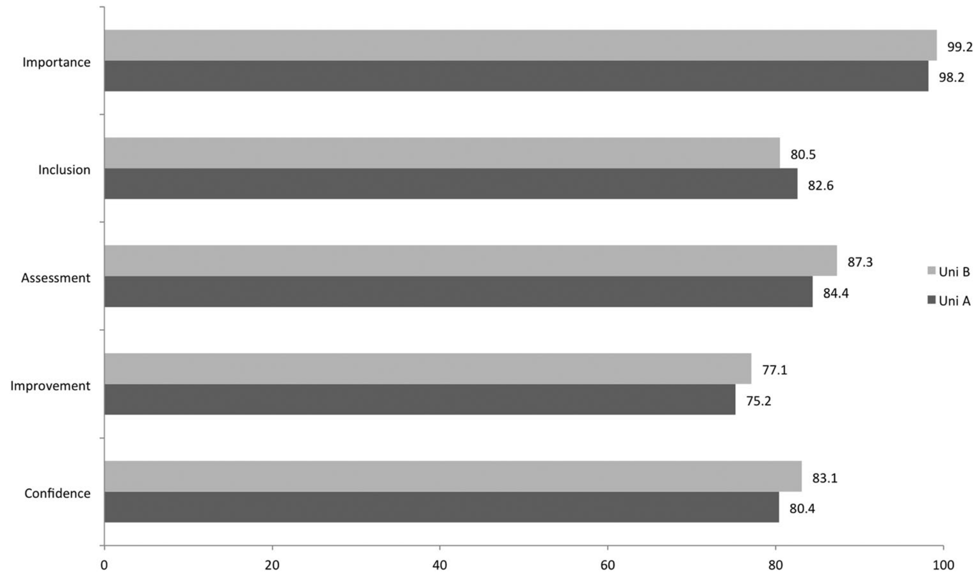

Figure 3. Per cent for high level of agreement for scientific writing skills by university (*statistically significant difference between universities).

Quantitative skills

Perceptions of quantitative skills varied across all demographic variables (Table 7, Figure 4). Males returned higher ratings than females for the importance ($p = .018$), inclusion ($p = .013$), and confidence in quantitative skills ($p < .001$).

University A students reported higher confidence than *University B* students in quantitative skills ($p = .031$). Ratings of quantitative skills also varied by graduate plans. In terms of confidence, students intending to do 'paid work' reported lower confidence in quantitative skills than students with 'professional postgraduate' study plans ($p = .004$).

Table 7. Differences in perception of *quantitative skills* by socio-demographic and academic factors.

Variables	Importance		Inclusion		Assessment		Improvement		Confidence	
	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*
Sex		**.018**		**.013**		.07		.14		**<.001**
Male	3.54 (±.58)		3.29 (±.66)		3.20 (±.69)		3.02 (±.78)		3.13 (±.74)	
Female	3.43 (±.57)		3.15 (±.69)		3.10 (±.73)		2.92 (±.78)		2.74 (±.76)	
University		.59		.66		.22		.17		**.031**
Uni A	3.48 (±.57)		3.20 (±.67)		3.16 (±.71)		2.94 (±.79)		2.93 (±.75)	
Uni B	3.45 (±.58)		3.23 (±.72)		3.07 (±.75)		3.05 (±.75)		2.75 (±.83)	
Graduate plans		.20		.66		.81		**.005**		**<.001**
Paid work	3.42 (±.58)		3.17 (±.69)		3.17 (±.74)		3.04 (±.76)		2.79 (±.75)	
Professional	3.52 (±.58)		3.21 (±.67)		3.11 (±.68)		2.85 (±.85)		3.05 (±.76)	
Research	3.55 (±.55)		3.30 (±.69)		3.14 (±.71)		3.11 (±.76)		3.00 (±.71)	
No set plans	3.44 (±.56)		3.18 (±.70)		3.17 (±.74)		2.99 (±.67)		2.67 (±.80)	
Other	3.33 (±.49)		3.27 (±.70)		3.00 (±.76)		2.60 (±.51)		2.87 (±.74)	
Year Level										
Uni A		.970		**<.001**		**<.001**		.138		**<.001**
First year	3.48 (±.58)		3.32 (±.65)		3.28 (±.68)		2.89 (±.79)		3.05 (±.69)	
Third year	3.48 (±.57)		3.08 (±.67)		3.04 (±.71)		2.99 (±.78)		2.81 (±.79)	
Uni B		.764		**.043**		.120		.249		.831
First year	3.44 (±.63)		3.34 (±.70)		3.15 (±.79)		2.99 (±.73)		2.73 (±.83)	
Third year	3.47 (±.50)		3.06 (±.73)		2.94 (±.67)		3.15 (±.78)		2.77 (±.84)	

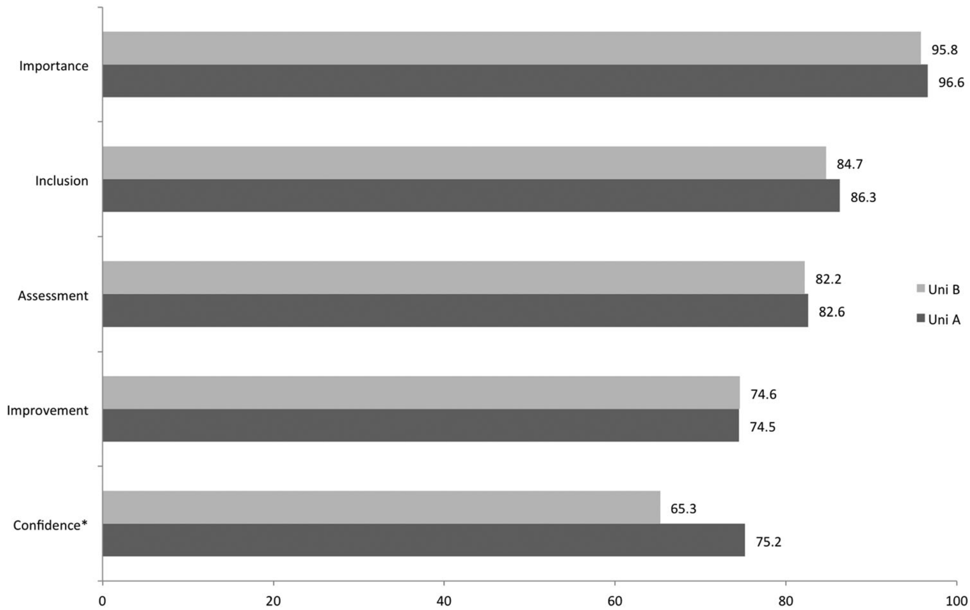

Figure 4. Per cent for high level of agreement for quantitative skills by university (*statistically significant difference between universities).

Students with no 'set plans' reported lower confidence than either 'professional' ($p < .001$) or 'research' students ($p = .043$).

There was also a difference between year levels in perceptions of quantitative skills.

Teamwork skills

Perceptions of teamwork skills (Table 8 and Figure 5) differed by gender, university, and graduate plans, but not by year level.

Table 8. Differences in perception of *team work skills* by socio-demographic and academic factors.

Variables	Importance		Inclusion		Assessment		Improvement		Confidence	
	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*
Sex		.32		**.001**		**.004**		.07		.90
Male	3.30 (±.65)		2.94 (±.79)		2.73 (±.76)		2.73 (±.79)		3.08 (±.74)	
Female	3.36 (±.64)		3.16 (±.72)		2.92 (±.82)		2.85 (±.80)		3.08 (±.71)	
University		.37		**<.001**		**<.001**		**.008**		.17
Uni A	3.35 (±.64)		2.98 (±.74)		2.75 (±.77)		2.76 (±.79)		3.06 (±.71)	
Uni B	3.29 (±.64)		3.44 (±.70)		3.28 (±.75)		2.97 (±.81)		3.16 (±.76)	
Graduate plans		.51		**.009**		**<.001**		**.003**		**.001**
Paid work	3.37 (±.65)		3.20 (±.75)		3.02 (±.75)		2.94 (±.81)		3.14 (±.74)	
Professional	3.37 (±.62)		2.94 (±.73)		2.66 (±.80)		2.67 (±.79)		3.06 (±.71)	
Research	3.26 (±.62)		3.13 (±.75)		2.96 (±.77)		2.93 (±.79)		3.29 (±.71)	
No set plans	3.28 (±.69)		3.06 (±.75)		2.82 (±.80)		2.73 (±.75)		2.83 (±.69)	
Other	3.20 (±.68)		3.13 (±.83)		3.00 (±.85)		2.67 (±.62)		3.00 (±.54)	
Year Level										
Uni A		.870		.464		**.005**		.107		.574
First year	3.35 (±.66)		2.96 (±.71)		2.65 (±.81)		2.70 (±.81)		3.04 (±.68)	
Third year	3.34 (±.63)		3.01 (±.76)		2.84 (±.73)		2.81 (±.77)		3.08 (±.75)	
Uni B		.184		**.026**		**.041**		.380		.529
First year	3.35 (±.64)		3.56 (±.60)		3.39 (±.69)		3.03 (±.77)		3.20 (±.67)	
Third year	3.19 (±.65)		3.26 (±.79)		3.11 (±.81)		2.89 (±.87)		3.11 (±.89)	

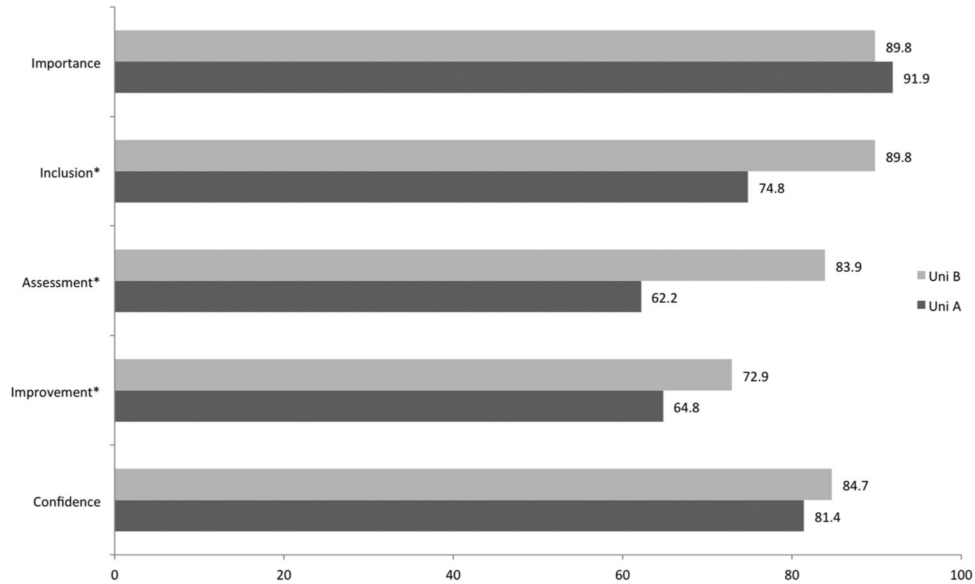

Figure 5. Per cent for high level of agreement for teamwork skills by university (*statistically significant difference between universities).

University B students reported more inclusion ($p < .001$), assessment ($p < .001$) and improvement in their teamwork skills ($p = .008$) than their *University A* peers.

'Paid work' students reported more inclusion ($p = .003$) and improvement ($p = .003$) of teamwork skills than did 'professional postgraduate' students. 'Professional postgraduate' study students, however, reported more assessment of teamwork skills than 'research students' ($p = .036$). Students with 'no set plans' reported lower confidence

Table 9. Differences in perception of *ethical thinking skills* by socio-demographic and academic factors.

Variables	Importance		Inclusion		Assessment		Improvement		Confidence	
	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*	M (SD)	*p*
Sex		**<.001**		.26		**.004**		**.016**		.69
Male	3.16 (±.72)		2.40 (±.78)		2.18 (±.75)		2.45 (±.89)		2.85 (±.81)	
Female	3.36 (±.67)		2.47 (±.77)		2.36 (±.74)		2.62 (±.82)		2.82 (±.81)	
University		**.001**		**<.001**		**.009**		**.008**		.32
Uni A	3.32 (±.68)		2.50 (±.74)		2.33 (±.73)		2.59 (±.84)		2.84 (±.80)	
Uni B	3.09 (±.74)		2.18 (±.83)		2.13 (±.80)		2.36 (±.87)		2.76 (±.82)	
Graduate plans		.105		.081		**.024**		.428		**<.001**
Paid work	3.21 (±.73)		2.57 (±.83)		2.42 (±.78)		2.62 (±.83)		2.78 (±.83)	
Professional	3.36 (±.65)		2.41 (±.70)		2.26 (±.73)		2.56 (±.83)		2.90 (±.76)	
Research	3.26 (±.72)		2.30 (±.80)		2.12 (±.73)		2.51 (±.96)		3.08 (±.73)	
No set plans	3.21 (±.70)		2.35 (±.75)		2.21 (±.71)		2.45 (±.84)		2.54 (±.85)	
Other	3.53 (±.74)		2.40 (±.91)		2.33 (±.82)		2.33 (±.72)		2.93 (±.88)	
Year Level										
Uni A		.583		.415		.981		.975		.702
First year	3.34 (±.67)		2.53 (±.71)		2.32 (±.74)		2.60 (±.86)		2.86 (±.79)	
Third year	3.31 (±.69)		2.48 (±.77)		2.33 (±.72)		2.59 (±.82)		2.83 (±.82)	
Uni B		.392		.310		.458		.296		.675
First year	3.14 (±.70)		2.24 (±.89)		2.17 (±.89)		2.30 (±.84)		2.79 (±.79)	
Third year	3.02 (±.79)		2.09 (±.75)		2.06 (±.64)		2.47 (±.93)		2.72 (±.88)	

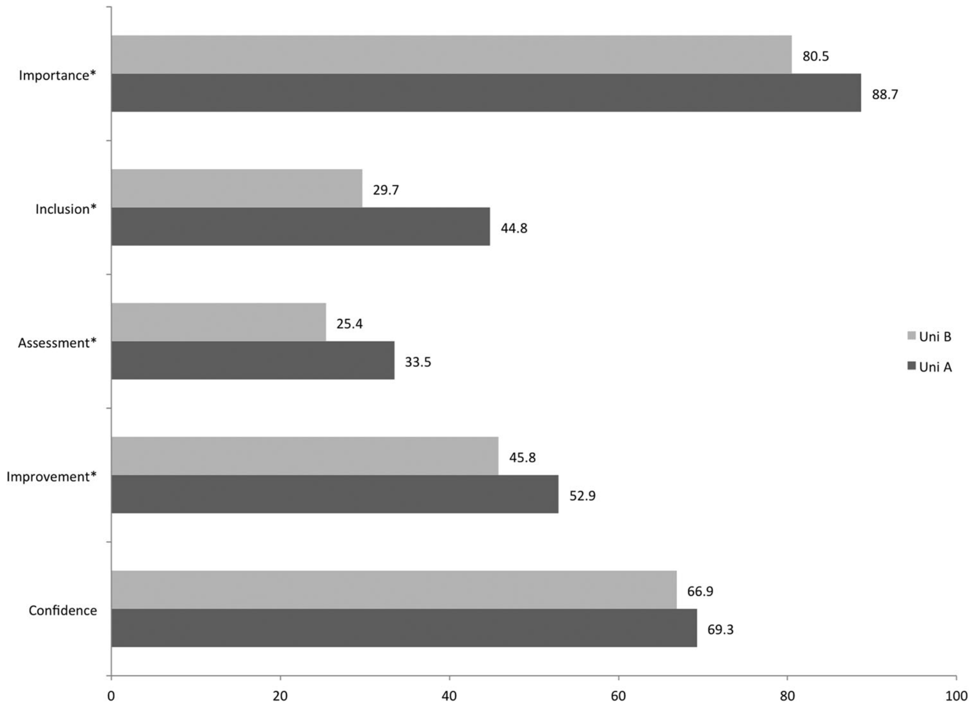

Figure 6. Per cent for high level of agreement for ethical thinking skills by university (*statistically significant difference between universities).

in their teamwork skills than either the 'paid work' ($p = .006$) or 'research students' ($p < .001$).

Ethical thinking skills

Table 9 and Figure 6 show perceptions of ethical thinking skills, which differed by gender, university, and graduate plans, but not by year level.

Universities also differed in perceptions of ethical thinking skills. *University A* gave higher ratings than *University B* in terms of importance ($p = .001$), inclusion ($p < .001$), assessment ($p = .009$), and improvement in ethical thinking skills ($p = .008$).

Students perceived ethical thinking skills differently in terms of assessment and confidence depending on graduation plans. 'Paid work' students reported more frequent assessment of ethical thinking skills than did students planning to do 'postgraduate research' ($p = .031$). Students with no 'set plans' reported lower confidence in ethical thinking skills than either 'postgraduate professional' ($p = .002$) or 'research plan' students ($p < .001$).

Discussion

Here, we investigated the perceptions of students from two universities with two different undergraduate science curriculum models: *University A* with a more traditional approach organised by disciplines, and *University B* with a first-year, first-semester interdisciplinary curriculum followed by the more traditional, discipline-orientated structure. Results reveal several noteworthy patterns with implications for curriculum development in undergraduate science degree programmes that enable progressive development of learning across year levels. The discussion is framed by the three research questions, followed by implications.

Overall perceptions of science graduate learning outcomes

Science students indicated that the six graduate learning outcomes were important outcomes that should form part of their university degree programmes, although none of the outcomes were included in the curriculum relative to students' perceptions of their importance with the exception of content knowledge. These trends match those of Varsavsky et al. (2014) suggesting that the observed patterns are robust. In that study, students also considered graduate learning outcomes very important although students' perceived that the outcomes were less included in degree programmes except for content knowledge. While Varsavsky et al. (2014) found ethical thinking and quantitative skills to have unanimously low levels of perception, students in our study had higher perceptions of gaining quantitative skills. A reason for this could be a greater national awareness in Australia now as ongoing curriculum reform accommodates the identified need for quantitative skills in undergraduate science (Matthews, Adams, & Goos, 2009, 2010, 2015; Matthews, Belward, Coady, Rylands, & Simbag, 2012, 2016). With our study and several recent studies revealing the lack of ethical thinking development in science degree programmes (Dvorakova & Matthews, 2016; Matthews & Mercer-Mapstone, 2016), a national focus is warranted to address this disconcerting shortcoming.

Differences between universities

In contrast to Varsavsky et al. (2014) who did not detect strong patterns of variation between students' perceptions of learning outcomes by institution, our study revealed several differences between students from the more traditional (*University A*) and more interdisciplinary (*University B*) institutions.

While some differences between universities were found, the overall patterns across both institutions showed high perception levels for scientific content knowledge as an outcome of the degree programmes. This suggests that both approaches to the science curriculum were effective for building content knowledge from the perspective of students. The focus on content in undergraduate science curricula is well acknowledged with calls for wider array of learning outcomes, particularly application and skill development (Jones et al., 2011). Proponents of interdisciplinary university education cite advantages over discipline-focused education that include enhanced cognitive ability and confidence in and abilities to solve problems (Jacob, 2015; Jacob & Frickel, 2009; Repko, 2008). Boix Mansilla and Duraisingh (2007) evaluated the benefits of interdisciplinary curricula for students and concluded that students can 'develop insights and modes of thinking that are informed by a variety of disciplines … ' (p. 215). By adopting an interdisciplinary philosophy to the first semester, *University B* made a deliberate effort to breakdown disciplinary silos and to think beyond content. The differences in students' perceptions of skill development suggest that this focus was effective.

While both cohorts of students indicated that oral communication skills and teamwork were equally important outcomes for a science degree, students at *University B* perceived that these skills were more included and assessed in their curriculum with a higher sense of improvement. The interdisciplinary curriculum model of *University B* emphasised collaboration, teamwork, and communicating science from the first year. The more traditional assessment modes of heavily weighted multiple-choice final exams, common in first year at *University A*, were replaced with in-depth group assignments requiring both written and oral examinations framed around 'wicked problems'. Although the benefits of interdisciplinary curriculum models in science centre on 'out of the box thinking' and creativity (Boix Mansilla & Duraisingh, 2007), this study suggests that students perceive additional benefits, particularly the development of skills deemed essential for tertiary science graduates (Jones et al., 2011).

Differences between year levels

The science graduate learning outcomes explored in this study have been shown to each require deliberate and varying approaches of curriculum development (Matthews & Mercer-Mapstone, 2016). For example, designing curriculum across the many years of a science degree programme to build students' quantitative skills will look different from how curriculum is developed to instil effective oral or written communication of scientific knowledge to non-scientists. Knight's (2001) overarching principle of progressive development of curriculum signals that all complex outcomes of learning must be deliberately scaffolded from year to year across the programme to build competency, mastery, and confidence. Thus, at each year level, students should indicate sufficient opportunities to practise and learn the graduate learning outcomes.

Exploring students' perceptions at first-year and final-year offers insight into the progressive development of the graduate learning outcomes across the curriculum. This is particularly interesting as *University B* has the single semester of an interdisciplinary curriculum at the start of the degree programme and then reverts to the traditional, discipline-oriented approach. Patterns emerged from this analysis suggesting that both universities struggled with progressive development of curriculum across the whole degree programme.

Students at *University A* reported lower levels of both oral communication and writing skills in first year than third year, indicating a lack of development across the programme. As more Australian students enrol in higher education and in science degree programmes (Norton & Cakitaki, 2016), class sizes have increased, which inhibits complex assessment of communication skills both oral and written in first year. *University A* enrolled more than twice the number of students compared to University B. Assessing content via electronically marked exams is common practice at *University A*, which varies from the collaborative written and oral assessment tasks positioned in the first year at *University B*. *University B's* interdisciplinary curriculum model in first year emphasised skill development that is typically not focused on in the curriculum until students move into upper level units. In particular, changing the assessment regime in first-year science units signal to students that skills applying content are important and as such, these skills are graded. This suggests that the interdisciplinary curriculum model made space for these outcomes to be developed in ways that traditional curriculum did not and that students at *University B* experienced a curriculum that progressively developed these skills across year levels. However, this was not the case for teamwork skills, where students at *University B* reported lower levels in third year compared to first year. This suggests that as students shifted from an interdisciplinary curriculum in first year to a progressively more traditional model in second and third year in *University B*, teamwork skills were not as emphasised.

Both *Universities A* and *B* showed a decreasing trend in the progressive development of quantitative skills with students reporting higher levels in the first year than in their final year. This suggests that quantitative skills learning opportunities and assessment tasks were positioned at the start of the degree programme and then were not progressively scaffolded in upper year units. These findings resonate with a national project that explored 13 (11 in Australia) undergraduate science degree programmes that found curriculum development for quantitative skills tended to focus on first year with upper level specialised units failing to build upon the first-year skills (Matthews, Belward, Coady, Rylands, & Simbag, 2016).

Limitations

Care must be taken if generalising the results of this study more broadly. First, the response rates at *University B* were lower compared to those at *University A*, which may have influenced the power of the analyses to detect differences between groups. Second, the SSSI collects snapshot data, which is reflective of students' views at only a single point in time. Finally, the study focused on specific graduate learning outcomes to compare experiences of two different curricula, rather than other potential measures (e.g. retention rates in first year, motivation, grades). It is important to note that the intent of this research was not to make evaluative judgements about the effectiveness of one type of curricula over another; rather, the aim was to explore students' perceptions of the science graduate learning outcomes across two differing curricular contexts.

Implications

Progressive development of curriculum

The differences between first- and final-year students highlight the need for progressive development of curriculum to build graduate learning outcomes. From the perspective of students, both the traditional and interdisciplinary curriculum models struggled with progressive development of learning outcomes across the curriculum. Regardless of curriculum model, reform efforts should focus on implementation across a sequence of units that suffuse the length of the programme; indeed, this initiative is beginning to emerge in the science higher education literature (Matthews et al., 2015; Mercer-Mapstone & Matthews, 2017). Such an approach shifts the focus from a single semester or year to curricular pathways that transverse the years of the programme.

Focus on assisting students to chart future plans

An interesting pattern emerged in the results around the variable of graduate plans. Where differences in perceptions of learning outcomes were found for this variable, students with 'no set plans' for life after graduation held lower perceptions. Thus, ensuring that content and skill development are linked to potential post-graduation pathways, and supporting science students to identify career options early on in their undergraduate degree, could strengthen students' perceptions and confidence in their own learning outcomes, and address the pressing issue of student employability (Oliver, 2013). Thus, curriculum development in the sciences should also assist students in charting their future plans from first year while making explicit links between skill development and their application to a range of future work or post-graduate study opportunities.

Focus on ethical thinking

Our findings echo those of other recent studies highlighting the low perceptions of university science students about the importance of ethics (Dvorakova & Matthews, 2016; Matthews & Mercer-Mapstone, 2016). The development of a more explicit focus on ethical thinking would benefit the sector. Studies like Healey (2014) that investigate how students engage with ethics and ethical thinking are urgently needed in the sciences.

Conclusion

Designing undergraduate curricula to develop graduate learning outcomes is of national relevance in the sciences (Jones et al., 2011). Understanding how differing curricular models shape students' perceptions of their learning is vital to inform future directions in higher education. This study found that an interdisciplinary curriculum model in first year can support students' perceptions of the development of transferrable skills (e.g. oral communication and teamwork skills) from first year. However, further work on the progressive development of graduate learning outcomes across degree programmes is needed as neither curricular model resolved misalignment from year to year.

Acknowledgements

We are grateful to Genesta Nicolson for assistance with statistical analysis, Lucy Mercer-Mapstone and Lorelei Hine for critical feedback on a draft of this manuscript, and the students who participated in our study. The manuscript was improved thanks to thoughtful commentary of the peer reviewers.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Barrie, S. (2006). Understanding what we mean by the generic attributes of graduates. *Higher Education*, *51*(2), 215–241.

Boix Mansilla, V., & Duraisingh, E. D. (2007). Targeted assessment of students' interdisciplinary work: An empirically grounded framework proposed. *The Journal of Higher Education*, *78*(2), 215–237.

Dvorakova, L. S., & Matthews, K. E. (2016). Graduate learning outcomes in science: Variation in perceptions of single-and dual-degree students. *Assessment & Evaluation in Higher Education*, 1–14. doi:10.1080/02602938.2016.1208804

Fraser, K., & Thomas, T. (2013). Challenges of assuring the development of graduate attributes in a bachelor of arts. *Higher Education Research & Development*, *32*(4), 545–560.

Healey, R. L. (2014). How engaged are undergraduate students in ethics and ethical thinking? An analysis of the ethical development of undergraduates by discipline. *Student Engagement and Experience Journal*, *3*(2) doi:10.7190/seej.v3i2.93

Jacob, J. W. (2015). Interdisciplinary trends in higher education. *Palgrave Communications*, *1*, 1–5. doi:10.1057/palcomms.2015.1.

Jacob, J. A., & Frickel, S. (2009). Interdisciplinarity: A critical assessment. *Annual Review in Sociology*, *22*(6), 43–65.

Jones, S., Yates, B., & Kelder, J. (2011). *Learning and teaching academic standards project: Science*. Canberra: Australian Learning and Teaching Council.

Knight, P. T. (2001). Complexity and curriculum: A process approach to curriculum-making. *Teaching in Higher Education*, *6*(3), 369–381.

Matthews, K. E. (2014). *Students' perspectives on quantitative skills in an undergraduate science curriculum: A mixed methods study of the experienced curriculum* (Doctoral thesis). The University of Queensland, Brisbane, Australia.

Matthews, K. E., Adams, P., & Goos, M. (2009). Putting it into perspective: Mathematics in the undergraduate science curriculum. *International Journal of Mathematics Education in Science and Technology*, *40*(7), 891–902.

Matthews, K., Adams, P., & Goos, M. (2010). Using the principles of BIO2010 to develop an introductory, interdisciplinary course for biology students. *CBE-Life Sciences Education*, *9*(Fall 2010), 290–297.

Matthews, K. E., Adams, P., & Goos, M. (2015). The influence of undergraduate science curriculum reform on students' perceptions of their quantitative skills. *International Journal of Science Education*, *37*(16), 2619–2636.

Matthews, K. E., Belward, S., Coady, C., Rylands, L., & Simbag, V. (2012). *The state of quantitative skills in undergraduate science education: Findings from an Australian study*. Brisbane: Office for Learning and Teaching.

Matthews, K. E., Belward, S., Coady, C., Rylands, L., & Simbag, V. (2016). Curriculum development for quantitative skills in degree programs: A cross-institutional study situated in the life sciences. *Higher Education Research & Development*, *35*(3), 545–559.

Matthews, K. E., & Hodgson, Y. (2012). The science students skills inventory: Capturing graduate perceptions of their learning outcomes. *International Journal of Innovation in Science and Mathematics Education*, *20*(1), 24–43.

Matthews, K. E., Hodgson, Y., & Varsavsky, C. (2013). Factors influencing students' perceptions of their quantitative skills. *International Journal of Mathematical Education in Science and Technology*, *44*(6), 782–795.

Matthews, K. E., & Mercer-Mapstone, L. D. (2016). Toward curriculum convergence for graduate learning outcomes: Academic intentions and student experiences. *Studies in Higher Education*, 1–16, doi:10.1080/03075079.2016.1190704

McManus, M. E., & Matthews, K. E. (2015). Review of the undergraduate science curriculum at university of Queensland. In G. Weaver, W. D. Burgess, & A. Childress (Eds.), *Transforming institutions: Undergraduate STEM education for the 21st century* (pp. 189–198). West Lafayette, IN: Purdue University Press.

Mercer-Mapstone, L. D., & Matthews, K. E. (2017). Student perceptions of communication skills in undergraduate science at an Australian research-intensive university. *Assessment & Evaluation in Higher Education*, *42*(1), 98–114.

Norton, A., & Cakitaki, B. (2016) *Mapping Australian higher education 2016, Grattan Institute*. Retrieved October 26, 2016, from http://grattan.edu.au/wp-content/uploads/2016/08/875-Mapping-Australian-Higher-Education-2016.pdf

Oliver, B. (2013). Graduate attributes as a focus for institution-wide curriculum renewal: Innovations and challenges. *Higher Education Research & Development*, *32*(3), 450–463.
Repko, A. F. (2008). Assessing interdisciplinary learning outcomes. *Academic Exchange Quarterly*, *12*(3), 171.
Schull, D. N., Morton, J. M., Coleman, G. T., & Mills, P. C. (2012). Final-year student and employer views of essential personal, interpersonal and professional attributes for new veterinary science graduates. *Australian Veterinary Journal*, *90*(3), 100–104. doi:10. 1111/j.1751-0813.2011.00874.x.
Varsavsky, C., Matthews, K. E., & Hodgson, Y. (2014). Perceptions of science graduating students on their learning gains. *International Journal of Science Education*, *36*(6), 929–951.