INTERNATIONAL JOURNAL OF MATHEMATICAL EDUCATION IN SCIENCE AND TECHNOLOGY, 2017
VOL. 48, NO. S1, S67–S80
https://doi.org/10.1080/0020739X.2017.1352044

Investigating students' perceptions of graduate learning outcomes in mathematics

Deborah King[a], Cristina Varsavsky[b], Shaun Belward[c] and Kelly Matthews[d]

[a]School of Mathematics and Statistics, The University of Melbourne, Parkville, Australia; [b]Faculty of Science, Monash University, Clayton, Australia; [c]College of Science and Engineering, James Cook University, Townsville, Australia; [d]Institute for Teaching and Learning Innovation, The University of Queensland, St. Lucia, Australia

ABSTRACT

The purpose of this study is to explore the perceptions mathematics students have of the knowledge and skills they develop throughout their programme of study. It addresses current concerns about the employability of mathematics graduates by contributing much needed insight into how degree programmes are developing broader learning outcomes for students majoring in mathematics. Specifically, the study asked students who were close to completing a mathematics major ($n = 144$) to indicate the extent to which opportunities to develop mathematical knowledge along with more transferable skills (communication to experts and non-experts, writing, working in teams and thinking ethically) were included and assessed in their major. Their perceptions were compared to the importance they assign to each of these outcomes, their own assessment of improvement during the programme and their confidence in applying these outcomes. Overall, the findings reveal a pattern of high levels of students' agreement that these outcomes are important, but evidence a startling gap when compared to students' perceptions of the extent to which many of these – communication, writing, teamwork and ethical thinking – are actually included and assessed in the curriculum, and their confidence in using such learning.

ARTICLE HISTORY
Received 8 April 2017

KEYWORDS
Undergraduate mathematics; graduate outcomes; employability skills; student perceptions

1. Introduction

In universities around the world, lists of graduate outcomes, attributes or capabilities are used to inform students, employers and the public at large, about the knowledge, skills and qualities that graduates are expected to develop over the span of a degree programme [1]. These broad statements of outcomes represent a 'set of intentions' that aim to guide academics in curriculum development and reform activities across the whole degree programme [2]. At the micro level, learning outcomes related to particular discipline areas are generally included in the description of individual subjects (unit of study) that ideally contribute to, and align with, broader outcomes of the degree programme. The subject-level outcomes indicate the more specific skills and content knowledge that students will develop alongside the degree programme-level outcomes that tend to feature more transferrable skills.

CONTACT Deborah King dmking@unimelb.edu.au

A recent Australian project, the *Learning and Teaching Academic Standards Project* (LTAS) [3], developed *Threshold Learning Outcomes* (TLOs) for various degree programmes, including mathematics. The TLOs describe a minimal set of discipline-based learning outcomes that all students are expected to have acquired throughout the degree programme. The TLOs reference knowledge and skills that can be measured (for example, ability to communicate to a range of audiences) rather than personal qualities (for example, being a global citizen) and are specifically contextualized to disciplines instead of broadly covering all university graduates. The mathematics TLOs [4] focus on: disciplinary knowledge of mathematics; communication of mathematical knowledge to experts and non-experts; ethical conduct of mathematics; quantitative problem-solving; writing skills; teamwork skills. Realizing these outcomes within a curriculum presents challenges for curriculum leaders, academics and students alike as development of these outcomes requires programme-level oversight. Thus, assuring that all programme-level outcomes are acquired by all undergraduate students remains an elusive goal, particularly in degree programmes that include mathematics which generally include few core compulsory units, allow numerous subject choices, have minimal programme structure and have no accrediting body [5].

1.1. Employability of mathematics graduates

The outcome statements for mathematics graduates, like other disciplines, have been linked to outcomes and skills that employers expect of graduates. In recent studies, canvassing the employer perspective [6–8] skills including creativity, communication and collaboration were rated as crucial skills in the current Australian workplace [7]. These skills combined with the technical skills that science, technology, engineering and mathematics (STEM) graduates possess, although highly valuable, are in short supply [9]. For mathematics graduates, employers rated, unsurprisingly, their discipline specific skills higher than average (problem-solving, logical thinking, reasoning), but their interpersonal skills and time-management skills lowest [7]. This phenomenon is not new, nor is it unique to the Australian context. In the U.K., a small study showed that employers of mathematics graduates ranked generic competencies to be as important as mathematics skills and noted that graduates from several other discipline areas (commerce, engineering and physics) also had sufficient levels of mathematical skills for their purposes [9].

Recent studies by the Australian Office of the Chief Scientist predict significant growth in the need for STEM graduates over the next decade. When asked about future workplace requirements, 45.1% of respondents expected that their need for STEM-qualified graduates would increase [7]. Coupled with the current reported shortage of STEM graduates, we may be led to think optimistically about the future employability of mathematics graduates. But in reality, although the STEM workforce is expanding, graduates are not being placed in the high numbers we might anticipate due to not meeting the skills sought by employers. According to a recent study, 31.5% of businesses reported experiencing difficulties recruiting STEM graduates, whilst 38.2% of those companies surveyed cited 'lack of interpersonal skills' as an issue when recruiting STEM graduates [7]. So whilst students may study mathematics to improve their chances of securing a well-paid job [10], it is clear that this alone does not guarantee it. Thus, the mathematics TLOs that emphasize mathematical knowledge alongside several transferrable skills expected by employer-groups, are a tremendously important framework to guide the development and reform of undergraduate mathematics curricula. The views of mathematics students – particularly the perceptions of those close to graduation – are important threads of evidence that can further our insights into the effectiveness of mathematics degree programmes and offer clearer guidance to where we should focus curriculum reform activities and resources.

1.2. Mathematics students' perceptions of their outcomes

There is limited literature that discusses the development of graduate learning outcomes and employability skills across a degree programme from the perspective of mathematics graduates. This is in contrast to recent studies that have explored the views of bioscience students at programme-level to inform ongoing efforts to reform such programmes [11–14]. Nonetheless, there are some studies that draw on mathematics students' perceptions of learning at the macro-level of the degree programme. For example, Wood's 2009 Australian study [15] reported on the views of 18 recent mathematics graduates about how they used their mathematic skills in the workplace. Of these students, 14 said that they used only second-year level or lower mathematical skills in the workplace. Most notably, graduates also highlighted their difficulties in communicating their mathematical ideas to non-mathematical colleagues.

A U.K. study [10] asked 223 first-year mathematics students if they expected to develop skills including communication and abstract thinking during their degree programme and if they expected these to be important to them in future life. Expectations about developing skills like logical thinking, analytical skills and applying mathematical knowledge came out on top of their list as important skills and students strongly felt that these would be developed during their programme. However, although students also felt that communication skills were highly important, they were much less confident that these skills would be developed by the time they graduated. A comprehensive 2011 U.K. survey [16] sought the views of 428 mathematics graduates who had been in the workplace for 3–4 years, about which skills they had developed in their degree and how useful these had been to their careers. Of these students, over 90% believed that analytical and logical thinking and problem solving were important to their careers and that these skills were developed during their degree programme. However, when commenting on the more transferrable skills of oral and written communication and teamwork, around 90% of students agreed that these skills were important to their careers, but less than 45% stated that these skills had been well developed during their degree programme.

To offer further depth of insight into research and curriculum development in mathematics, we investigate the perceptions of students graduating with mathematics majors from four Australian universities about the importance they ascribe to, and the degree to which they believe they have developed, a range of skills linked to broader employability skills.

2. Purpose of study

The purpose of this study is to explore the perceptions mathematics students have of the knowledge and skills they develop throughout their programme of study, and how these align with their perceptions of the importance they place on the skills, the improvement they made throughout the programme and the level of confidence they have in applying them. The study involved students undertaking their final year of mathematics studies at four Australian universities. The following two questions provided the focus for this research:

(1) What perceptions do undergraduate mathematics students have of the importance of developing mathematics graduate skills during their degree programme? What is their perceived confidence and improvement in these skills, and how much do they think these skills were included and assessed in their degree programme and will be used in the future?
(2) Are there mismatches between student perceptions of mathematics graduate skills and their perceptions of (1) the improvement they made within the whole programme, (2) how much they saw them included in the programme, (3) their confidence with these skills and (4) how much they will use them after graduation?

3. Methodology

3.1. The survey

The study involved a quantitative methodology, using the Science Students Skills Inventory (SSSI). This survey instrument, developed by Matthews and Hodgson [17], and modelled on the Student Assessment of Learning Gains [18], has been used previously in various studies involving science students at several Australian institutions [14,19,20]. The SSSI was adapted to the context of mathematics studies, by adding a statement at the front of the survey asking students to answer the questions in the context of their mathematics majors. This was necessary, because as is common in the Australian higher education system, in all participating institutions students undertake mathematics studies as a major within the Bachelor of Science. Furthermore, many students study towards two degrees, taking concurrently the Bachelor of Science with another bachelor course such as engineering, commerce or arts.

The following seven graduate skills were explored:

- discipline content knowledge (mathematics)
- communication to non-experts
- communication to experts
- writing skills (writing essays, reports, documents)
- quantitative skills (mathematical and statistical reasoning)
- teamwork skills (working with others to accomplish a shared task)
- ethical thinking (ethical approaches)

For each of these seven skills, students were asked the following five questions:

- How important is it to have activities that develop [*graduate skill*] included in the science degree programme?
- To what extent were activities to develop [*graduate skill*] included in your science degree programme?

Table 1. Survey response rate by institution, and composition of final sample by institution, gender and programme type.

	Students invited to complete survey		Final sample	
	n	Response rate (%)	*n*	%
University				
JCU	8	50.0	4	2.8
MU	214	31.3	67	46.5
UoM	196	28.0	55	38.2
UQ	65	27.7	18	12.5
Total	483	36	144	
Gender				
Female			49	34.0
Male			90	62.5
Not specified			5	3.5
Type of programme				
Single			88	61.1
Double degree			56	38.9

- Throughout your entire science degree programme, how often were [*graduate skill*] assessed?
- As a result of your overall science degree programme, please indicate the level of improvement you made in [*graduate skill*].
- To what extent do you feel confident in the following [*graduate skill*] as a result of your science degree programme?

These questions led to the five indicators: 'importance', 'included', 'assessed' 'improvement' and 'confidence.' Students were asked to answer each of these questions on a 4-point numeric scale, ranging from '1. Not at all' to '4. A lot.'

3.2. Participants

Four Australian universities participated in this study, namely James Cook University (JCU), Monash University (MU), The University of Melbourne (UoM) and The University of Queensland (UQ). Different approaches were used to identify final year mathematics students. At JCU and UQ, it was possible to identify students who are studying towards a major in mathematics; of these, those who were undertaking their final semester of study were selected for the survey. At UoM and MU, students have more flexibility with nominating their major; hence, all students undertaking mathematics studies at level 3 within the Bachelor of Science single or double (dual) degree were invited to participate in the survey. A total of 483 students were identified as shown in Table 1. The survey was administered online, and 173 responses (36%) were received. Of these, 29 incomplete responses were removed, resulting in a final sample of 144 responses with details of institutional response rates and demographic information outlined in Table 1.

3.3. Analysis

Descriptive statistics methods were used to summarize and visualize the data, including means of the 4-point scales for each of the seven skills and five indicators and the respective standard deviations. A percentage agreement was also calculated as the percentage of students who selected 3 or 4 as their response.

Table 2. Summary of responses for overall sample across indicators: mean (standard deviation) and percentage agreement.

	Importance		Included		Assessed		Improvement		Confidence	
	M (SD)	% Agree	*M* (SD)	% Agree	*M* (SD)	% Agree	*M* (SD)	% Agree	*M* (SD)	% Agree
Scientific content knowledge	3.48 (.63)	93.1	3.49 (.68)	90.9	3.50 (.70)	89.6	3.52 (.68)	91.0	3.14 (.70)	84.8
Non-expert communication skills	3.15 (.79)	83.3	1.95 (.82)	21.6	1.72 (.73)	13.9	2.07 (.87)	31.3	2.34 (.94)	45.8
Expert communication skills	3.18 (.73)	84.0	2.06 (.79)	25.7	1.86 (.79)	18.1	2.17 (.87)	38.2	2.15 (.88)	36.2
Writing skills	2.99 (.70)	78.5	2.43 (.87)	48.6	2.48 (.83)	45.8	2.42 (.97)	48.6	2.47 (.94)	54.2
Quantitative skills	3.69 (.49)	98.6	3.69 (.52)	97.2	3.68 (.52)	97.2	3.60 (.65)	92.4	3.30 (.67)	89.6
Teamwork Skills	3.07 (.81)	77.7	2.47 (.84)	45.8	2.17 (.82)	30.6	2.33 (.88)	44.4	2.55 (.93)	56.3
Ethical thinking	2.69 (.90)	61.2	1.91 (.88)	23.7	1.64 (.75)	11.1	1.92 (.90)	27.8	2.14 (.94)	36.8

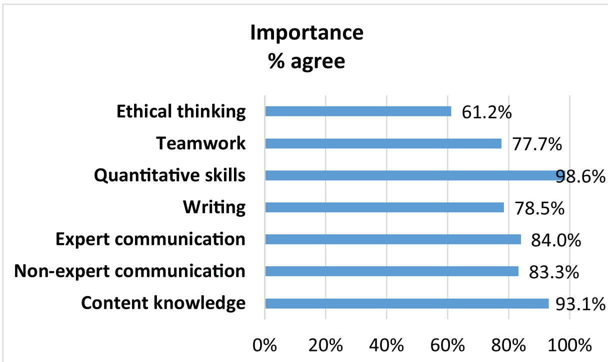

Figure 1. Student views on the importance of skills.

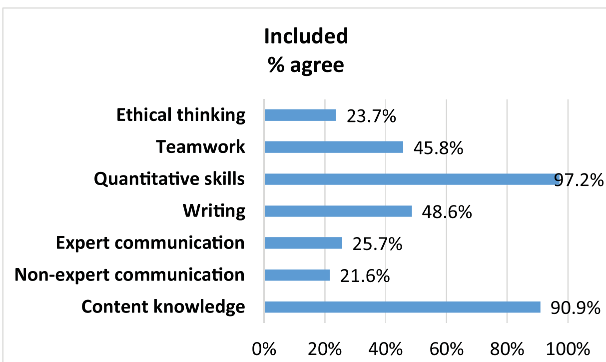

Figure 2. Student views on the degree of skill inclusion in curriculum.

4. Findings

Table 2 gives the means, standard deviation and percentage agreement for each of the seven skills and five indicators. Figures 1–5 give a visual depiction of the percentage agreement for each of the five indicators across all seven skills, and Figures 6–12 present the percentage agreement for each of the seven skills and across all five indicators.

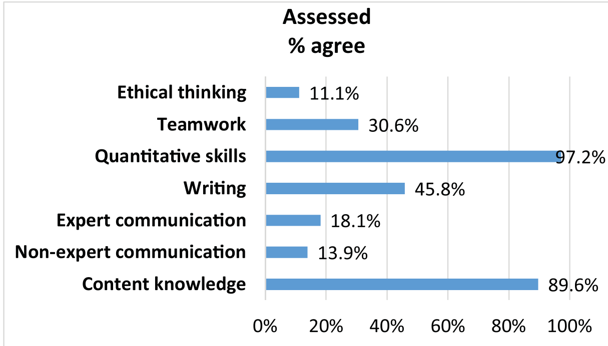

Figure 3. Student views on degree to which skills are assessed in coursework.

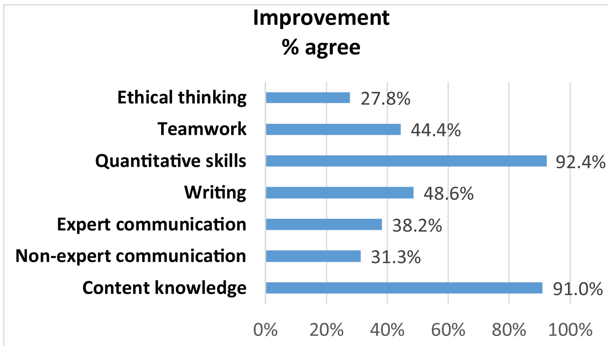

Figure 4. Student views on their skills improvement during degree.

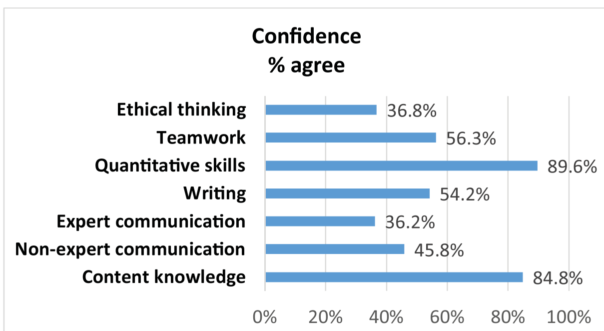

Figure 5. Student views on their confidence when using skills.

4.1. Perceptions of importance, inclusion, assessment, improvement and confidence of the seven skills

4.1.1. Importance

Figure 1 and Table 2 (column 1) show that students assign the highest importance to the development of quantitative skills and mathematical content knowledge (98.6% and 93.1% agreement; means of 3.69 and 3.48, respectively). Expert and non-expert communication are rated equally high (84% and 83.3% agreement; means of 3.18 and 3.15, respectively).

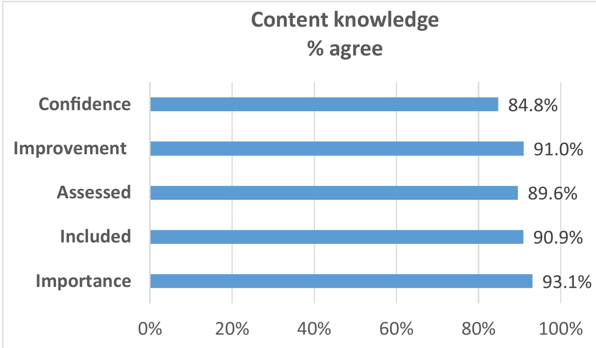

Figure 6. Student views on alignment of the importance, inclusion, assessment, improvement and confidence of content knowledge.

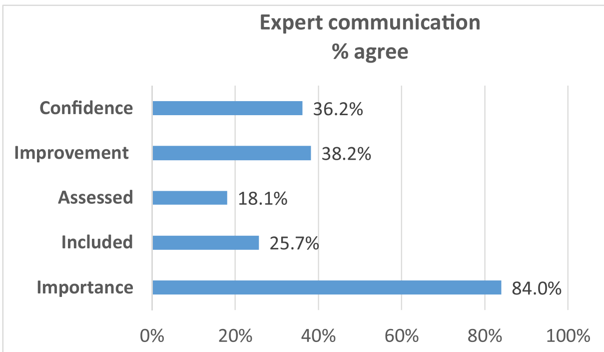

Figure 7. Student views on alignment of the importance, inclusion, assessment, improvement and confidence of their skills in communication to expert audiences.

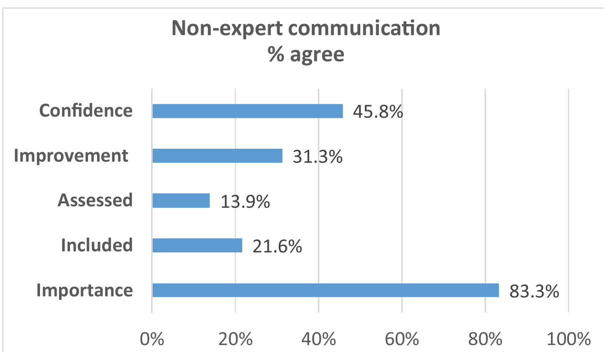

Figure 8. Student views on alignment of the importance, inclusion, assessment, improvement and confidence of their skills in communication to non-expert audiences.

Over three-quarters of students thought that teamwork and writing skills were important (77.7% and 78.5% agreement; means of 3.07 and 2.99, respectively). Ethical thinking skills, while still rated as important by the majority of the students (61.2% agreement; mean of 2.69), were rated the lowest.

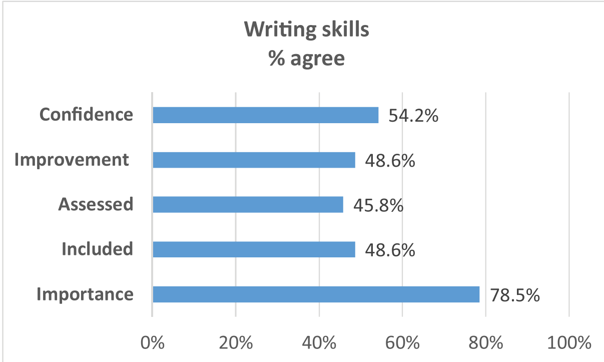

Figure 9. Student views on alignment of the importance, inclusion, assessment, improvement and confidence of their writing skills.

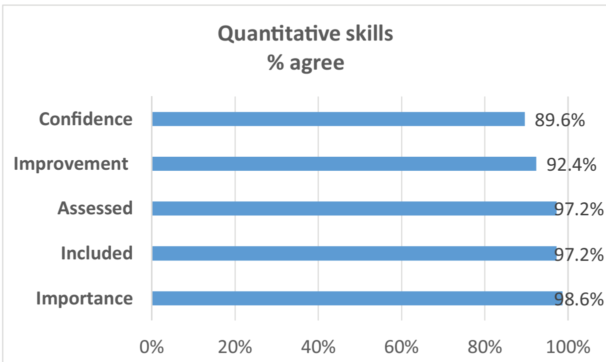

Figure 10. Student views on alignment of the importance, inclusion, assessment, improvement and confidence of their quantitative skills.

4.1.2. Inclusion in teaching and learning activities

Student perceptions of how much the skills were included in the curriculum across the mathematics subjects are shown in Figure 2, and also in column 2, Table 2. Again, there is overall agreement that quantitative skills and mathematical content knowledge were included throughout (97.2% and 90.9% agreement; means of 3.69 and 3.49, respectively). The percentage agreement on the inclusion of all other skills fell below 50%, with ethical thinking, expert and non-expert communication most notably at or below 25% (23.7%, 25.7% and 21.6%, respectively; means of 1.91, 2.06 and 1.95, respectively), and writing and teamwork skills close to but below 50% (48.6% and 45.8%; means of 2.43 and 2.47, respectively).

4.1.3. Assessment

A pattern similar to that of the inclusion indicator is observed with the perception of how much these skills were assessed throughout the mathematics programme (Figure 3 and Table 2, column 3). There was almost unanimous agreement with quantitative skills and mathematical content knowledge being assessed frequently (97.2% and 89.6%; 3.68 and 3.50, respectively), with almost no agreement that this was the case for ethical thinking

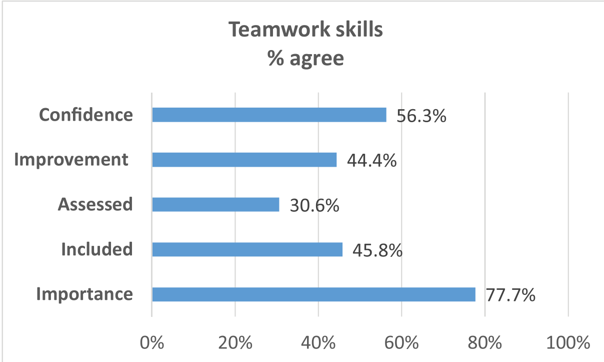

Figure 11. Student views on alignment of the importance, inclusion, assessment, improvement and confidence of their teamwork skills.

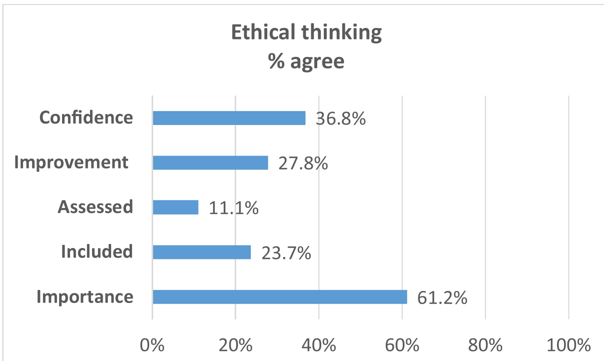

Figure 12. Student views on alignment of the importance, inclusion, assessment, improvement and confidence of their ethical thinking.

(11.1%; 1.64), expert and non-expert communication skills (18.1% and 13.9%; 1.86 and 1.72), and only to some extent for the assessment of teamwork skills (30.6%, 2.17). Regarding writing skills, 45.8% of the students saw their presence in assessment (with mean 2.48).

4.1.4. Improvement

Figure 4 and column 4 in Table 2 quantify student perceptions of how much they improved each skill over the course of their programme. As before, students agree almost unanimously that they have improved their quantitative skills and content knowledge (92.4% and 91.0%; 3.60 and 3.52). All other skills show percentage agreement less than 50%, with 48.6% for writing skills, 44.4% for teamwork, 38.2% for expert communication, 31.3% for non-expert communication and 27.8% for ethical thinking (with respective means of 2.42, 2.33, 2.17, 2.07 and 1.92).

4.1.5. Confidence

Student confidence by using the seven skills is shown in Figure 5 and in Table 2 (column 5), showing a pattern very similar to the previous indicators, but with a closer gap between the highest and lower levels of satisfaction. Quantitative skills and mathematics content knowledge are at the highest end of percentage agreement (89.6% and 84.8) and mean (3.30

and 3.14), teamwork and writing skills are placed in the middle (56.3% and 54.2%; 2.55 and 2.47), followed by non-expert communication (45.8%; 2.34), with expert communication and ethical thinking (36.2% and 36.8%; 2.15 and 2.14) at the lowest end.

4.2. Alignment of importance, inclusion, assessment, improvement and confidence for each skill

4.2.1. Content knowledge and quantitative skills

Content knowledge and quantitative skills show very similar patterns (Figures 6 and 10, Table 2), with almost unanimous student agreement on importance, inclusion, assessment and improvement (93.1%, 90.9%, 89.6%, 91.0% and 98.6%, 97.2%, 97.2%, 92.4%, respectively). Although confidence with content knowledge and quantitative skills shows high agreement, it is still at a somewhat lower agreement level than the other four indicators (84.8 and 89.6%; 3.14 and 3.30).

4.2.2. Communication

Patterns across the five indicators are also similar for expert and non-expert communication (Figures 7 and 8, and Table 2). The importance of these is rated very highly (84% and 83.3%; 3.18 and 3.15). The inclusion of communication skills in teaching and learning activities are seen by 25.7% of students (expert communication) and 21.6% of students (non-expert communication) with a lower percentage of students seeing the assessment of these skills (18.1% and 13.9%, respectively). Around a third of the students perceived that they have improved these skills (38.2% and 31.3), and a few more are confident in using non-expert communication skills as compared to expert communication skills (36.2% and 45.8%).

4.2.3. Writing skills

More than three-quarters of the respondents thought that developing writing skills in the programme was important (78.5%; 2.99) (Figure 9, Table 2). However, only about half of them perceived writing being included in teaching and learning (48.6%) and in assessment (45.8%), and just as many felt they have improved their writing (48.6%) and felt confident about applying this skill (54.2%).

4.2.4. Teamwork

Teamwork was also seen as important by more than three-quarters of the students (77.7%; 3.07) (Figure 11, Table 2). Close to half of the respondents reported teamwork to be included in teaching and learning (45.8%; 2.47), but less than one-third thought that this was assessed (30.6%; 2.17). However, more than half felt confident with working in teams to accomplish a shared task (56.3%; 2.55).

4.2.5. Ethical thinking

Ethical thinking is the skill that attracted the lowest percentage agreement and lowest means across all five indicators (Figure 12, Table 2), and there is no alignment between them. Sixty one per cent of the respondents thought this to be an important skill, but only 23.7% perceived it as included in their programme, and 11.1% saw it assessed. Less than a third reported to have improved their ethical thinking skills (27.8%; 1.92) and a few more felt confident in applying them (36.8%; 2.14).

5. Discussion

Overall, the findings reveal a pattern of high levels of student agreement that broad learning outcomes are important but there is a clear gap between students' perceptions of the importance of many of these – communication, writing, teamwork and ethical thinking – and their views about the inclusion and assessment of them in the curriculum, and also in their confidence in applying these skills. While students perceive that their confidence and knowledge of mathematical content and quantitative skills improved during their programme, this is hardly surprising, and aligns with previous work in this area [9,10,16] which found that mathematical knowledge is well integrated and assessed across curricula.

5.1. Implications for curriculum design to develop employable mathematics graduates

Our study shows that from the perspective of students key employability skills such as communication, writing and teamwork were lacking on most indicators (inclusion, assessment, development, confidence; see Table 2). Whether it is true that these skills have not been included in the curricula or that students' perceptions are simply wrong and such outcomes are included and assessed in their degree programme, the fact remains that students in this study are indicating that they cannot identify that these important skills are being developed and they lack confidence in applying them. Either way, this is cause for considerable concern since such students are unlikely to be able to articulate the highly desired transferrable skills to potential employers. The results of this study have implications for curriculum development in mathematics programmes. They highlight a clear and pressing need to focus on embedded transferrable skill development. It also suggests that assessment in mathematics needs to be examined to ensure students' have many scaffolded opportunities to apply mathematical knowledge in the context of communication, writing, teamwork and ethical thinking. A recent study on assessment practices in mathematics [21] shows that in most Australian universities this is not currently the case, with the traditional assignment- test-examination approach to assessment being overwhelmingly predominant.

5.2. Implications for academics

Attitudes of academics to their responsibilities as educators may perpetuate the notion that the purpose of a mathematics degree is primarily for graduates to master mathematical content so they are well prepared for future graduate studies in mathematics, in spite of the fact that only relatively small numbers of students pursue graduate studies in mathematics.[1]

These contradictory perceptions and expectations from various stakeholders (academics, students, employers) may cast the role and purpose of the mathematics degree as a wicked problem in that no single design solution can meet the needs and expectations of all stakeholders. This suggests that further consideration of the alignment between the learning outcomes of a mathematics degree programme and broad graduate attributes is warranted, and should be investigated from a variety of different perspectives.

5.3. Limitations

We considered only student views in this study. Although students are an important stakeholder group in this discussion, they represent only one perspective and so drawing on the views of other stakeholders would enrich further research. For example, a comparative study between students and academic views, similar to that of Matthews and Mercer-Mapstone [13], conducted in the biosciences provides a model worth considering.

6. Conclusions

One pressing need evident from this discussion is to develop deeper communication between academic staff, students and employers to better understand the workplace expectations of mathematics graduates. As in this study, surveys often use broad terms like 'teamwork' and 'communication skills' to describe skills required of graduates. Whatever these terms mean to students, those participating in our study felt them important but not included or assessed in the curriculum. Students' understanding of the meaning of these outcomes, and when and how they are developed in the curriculum, is vital. Even if academics and employers agree on what the key skills to be developed are, if students cannot 'see them' and articulate them to potential employers, then the curriculum has failed in terms of employability skills.

Employers also need to be included in addressing this challenge. A recent Australian forum[2] brought experts from industry and teaching academics together to discuss the benefits of problem-based learning for employability skills development and the expectations that employer groups have of mathematics graduates. More opportunities like these are needed if we are to come to a clear understanding of a way forward.

Whilst it may be unrealistic to expect that all mathematics subjects can address all employability skills, or that any single subject can, it is not unreasonable to expect that these skills be addressed across an entire programme of study. If transferrable skills are to be developed alongside core requirements, then students need to be made aware that this is the design of the course and it should be illustrated with model pathways. This takes careful consideration and planning of curricula; a whole-of-programme approach, including clear statements to students about the purpose of assessment tasks and how they map to the development of broader learning outcomes linked to employability.

Notes

1. Discipline Profiles of the Mathematical Sciences and Annual Surveys: Mathematical Sciences at Australian Universities, Australian Mathematical Sciences Institute.
2. Problem-based learning in mathematics https://fyimaths.org.au/pbl-forum/

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1] Barrie S. Understanding what we mean by the generic attributes of graduates. High Educ. 2006;51(2):215–241.

[2] Oliver B. Graduate attributes as a focus for institution-wide curriculum renewal: innovations and challenges. High Educ Res Dev. 2013;32(3):450–463.
[3] Learning and Teaching Academic Standards Project. Science, learning and teaching academic standards statement. Australian Learning and Teaching Council; 2011.
[4] ACDS mathematical sciences standards statement and threshold learning outcomes. FYiMaths [Internet]. Melbourne, Australia; 2013 Feb. Available from: https://fyimaths.org.au/resources/tlos/
[5] Fraser K, Thomas T. Challenges of assuring the development of graduate attributes in a Bachelor of Arts. High Educ Res Dev. 2013;32(4):545–560.
[6] Prinsley R, Baranyai K. Stem skills in the workforce: what do employers want? Office of the Chief Scientist, Australian Government; 2015. (Occasional Paper Series; 9).
[7] Deloitte Access Economics. Australia's STEM workforce: a survey of employers. Office of the Chief Scientist, Australian Government; 2014.
[8] Baranyai K, Bowles, J, Hassan S, et al. Australia's STEM workforce Parts 1 and 2. Canberra: Office of the Chief Scientist, Australian Government; 2016.
[9] Hibberd S, Grove M. Developing graduate employability skills with a mathematical sciences programme. MSOR Connect. 2009;9(2):33–39.
[10] Challis N, Robinson M, Thomlinson M. Employability skills in mathematical courses. MSOR Connect. 2009;9(3):38–39.
[11] Dvorakova LS, Matthews KE. Graduate learning outcomes in science: variation in perceptions of single-and dual-degree students. Assess Eval High Educ. 2016;42:900–913.
[12] Matthews KE, Firn J, Schmidt S, et al. A comparative study on student perceptions of their learning outcomes in undergraduate science degree programmes with differing curriculum models. Int J Sci Educ. 2017;39:742–760.
[13] Matthews KE, Mercer-Mapstone LD. Toward curriculum convergence for graduate learning outcomes: academic intentions and student experiences. Stud High Educ. 2016:1–16. DOI:10.1080/03075079.2016.11907.04.
[14] Varsavsky C, Matthews K, Hodgson Y. Perceptions of science graduating students on their learning gains. Int J Sci Educ. 2014;36(6):929–951. DOI:10.1080/09500693.2013.830795.
[15] Wood L. Graduate capabilities: putting mathematics into context. Int J Math Educ Sci Tech. 2010;41(2):189–198. DOI:10.1080/00207390903388607.
[16] Inglis M, Croft T, Matthews J. Graduates' views on the undergraduate mathematics curriculum. Loughborough: National HE STEM Programme and MSOR Network; 2012.
[17] Matthews K, Hodgson Y. The science students' skills inventory: capturing graduate perceptions of their learning outcomes. Int J Innov Sci Math Educ. 2012;20(1):24–43.
[18] Seymour E, Wiese DJ, Hunter A, et al. Creating a better mousetrap: on-line student assessment of their learning gains. Proceedings of National Meeting of the American Chemical Society; San Francisco (CA); 2000.
[19] Hodgson Y, Varsavsky C, Matthews K. Assessment and teaching of science skills: whole of programme perceptions of graduating students. Assess Eval High Educ. 2014;39(5):515–530. DOI:10.1080/02602938.2013.842539
[20] Matthews K, Hodgson Y, Varsavsky C. Factors influencing students' perceptions of their quantitative skills. Int J Math Educ Sci Tech. 2013;44(6):782–795. DOI:10.1080/0020739X.2013.814814
[21] Varsavsky CT, Hogeboom K, Coady C, et al. Undergraduate mathematics and statistics assessment practices in Australia, Lighthouse Delta 2013. Proceedings of the 9th Delta Conference on Teaching and Learning of Undergraduate Mathematics and Statistics; Australia; 2013. p. 209–216.