# PERCEPTIONS OF MATHEMATICS AMONG UNDERGRADUATE BIOMEDICINE STUDENTS

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## ABSTRACT

Mathematics plays an important role in 21st century biology, but is its importance recognised by students? How do students of the biological and health sciences view the role of mathematics in these disciplines, and the relevance of mathematics in their courses? These considerations may be important as undergraduate biology and biomedicine curricula increasingly incorporate specialised biology-oriented mathematics subjects. In this paper we investigate perceptions amongst undergraduate biomedicine students of the role of mathematics in biomedical science, and the relevance of mathematics in the undergraduate biomedicine curriculum. Student attitudes were found to be generally positive regarding the role of mathematics in biomedical science and its relevance in the curriculum, and persisted throughout the degree programme.  Themes arising from student survey responses included whether mathematics is relevant to all or only to some disciplines or careers, and the value of specific mathematical content versus generic skills.

## BACKGROUND

Mathematics plays an important role in 21st century biology and health sciences (National Research Council, 2003).  This is increasingly being reflected in the curricula of undergraduate Australian biology and biomedicine programmes, for instance (Matthews, Adams, & Goos 2010; Poladian 2013; Carnie & Morphett 2017).  The importance of mathematics in these fields is certainly accepted by practitioners in these areas, but is it recognised by undergraduate students? How do undergraduate students in the life and health sciences feel about studying mathematics as part of their course – especially specialised, biology-focussed mathematics subjects?

Matthews, Adams and Goos (2010, 2009) investigated biology students' attitudes towards mathematics and computer programming, following an interdisciplinary first-year science subject incorporating mathematics and programming.  They observed high agreement that mathematics was important, and high enthusiasm about mathematics, but lower levels of intention to study further mathematics.  Although these students recognised that mathematics was important in biology, this did not translate into a strong impetus for them to choose additional mathematics courses in their degree. They also identified that higher-achieving students are more able to draw links between mathematics and other sciences than lower-achieving students, and noted that students' experiences from school mathematics can shape their beliefs about mathematics in science.

Poladian (2013) reported on a redesign of a mathematics subject aimed at life science students, and the resulting impact on student motivation and perceptions of the relevance of mathematics.  He found that the addition of authentic biological examples to the subject increased students' perceptions of the subject's relevance, but noted that the personalities or experiences of individual students seem to strongly influence such perceptions.

## CONTEXT

The population of students under consideration are those enrolled in the 3-year undergraduate Bachelor of Biomedicine degree programme at a large research-intensive Australian university.  Students in the programme complete a fixed sequence of core subjects and subjects leading to a major (specialisation) such as immunology, genetics or biotechnology, and elective science and non-science subjects.  The core subjects include first-year biology, chemistry, physics, mathematics and statistics, and second- and third-year physiology, biochemistry and cellular biology. Many students aspire to study postgraduate medicine or other professional health qualifications after their undergraduate degree, though the programme also offers pathways to research or to graduate study in other areas such as bioengineering. The enrolment in the programme is approximately 500 students each year, of which about 65% are domestic Australian students and 35% are international students.  Entry to the programme is competitive and (for domestic students) most entrants are drawn from the top 3-4 percentiles of secondary school graduates.

The core first-year subjects in the programme include one statistics and one mathematics subject. Both subjects are compulsory for most students in the programme (except for bioengineering and health informatics majors who replace one or both of these with standard calculus or computing subjects) and are not available to students from other degree programmes. The mathematics subject teaches mathematical concepts and modelling in biomedical contexts. The mathematical content includes difference equations, ordinary differential equations (ODEs) and systems of ODEs. The mathematical concepts and techniques are motivated and introduced through authentic mathematical models from population genetics, chemistry and epidemiology, and the process of modelling and the role of models are discussed extensively through the course. A more detailed description of the subject, and its development, is given by Carnie & Morphett (2017). The core statistics subject includes study design, introductory descriptive and inferential statistics, and use of statistical software.

## FIRST-YEAR STUDENT ATTITUDES TOWARDS MATHEMATICS

To investigate biomedicine student attitudes towards mathematics at the start of their degree programme, an online survey was administered to all students enrolled in the core mathematics subject at the start of semester, over 3 semesters' offerings of the subject (2015S2, 2016S1, 2016S2). The total enrolment across these semesters was 686 students, and there were 250 responses (36% response rate). The survey was run in the week before semester commenced. In this time, students had access to some subject materials via the LMS but had not yet attended any classes. Questions 1-4 of the survey asked students about various potential roles of mathematics in biomedical science. Question 5 asked students about the relevance of studying mathematics in the Bachelor of Biomedicine. Question 6 asked students whether they were interested in studying additional mathematics in the future. All questions used a 5-point Likert scale, and question 5 also had an open-response section asking students to comment on their answer. The questions and summarised results are shown in Table 1. The survey was repeated at the end of the semester after the last lecture.

The design of the survey was informed by a pilot study conducted in semester 1, 2015. The pilot survey used a single Likert-scale question "I feel that mathematics is important in the discipline of biomedical science" with an open-response section instead of questions 1-4. The written comments from the pilot phase suggested that some students did not appear to distinguish between mathematics as a discipline, and 'mathematics' as the subject in which they were enrolled. Because of this, the question was replaced with questions 1-4 in subsequent semesters, which were intended to address different aspects of the role of mathematics in biomedical science.

**Table 1: Survey questions and results of pre-semester surveys of first-year students. %A/SA = percentage of respondents who agree or strongly agree, N = number of responses.**

| Question | %A/SA | N |
|---|---|---|
| 1. Mathematics is important in biomedical science as a tool for performing calculations. | 92% | 250 |
| 2. Mathematics is useful to help interpret data from experiments. | 96% | 249 |
| 3. Mathematics can help us understand natural phenomena in biomedical science. | 79% | 250 |
| 4. Mathematics can help guide decision making in medicine and health. | 87% | 249 |
| 5. Studying mathematics in the Bachelor of Biomedicine is relevant to me. | 78% | 250 |
| 6. I am interested in studying more mathematics in the future (for instance, as a selective). | 41% | 250 |

### QUANTITATIVE RESULTS

Questions 1-4 of the survey were intended to investigate student perceptions of the role of mathematics in biomedical science. We see that a strong majority of students agree that mathematics has a positive role in biomedical science. Perhaps unsurprisingly, agreement is strongest for question 2, which addresses a role of mathematics which is likely to be familiar to students from secondary school, and weakest for question 3, for which students are less likely to have encountered examples previously. Questions 5 and 6 were intended to investigate student perceptions of the relevance of mathematics in undergraduate biomedical science programmes. Question 5 asked students directly whether studying mathematics is relevant to them. Most respondents (78%) agreed that studying mathematics in their Biomedicine degree programme was relevant to them. We note that the level of agreement with question 5, which concerns the relevance of studying mathematics, although high, is lower than that of questions 1-4, which concern the role of mathematics in biomedical science. Some students appear to believe that mathematics is important in biomedical science, but that studying it is not relevant. The open response comments suggest an explanation for this: some students feel that mathematics is relevant only for certain disciplines or career paths, and in particular is less relevant for students pursuing a career in medical practice. This is discussed further below.

Question 6 investigated students' intentions to study additional mathematics. This question was intended as an indirect measure of student perception of the relevance of mathematics, as it was expected that a perception that mathematics is relevant would translate to a greater interest in studying additional mathematics. Despite high rates of agreement that mathematics has a positive role in biomedical science and is relevant to their course, only 41% of respondents agreed that they were interested in studying more mathematics in the future. This indicates that a perception that mathematics is important and relevant is not sufficient to motivate students to study additional mathematics. The survey did not provide a space for written comments for question 6, so we do not have evidence to explain this. However, we can suggest some possible explanations. Perhaps students feel that the compulsory one-semester mathematics subject is sufficient, and do not see a need for additional mathematics studies beyond this. Or perhaps motivation to study additional mathematics is more influenced by pre-existing personal attitudes towards mathematics, such as a 'love' or 'dislike' of mathematics, than by any perceived benefits of additional mathematics, as noted by Poladian (2013). The overall level of interest seen here agrees with Matthews et al. (2010), who found similar levels of intention to study more mathematics after an interdisciplinary mathematics and quantitative modelling subject.

We omit any discussion of the quantitative results of the post-semester survey in this paper.

## QUALITATIVE RESULTS

Further insights into student perceptions of the role and relevance of mathematics can be obtained from the open response comments. The written responses were analysed by the author using a conventional content analysis methodology (Hseih & Shannon, 2005). Preliminary qualitative analysis found the same themes present in both the pre-semester and post-semester survey responses. Hence, for the content analysis, the comments from all pre- and post-semester surveys were pooled, including those from the pilot phase. In total, 240 responses included written comments (158 from pre-semester surveys and 82 from post-semester surveys). In this section we describe some common themes identified from these comments. We do not mean to suggest that any of the opinions described below are held by a majority of the cohort, but rather to illustrate some common views and the diversity of attitudes encountered in the study.

One notable theme was the opinion that mathematics is relevant for some fields of biomedical science but it is not relevant for all disciplines or careers. Twenty-seven responses were classified in this category (14 from pre-semester, 13 post-semester). In particular, studying mathematics was often seen as important for a career in research, but less important for a career in medical practice. Some typical comments illustrating this are:

*'It has made me appreciate the uses of maths in biomedicine within the contexts that we studied, however I don't feel it was very relevant or interesting for me personally, as I want to study medicine and practice as a doctor, where such detailed maths (I don't believe) will be required on a daily basis.' (2015S1 post-semester)*

*'It depends on what you want out of the Biomedicine bachelor. If one were to become a doctor [...] their [sic] really is no use for mathematics in their undergraduate degree.... However, for research mathematics is important.' (2016S1 pre-semester)*

Similar attitudes were seen previously, amongst students in the same degree programme, by Familari, Elliott, Watson & Matthews (2012). Medical educators commonly agree that mathematics is required for postgraduate medicine. The American Association of Medical Colleges (AAMC-HHMI Committee, 2009) lists the ability to "apply quantitative reasoning and appropriate mathematics to describe or explain phenomena in the natural world" as one of the competencies expected of students entering medical school. A view such as those expressed in the comments above might therefore be problematic for the student as they progress to postgraduate medical studies. One approach to counter such attitudes could be to explicitly highlight the role of mathematics in medical practice, for instance by using practice-oriented examples when teaching aspiring medical students. Another approach may be to emphasise the transferrable skills developed by studying mathematics, discussed further below.

On the other hand, some (3 respondents: 2 pre-semester, 1 post-semester) explicitly state that mathematics is useful for medical practice: '*I believe Mathematics will be useful in many careers in the future, even in medicine*' (2015S1 pre-semester). Others (22 responses: 13 pre-, 9 post-semester) feel that mathematics is generally useful for all fields of science: *'Mathematics is the key underlying principle for most of science'* (2016S1 pre-semester). Another common attitude (22 responses: 17 pre-, 5 post-semester) was that mathematics is indirectly useful as it aids in scientific understanding: *'Even though mathematics may not be*

*required in our eventual professions, it is needed to understand the basic core concepts that we use in our profession.'* (2016S1 pre-semester)

This leads to another theme identified from the comments: the importance of specific mathematical content versus generic skills. Does the value of studying mathematics for biology or health sciences lie in the specific *content* taught in the subject, for instance the mathematical concepts or techniques mastered, or in the *generic skills* it develops, for instance problem-solving, communication or critical thinking?  Here the views of students are mixed. Some (11 respondents: 8 pre-, 3 post-semester) clearly identify generic skills as an important outcome:

> *'The critical thinking and problem solving needed for maths also applies to many other subjects'* (2016S2 pre-semester)

> *'Studying maths definitely help me improve my problem-solving skills and interpret information logically and methodically.'* (2015S2 post-semester)

Others (17 respondents: 3 pre-, 14 post-semester) feel the value of studying mathematics lies only in the specific content:

> *'Allows for an understanding of modern genetics, modelling for disease spread etc. thus broadening outlook on future careers.'* (2016S1 post-semester)

> *'It just seems that unless I intend on studying population genetics/disease modelling/biochemistry (which I do not) then most of what I have learnt in [the core mathematics subject] isn't very helpful.'* (2015S2 post-semester)

These commenters have focussed on specific contexts explored in the mathematics subject – genetics, reaction kinetics and infectious disease modelling – and do not appear to see the skills or concepts developed in the subject as transferrable to other contexts.  In this case, the development of transferrable general skills was an aim of the core mathematics subject (Carnie & Morphett, 2017), but this was not greatly emphasised to students.  Perhaps being explicit with students about the intended skills to be developed, and how they transfer to other areas, may help students better recognise and appreciate this aspect of their learning.

The same themes were seen in both pre- and post-semester responses, and with broadly similar prevalence in terms of the frequency of responses. (The exception is the last theme, which was far more common in the post-semester responses. This is understandable considering the pre-semester respondents had not yet been exposed to most of the specific content of the subject.)  In broad terms, except for an increased focus on the specific content of their mathematics studies, there does not appear to be much qualitative shift in student attitudes over the course of a biomedicine-focussed mathematics subject.  Does this change as students progress through the later years of their course?

## LATER-YEAR STUDENT ATTITUDES TOWARDS MATHEMATICS

In the context of engineering, Coupland, Gardner & Carmody (2008) noted that engineering students' perceptions of the relevance of statistics and mathematics can change over the course of their degree programme, as its utility became apparent in their later-year subjects and projects. To investigate whether biomedicine student attitudes towards mathematics change over the course of their degree programme, the online survey was repeated for final-year students of the Biomedicine programme. The survey consisted of questions 1-5 from Table 1 (except that Q5 was expressed in the past rather than present tense). Students enrolled in a core third-year subject of the Bachelor of Biomedicine were surveyed in August 2015 and in April 2017 (865 students in total).  The response rate was 20% (172 responses). Most of the students surveyed took the core mathematics subject in their first year. Responses from 9 students who took the Bioengineering Systems major were excluded from this analysis, as they took a series of standard calculus and linear algebra subjects instead of the core Biomedicine mathematics subject, and are likely to have different attitudes towards mathematics due to the mathematically intensive nature of their chosen specialisation.

### QUANTITATIVE RESULTS

Results from the survey are shown in Figure 1, alongside the results of the pre-semester survey of first-year students for comparison. None of the differences in levels of agreement differed significantly (Fisher exact test, α = 0.05).

**% Agree/Strongly agree**

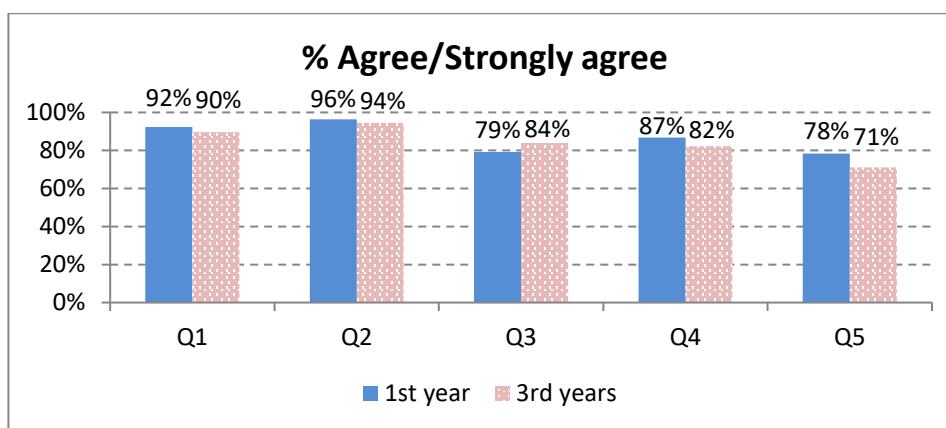| | Q1 | Q2 | Q3 | Q4 | Q5 |
|---|---|---|---|---|---|
| 1st year | 92% | 96% | 79% | 87% | 78% |
| 3rd years | 90% | 94% | 84% | 82% | 71% |

**Figure 1: Comparison of levels of agreement with each question between pre-semester first-year students and third-year students. The number of later-year respondents were N = 163 for Q1, Q4, Q5, and N = 162 for Q2, Q3.**

These results give little evidence of any quantitative change in student attitudes regarding the role and relevance of mathematics over the course of their studies, and the generally high levels of agreement persist throughout the programme.

## QUALITATIVE RESULTS

Written comments were given by 80 respondents (out of 163). Some familiar themes were still present in the third-year student responses. The view that mathematics is more relevant for research than for other career paths was seen in 5 comments (6%), though it was less common than in the first-year responses (11% of responses). The question of specific content versus generic skills was again apparent in the third-year responses. Some students (11 comments) appeared to focus primarily on the content of the first-year mathematics and statistics subjects they studied:

> 'Only a small number of concepts I learnt in [mathematics and statistics] subjects have been relevant to me throughout my course. I believe some aspects of the subjects were useful in helping me understand concepts in other subjects (significance of data, types of studies, confounding factors, Michaelis-Menten kinetics for example), but I cannot recall much else, which to me indicates that other concepts learnt in [mathematics and statistics] subjects have not recurred in my degree and may not be relevant.'

> 'the content [of first-year mathematics] was great and relevant.'

Others (4 comments) explicitly mentioned transferrable skills as an outcome of these subjects:

> 'Very relatable skills, use maths as tool to assess biological questions.'

One notable attitude seen in the comments (12 responses) was the view that statistics is more relevant than mathematics: *'[introductory statistics] had much greater relevance to understanding scientific research papers and being able to comprehend them'.* This attitude could be a reflection on the curriculum: despite its increasing importance in biomedical research, perhaps mathematical modelling has not yet been incorporated into the core second- and third-year biomedicine curriculum to the same extent as statistics. However, the strong focus noted above by students on content may provide another possible explanation for this. Perhaps mathematical skills, where they are used in the students' later-year studies, tend to be in the form of generic skills rather than the application of specific mathematical concepts or techniques, and are thus less likely to be recognised by students, whereas the use of statistical techniques are often explicit and clearly visible to students in research articles or lab activities.

## CONCLUSION

We have seen that a majority of biomedicine students see mathematics as having an important role in biomedical science and as being relevant to their studies. These views generally persisted throughout the degree programme. Some students see mathematics as relevant only for certain scientific disciplines or careers, however, and high levels of positive perceptions of the role and relevance of mathematics did not translate into similarly high levels of interest in studying additional mathematics subjects. Another point of difference among student views was the value of mathematics for developing generic skills. Some students saw mathematics as a source of valuable transferrable skills; others saw the value of studying mathematics

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mainly in the particular content covered. These observations suggest several considerations for academics designing or teaching mathematics in biomedicine programmes. The use of practice-oriented examples may help students see the relevance of particular content for medical practice, and being explicit about the generic or transferrable skills intended to be developed in a subject may make students more aware of this aspect of their learning and better recognise its applicability in later studies.

We close with some quotes showing positive perceptions of a biomedicine-specific mathematics subject in the Bachelor of Biomedicine programme:

*'I thought the content [of the biomedicine-specific mathematics subject] was great and relevant. It aided in the genetics component of 1st and 2nd year biology and genetics subjects. Enzyme kinetics and epidemiology was also very relevant to understanding my 2nd year subjects. I think the subject definitely benefited me more than just a basic calculus subject with no biology context attached.' (3rd-year)*

*'[The core biomedicine-specific mathematics subject] has most definitely changed my perception of the role of mathematics in biomedical sciences. Previously, I had thought that mathematics played only a minor role in biomedical sciences. However, having seen its various uses in biomedicine (such as modelling the spread of infectious diseases and predicting future population sizes of particular species), I now know just how important and significant mathematics is in biomedical sciences.' (2015S1 post-semester)*

## ACKNOWLEDGEMENTS

## REFERENCES

AAMC-HHMI Committee, (2009). *Scientific foundations for future physicians*. Washington, DC: Association of American Medical Colleges.

Carnie, S., & Morphett, A. (2017). Subject design and factors affecting achievement in mathematics for biomedical science. *International Journal of Mathematical Education in Science and Technology*, *48*(1), 31-47.

Coupland, M., Gardner, A., & Carmody, G. (2008). Mathematics for engineering education: What students say? In M. Goos, R. Brown & K. Makar (Eds.), *Navigating currents and charting directions: Proceedings of the 31st Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 139-146). Brisbane: MERGA.

Familari, M., Elliott, K., Watson, R., & Matthews, K. E. (2012). Embedding case studies into statistical teaching to enhance quantitative skills of biomedicine students. *International Journal of Innovation in Science and Mathematics Education*, *20*(1), 44-56.

Hseih, H.-F., & Shannon, S. (2015). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277-1288.

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

Matthews, K. E., Adams, P., & Goos, M. (2010). Using the principles of BIO2010 to develop an introductory, interdisciplinary course for biology students. *CBE-Life Sciences Education*, *9*(3), 290-297.

National Research Council (2003) *BIO2010: Transforming undergraduate education for future research biologists.* Washington, DC: National Academies Press.

Poladian, L. (2013). Engaging life-sciences students with mathematical models: does authenticity help? *International Journal of Mathematical Education in Science and Technology*, *44*(6), 865-876.