Mathematical Sciences
Standards statement and Threshold learning outcomes

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This document, detailing Threshold Learning Outcomes (TLOs) for the Mathematical Sciences, has been prepared by adapting the work of the ALTC-supported project on Learning and Teaching Academic Standards in Science [1]. The work has been undertaken collaboratively by academics in the Mathematical Sciences from around Australia throughout 2011-2013 at various nationally advertised events including conference workshops and dedicated Access Grid TLO workshops, as well as more targeted small roundtables with teaching and learning leaders and local university-based workshops. These activities have included representatives from

- Australian Council of Deans of Science
- Australian Council of Heads of Mathematical Sciences
- Australian National University
- Bond University
- Central Queensland University
- Deakin University
- Edith Cowan University
- Flinders University
- Griffith University
- James Cook University
- La Trobe University
- Macquarie University
- Monash University
- Queensland University of Technology
- RMIT University
- Swinburne University
- University of Auckland
- University of Ballarat
- University of Melbourne
- University of Newcastle
- University of New England
- University of Queensland
- University of Southern Queensland
- University of the Sunshine Coast
- University of Sydney
- University of Technology, Sydney
- University of Western Australia
- University of Western Sydney
- University of Wollongong

This work was initiated by the "Mathematics working party" formed to collaborate with the LTAS Discipline Scholars, and comprised Professor Peter

Adams (UQ), A/Professor Leigh Wood (Macquarie), Professor Merrilyn Goos (UQ), Professor Tim Marchant (Wollongong) and Dr Peter Howley (Newcastle). Efforts were then continued through the ALTC/OLT funded Australian Mathematical Sciences Learning and Teaching Network (AMSLaTNet), and particularly through the efforts of Associate Professor Dann Mallet (QUT), Associate Professor Carmel Coady (UWS) and Dr Deb King (Melbourne).

Mathematical Sciences Standards Statement

This Mathematical Sciences Standards Statement contains a statement of the Mathematical Sciences Standards expressed in the form of Threshold Learning Outcomes, and finally, descriptive notes that provide a framework for understanding, interpreting, and applying the TLOs in practice. In conjunction with the Science Standards Statement [1], the document provides a foundation for the evaluation of current mathematics and/or statistics Bachelor degree programs, and for future curriculum development, *particularly* where those degree programs sit as majors in a Bachelor of Science (or equivalent).

Bachelor level Threshold Learning Outcomes for Mathematical Sciences

This set of TLOs is designed to refer to the threshold learning outcomes for Bachelor of Science (or equivalent) graduates with a major in mathematics and/or statistics.

		Upon completion of a Bachelor of Science with a major in mathematics and/or statistics, graduates will demonstrate:
TLO1 **Understanding** (Demonstrate a coherent understanding of the mathematical sciences)	1.1	ability to construct logical, clearly presented and justified arguments incorporating deductive reasoning,
	1.2	understanding of the breadth of the discipline, its role in other fields, and the way other fields contribute to development of the mathematical sciences.
TLO2 **Knowledge** (Exhibit depth and breadth of knowledge in the mathematical sciences)	2.1	knowledge of the principles and concepts of a broad range of fundamental areas in the mathematical sciences,
	2.2	well-developed knowledge in at least one sub-discipline of the mathematical sciences.
TLO3 **Inquiry and problem solving** (Investigating and solving problems using mathematical and statistical methods)	3.1	ability to formulate and model practical and abstract problems in mathematical and/or statistical terms using a variety of methods,
	3.2	ability to apply mathematical and/or statistical principles, concepts, techniques and technology to solve practical and abstract problems and interpret results critically.
TLO4 **Communication** (Communicate mathematical and statistical information, arguments, or results for a range of purposes using a variety of means)	4.1	appropriate interpretation of information communicated in mathematical and statistical form,
	4.2	appropriate presentation of information, reasoning and conclusions in a variety of modes, to diverse audiences (expert and non-expert).
TLO5 **Responsibility** (Demonstrate personal, professional and social responsibility)	5.1	ability to self direct learning to extend their existing knowledge and that of others,
	5.2	ability to work effectively and responsibly in an individual or team context,
	5.3	ethical application of mathematical and statistical approaches to solving problems.

Notes on the Threshold Learning Outcomes for the Mathematical Sciences

The following notes provide guidance on how to interpret the above Threshold Learning Outcome statements for the Mathematical Sciences. In line with the Science Learning and Teaching Academic Standards Statement [1], Threshold Learning Outcomes refer to minimum standards of achievement/attainment (threshold) and the set of knowledge, skills and/or competencies a person has acquired and is able to demonstrate after completion of a learning process (learning outcomes).

The TLOs have been developed to describe a *pass level graduate* from a bachelor degree program. A 'bachelor degree' is defined according to the Australian Qualifications Framework (AQF), within which it represents a level 7 qualification. In the appendices, the Mathematical Sciences TLOs are mapped side-by-side with the level 7 AQF specifications. As with the higher level Science TLOs, the present set for the Mathematical Sciences are not intended to be equally weighted across the degree program and are in no way presented in order of importance.

TLO1

1.1 In addition to a knowledge of various topics in the mathematical sciences (TLO2.1) and understanding the two-way relationship between mathematical sciences and fields of application, it is acknowledged that there is a fundamental, defining nature of mathematical thinking. As such, it is expected that graduates in the mathematical sciences demonstrate the ability to construct arguments that are logical and deductive and that are clearly presented and fully justified. This type of thinking could be observed, for example, in the proof of a theorem, or in the application of a learned approach to solving an applied problem.
Particular degree programs at specific institutions might focus on different forms of reasoning from others, including for example proof, derivation, statistical inference, stochastic experimentation, and so on.

1.2 Knowing about the broad range of applications of mathematics is a fundamental part of mathematical thinking. Graduates should demonstrate an understanding that the mathematical sciences play a role both in self-advancement and in the advancement of other fields such as the sciences, engineering, medicine, economics and finance, and the social sciences. In doing so, graduates should have demonstrated understanding of how these areas of application have contributed in return, to the mathematical sciences.
All graduates should be able to demonstrate a capacity for quantitative thinking and reasoning.

TLO2

2.1 Naturally, all graduates should have a solid working knowledge of elementary mathematics as may have been seen prior to entry to

university. For example algebra, arithmetic and consideration for simple data analysis.

In addition, there is general agreement that all graduates of mathematical sciences degree programs should have knowledge of the principles and concepts of a number of "generic" topics covered early in a mathematics degree, including statistical data analysis, logic, single and multivariate calculus, algebra, differential equations, linear algebra, numerical methods, proof and logic.

2.2 Upon building such a broad base of knowledge, graduates then develop further depth of knowledge in at least one area (which may include these aforementioned topics). It is here that defining characteristics of different university degree programs are observed and also where individual student diversity (in terms of skills and interests) is catered for.

TLO3

3.1 Graduates should be able to formulate and to model problems. This includes both problems of a mathematical or abstract nature as well as problems taken from areas of application (for example, the sciences or finance). This TLO refers to the ability to convert a problem to an abstracted mathematical or statistical format that can be later analysed using the methods or techniques of the subdisciplines of the mathematical sciences.

Students should be encouraged to avoid thinking of a dichotomy between abstract and applied mathematics – mathematics *is* applicable *because* it is abstract.

This TLO should not be interpreted as saying that a mathematics graduate should be able to formulate and model *all* problems of an arbitrary complexity. Rather, that graduates are able to formulate and model problems, and know how to begin approaching a problem through further research, where that problem is too difficult for their existing level of skill.

3.2 In addition to formulating and modelling problems, graduates should be able to apply the principles, concepts and methods of the mathematical sciences to investigate and solve straightforward problems, both abstract and applied. Generally, this would require the use of "technology" which may be interpreted in a number of ways including the use of mathematical typesetting software to aid in communication, but also the use of computer algebra software, computing languages and other mathematical software, where appropriate.

Similarly, to TLO 3.1, TLO 3.2 should not be interpreted as saying that a mathematics graduate should be able to solve *all* problems of an arbitrary complexity. Graduates should demonstrate ability to apply principles, concepts and methods, and possibly how to go about approaching a problem through further research, where that problem is too difficult for their existing level of skill.

TLO4

4.1 Graduates should be able to interpret mathematical information communicated *to* them. Graduates should be able to read and relate to documents such as text books, reports and papers of a mathematical or

statistical nature. Students should be capable of interpreting commonly used notations and symbols.

4.2 Information should also be appropriately communicated *by* graduates. Graduates should be able to present mathematical information logically, write proofs where necessary, provide step-by-step explanations or reasoning, clearly detail assumptions, and express conclusions in a relevant way using correct notation and symbols.

Appropriate communication should be demonstrated in a variety of ways, especially written form and oral presentation, in a manner commonly observed in the field or the related professions.

Consideration of communication with diverse audiences is required. Graduates should be able to communicate with their mathematically trained peers as well as with non-mathematically trained people including the general public and colleagues in a place of employment.

TLO5

5.1 Throughout their studies students need to show that they are able to supplement guided study with self directed learning in order to extend their own pre-existing knowledge to tack problems beyond their current level of problem solving ability. This is an important skill for students to employ post-graduation when they continue on to further, less directed, study or to the workplace where they may need to develop new mathematical and statistical skills and understanding, and to pass that understanding on to others.

5.2 Graduates should be able to work individually and as a member of a team. In particular, they should demonstrate this ability through a responsible approach to, and effective attempts at, tasks associated with developing understanding and knowledge, applying methods of inquiry and problem solving, and communicating results of mathematical and statistical inquiry and problem solving (that is, tasks associated with the other threshold learning outcomes).

5.3 Graduates should demonstrate ability to conform to expected ethical standards of the community when disseminating findings or solutions of their work. This includes providing a transparent record of methodology and the recording of citations to the work of others, where appropriate.

References

[1] Jones S, Yates B, and Kelder, J-A, (2011) *Learning and Teaching Academic Standards: Science Standards Statement, June 2011*, ALTC report.