UniSQ College

Academic Numeracies Framework

University of Southern Queensland

Introduction

Academic numeracy has been defined as the "*capacity to confidently and competently use mathematics at University level, and to be able to apply, interpret, critique and communicate mathematical concepts in particularly disciplinary contexts*" (Brady 2017). Having adequate numeracy is critical not only to succeed in a wide range of tertiary studies, but also to perform in the workplace. Importantly, the dimensions of "confidence" and "critical awareness" - of the mathematics needed in the chosen profession as well as the students' own knowledge - are integral aspects of being numerate (e.g. Galligan 2013a). For example, a recent study (Peters et al. 2019) reported that both objective numeracy (the ability to do the mathematics correctly) and self-efficacy (confidence, leading to persistence) were important for an individual to attain numeracy's benefits. Conversely, a mismatch in these dimensions (that is, high objective numeracy paired with low self efficacy or vice versa) led to poor outcomes.

A systematic approach to academic numeracy development in tertiary institutions (e.g. see Galligan 2013b, Brady 2017) brings key benefits, as it promotes alignment, continuity and sustainability of programs, courses, resources and initiatives implemented by the institution. In this context, having a tool such as the Academic Numeracies Framework to assess the assumed, target and actual numeracy skills of students would be very useful in order to inform the development and delivery of courses and programs, assist academic and learning support staff on how to best support the development of students' academic numeracy skills, and assist with the design, development and implementation of intervention initiatives seeking to embed numeracy in university curricula.

The Academic Numeracies Framework was envisioned to be developed as part of an Academic Skills Model (ASM), which was co-developed by one of the co-investigators of this research project at Griffith University. The Academic Skills Model is a tool designed specifically to place academic, information and digital literacies and learning at the forefront of undergraduate course design and implementation through professional collaborations between academic and learning development staff. In this context, the Academic Numeracies Framework is an integral part of the ASM, as it enables the mapping of required, assumed and actual numeracy to curriculum programs.

Academic Numeracies

Galligan (2011) suggests that "academic numeracy" consists of three components: "mathematical competence" in the learner's chosen profession; a "critical awareness" both of the mathematics itself and of their own mathematical knowledge, and "confidence, highlighting its deeply affective nature" (p. 289). It also involves applying, interpreting, critiquing, and communicating mathematical concepts, especially in particular disciplinary and applied contexts (Brady, 2017).

Taylor and Galligan (2005) investigated academic numeracy in non-mathematical university courses and found a significant mismatch in skills prevalent in commencing students and the expectations or demands of numeracy embedded in these courses. A fraction of these students failed to meet academic numeracy expectations throughout their studies (Quinnell & Thompson 2010). This situation is exacerbated by the fact that the majority of university degree programs have very few mathematical pre-requisites. This results in what could be seen as an assumed

knowledge gap within, particularly, those undergraduate students who commence courses that require numeracy skills. In addition, most adult learners demonstrate a varying degree of mathematical experiences, confidence, ability, motivation, and needs, when dealing with mathematical tasks (Jain & Rogers, 2019).

The Academic Numeracies Framework can be an important tool to facilitate the embedding of academic numeracy at the university, program, and individual student and teacher level levels, because it offers a systematic way of assessing the mathematics needs of students, comparing the target, assumed and actual mathematics skills of students and informing the development and delivery of courses and programs, and study-support initiatives tailored to these needs. This is, in turn, needed in order to enhance the learning experience of students and promote their competence and independence.

The numeracies represent seven fundamental ***mathematical competencies*** adapted from the Programme for International Student Assessment (PISA) 2015 (Organisation for Economic Co-operation and Development [OECD], 2017). The competencies include, *"communication, mathematising, representation, reasoning and argument, devising strategies using symbolic formal and technical language and operations, and using mathematical tools*" (p. 68). These competencies support the processes required of students to engage with mathematical problems and the capabilities needed to demonstrate expected outcomes The mathematical processes for each competency are:

- "Formulating situations mathematically",
- "Employing mathematical concepts, facts, procedures and reasoning", and
- "Interpreting, applying and evaluating mathematical outcomes." (OECD, 2017, p. 68).

As these skills and capabilities increase, students demonstrate greater competence and confidence in their mathematical behaviours, so they should graduate with a greater critical awareness of the mathematics needed in their disciplines, professions, and personal lives.

The following level indicators are applied to the academic numeracies to enable alignment with course (unit, subject, and module) or program (degree) learning outcomes:

- Level 1 – Scaffolded: Students require high levels of scaffolding to develop numeracy within a topic area
- Level 2 – Supported: Students require some level of scaffolding to develop numeracy within a topic area
- Level 3 – Supervised: Students require some level of scaffolding to develop numeracy within a discipline
- Level 4 – Independent: Students independently develop numeracy within a discipline.

Academic Numeracies Framework	***Numeracy Levels***			
	Level 1	***Level 2***	***Level 3***	***Level 4***
	Scaffolded *Students require significant scaffolding to develop numeracy skills and knowledge within a topic area.*	***Supported*** *Students require some scaffolding to develop numeracy skills and knowledge within a topic area.*	***Supervised*** *Students require some scaffolding to develop numeracy skills and knowledge within a discipline.*	***Independent*** *Students independently seek out and develop numeracy skills and knowledge within a discipline.*
Academic Competencies **Communication** Mathematising Representation Reasoning and argument Devising strategies Using symbolic formal and technical language & operations Using mathematical tools	**Communication** • **Formulating mathematical problems** ○ Read, recall, and understand statements, questions and tasks ○ Extract and Interpret information to form a mental model of the task • **Using mathematical concepts, procedures and reasoning** ○ Explain a procedure ○ Show step-by-step work conducted to arrive at a solution • **Interpreting, applying and evaluating solutions** ○ Formulate and convey explanations based on interpretations and reasoning ○ Present results (orally/in writing/visually)			
1. Understand others' written or oral statements about mathematical and numerical content and concepts.	Students read, recall and extract basic information from limited sources, following explicit instructions.	Students identify, extract, understand and interpret required information from various sources to build a simple model.	Students identify, extract, understand and interpret required information from relevant sources to build an applied model.	Students identify, extract, understand, interpret and generalise information, linking sources to build complex, applied models.
2. Convey mathematical and numerical information in various ways.	Students organise and convey information requiring, at most, direct inference; and perform literal interpretation of the results.	Students organise and convey information from simple reasoning and interpretation of the results.	Students organise and convey relevant information using appropriate mathematical concepts and sound interpretations.	Students confidently organise, convey information using a range of complex strategies and well-developed interpretations.

Academic Numeracies Framework	*Numeracy Levels*			
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Academic Competencies Communication **Mathematising** Representation Reasoning and argument Devising strategies Using symbolic formal and technical language & operations Using mathematical tools	**Mathematising** • **Formulating mathematical problems** ○ Identify variables and assumptions ○ Develop a mathematical model to solve a task • **Using mathematical concepts, procedures and reasoning** ○ Use context to guide and streamline solving process ○ Use key constraints and assumptions to arrive at the solution • **Interpreting, applying and evaluating solutions** ○ Recognise the relationship between the mathematical solution and the context of the problem ○ Understand the validity and limitations of the solution, based on the adopted mathematical model			
Students ethically transform a real-world problem into a mathematical problem, identifying assumptions and problem context, and the limitations of the solution.	Students develop and evaluate simple models of basic problems, using limited knowledge.	Students develop and evaluate models to analyse and solve a range of problems, using sound knowledge.	Students develop, analyse, synthesise and evaluate models for applied situations.	Students confidently develop, analyse, synthetise and evaluate models for complex, applied situations, and new contexts.

Academic Numeracies Framework	*Numeracy Levels*			
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Academic Competencies Communication Mathematising **Representation** Reasoning and argument Devising strategies Using symbolic formal and technical language & operations Using mathematical tools	**Representation** • **Formulating mathematical problems** ○ Develop a mathematical representation of a task ○ Use different representations to formulate problems • **Using mathematical concepts, procedures and reasoning** ○ Select, develop and use a range of representations when solving a problem ○ Integrate and link different representations of a problem, and translate among them • **Interpreting, applying and evaluating solutions** ○ Interpret solutions presented in different formats ○ Compare and evaluate different representations of solution			
Students ethically generate, use and interpret various representations of mathematical information relevant to a problem or situation (i.e., graphs, tables, diagrams, pictures, equations, formulae, text, etc.).	Students create, understand, use and interpret basic representations of mathematical information from limited sources.	Students create, understand, use and interpret simple representations of mathematical information from various sources.	Students create, understand, use, integrate, compare and interpret representations of mathematical information from diverse sources relevant to their disciplines.	Students independently create, understand, use, integrate, compare, and interpret complex mathematical representations relevant to their disciplines.

<table>
<tr><td rowspan="2">Academic Numeracies Framework</td><td colspan="4">Numeracy Levels</td></tr>
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<tr><td>Academic Competencies
Communication
Mathematising
Representation
Reasoning and argument
Devising strategies
Using symbolic formal and technical language & operations
Using mathematical tools</td><td colspan="4">Reasoning and argument
• Formulating mathematical problems
○ Explain and justify selected mathematical models and representations of mathematical problems
○ Provide interpretations and insights regarding the formulation of mathematical problems
• Using mathematical concepts, procedures and reasoning
○ Explain and justify the adopted methodology and process to solve a mathematical problem
○ Link, integrate and /or generalise information to solve problems
• Interpreting, applying and evaluating solutions
○ Interpret and evaluate mathematical solutions
○ Develop explanations and arguments to justify the solution of a task.</td></tr>
<tr><td>Students convincingly and ethically explain, defend, and justify selected representations, solving-process and obtained solutions.</td><td>Students provide limited explanations and justifications of the strategies used to formulate a problem, determine a solution and its validity.</td><td>Students provide comprehensive explanations and justifications of the strategies used to formulate a problem, determine a solution and its validity.</td><td>Students provide well-developed explanations, justifications and insights of the strategies used to formulate an applied problem, determine a solution and its validity.</td><td>Students provide well-developed explanations, justifications and insights of the strategies used to formulate complex, applied mathematical problems, determine solutions and their validity.</td></tr>
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Academic Competencies
Communication
Mathematising
Representation
Reasoning and argument
Devising strategies
Using symbolic formal and technical language & operations
Using mathematical tools
	Devising strategies
	• **Formulating mathematical problems**
	  ○ Select and / or develop a strategy or approach to formulate a mathematical problem
	• **Using mathematical concepts, procedures and reasoning**
	  ○ Develop, select, compare and evaluate strategies to solve problems
	  ○ Follow a strategy to obtain a solution
	• **Interpreting, applying and evaluating solutions**
	  ○ Select and / or devise a strategy to interpret, evaluate and validate a solution			

Students ethically select, devise or develop a plan or strategy to solve mathematical problems.	Students select and apply simple strategies to solve basic problems.	Students select and apply sound strategies to solve a range of problems.	Students select, compare, evaluate and apply sound strategies to solve applied problems.	Students select, compare, evaluate and adapt sound and novel strategies to solve complex, applied problems, including tackling new situations.

Academic Numeracies Framework	*Numeracy Levels*			
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Academic Competencies Communication Mathematising Representation Reasoning and argument Devising strategies **Using symbolic formal and technical language & operations** Using mathematical tools	**Using symbolic formal and technical language and operations** • **Formulating mathematical problems** ○ Use appropriate mathematical notations, symbols and expressions to formulate a mathematical problem • **Using mathematical concepts, procedures and reasoning** ○ Employ algorithms, formulas and procedures to solve problems ○ Use appropriate symbols and mathematical constructs to solve the problem • **Interpreting, applying and evaluating solutions** ○ Use meaningful symbolic and technical language to assist with interpretations and potential limitations of the solution			
Students understand, interpret, ethically manipulate, and make use of suitable variables, symbols, arithmetic expressions, and operations, or rules to solve mathematical problems.	Students recognise and understand symbolic expressions, technical language, operations and rules; and solve simple problems following clear instructions via basic algorithms, formulas or procedures.	Students recognise and understand symbolic expressions, technical language, operations and rules, and solve a range of problems via sound procedures.	Students understand and interpret symbolic expressions, technical language, operations and rules, and can solve applied problems via sound procedures.	Students understand, interpret and confidently use advanced symbolic expressions, technical language, operations and rules, and can solve applied problems via complex procedures.

Academic Numeracies Framework	***Numeracy Levels***			
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	Scaffolded *Students require significant scaffolding to develop numeracy skills and knowledge within a topic area.*	***Supported*** *Students require some scaffolding to develop numeracy skills and knowledge within a topic area.*	***Supervised*** *Students require some scaffolding to develop numeracy skills and knowledge within a discipline.*	***Independent*** *Students independently seek out and develop numeracy skills and knowledge within a discipline.*
Academic Competencies Communication Mathematising Representation Reasoning and argument Devising strategies Using symbolic formal and technical language & operations **Using mathematical tools**	**Using mathematical tools** • **Formulating mathematical problems** ○ Use appropriate mathematical tools to understand a problem and recognise / portray mathematical relationships • **Using mathematical concepts, procedures and reasoning** ○ Use mathematical tools to implement procedures and methods to obtain mathematical solutions • **Interpreting, applying and evaluating solutions** ○ Use mathematical tools to evaluate the validity of solutions and / or determine solution constraints			
Students use appropriate mathematical tools, such as calculators, computer-based tools, and geometry tools, to ethically carry out mathematical procedures.	Students use mathematical tools to carry out simple procedures to solve problems.	Students use mathematical tools to carry out a range of procedures to solve problems.	Students use mathematical tools to carry out a range of procedures to solve applied problems.	Students confidently use a range of mathematical tools to carry out complex procedures to solve applied problems.

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