



Numeracy Across the Curriculum- A Pathway to Critical Thinking

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This writing seeks to identify and explore the ways in which mathematical competencies, skills and conceptual understandings underpin all the discipline areas across the mainstream primary school curriculum as numeracy competencies. It considers how these numeracy capacities can be investigated and acknowledged in each of the major areas of disciplinary study and how these foundational, embedded numeracy components can facilitate the development of critical thinking skills that are subject dominated but generic in nature. A framework is presented to illustrate the ways in which sound logic and the development of skills in various types of reasoning supports the intuitive compulsion of students to investigate diverse perspectives, assess these in relation to problem solving and decision making and evaluate their subsequent proposals in a critical manner. In this way, opportunities are provided in diverse contexts for the development of two essential skills for 21st century success: numeracy competencies and critical thinking skills.



Introduction

Twenty - first century living may be easier in many ways than that experienced by past generations but it is also more complex in many ways. There are several reasons for this, but one of the most salient is the impact of technology in many aspects of everyday life. Consequently, access to information has never been easier, but the sheer quantity of information that students must process, consider and analyse has highlighted the need for critical, logical reasoning skills to be afforded multiple opportunities to develop and become increasingly prominent in educational contexts. Traditionally, mathematical reasoning has been credited with the development of rational thinking and students who studied mathematics at an advanced level of abstraction were considered to be something of a scholarly elite. While that may still hold true for many students, the necessity for all students to develop the skills of critical thinking and become increasing discerning in the ways in which they interpret and use the copious amount of information available to them necessitates a closer, more critical perspective of the prospects of these cognitive capacities being developed in the context of regular school environments from a young age.

Understanding and Identifying Numeracy

Numeracy is perceived by some as a less sophisticated mathematical activity which is pursued by those students who lack the competencies to engage with 'real' mathematical activities. It is understood in some contexts to be all about numbers whilst ignoring the diverse nature of mathematical conceptualizing around the other areas of mathematical study (Sullivan, 2011). It may be that the term used in American contexts captures the authentic nature of concept of numeracy more accurately than its British counterpart. The notion of quantitative literacy prompts a more inclusive understanding of mathematical knowledge and processes as applied in both formal and informal learning contexts (Parviz & Somayyeh, 2012). Considered to be the most important literacy for the 21st century (Steen, 1990), numeracy is embedded as a foundational tenet of all discipline areas, irrespective of content and subject specific pedagogical approaches. Numeracy competencies are critical to reasoning, interpreting graphical and numerical data and identifying how the readily available information is used in various types of communications to persuade, to justify, and even to manipulate opinion or disadvantage others (Skovsmose, 1994; Steen, 2001; Stoessiger, 2002).

While there is a body of literature which investigates numeracy as a critical orientation in secondary classrooms (see, for example, Geiger, Forgasz, & Goos, 2015; Geiger, Goos, & Bennison, 2013;



Geiger, Goos, & Forgasz, 2015), who examine critical numeracy in diverse areas of learning, much of the focus is on reasoning and critically examining data. Another perspectives on examining numeracy across the curriculum involves making connections between the mathematical foundations of the disciplines so that, from a young age students are encouraged to understand the impact of mathematical knowledge and thinking in all areas of learning and identify the connections for themselves. In this way, students develop the capacities to more readily recognise and think critically about the ways in which mathematical tools, concepts and representations are used to privilege certain perspectives over others.

In the context of primary education, even in situations where integrated units of work and project based learning are not utilised as pedagogical strategies, the numeracy components are essential. It is impossible to teach history for example without an understanding of time, sequencing and probability. Developing a timeline offers an opportunity for students to critically reflect on the authenticity of the data representation in addition to requiring practical mathematics skills such precision in calibration, determining scale and ordering events. Geography, visual arts, sculpture, dance, sports amongst other subjects are intrinsically reliant on students' understanding of spatial concepts, position, and measurement in addition to manipulating data and its representations. Similarly, time, pattern and space are essential cognitive capacities for studying music, dance, and different structures in language literacy.

Language is a learning area which has been acknowledged as being particularly reliant on reason and logic (Steen, 1990) but it is also heavily dependent on position and sequencing. This is apparent in simple placement of letters for conventional spellings and their manipulations, for meaningful punctuation and for the structure of texts for various purposes. Science is most associated with mathematical knowledge, requiring sound conceptual knowledge of chance and probability, an understanding of both repeating and growing patterns and function in addition to reasoning and logical thinking. Although there is limited support material available at present to support the identification of the numeracy foundations of the learning across the curriculum, the current emphasis on numeracy as a basic capability and life skill is leading to considerable interest in engaging students meaningfully with opportunities to develop their mathematical knowledge skills and process in all learning domains (Sellars, 2017).



Learning to Reason

One of the major benefits of identifying and exploring the foundational numeracy components across the curriculum in primary educational contexts is the opportunity to explore mathematical tools, representations, processes, and knowledge in diverse contexts and provide contexts in which students can understand mathematics in new ways as numeracy concepts. In this manner, students can learn to use and appreciate the value of their mathematical learning in supporting their success in other subject domains (Askew, Brown, Rhodes, William, & Johnson, 1997). The connections that they are to develop whilst engaging in this process not only supports the notion mathematics learning is useful and could be engaged in productively and positively, but also gives opportunities for mathematical reasoning and the development of strategies for thinking logically across all the about other learning domains. The various definitions of logic include the capacities to reason, usually in the content of deciding if a proposition or a statement is true or false.

There are several strategies that can be taught to students to help them reason in different ways and in different contexts (Ennis, 1987; Synder & Synder, 2008). Students can begin to develop *inductive* reasoning skills by seeking out and identifying the main ideas in their mathematics learning, usually termed mathematical generalizing, which can then be applied to learning contexts. Engaging in activities which require *deductive* reasoning skills demand that students work from general statements to apply ideas and processes to specific examples, which is the reverse of inductive reasoning. The results of deductive reasoning can generally be proven to be true if the logical process is followed. Developing these skill with young students requires multiples, diverse opportunities to engage with these types of reasoning, to discuss and to justify their thinking and possible solutions and to work collaboratively to check and to trial ideas.

The initial development of these cognitive skills depends heavily on the students' chances to investigate, reflect on, and manipulate what they already know and how their prior learning may be utilised in reasoning tasks that are novel or unfamiliar. In this way, students in primary school classrooms have ideal contexts to use the learning from one domain to inform the learning in another and may use another strategy that originates in mathematical contexts; *adaptive* reasoning (Kilpatrick, Swafford, & Findell, 2001). This cognitive capacity requires students to interrogate new ideas and problems by finding the relationships and patterns in new concepts and to reflect upon these in order to explain and justify their correctness or appropriateness as solutions to the integration of new knowledge or skills or to the resolution of problems. However, it is the capacity



for *abductive* reasoning that may link these other types of logical thinking to the notion of critical thinking. Defined as ‘the ground state, or default mode of cognition’ (Shank, 2016), this reasoning is initiated by an observation which is then explained in the simplest and most probable explanation. There is no guarantee of the truth of the explanation but simply that it is the most likely and the result of the basic, sometimes unconscious, logical process.

Becoming a Critical Thinker

There are multiple definitions of the notion of critical thinking but the common characteristics are captured in this definition from Scriven and Paul (2008). They conceptualize critical thinking as

Critical thinking is the intellectually disciplined process of actively and skilfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. In its exemplary form, it is based on universal intellectual values that transcend subject matter divisions: clarity, accuracy, precision, consistency, relevance, sound evidence, good reasons, depth, breadth, and fairness.

It entails the examination of those structures or elements of thought implicit in all reasoning: purpose, problem, or question-at-issue; assumptions; concepts; empirical grounding; reasoning leading to conclusions; implications and consequences; objections from alternative viewpoints; and frame of reference...the development of critical thinking skills and dispositions is a life-long endeavor.

Whilst this understanding of critical thinking is informative and inclusive of many of the cognitive capacities that its name implies, it is not a discrete set of skills that are without context or consequences. It is generally understood that these competencies are developed gradually, and are grounded in a particular subject area of area of expertise (Mc Peck, 2016). It is this assertion that necessitates the identification of the mathematical foundations of all subject domains as an initial pathway for engaging with critical thinking skills using the various strategies of reasoning that are embedded in the authentic understanding and use of mathematical processes that are incorporated across the curriculum as elements of numeracy. As with other areas of development, foundational learning in the disposition to become critical thinkers, finds an ideal context in the formal learning environments of school classrooms which promote investigation, debate, exploration, and reasoning strategies as habits of mind (Baars & Gage, 2010; Pithers & Soden, 2000). The content of school based learning also provides fertile opportunities for innovative and creative problem solving and the resolution of dilemmas that naturally arise from engagement with investigation and exploration. This may occur, particularly in primary school environments, where the



possibilities of reducing the challenges presented in contemporary educational systems of developing students' critical thinking skills, personal understandings and justifications (Garrison, 2011) need not necessarily be defined as subject specific but as more integrated generic skills based on implementing the strategies of reasoning that can be initiated in mathematical teaching and learning tasks.

However, critical thinking is not necessarily confined to strategies of logical thinking. Many theorists have acknowledged the role of intuition (Ennis, 1962; Facione, 2011; Lipman, 1998; McPherson). 'Intuitive thinking is the ability to take what you may sense or perceive to be true and, without knowledge or evidence, appropriately factor it in to the final decision' (Green, 2012). In the overall framework, the aspect of criticality closely resembles the 'ground state, or default mode of cognition' (Shank, 2016) which is identified as abductive reasoning. This is because it relies heavily on the personal interpretation of the problem to be solved or dilemma to be resolved and reflects an individual perspective as the simplest solution to making subjective meaning of the situation without any evidence of its truth or validity.

Developing a Framework

The development of a conceptual framework which illustrates the relationships between the mathematical process and strategies related to reasoning and the characteristics of critical thinking as defined by Scriven and Paul (2008) facilitates an understanding of the numeracy pathways that are presented as appropriate for learners in primary classrooms to develop wider, more critical perspectives on their learning by enabling the development of reasoning skills.

Conclusion

The realization that mathematics provides the foundational tenets for all discipline domains across the curriculum affords new opportunities for educators to utilise the skills, strategies and cognitive processes that are essential for the authentic understanding of this discipline in their attempts to develop students' understandings, dispositions and skills in critical thinking. It affords opportunities for basic skills in analysis, reasoning and logical thinking strategies, which can be increasingly cultivated as students gain experience and encounter novel learning situations in which to practice. As a developmental process, the stages and ages of students in primary contexts will naturally determine their capacities for engaging these cognitive processes, as various parts of the brain and become accessible in individual timelines, as does language acquisition and use and the

sophistication with which students can engage in mathematical concepts and strategies. However, with appropriate tasks which occupy students as active participants in their learning, most especially in investigating and exploring, reasoning and justifying, all students can experience the ways in which reasoning strategies improve their personal understandings and broaden their learning perspectives in order to create critical thinkers.

Numeracy Skills	Critical thinking components (Scriven & Paul, 2008)
Mathematical Processes <ul style="list-style-type: none"> • Adaptive reasoning • Reflection • Flexible thinking • Inductive reasoning • Deductive reasoning • Explanation • Justification • Abductive reasoning 	Intellectually disciplined processes <ul style="list-style-type: none"> • Reasoning • Applying knowledge • Analysing • Evaluating information • Synthesizing Predicated on <ul style="list-style-type: none"> • Observation • Experience • Reflection • Various types of reasoning • Relevance (explaining) • Sound evidence • Good reasons • Fairness
Generalizing <ul style="list-style-type: none"> • Finding the bigger picture from specifics • Inductive reasoning • Adaptive reasoning • Applying to abstractions to make meaning 	<ul style="list-style-type: none"> • Transcending subject matter • Precision and consistency • Depth and breadth • Conceptualizing • Making personal meaning

Table 1. The conceptual relationships between mathematical processes and critical thinking skills.

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