Developing Pre-service Teachers' Understanding of Numeracy

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In Australia, all teachers are expected to explicitly attend to numeracy in the subjects they teach. Pre-service teachers, therefore, need to begin to develop effective numeracy teaching strategies but there is a limited research base to inform the design of courses that address this need. This paper reports on findings from a study investigating the impact of one such course. The paper draws on data from two pre-service teachers: two course tasks completed at the beginning of the course and interviews conducted at the end of the course. Data were analysed using the 21st Century Numeracy Model. Findings suggest there were changes to the pre-service teachers' understanding of numeracy and their capacity to embed numeracy in the subjects they will teach.

Numeracy (or mathematical literacy) encompasses the capacity to use mathematics effectively across a wide range of contexts—in private and public life situations and for civic participation (Geiger, Goos, & Forgasz, 2015). The question of how to best provide opportunities for students' numeracy development, however, remains unanswered with a range of approaches being adopted internationally (e.g., European Commission, 2011; South African Department of Basic Education, 2011). Two forms of curriculum integration that appear to be showing promise are interdisciplinary enquiry and across the curriculum approaches (Geiger, Goos, & Forgasz, 2015). The latter approach takes advantage of numeracy learning opportunities inherent in all subjects and is the approach that has been adopted in Australia.

Numeracy is identified in the *Australian Curriculum* (Australian Curriculum, Assessment and Reporting Authority, n.d.) as a one of seven General Capabilities to be developed in all learning areas. Consequently, all teachers have a responsibility to explicitly address numeracy inherent in the subjects they teach. The place of numeracy in the Australian Curriculum is supported by the Australian Professional Standards for Teachers (APSTs) (Australian Institute of Teaching and School Leadership [AITSL], 2011). Graduates of Initial Teacher Education (ITE) programs, for example, must be able to demonstrate knowledge and understanding of "numeracy teaching strategies and their application in teaching areas" (p. 13). As part of accreditation requirements, ITE providers must provide evidence of how programs support pre-service teachers to meet this standard through whole of program approaches that may include courses with a specific focus on numeracy. The research base to inform the design of courses that build pre-service teachers' capacity to explicitly address numeracy in the subjects they will teach is, however, just beginning to emerge (e.g., Bennison, 2019; Forgasz & Hall, 2019). The aim of the study reported on in this paper is to add to this research base.

The study builds on earlier work with practising teachers in which teacher identity was used as a theoretical lens to investigate the learning and development of teachers participating a larger study that supported them to embed numeracy into subjects across the curriculum. The earlier work developed a framework for teacher identity as an embedder-of-numeracy and provided insights into the development and trajectory of this identity (Bennison, 2022). The present study shifts the focus to pre-service teachers and investigates how a course in an ITE program—*Literacy and Numeracy Across the Curriculum*—contributes to shaping a future teacher's initial identity as an embedder-of-numeracy.

The framework for teacher identity as an embedder-of-numeracy (Bennison, 2022) is organised by five Domains of Influence: Life History, Knowledge, Affective, Social and Context. Each Domain includes factors particularly relevant for teachers embedding numeracy across the curriculum. The Life History Domain, for example, encompasses a teacher's past experiences of mathematics, pre-service teacher education, and initial teaching experiences.

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These factors will contribute to forming a pre-service teacher' s attitudes towards mathematics, personal conception of numeracy and influence their beliefs about the place of numeracy in the subjects they will teach (factors in the Affective Domain). Factors in the Life History Domain also play a role in developing pre-service teachers' knowledge to design tasks that develop students' numeracy capabilities while enhancing subject learning (factors in the Knowledge Domain). While it is difficult to isolate the impact of a single course within an ITE program on a pre-service teacher's identity as an embedder-of-numeracy, the aim of the present study is to investigate how the *Literacy and Numeracy Across the Curriculum* course contributes to a pre-service teacher's initial identity as an embedder-of-numeracy. Specifically, the research question addressed in this paper is: What impact does the *Literacy and Numeracy Across the Curriculum* course have on secondary pre-service teachers' understanding of numeracy and their capacity to embed in the subjects they will teach?

Theoretical Framework

Because of the number of terms used and the range of perspectives taken in research on numeracy, researchers need to be explicit about the interpretation of numeracy that underpins any study (Geiger, Goos & Forgasz, 2015). The conceptualisation of numeracy articulated though the *21st Century Numeracy Model* developed by Goos, Geiger and Dole (2014) underpins this study and is the theoretical framework used to analyse participating teachers' conceptualisations of numeracy. This model was chosen because (1) it is consistent with widely accepted definitions of numeracy (e.g., OECD, 2019) and (2) Goos and colleagues have demonstrated the utility of the model for analysing classroom activities, interview transcripts, and other data (e.g., Geiger, Goos, 2015).

The 21st Century Numeracy Model comprises five dimensions: *context*, *mathematical knowledge*, *tools*, and *dispositions* which are embedded in a *critical orientation* (for a full description of each of the dimensions of the model see Goos et al., 2014). The use of the model as a theoretical framework is illustrated by Geiger, Goos and Dole's (2015) analysis of a task developed by a teacher participating in one of their research and development projects. The teacher designed a task for a physical education class in which students used a pedometer to investigate their level of physical activity. Students recorded the number of paces they took over a week and converted the total number of paces to the distance travelled. Individual and class data were analysed using the graphing tool in Excel. Geiger, Goos and Dole identified the following dimensions of numeracy in the activity: a problem in a life-related *context*; *mathematical knowledge*, including measurement and ratio, and selection of an appropriate graphical representation of the data; *tools*, including pedometers, tape measures, calculators, and an Excel spreadsheet; *dispositions* were addressed through the use of digital tools to enhance student engagement and requiring students to think flexibly about how to represent their data; and students were required to adopt a *critical orientation* when comparing their results and speculating on possible differences between themselves and others. A similar approach can be used to utilise the 21st Century Numeracy Model to analyse text such as interview transcripts.

Research Design

The study commenced in 2018 and was funded by a School of Education Pilot Research Grant. It was conducted with successive cohorts of pre-service teachers enrolled in the *Literacy and Numeracy Across the Curriculum* course at a university located in Queensland. The course was offered in Semester 2 and during the Summer Semester. Ethics approval was granted for the study by the university's Ethics Committee (A181104) and all participants gave informed consent. Some findings from the 2018/19 Summer Semester cohort are reported in this paper.

Participants

All pre-service teachers enrolled in the *Literacy and Numeracy Across the Curriculum* course in the 2018/2019 Summer Semester were provided with information about the study and invited to participate. Thirty-four of the 66 pre-service teachers enrolled in the course gave informed consent to participate in the study. Five of these pre-service teachers also gave additional informed consent to be interviewed.

The Course: Literacy and Numeracy Across the Curriculum

The *Literacy and Numeracy Across the Curriculum* course was a compulsory course for all pre-service teachers enrolled the Master of Teaching (Secondary) program, which could be completed over 2 years or in eighteen months if an accelerated pathway was chosen, and dual degree programs (e.g., Bachelor of Arts/Bachelor of Education), which were completed over four years. The *Literacy and Numeracy Across the Curriculum* course was co-taught to postgraduate and undergraduate cohorts with differences in course learning outcomes and assessment. There were no prerequisites so pre-service teachers could enrol in the course in any year of their program. The course comprised a Numeracy Module taught by the author of this paper and a Literacy Module taught by a literacy specialist. The main aim of the Numeracy Module was to assist pre-service teachers to identify and plan for numeracy demands and opportunities in the subjects they will teach, thereby assisting them to develop the knowledge and understanding of numeracy appropriate for their intended teaching area as required by the APSTs (AITSL, 2011). The module promoted engagement with the 21st Century Numeracy Model (Goos et al., 2014) as a tool for planning and analysis of tasks. Pre-service teachers were given opportunities to explore and analyse tasks developed by practising teachers in earlier projects, such as the use of timelines in science to understand geological time (Bennison, 2015) and the use of pedometers in Health and Physical Education to monitor physical activity (Geiger, Goos & Dole, 2015). The course content for this part of the course was very similar for both postgraduate and undergraduate offerings as it was assumed that the pre-service teachers had limited previous knowledge of how numeracy can be embedded in subjects across the curriculum.

The Summer Semester offering of the course was delivered using an intensive teaching mode. All teaching took place during Week 1 (mid-November) of the Summer Semester. Teaching was face-to-face and took place in form of lectorials that combined interactive activities with the presentation of course content. Students undertook independent study and completed assessment tasks over the remaining 6 weeks of the semester which concluded in mid-January.

Data Collection

All pre-service teachers enrolled in the *Literacy and Numeracy Across the Curriculum* course were asked to complete a Numeracy Confidence Survey and Understanding Numeracy Task during the first lectorial for the Numeracy Module in Week 1 of the Summer Semester. The purpose of these tasks, as well as serving as sources of data for the study, was to get pre-service teachers to reflect on their current understanding of numeracy and preparedness to embed numeracy in the subjects they were going to teach. Both data collection instruments have been used in previous research (e.g., Goos et al., 2014). The Numeracy Confidence Survey contained 22 items around the domains of professional knowledge, attributes and practice. Respondents were asked to rate their confidence on each of the items (e.g., Understand the meaning of numeracy within their curriculum area; Promote active engagement in numeracy learning within their own curriculum context) using a 5-point Likert-type scale (1 = very unconfident to 5 = very confident). For the Understanding Numeracy Task, respondents

completed five numeracy stems (Numeracy involves ...; A numerate person knows …; A numerate person is …; A numerate person can …; An individual's numeracy can be improved by …). Only data from those pre-service teachers who had consented to participate in the study were analysed.

Semi-structured interviews were conducted in February 2019 after finalisation of grades for the *Literacy and Numeracy Across the Curriculum* course. Pre-service teachers were asked about their backgrounds (reasons for becoming a teacher, mathematics subjects studied at school, feelings about mathematics, intended curriculum areas), perceived role in developing the numeracy capabilities of their students, experiences in relation to numeracy during their Supervised Professional Experience (teaching practicum) and reflections on the Numeracy Module. Interviews lasted between 21 and 33 minutes, were audio recorded and transcribed.

Data Analysis

The Likert-type scale ratings for items on the Numeracy Confidence Survey are reported for the two pre-service teachers whose case studies are presented. No further analysis of these data is required for the purposes of this paper. Analysis of the Understanding Numeracy Task and interview data was through the lens of the 21st Century Numeracy Model (Goos et al., 2014). The five dimensions of the model were used to code written responses and transcripts, respectively. Comparing findings from data collected at the beginning of the course with findings from the interviews provides insights into changes in the pre-service teachers. Case studies of Sally and Jodie (pseudonyms) were chosen to represent different learning trajectories of participating pre-service teachers.

Findings

Sally

Sally was enrolled in the accelerated pathway of the Master of Teaching (Secondary). Her teaching areas were Biology and Agricultural Science. She had completed 12 months of the program, including two science curriculum courses, when she enrolled in the *Literacy and Numeracy Across the Curriculum* course. Sally's previous degree was in science, with a major in Agriculture. She had worked in agribusiness and other industries before deciding to become a teacher. Sally had completed two mathematics subjects involving the study of calculus in her final two years of schooling and in the interview described her previous experiences of mathematics as "very positive, I love maths".

Sally's responses to the Understanding Numeracy Task included that a numerate person knows "how to manipulate quantities to make decisions based on accurate information" and numeracy involves "interpreting, understanding and applying patterns and proportions in our everyday life". These responses indicates that her understanding of numeracy included *mathematical knowledge*, *context*, and *critical orientation*. Her lowest self-rating for any item in the Numeracy Confidence Survey was 3 (*unsure*). Sally rated herself as unsure for two items: *demonstrating knowledge of a range of appropriate resources and strategies to support students' numeracy learning* in her curriculum area and *recognising the knowledge and experiences that learners bring* to her classroom. Thus, Sally began the course with an understanding of numeracy that included three of the five dimensions in the 21st Century Numeracy Model and she was unsure how to effectively embed numeracy into science lessons.

In the interview following the completion of the course, Sally was asked if she thought her views about numeracy had changed in any way since she started the course. The response she gave was in the context of her teaching:

> Well, I definitely see the difference between numeracy and maths in that numeracy is the application to real life. Similarly, to literacy, I would incorporate it more and I think I was challenged to – by being challenged to incorporate it – forgot the name of the model [referring to the 21st Century Numeracy Model] … By, yeah, not just thinking, okay, what's the maths in it, the mathematical skills but how does it relate to the kids? How can you make it authentic and use critical numeracy thinking?

Sally did not express any concerns about addressing numeracy in science because "maths is sort of part of science". She was able to describe how explicit attention to numeracy can enhance understanding of size in science:

> Biology, the unit typically starts with the size of cells and looking at cells and this whole proportional – I mean it's maths, numeracy, no, more numeracy and getting them to think about the size of cells. That cells can be the size of a water molecule through to the size of a human egg. To be able to appreciate that size difference and then that – you can build on that to go to the next topic, which is membrane, the cell membrane. Appreciating the proportional size of things and making that real, relative to a millimetre. A millionth of a millimetre is what you're looking at.

Later in the interview she came back to the issue of size in science, relating the geological timeline example discussed in the course to understanding the vast distances between the planets and the very small units used for measuring the size of cells:

> Having those examples, so the timeline for example, for me that was like okay, well it's not just time, but space. So, the different sizes and that there's lots of little videos you can watch but pulling it away from a video and trying to make it hands on, even for something that's nanometres is a challenge. But I think you can get there, just as that exercise about how far the planets are. The standard model doesn't give a true representation of the space and so a simple exercise where you – this is the earth, now relative scale [pause] walk it out. I think you could do the same sort of thing at the nano size.

Sally was also keen to encourage students to adopt a *critical orientation* towards the results of experiments as she saw this as a skill that was transferrable beyond school:

> Do rough estimates in your head. Could that answer be roughly, right? If you're doing a water rocket balloon, so let's think through it roughly. So, this is a skill that they would be able to take into their daily life.

Sally's understanding of numeracy and her capacity to address numeracy in science seems to have been enriched by her participation in the *Literacy and Numeracy Across the Curriculum* course. Her responses to the Understanding Numeracy task included *mathematical knowledge, context*, and the need to adopt a *critical orientation*. Following her participation in the course, the examples Sally gave in the interview indicate that her understanding of numeracy now also included also included *tools* and *dispositions*. The use of *tools* is implicit in the need to "walk it out" to show relative sizes and distances and, it could be argued, that her desire to "make it authentic" and "relate to the kids" is evidence that she understands the importance of dispositions. Sally's examples and her descriptions of how explicit attention to numeracy helps understanding in science indicate that she can identify numeracy in this subject and is likely to have developed some strategies for embedding numeracy in science.

Jodie

Jodie was enrolled in a Bachelor of Arts/Bachelor of Education (Secondary) and had completed two years of her program when she enrolled in the *Literacy and Numeracy Across the Curriculum* course. Her teaching areas were English and History. Jodie's previous studies included two history courses and an English curriculum course, but she was yet to enrol in any history curriculum courses. In her final two years of schooling, Jodie completed a single mathematics subject that did not include the study of calculus. In the interview, she described her school experiences of mathematics in the following way:

> I hated maths. I won't lie. It was definitely English, History or the creative stuff were all of my strengths. I guess it was just because picking it up was hard and falling behind. I would just constantly get frustrated with it. So that's why. Yeah, I just grew a hate for it.

In the Understanding Numeracy Task, Jodie wrote that numeracy involves "problem solving, mathematical understanding (formulas etc)" but also indicated that a numerate person can "apply these problem-solving skills within other subject areas e.g., measurements of an archaeological site (History)". Her understanding of numeracy, therefore, included the use of *mathematical knowledge* in the *context* of history. Jodie rated herself as 2 (*unconfident*) on three items in the Numeracy Confidence Survey: her capacity to *demonstrate knowledge of appropriate resources and strategies to support students' numeracy learning*; *model ways of dealing with numeracy demands;* and *providing all students with opportunities to demonstrate numeracy knowledge* in her curriculum area. She rated herself as 3 (*unsure*) on ten additional items. Jodie, therefore, began the course with an understanding of numeracy that included two of the five dimensions in the 21st Century Numeracy Model and was unconfident or unsure about many aspects of how to effectively embed numeracy into history.

In the interview following the completion of the course, Jodie was asked if she had recognised numeracy in any of the history courses she had studied previously. Her response indicated that she saw the mathematical aspects she encountered in these studies "as a part of learning history" and that she had a growing awareness of the use of mathematics in the broader context of everyday life:

> I've noticed definitely since the literacy and numeracy course just how maths is so important for everyday things that we do. Yeah, you've definitely made me aware of that.

Jodie said that before completing the *Literacy and Numeracy Across the Curriculum* course, she had found it "very daunting that we actually have to do that [explicitly attend to numeracy in history]. Because I think it's a case of if I can't fully understand it myself how can they expect me to teach it to kids". When asked if she could now see how she could incorporate numeracy in history, she was able to provide several examples:

> Yeah, in history, population. How it's decreased and increased over time in certain civilization. Or, what's another good example? Yeah, timelines. Understanding timelines … Something to do with archaeological sites. So, if you compare the pyramids of Egypt to, I don't know, some other historical site to do with the Romans maybe, the ancient Greeks. You can compare how big the site there is in comparison to Egypt maybe. I'm just throwing an idea out there. Of course, it would have to align to the curriculum … Maybe even looking at the architecture, Roman architecture and comparing that to the South American architecture and how big it was. That sort of thing.

Jodie said that her ideas about numeracy in history had changed since completing the *Literacy and Numeracy Across the Curriculum* course, perhaps leading to increased confidence in her capacity to embed numeracy in this subject:

> Yeah, they have [her ideas about numeracy in history]. I still feel they need to be developed more … but I do feel I have more of an idea of how to approach it and what I could set as a task if I just really work hard at developing a few ideas. I think you've shown that such simple things, graphs and timelines, are considered numeracy. So, it's not all big and scary and not all about algebra and everything.

There were changes to Jodie's understanding of numeracy and her capacity to address numeracy in history following her completion of the *Literacy and Numeracy Across the Curriculum* course. At the beginning of the course, Jodie's understanding of numeracy encompassed the use of mathematical *knowledge* in *contexts*. Although she did not mention the use of *tools* explicitly, representational tools (tables of population data, graphs, and timelines) were evident in the examples of numeracy in history she provided in the interview. There is no evidence to suggest she saw *dispositions* and *critical orientation* as important aspects of embedding numeracy in history. Jodie's apprehension about addressing numeracy in history, something she initially described as "very daunting," seemed to have lessened. She seemed

more aware of numeracy and was able to provide several examples of numeracy in history thereby suggesting that she could *see* numeracy in this subject and may have developed some strategies for embedding numeracy in history.

Discussion

A framework for identity as an embedder-of-numeracy was developed and used in earlier research as an analytic lens through which to view the identities of practising teachers as they developed the capacity to embed numeracy into the subjects they were teaching (Bennison, 2022). Teachers' past experiences of mathematics and their Initial Teacher Education program were seen as likely to influence their initial identity as an embedder-of-numeracy by shaping their attitudes towards mathematics, personal conception of numeracy and capacity to identify and design tasks that are effective in developing students' numeracy capabilities. Pre-service teachers enter their Initial Teacher Education programs with varied past experiences that result in different levels of mathematical knowledge, attitudes towards mathematics and understandings of numeracy. Sally and Jodie, for example, commenced the *Literacy and Numeracy Across the Curriculum* course with very different previous experiences of mathematics at school, resulting in different levels of mathematical knowledge and extreme attitudes towards mathematics—Sally's mathematical knowledge could be considered more comprehensive than Jodie's based on the subjects they had completed at school. Furthermore, Sally loved mathematics whereas Jodie hated it. There were also differences in the way the two pre-service teachers conceptualised numeracy.

The *Literacy and Numeracy Across the Curriculum* course appears to have had an impact on both pre-service teachers' understanding of numeracy and their capacity to embed numeracy in the subjects they will teach. Sally and Jodie were able to articulate a richer personal conception of numeracy following their participation in the course. Sally, it could be argued, had a much richer understanding of numeracy than Jodie both before and after the course. Her understanding initially encompassed adopting a critical orientation to the use of mathematical knowledge in real-world contexts and, following the course, she gave examples of numeracy in science that included references to tools and dispositions. Jodie, on the other hand, began with a narrower understanding of numeracy that seemed to encompass only the use of mathematical knowledge in contexts. The examples of numeracy in history she gave following the course included references to the use of tools but there was no evidence that she saw dispositions or a critical orientation as part of numeracy. Before completing the course, neither pre-service teacher was confident in her capacity to demonstrate appropriate strategies to support students' numeracy learning in their respective curriculum areas. Jodie was unconfident or unsure on many aspects of embedding numeracy in history whereas Sally's responses to the Numeracy Confidence Survey indicated greater confidence than Jodie on these aspects. Following the course, both pre-service teachers were able to provide several examples of how numeracy could be embedded in their respective teaching areas, indicating that they could see numeracy opportunities in these subjects. The *Literacy and Numeracy Across the Curriculum* course, which promoted the use of the 21st Century Numeracy Model (Goos et al., 2014), is likely to have contributed to the changes observed in both pre-service teachers. Sally referred to the model even though she could not remember its name, and Jodie now thought she "had more of an idea how to approach it [numeracy in history]."

Strong claims cannot be made about the impact of the *Literacy and Numeracy Across the Curriculum* course on pre-service teachers' understanding of numeracy and their capacity to embed numeracy in the subjects they will teach because of the small number of pre-service teachers who participated in the study. One of the challenges of conducting any form of research, particularly with pre-service teachers, is dealing with recruitment and attrition. Even though approximately half of the cohort agreed to participate in the study, only a small number

completed the two course tasks during the Summer Semester and none, not even the five pre-service teachers who were interviewed, completed the Understanding Numeracy Task and Numeracy Confidence Survey that were emailed to them in February 2019. The findings presented in this paper do, however, add to those from an earlier offering of the course where increased levels of confidence in addressing numeracy were found among pre-service teachers who completed the course (Bennison, 2019).

Concluding Remarks

In Australia, all teachers are required to explicitly address numeracy inherent in the subjects they teach (ACARA, n.d.). Pre-service teachers, therefore, need to begin to develop the capacity to do so during their Initial Teacher Education program. The study reported in this paper investigated the impact of the *Literacy and Numeracy Across the Curriculum* course on pre-service teachers' initial identity as an embedder-of-numeracy (Bennison, 2022). The aim of the study was to address a gap in the literature by contributing to the research base informing the design of courses in Initial Teacher Education programs. Specifically, this paper focussed on the impact of the course on pre-service teachers' understanding of numeracy and their capacity to embed numeracy in the subjects they will teach Findings suggest that the course had some impact on Sally's and Jodie's understanding of numeracy and their capacity to identify how it could be embedded in science and history, respectively. The findings also highlight the very different starting points and learning trajectories for pre-service teachers completing such courses. The challenge remains to encourage participation in the study to further grow the research base underpinning the design of courses supporting pre-service teachers to embed numeracy in the subjects they will teach.

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