IDENTITY AS AN EMBEDDER-OF-NUMERACY: A CROSS CASE ANALYSIS OF FOUR TEACHERS

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Numeracy needs to be developed across the curriculum. However, if teachers are to effectively embed numeracy into the subjects they teach, they need to be supported to develop this capacity. Using an adaption of Valsiner's zone theory, a cross case analysis of four teachers is presented. The findings suggest that assisting teachers to broaden their personal conception of numeracy and providing opportunities for them to develop appropriate pedagogical content knowledge may enhance their capacity to exploit numeracy learning opportunities across the curriculum.

INTRODUCTION AND BACKGROUND

Proficiency in literacy, numeracy, and problem-solving in technology-rich environments - competencies that the Organisation for Economic Co-operation and Development (OECD) describes as the *key information-processing skills* - has an effect on an individual's economic and social well-being (OECD, 2013). Although numeracy encompasses much more than mathematics (OECD, 2013), an individual cannot be numerate without sound mathematical knowledge. Gal (2013) has argued that mathematics education, in school and other settings, should focus on how individuals can be assisted to develop the capacity to act in a numerate way. For schools, he suggests that this means rethinking the tasks, pedagogy, and assessment used. However, while mathematics education has a role to play in developing students' numeracy capabilities (or mathematical literacy, as it is sometimes called), numeracy needs to be developed in a range of contexts and, for students at school, this means in their other subjects (Steen, 2001).

One way of promoting numeracy learning beyond the mathematics classroom involves taking an *embedded* approach by encouraging all teachers to exploit the numeracy learning opportunities that exist *across the curriculum* (e.g., ACARA, 2014). However, for this approach to be successful, teachers need to be able to effectively embed numeracy into the subjects they teach; in other words, identify opportunities within curriculum documents and design tasks that support both discipline and numeracy learning. In this paper, some findings from a study that aims to identify how teachers can be supported to develop this capacity are reported.

Teacher identity, specifically identity as an embedder-of-numeracy (hereafter referred to as *EoN Identity*) was used as the lens to enable a focus to be placed on factors, both cognitive and non-cognitive, that are likely to have most impact on a teacher's capacity to embed numeracy into the subjects they teach. A conceptual framework for EoN Identity was developed (Bennison, 2014a) and an adaptation of Valsiner's (1997) zone theory has been used as the theoretical framework for describing and analysing each participant's EoN Identity (e.g., Bennison, 2014c). Building on this

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previous work, a preliminary cross-case analysis of four teachers is presented. This analysis was informed by the following research question:

In what ways can teachers be supported to develop the capacity to embed numeracy into the subjects they teach?

THEORETICAL FRAMEWORK

The EoN Identity framework (Bennison, 2014a) can be employed to assist in the design of empirical studies because it provides a focus for data collection. However, the framework has limited use for analysing data collected in such studies because it is difficult to conceptualise how the characteristics identified in the framework interact to produce a particular EoN Identity. On the other hand, the framework is consistent with a sociocultural view of learning and readily aligns with the adaptation of Valsiner's (1997) zone theory used by Goos (2013) to understand teaching learning.

Valsiner (1997) drew a distinction between learning that was possible and learning that actually occurred and conceptualised this as the interaction between an individual's Zone of Proximal Development (ZPD), Zone of Free Movement (ZFM), and Zone of Promoted Action (ZPA). He defined the ZPD as an individual's current state of development, constituted by the knowledge and past experiences that an individual brings to any situation; the ZPA was defined as actions that were being promoted by others; and the ZFM as actions that were permitted within the environment. He argued that the ZFM and ZPA worked together in a ZFM/ZPA complex to structure development. Thus, learning will only occur if the individual has the capacity (ZPD) and is permitted within the environment (ZFM) to act in the way promoted (ZPA).

Goos (2013) viewed the zones from the perspective of teacher-as-learner. For her, the ZPD represented the ways in which a teacher could develop under the influence of teaching actions that were being promoted (ZPA) within the teacher's professional context (ZFM). Her approach involved mapping the characteristics known to influence teachers' use of technology onto their ZPD, ZFM, and ZPA. Therefore, applying this approach to the current study entailed mapping the characteristics within the EoN Identity framework onto a teacher's ZPD, ZFM, and ZPA (see Figure 1). For example, opportunities to learn about embedding numeracy across the curriculum (e.g., professional development activities) were included in a teacher's ZPA (see Bennison & Goos, 2013 for a description of this mapping process).

While Shulman (1987) suggested that seven types of knowledge were needed for teaching, only three are included in the ZPD; mathematical content knowledge (MCK), pedagogical content knowledge (PCK), and curriculum knowledge (CK). In the EoN Identity framework, CK was defined as the knowledge needed to identify numeracy learning demands and opportunities across the curriculum, PCK as the knowledge needed for designing activities to exploit these, and MCK as the associated mathematical knowledge (Bennison, 2014a).

Valsiner's zones	Characteristics of EoN Identity
Zone of Proximal Development (ZPD)	Mathematics content knowledge (MCK) Pedagogical content knowledge (PCK) Curriculum knowledge (CK) Beliefs about numeracy Confidence with numeracy
Zone of Free Movement (ZFM)	Support from colleagues and administrators Curriculum requirements Characteristics of students
Zone of Promoted Action (ZPA)	Professional development Participation in research projects Informal interactions with colleagues

Figure 1: Valsiner's zones and characteristics of EoN Identity

RESEARCH DESIGN AND METHODOLOGY

The study (2013 – 2014) reported on in this paper involved eight teachers in two schools in Australia and was conducted within the context of a larger project (hereafter referred to as the *Numeracy Project*). The four teachers whose case studies are presented in this paper were from one of the schools.

Data was collected, during four visits to the school, through lesson observations and interviews with the teachers. Lesson observations focused on the tasks used and how these tasks provided opportunities for students to develop the five dimensions of the numeracy model developed by Goos, Geiger, and Dole (2014): *context*, *mathematical knowledge*, *tools*, and *dispositions* which are embedded in a *critical orientation*. The subsequent interviews were about planning and implementation of tasks, student and teacher learning as well as teacher reflections on the lesson. Each teacher also participated in a scoping interview that sought information about background, beliefs about numeracy, school context, and past opportunities to learn about numeracy across the curriculum.

Interview transcripts were annotated to identify comments related to characteristics within each teacher's ZPD, ZFM, and ZPA. For example, comments a teacher made about access to resources contributed to their ZFM. However, the characteristics of the ZPD are internal and must be inferred from the actions of the teacher in conjunction with their comments. Therefore, assessment of PCK was based on past opportunities a teacher had to learn about embedding numeracy into subjects they teach and analysis of their classroom practice using Goos et al.'s (2014) numeracy model. This analysis enabled each of the zones to be "filled in" and a narrative constructed in which each teacher's EoN Identity was described in terms of their ZPD, ZFM, and ZPA, enabling identification of factors that that contribute significantly to the teacher's EoN Identity.

FINDINGS

The teacher's shared Zone of Free Movement

As the teacher's professional context constitutes the ZFM (Goos, 2013), this section situates the research within Australia, the Numeracy Project, and the school. Firstly, numeracy is identified in the Australian Curriculum (ACARA, 2014) as a general capability to be developed in all subject areas. However, the use of the National Assessment Program – Literacy and Numeracy (NAPLAN) as a measure of school performance and accountability places pressure on schools to improve NAPLAN results, which influences school organisation, curriculum, and pedagogy (Hardy, 2014). Secondly, the teachers had previously agreed to participate in the Numeracy Project (2012 - 2014), where the potential of a professional development approach based on Goos et al.'s (2014) numeracy model was being investigated. Finally, the school was a large metropolitan school where school NAPLAN results were substantially below the Australian schools' average. Junior classes (Grades 8 and 9) were organised in *POD groups*, where one teacher taught English and history and another teacher took mathematics and science, with these teachers located to the same multidisciplinary staffroom. There were four 70-minute lessons in a school day and three lessons per week for each of the subjects mentioned above. While the school had a laptop hire scheme, the teachers reported limited uptake by students.

The teachers

The four teachers were Michael, Michelle, Karen and Martin (pseudonyms). In this section, the case of Michael is presented to illustrate how a case study was developed for each teacher. This is followed by summaries of the cases of the other teachers.

Michael was a mid-career science teacher. He completed his pre-service teacher education about eight years ago, completing curriculum subjects in physical education and mathematics but no subjects that specifically addressed numeracy across the curriculum. Since he began teaching, Michael had not had any professional development related to numeracy other than his involvement in the Numeracy Project. He agreed to participate in the project because Michelle, who shared his Grade 9 POD group, was a participant. When POD classes were introduced at the school two years ago, Michael was given a Grade 9 POD class for mathematics and science. He claimed that he had the appropriate science content knowledge, having completed an Applied Science degree, but found managing practical work difficult. In this paper, the focus was on Michael's EoN Identity in science.

Michael saw numeracy as basic school mathematics, describing it as:

> a form of mathematics that has been taught in a maths class somewhere along the line, maybe more primary school or early, like [Grade] 8 or 9. So I think they are the same thing … the basics of mathematics that every student should know.

While he saw a relationship between *mathematics* and science ("science does have a fair bit of *maths* involved in it"), Michael conceded that he didn't focus on

developing these skills as his main focus was *covering the content* ("we have a curriculum that we have to meet"). Michael reported that he found it difficult to keep students engaged for the duration of lessons, especially if he had mathematics and science in consecutive sessions, and that behaviour management issues influenced his classroom practice, as making lessons more student-centred would not enable him to "get to that goal at the end". A high level of student absenteeism presented an additional challenge for Michael, as if students missed a lesson they were "missing a whole concept".

This example of Michael's classroom practice comes from a unit on ecology that focussed on the impact of rabbits on native animals. Michael told students that two areas of land were studied over a five-year period. While both had bandicoots, dingoes, and wallabies, a small number of rabbits were introduced to one of the areas at the beginning of the study. Michael provided students with the feeding habits of the animals and asked them to predict the effect of rabbits on the native animal populations. He then presented data from the study and led a discussion about what to consider when displaying the data graphically. After giving students time to graph the data, a limited discussion about potential reasons for the observed population changes occurred. Michael's goals for this lesson were for students to *display* the data graphically and to *interpret* the data. He would have liked to focus on the latter goal but limited access to laptops meant that most of the lesson was devoted to drawing the graphs by hand. While the lesson provided a context (understanding the impact of introduced species) for the use of mathematical knowledge (translating data from tabular to graphical form) and tools (using tables and graphs to mediate thinking about the situation), the opportunity for students to apply a critical orientation was limited (due to lack of time) and there was no opportunity for students to develop positive dispositions towards using mathematics in the situation.

Michael's ZPD seemed to be limited by his personal conception of numeracy which focused on mathematical skills and limited PCK that resulted from the lack of opportunities he had to learn about embedding numeracy into the science curriculum. His ZFM appeared to be mainly constituted by elements that impeded his development of an EoN Identity. The need to cover the content, lack of access to resources, and the behaviour management issues he experienced combined to limit his capacity to fully exploit numeracy learning opportunities in science. The only element within his ZPA that would assist him to make the most of these opportunities was the Numeracy Project, where his participation was less than enthusiastic.

Michelle had been teaching for just less than ten years. After completing a Bachelor of Arts, majoring in Geography, she worked for a while then returned to university to complete a Graduate Diploma in Education. Michelle taught history and English but the focus in this paper is on her EoN Identity in history. While she appeared to have adequate MCK, her opportunities to develop the requisite PCK for embedding numeracy in history had been limited. She believed that numeracy was needed in everyday life but her personal conception of numeracy seemed to be mainly focussed

on mathematical knowledge and context. Classroom observations suggested that she was able to identify numeracy learning opportunities in history (e.g., the use of budgeting to help students to understand what life was like in Australia in 1901) but she did not fully exploit the potential of this activity.

Michelle's ZPD seemed to lack the rich personal conception of numeracy and PCK that would facilitate her developing a strong EoN Identity. Her ZFM included the views of her colleagues, who saw numeracy as the domain of the mathematics department, and the limited availability of technology. Michelle was an enthusiastic participant in the Numeracy Project and actively sought to develop her PCK through her own reading; thus, her ZPA promoted embedding numeracy in history.

Karen was a recently graduated science teacher with no formal preparation to embed numeracy in science. She was keen however, to develop this capacity and sought to do so through her participation in the Numeracy Project, mentoring from more experienced colleagues, and her own reading. While Karen believed there was a place for numeracy in science, her personal conception of numeracy seemed limited to mathematical knowledge and context. Classroom observations revealed that Karen was able to identify numeracy learning opportunities in the science curriculum (e.g., the use of a scaled geological timeline) however she did not fully exploit these.

Within her ZPD, Karen was in the process of developing PCK, had a narrow personal conception of numeracy but believed that numeracy was a part of science. Karen's ZPA was promising, with the presence of several actions that support embedding numeracy in science. Her ZFM allowed her to utilise numeracy learning opportunities in science (new curriculum, supportive colleagues) but she felt constrained in how she implemented tasks by lack of access to appropriate technology and student attitudes towards school (see Bennison, 2014b).

Martin, an experienced history teacher with over thirty years of experience, shared a POD group with Karen. His teaching areas were physical education and history. Numeracy across the curriculum had not been part of his pre-service teacher education nor had he participated in any numeracy-related professional development, possibly resulting in inadequate PCK. While he believed that numeracy was part of everyday life and he wanted to utilise numeracy learning opportunities in history, Martin expressed lack of confidence with embedding numeracy in history that he attributed to his lack of formal mathematics education. During classroom observations, he demonstrated that he was able to identify numeracy learning opportunities (e.g., using data to help students understand the impact of the Industrial Revolution) but increased attention to the inherent mathematical knowledge would have enriched the tasks he used.

Martin's beliefs appeared to support embedding numeracy into history. However, his ZPD seemed to lack appropriate MCK and PCK and included a narrow personal conception of numeracy. Within his ZFM, the new curriculum presented challenges because of limited chances to interact with other history teachers. Martin's only

exposure to professional development that promoted embedding numeracy across the curriculum (ZPA) was the Numeracy Project, but his engagement with this project appeared to have been limited (see Bennison, 2014c).

Discussion

Michael, Karen, Martin, and Michelle had different disciplinary backgrounds and levels of experience. Not surprisingly, differences emerged in their ZPDs. but there were also similarities. All teachers identified numeracy learning opportunities (demonstrating CK); however, none fully exploited these to develop all dimensions of Goos et al.'s (2014) numeracy model. This may have been due to inadequate PCK, as there had been limited opportunities for any of the teachers to develop this type of knowledge, or the teachers' narrow personal conceptions of numeracy that restricted their ability to "see" the full extent of numeracy in the activities used.

Although the four teachers were at the same school and, on the surface, appeared to have the same professional context, their individual ZFMs differed, sometimes as a result of how a teacher interpreted his/her individual context. For example, all the teachers were implementing the new curriculum that gave them permission to embed numeracy across the curriculum. On the other hand, the arrangement of classes into POD groups, with the resultant allocation of teachers to staffrooms, presented problems for Martin (limited opportunities to interact with other history teachers), whereas this arrangement presented an opportunity for Michelle to reorganise the time between history and English to achieve her goals in both subjects. Participation in the Numeracy Project was part of all the teachers' ZPA; however, while Martin and Michael were indifferent towards the project, Karen and Michelle were enthusiastic participants who engaged in other activities to develop their PCK.

CONCLUDING REMARKS

These findings suggest that assisting teachers to broaden their personal conception of numeracy and develop appropriate PCK (both part of the ZPD) may enable teachers to embed numeracy across the curriculum. Although based on the cross case analysis of only four teachers, the findings do illustrate how comparison of teachers' ZPDs, ZFMs, and ZPAs enables suggestions to be made about how to support teachers to strengthen their EoN Identity. However, teacher learning will only occur if actions that promote embedding numeracy across the curriculum are permitted in the teachers' professional context. Therefore, further work is needed to examine how the ZFM/ZPA complex can be mapped onto each teacher's ZPD to direct development. This may assist in deciding whether the focus for assistance should be individual teachers, groups of teachers of the same discipline, or the whole school community.

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