Disciplinary Literacy in the Mathematics Classroom

Gail Hager
Griffith University
<g.hager@griffith.edu.au>

Nationally and internationally, teachers are being held increasingly accountable for student achievement, particularly in light of high stakes literacy and numeracy tests. Policies have been implemented that are designed to improve educational outcomes through raising student literacy levels across all school years in all subject areas. This has resulted in all teachers being seen as teachers of literacy. Research around the teaching of literacy in mathematics supports the view that focusing on the language of mathematics will assist students to move from the concrete to the more abstract understandings required in the older year levels (Schleppergrell, 2007). However, this can be challenging for teachers who might be subject, but not language, specialists. In this paper, we report on a case study that investigated literacy teaching practices in a Year 7 mathematics classroom and specifically, the practices around teaching mathematical report- writing and the conditions that might have enabled or constrained them. Findings suggest that while teaching the general writing required in mathematics might be part of teaching practice, if practices are to change, school leaders need to provide both time and money to enable teachers to develop their knowledge of specific disciplinary writing practices.

Introduction

Learning mathematics encompasses learning the language of mathematics. In general, the significance of literacy and its connection to student achievement has been established with Wise (2009) stating that "literacy is, in reality, the cornerstone of student achievement, for any student in any grade" (p. 46). There have been concerns over the literacy levels of adolescent students, given the decline in the performances nationally in National Assessment Program - Literacy and Numeracy (NAPLAN) and internationally [Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS)]. However, as Wise (2009) has emphasised, the impact of poor performance is "not just on the individuals, but on the national economic condition and the strength and stability of our society" (p.46). It is for these reasons that literacy has been flagged as an essential twenty-first century skill and is reflected in policies and curriculum reforms at the national Melbourne Declaration of Educational Goals for schooling (MCEETYA, 2008) and the international level (for example, No Child Left Behind, 2001). On a national level literacy is embedded in all Australian subject area curriculum documents.

In the field of mathematics, research has shown how the nature of the mathematics classroom has also changed (Thompson & Rubenstein, 2014) so that the literacy of mathematics is increasingly important. Research has focussed on the language required to succeed, especially in the higher levels of schooling (Schleppergrell, 2007) and strategies have been suggested to incorporate mathematical literacy into the classroom (Hillman, 2014; Thompson & Rubenstein, 2014). However, this can be difficult for teachers, especially at the middle and senior school phases of schooling, with teachers being content area specialists but often less overtly familiar with the language of their subject (Gillis, 2014; Moje, 2008). Moreover, a renewed emphasis on writing in the disciplines (van Drie, Van Boxtel, &

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Braaksma, 2014), is also showing that content area writing has resulted in more generic literacy skills being taught, rather than those writing skills specifically required in the disciplines (Fang & Schleppergrell, 2010). Bazerman (1988) also showed how reasoning and rhetoric was different in each discipline. Thus, discipline-based literacy teaching practices are needed that are less general in nature and instead, focus on the subject specific requirements for each task.

Disciplinary Literacy

Over the last few decades there have been a variety of ways of describing how to teach literacy across the curriculum. These range from content area reading, content area writing, to writing across the curriculum. In Australia, the term "curriculum literacies" (Cumming & Wyatt-Smith, 2001) has been used, though increasingly, the term "disciplinary literacy/ literacies" is being employed (Moje, 2008; Shanahan & Shanahan, 2008). Current research into disciplinary literacy has shown how each discipline understands and uses language differently (Fang & Schleppergrell, 2010; Schleppergrell, 2007). Therefore, teachers need to engage students in the specific writing practices required to compose the required texts of the subject or field (Shanahan, 2015; Wyatt-Smith & Cumming, 2001). However, Klein, Boscolo, Gelati, and Kirkpatrick (2014) argued that while students may be taught discipline specific writing strategies in some subjects (e.g., History), it is more likely that they are taught only to write a more general text rather than one that is specific to the particular discipline. Fang and Schleppergrell (2010) argued similarly that content area writing has resulted in more generic literacy skills being taught, rather than those writing skills specifically required in each discipline.

Furthermore, education has grown increasingly complex and the nature of tasks students encounter daily in the classroom requires a flexible repertoire of language skills (Cumming & Wyatt-Smith, 2001). Adolescent students, in particular, encounter a wide range of tasks and topics and are expected to master a range of written genres, sometimes from one lesson to the next. Assessment tasks often favour the written mode and so writing to demonstrate learning requires students to write for specific audiences and purposes. They also need to use specific generic structures. In mathematics, such tasks often take the form of reports. These reports need to follow specific rules in terms of structure, grammar and language choice (Michigan Department of Education, 2012).

The Literacy of Mathematics

Mathematical learning is a complex process, and as an integral part of students' mathematics education, they need to be able to write effectively to communicate their findings to a range of audiences (Michigan Department of Education, 2012). Thompson and Rubenstein (2014) suggested that mathematical literacy requires "the ability to connect and translate … mathematical modes of communication" (p. 105). Hillman (2014) argues that students need to be introduced to "reading, thinking, speaking and writing" (p. 399). Teachers can use any number of strategies to teach writing, however, there is often little explicit teaching of the specific writing required to succeed (Kibler, 2011). Research has also shown that literacy instruction in mathematics often focuses primarily on vocabulary and word meanings (Wilson, McNaughton & Zhu, 2017). As all teachers are teachers of the specific literacy of their disciplines, and with the focus on improved student outcomes, there is an increasing need to incorporate the teaching of literacy and writing into daily education practices. In Australia, this teaching will be informed by the national curriculum documents

but as Kitson (2015) has shown, these documents may not be particularly supportive. In this paper there is a focus on the mathematics teaching practices of one teacher to examine what she taught about report writing, and what enabled and constrained her teaching practices. The theory of practice architectures (Kemmis & Grootenboer, 2008; Kemmis, Wilkinson, Edwards-Groves, Hardy, Grootenboer, & Bristol, 2014) is used as the analytical framework.

The Theory of Practice Architectures and Mathematics Education

A practice perspective on mathematics education has been outlined previously (see Grootenboer & Edwards-Groves, 2013; 2014), but briefly the theory of practice architectures conceptualises practices, which are comprised of characteristic "sayings, doings and relatings", as being enabled and constrained by conditions and arrangements (i.e., practice architectures) in any given site (Kemmis, et al., 2014). For example, the practice of teaching fractions uses characteristic *sayings* like 'denominator' and 'equal parts'; *doings* such as 'completing exercises'; and, *relatings* including the students relationship to the teacher and their peers. These are enabled and constrained by *cultural-discursive* arrangements like the shared understandings of mathematical language; *material-economic* arrangements such as the teaching space and resources; and, *social-political* arrangements including the school rules and students' emotional relationships to fractions from their previous experiences. There are two relevant implications of this theory here: (1) that practices, including mathematics education practices, are realised, and need to be understood, as site-based; and, (2) to develop practices there needs to be a concurrent development of the practice architectures that enable and constrain the practices.

The Study

The data reported here is part of a larger study conducted in 2016 that examined the teaching of literacy across the curriculum in the middle years at an independent school in South-East Queensland, Australia. The study was ontological in nature and employed qualitative methods to examine and explore teaching practices at this specific site. The study identified literacy teaching practices across several subject areas and examined relationships between these practices and the practice architectures that enabled and constrained them.

Data Collection

The participant group in the larger study was comprised of middle school teachers across various school subjects including mathematics. Data were gathered via classroom observations, in-depth semi-structured interviews, and document analysis. The school had recently embarked on a period of teacher professional learning that encouraged mentoring and coaching which included classroom observations and personal reflections on their teaching journey. Therefore, the participants all mentioned they were comfortable with the researcher's presence in the classroom. For the purposes of this paper, the findings related to the literacy teaching practices of the mathematics teacher (Diane – a pseudonym) are the focus. Diane is an experienced teacher having taught for over 25 years. She also was Co-Head of Mathematics at the time of the study, taking responsibility for the Year 7 to 9 mathematics program. Data collection was negotiated with the teacher and took place at the start of and towards the end of term one, and one lesson in term three, in 2016. The lessons were audio-recorded and detailed field notes taken. Diane nominated the lessons that were observed but she mentioned to the researcher that she had not specifically changed any of her practices because of the study. Diane also participated in two semi-structured interviews,

and some informal discussions that occurred after each lesson had been observed. The interviews were recorded and lasted around 30 to 45 minutes each. She also participated in a group interview with all participating teachers at the conclusion of the study. The group interview lasted around 45 minutes. During the individual and group interviews, key aspects of practice were discussed.

Data analysis

Data were analysed using several steps consistent with the theory of practice architectures. Initially, the transcripts of the classroom observations were analysed to identify general themes that emerged. After the initial identification of themes, transcripts were re-read and analysed specifically for the practices related to the literacies of mathematics and then, using the lens of practice theory (Kemmis et al., 2014), data were re-analysed for what they revealed about the specific "sayings", "doings" and "relatings" of these practices. Finally, in order to establish what enabled or constrained these practices, the data were examined to clarify the particular conditions and arrangements - the cultural-discursive, material-economic and social-political condition that existed in the site. Collectively, the analysis generated findings related to literacy teaching practices in reading, writing, speaking, listening and viewing of texts in mathematics. However, for the purposes of this paper, only the writing practices, and specifically, how Diane taught report writing, will be discussed.

Findings and Discussion

During the research period, Diane was observed initiating students into practices that saw writing as a product to demonstrate learning. In particular, Diane taught the report writing practices prior to an examination. The purpose of the lesson was to review the structure and contents of a mathematics report. Discussions with Diane revealed this was the only lesson that would be devoted to teaching students about report writing that year. During this lesson, Diane utilised scaffolding and modelling strategies to teach the students the particular writing required. In this case, the mathematics assessment required a very specific report format to be used. Diane's teaching practices around the structure can be analysed using her "sayings" "doings" and "relatings".

Practices of Teaching Mathematical Report Writing

Diane used scaffolding language (sayings) to teach the students about the particular structure the mathematics report required. Her opening question was related to the contents of a mathematics report; "who can think what are some of the things in a maths report?" She scaffolded the students further by asking a clarifying question; "Who can think what goes first?" This language demonstrated that writing a mathematics report requires sequential thinking, as indicated by the adjective "first". Diane also led the students through the order required in the contents of a mathematics report utilising time markers such as; "and then your name and then you'd put, …". Diane stressed the importance of following this order by using repetition to reinforce this practice, and further reinforced this practice by writing the list on the whiteboard (field notes, 17/8/16).

Diane also used suggestive language to prompt students to think further about the requirements using words such as; "And maybe a photo …, you can do a screenshot ", thus teaching the students that it was possible to add images to the report. The practice of writing a report also included aspects related to the vocabulary of the structure as evident in words

such as "title page, table of contents, reference list", and some associated synonyms; "some people just call it Contents", as well as the purpose of some of the headings; "So that I can actually find – or whoever is reading the report can find what they're looking for". Thus, while Diane was teaching the students about the necessary structure, she was also teaching secondary mathematical literacy practices such as the acceptability of using synonyms (e.g., "I don't mind if you vary that a little bit, I just want you to basically do this"), the purposes behind the content and also the necessity of using templates while writing the report: "You have to set it up first. You can have a template". Alongside this, she taught incidental vocabulary and structure that was not an accepted part of this particular report; "Not an Index that goes at the back – you don't need one for a report; Yes, a bibliography is when you include all the things you look at, the whole research job. This is only the ones you used", and also other unacceptable practices (e.g., "You don't have to print your report off – it's on Haiku").

Diane also taught practices associated with specific report structure – the introduction and conclusion explaining that both introductory and concluding paragraphs need to contain certain points and be of a certain length; "Introduction, I would think you would probably have five to ten lines. And what is an introduction? What's it need? Conclusion. And what is a conclusion?" Here, Diane was using the question and answer teaching strategy to encourage students to consider what they already knew about writing introductions and conclusions and to relate this prior knowledge to the current task. However, what was evident in her *sayings* was a distinct lack of specifically mathematical language. Hence, while this pedagogical practice addresses an important part of a well-rounded mathematics education, it does not 'sound' particularly mathematical.

During the teaching of the relevant practices related to writing a mathematics report, the teacher and students were involved in specific actions (*doings*), and the writing of the report also involved specific actions. The scaffolding provided by Diane helped the students to be *apprenticed* (Hillman, 2014) into the required practices. In this case, we see how Diane helped the students develop some of the specific requirements for this report – the structure, some of the vocabulary, some of the thinking involved – using scaffolding, 'question and answer', and repetition of key points in particular.

As part of the apprenticeship approach (Hillman, 2014), students were invited to participate actively in their learning but to be guided through this learning. During this lesson, Diane related to the students as the guide or mentor, and as the authority in the classroom (*relatings*). She controlled the activities for most of the time, asking questions and encouraging students to consider what they already might know about writing a report, its structure and associated vocabulary. In an interview with Diane, she affirmed this relationship describing herself; "I would like to think I was a warm demander" (interview 14/3/2016*)*. Again, these doings and relatings do not appear to be particularly 'mathematical', and yet they are an integral part of the literacy of mathematics.

The Practice Architectures of Teaching Mathematical Report Writing

According to Kemmis et al. (2014) practices do not exist in isolation, but they are enabled and constrained by the specific practice architectures in the site. The data presentation now turns to a description of the specific site arrangements and conditions and a discussion of how they enabled and constrained Diane's teaching practices. While there is much that can be discussed about the site-specific cultural-discursive, material-economic and social-political arrangements, only those relevant to Diane's teaching of report writing will be discussed here. In particular, Diane's practice of teaching report writing was enabled

and constrained by the cultural-discursive arrangements that existed at the site. The cultural-discursive arrangements included an assessment sheet of eight pages that contained language related to both the assessment and the mathematics. The language of assessment used here mentioned "Understanding and Fluency" and "Problem solving and reasoning" as two criteria for marking, and later these criteria were detailed using words related to writing such as "description, use of appropriate language, clear explanation". This shows how the mathematical processes were assessed using literacy skills and knowledge. The inclusion of these criteria likely enabled Diane's teaching as she was able to teach the students about some of the language of the report genre. However, there was an assumption that students shared her understanding of these terms as she did not explain them further.

Further enabling and constraining conditions included the mathematical language in other words such as "facts", "procedures", "investigate", "evaluate" and "justify". While these words were part of key marking criteria, and key to effective communication in mathematics (Hillman, 2014), they were not taught as part of the writing lesson observed. Thompson and Rubenstein (2014) indicated that in order for students to achieve success in mathematics, they must be able to "write in ways that expose their reasoning" (p. 105). Hence, it is likely that whilst the assessment sheet provided some of the cultural-discursive arrangements that enabled the explicit teaching of the structure, other arrangements might have constrained her explicit teaching of the more abstract mathematical language. The assessment sheet contained three pages scaffolding the structure of the report but these three pages only mentioned the use of "correct formal, impersonal language". Research has demonstrated how useful the explicit teaching of mathematical language is (Shanahan & Shanahan, 2008; 2012), but also that many subject teachers do not have this literacy knowledge.

Diane admitted in an interview (14/3/2016) that she lacked professional learning in literacy and suggested the lack of time available for professional learning for topics other than those related to mathematical content or other specific school initiatives (for example, using technology) might have played a role. Thus, the material-economic arrangements at the site, leading to a lack of professional learning in literacy, might have constrained Diane's teaching of these important aspects of mathematical learning.

The social-political arrangements at the school favour a traditional, hierarchical structure. Teachers are expected to be both authority and expert. This was evident in an observation of a staff meeting at the start of the year (20/1/2016) where the Deputy Principal spent an hour reminding teachers of the discipline code in the school, using words such as 'follow the framework" without inviting feedback, and reflected also in seating arrangements – staff were seated in rows in a classroom whilst the Deputy stood at the front. Diane utilised a similar traditional transmissive pedagogy that reinforced her role as the authority in the classroom. Her authority was also evident in her language choices: "Go get what you need (to one student). Keep still (to another student). No, it has to be done through Turn It In". The tone of command in modal verbs such as "Go, Keep, Has to" indicated her role as authority in the classroom. There was another arrangement that possibly enabled Diane's teaching. The class had been streamed and this was the "top" class in Mathematics. This arrangement might also have enabled Diane to teach the report structure required to demonstrate learning quite easily, unhindered by other potential constraints such as behaviour management that was observed in other classes during this study.

Conclusion and Implications

The writing practices evident in this lesson showed Diane teaching students about the particular structure associated with writing the mathematics report to demonstrate their learning. Diane taught certain aspects of the report genre to the students, more specifically scaffolding and modelling the structure of the report. She also focused on some vocabulary, supporting similar research findings (Wilson, McNaughton & Zhu, 2017). Nevertheless, Diane is a mathematics teacher and not a literacy teacher, and secondary school teachers are usually content experts rather than literacy experts. While she scaffolded and modelled aspects of writing the report for the students, she did not appear to focus on the other necessary, but more abstract, language features. Diane taught some related vocabulary but mathematical language is much "more complex than just studying vocabulary" (Thompson & Rubenstein, 2014). She also needed to focus on aspects such as analysis and reasoning. As Hillman (2014) states, "mathematically literate students are able to analyse, reason and communicate ideas effectively" (p. 401).

We have shown how the lack of professional development in the literacy of mathematics might have constrained Diane's teaching. Hillman (2014) has argued the need for more professional learning for subject teachers to enable them to identify the specifics of the literacy of mathematics. Researchers such as Moje (2008), and Fang and Schleppergrell, (2010), have offered a range of pedagogical approaches and strategies that can be employed in order to identify and then teach students about the underpinning literacies of a subject, and Fang and Schleppergrell (2010) argue for teachers to make writing practices more visible and allow students to critique them. This suggests that while Diane's teaching practices demonstrated a commitment to teaching aspects of literacy, there is much more that can be done. What is clear from this particular case is that if practices are to change at the individual level, then changes need to occur in the allied practice architectures. Thus, it is not sufficient simply to mandate practice change through policy reform, and specifically here it seems that professional learning is needed to provide time and space for teachers to become more knowledgeable and skilful in the specific subject literacies of mathematics. School leaders must recognise this need for teachers to be both content experts and to develop their knowledge of specific disciplinary literacy to enable them to initiate students into the required complex disciplinary writing practices. School leaders need to provide time and money for professional learning in literacy. In this way, we might see the improved learning outcomes required. This is an important time to develop teachers' knowledge and dedicated teachers such as Diane have commenced the journey.

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