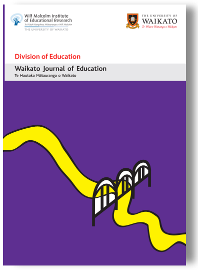

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Your words matter: The language of fractions

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Abstract

This article is based on the main finding of an action research study that investigated how primary school teachers could improve the teaching of fractions. The study primarily focused on what pedagogical strategies might be employed when shifting teaching and learning from procedural application to conceptual understanding. The research aimed to unpack what key elements of lesson design could be utilised to raise student achievement and understanding of fractional concepts. Language development was deemed to be one of the most beneficial to the teachers' practice and the research team explored the significance of developing shared mathematical language and the important role vocabulary plays in conveying meaning and internalising understanding. The journey of two teachers is described here in this article.

Keywords

Conceptual understanding; fractions; vocabulary; talk strategies; language

Introduction

Vocabulary development is important as it helps students
articulate their thinking in mathematically correct ways (Mills, 2018).

Proficiency and mastery within the mathematics classroom is dependent on knowing what to do and why; understanding topic-specific language and its associated meanings is central to the students being able to make sense of mathematical experiences (Rollins, 2014; Skemp, 2006). Classrooms are dynamic places, characterised and influenced by a multitude of factors. Constructive and productive learning environments, which value mathematical practices and participation, provide students and teachers alike with a multitude of opportunities to actively engage with concepts, through mental, verbal, and physical constructs (Hunter, 2014). Developing a shared language of mathematics promotes articulation and different ways of thinking without a total reliance on symbols and numbers. Mathematicians engage in specialised dialogue to communicate their ideas, to reason and to justify; true understanding is shown through well-articulated mathematical dialogue (Anthony & Walshaw, 2007). Through continual

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practice, students become more familiar with actions and rules that regulate discussions and discourse (Anthony & Walshaw, 2007).

Developing language, especially vocabulary and oral talk structures, across the curriculum sets high expectations for complete and well thought through answers, and collaborative talk in ways that promote positive and productive classroom discourses. Mathematical discussions require a particular way of speaking and thinking which involves a shift in "students' cognitive attention from procedural rules towards making sense of their mathematical experiences" (Anthony & Walshaw, 2007, p. 124). Providing the correct answer is not enough: students should work towards being able to describe and justify how they reached the solution and explain why their methods work. As the more experienced users of language, teachers guide students towards using and understanding precise and generalised language components of effective mathematical communication—vocabulary, syntax, semantics, and symbols (Anthony & Walshaw, 2007; Chinn, 2017).

Language development in the mathematics classroom

Being able to effectively communicate is essential to conceptual understanding, and the teacher's role is crucial in providing their students with the opportunities to learn how to verbally structure information and articulate processes in logical ways. Traditionally, teacher-led discussions have dominated classroom discourse, with students being led or "funnelled" through pre-determined directions and strategy use (Wood, 1998). Within this, teachers undertake much of the mathematical thinking. However, leading students to the "correct answer" or "correct way of thinking" about a particular problem set is not enough to demonstrate understanding. Instead, they should work towards describing and justifying how solutions are reached and explain why their methods work.

Difficulties in obtaining mathematical language skills can be attributed to the dual nature of the vocabulary used; one word will have different meanings in mathematical versus home life. Chinn (2017) concluded that students may be confused or misinterpret understandings due to their fixed notion of the meanings of words, i.e., left as in direction or left as in a subtraction answer. In addition, there are many exceptions to patterning rules; for example, teen numbers. Even within the teen numbers, there are inconsistencies in pronunciation and language used, for example, eleven and twelve do not have "teen" in them and thirteen does not have the number three in it (Chinn, 2017). This language inconsistency also holds true within the fractions domain, as terms such as "half" or "third" do not fit the "th" pattern. Another contributing factor is that symbols have a variety of words associated with them, such as "times", which includes vocabulary like multiply, groups of, product, and so on. Students look to teachers to model the correct use of mathematical language through introducing words and terms in context as well as revoicing (Askew, 2016a) contributions to match communication expectations.

"Language plays a key part in shaping students' mathematical experiences" (Anthony & Walshaw, 2007, p. 54). Talking is powerful; being able to explain, describe, and justify one's own thinking helps internalise constructs and rules. Students learn to recognise when they have been unclear in expressing their thinking while developing a growing awareness regarding misconceptions they hold and gaps in their understanding (Franke et al., 2009). Enhancing the connections between language and specific conceptual ideas is brought about by the teacher reframing and refining student contributions. Creating a shared dialogue means students can "reorganise and clarify material in their own minds, fill in gaps in understanding, internalise and acquire new strategies and knowledge, and develop new perspectives and understanding" (Franke et al., 2009, p. 382). Subsequently, students learn to monitor their own learning. No matter the task or goal, students should have the time and space to rehearse, be allowed to make mistakes, try out half-formed ideas and refine their thinking free from the demands and pressures of the teacher and the entire class (Askew, 2016a; Askew 2016b). In terms of fractional understanding, language is a critical component. Gupta and Wilkerson (2015) identified fractions as a "critical conceptual base for proportional reasoning and other mathematical concepts" (p. 27) for higher levels of the curriculum and for use in everyday life.

Research approach

This article is based on one of the findings and outcomes of an action research study that sought to answer the question—What factors might teachers consider during the teaching and learning of fractions to deepen their students' understanding and accelerate learning? It was identified that, prior to the research, the educators involved required a concise and thorough understanding of the language development to enhance conceptual understanding of the key ideas of fractions for their students.

The participating school—a decile nine contributing, urban co-educational primary school—informed the researcher that fractions was an area of pedagogical weakness across all year levels (Years One to Six). The two participating teachers (pseudonyms Whitney and Kylie), from two Year Three and Four composite classes, partnered with the outsider researcher to form what will be referred to as the "research team". The participating teachers selected students from their classes based on similar learning needs identified through the pre-unit test—developed and marked by the researcher. Additionally, the participating teachers noted that these students had been marked as competent for various fraction progressions. However, both teachers suspected that the students' understanding was more likely to be superficial and procedural based. All students were identified as having made limited progress in Number and Algebra over the six months prior to the study commencing. The students were formally invited to participate, and parents' consent was sought and obtained. To uphold confidentiality, students were assigned a pseudonym code (S1–S7).

An important underpinning aspect of this study was on the development and progress of mathematical thinking; learning that makes a difference, not just a tick in a check box. Connectedness between more substantial mathematical ideas was developed as teaching and learning practices moved past simple sharing towards justification, explanation, and understanding of ideas through the rich learning task of "Words of the Week".

The "Words of the Week" mini-lesson develops understanding through talk—the language of fractions and learning to explain.

Methodology

The action research design used within this study aligned with the interpretive paradigm as it focused on action which was "characterized by a concern for the individual" (Cohen et al., 2007, p. 21); the students needed to benefit from the research. This paradigm encouraged collaboration between the outsider researcher and the participating teachers, as the merging of different perspectives and ideas would form a more comprehensive understanding of what was happening for individuals and groups within the learning tasks of this study and across contexts (Morehouse, 2011).

A range of data types were used and analysed to capture and "explain more fully, the richness and complexity" of what was developing and occurring throughout the action research cycle (Cohen et al., 2007, p. 141). The data was mainly qualitative in nature and collected primarily by the researcher, with the support of the teacher participants. The qualitative data collection methods that were utilised over the entire study provided information and evidence for each stage of the action research cycle: plan, act, observe, and reflect. Data was gathered through a variety of avenues, such as reflective research team meetings, observation, photographs, video recordings, semi-structured interviews, pre- and post-testing, and collecting samples of students' work.

To provide validity and reliability of the results, triangulation of multiple sources was used. The weekly team meetings (five in total) and direct observation of four lessons, as well as the pre- and post-research semi-structured interviews of the teachers and the students provided the research team with the information needed to inform the language development factor of the study. Whitney and Kylie were formally observed twice during the study. Data collected during the observations included video and audio recordings, photographs, and handwritten notes. Data was hand coded into broad themes, such as “talk”, and later refined as sub-categories, i.e., vocabulary.

Ethical considerations

This research adhered to the guidelines set out in The University of Waikato Code of Ethics. All material associated with ethical practice was approved by Te Kura Toi Tangata Faculty of Education Research Ethics Committee, prior to commencement of the research. Informed consent and assent procedures were adhered to, and all intents and purposes of the research were clearly communicated and understood by each participant. Ethical standards were “kept in mind and regularly revisited at every stage of the research process” as research will “evolve over time and different issues might arise which have not been considered at an earlier point” (Winwood, 2019, p. 20).

Findings and discussion

The language of fractions

The active research cycle (see Figure 1) indicated several gaps in the students’ knowledge and understanding. While unpacking why the students struggled to articulate their thinking during the second meeting, the research team reasoned that the students lacked a bank of essential vocabulary. For example, during a planned learning experience, one participating student (S6) commented to the researcher that she had never heard of the terms “multiplication” or “groups of”. Each week, the team planned five new words to teach at the beginning of each mathematics session (see Table 1).

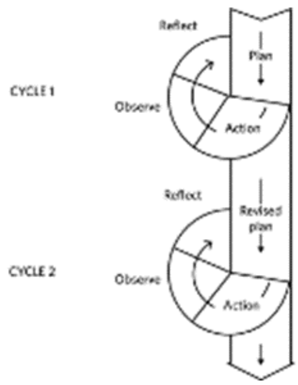

Figure 1. Action research cycle. Model created by Kemmis and McTaggart (1990).

The research team’s reasoning and justification of focusing on vocabulary aligned with that of Askew (2016a) who stated that to be able to talk mathematically and about mathematical ideas “means that mathematical vocabulary becomes part of the classroom discourse. It’s not a list of words that you select from to put your ideas ‘into’: it is the words through which ideas are formed” (p. 156).

Proficiency and mastery in mathematics is dependent on knowing what to do and why; understanding topic-specific language and their associated meanings is central to the students being able to make sense of mathematical experiences (Rollins, 2014; Skemp, 2006). Pre-research interviews and testing indicated that the students lacked common vocabulary for fractions; they could name some unit fractions; for example, one-half, but could not explain what numbers in the fraction symbol meant; for example, the denominator. Fractions were explained as "splitting" and "cutting". Book Seven of the Numeracy Development Project (Ministry of Education, 2008a) outlined these as key mathematical ideas within the Advanced Counting stage. However, all the students were deemed as working within the Early Additive stage, which suggested that they had been placed at an incorrect stage, or else they should have already been competent users of such baseline vocabulary and language.

The vocabulary mini-lesson

As the research team focused more deliberately on mathematical language, discourse, and dialogue, a mini-lesson structure for teaching vocabulary emerged (see Tables 1 and 2). The weekly reflective meetings allowed the research team dedicated time to map out key words, which would assist the students in understanding the upcoming content and concepts. The concept of "preloading" builds on the students' prior knowledge, so that they "latch on more readily to new concepts" (Rollins, 2014, p. 11). Each week, five new words were planned, and it was collectively decided that these would be explicitly taught at the beginning of each mathematics session (see Table 1); the intention was to introduce one new word per day, while reflecting on and recapping past words. Focus words were taken from anecdotal notes, teacher and researcher classroom observations, and workshops. The research team considered which words were "instrumental to students' attainment of the content" and which words would minimise the barriers to understanding (Rollins, 2014, p. 84). The team was able to anticipate the areas—words, concepts, actions, and constructs—students most likely would have difficulty with. This pre-thinking provided opportunities to examine how the learning would be scaffold and connected to real-life, as well as different, non-traditional methods.

Table 1. ***Words of the Week***

Week 2	**Week 3**	**Week 4**
Linear Equation Equals Denominator Numerator	Set Symbol Compare Divide Strategy	Words that mean to multiply—Groups of / sets of / lots of Words that mean multiplication—multiply / multiplication / times / product Factor Improper

Initially, the teachers had freedom over the enactment of vocabulary instruction. Whitney provided the strongest and most engaging learning model; this paralleled Rollin's (2014) principles of strategic vocabulary instruction and the Department of Education and Training's (2020) high impact teaching strategies. Whitney implemented Words of the Week during the first five minutes of every fractional learning session. The teacher created her own structure for the mini-lesson (see Table 2) and kept a record of the week's words on her modelling board (see Figure 2). After feedback from the researcher, Whitney created a permanent display of vocabulary (on word jar templates). Recording new mathematical vocabulary on the modelling board gave Whitney and her students a place to continually refer to and reflect on. This, combined with the structure of the mini lesson that emerged (see Table 2) and the teacher's emphasis on connecting the vocabulary to action, provided the students with multiple exposures and opportunities to consolidate new learning and connect to that of previous research (for example: Rollins, 2014; Shulman, 1987, as cited in Mills, 2018).

Table 2. ***Words of the Week: Mini-Lesson Structure***

Steps	**Strategy**	**Question stems**
Note: One new word a day		
Activate prior knowledge	Recap past words (from the week or previous week). Look at the meaning and clues within words Make connection between words	How could you explain … What do you mean by …
Introduce new word	Write in words Pronunciation Explain Example/use Refer to learning activities that relate	What could this word mean? What does it tell you? What is its purpose? How can you build on … idea?
Reinforce understanding	Link to mathematics topic or across contexts (connections to real life examples) Student self-explanation	For example, symbols Where else would we find symbols? Outside on the road? What about in writing? Can you explain it in your own words? Can you create a picture to match the meaning?

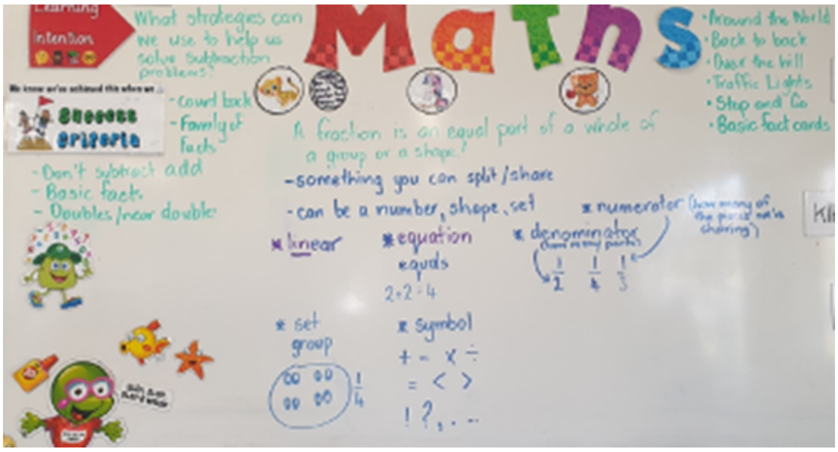

Figure 2. Whitney's words of the week as recorded on the modelling board.

Whitney utilised both written and visual information to maximise understanding and to accommodate the different learning styles of the students. She engaged the students in the lesson through interactive strategies, such as questioning, discussions, and using the vocabulary in real-life examples, in what Anthony and Walshaw (2007) described as grounding the learning into the life of the learner. Whitney used explicit instruction and encouraged her students to make connections to their prior knowledge and to cues within new words, and to use their peers as a source of information. Incidental vocabulary was modelled through direct explanations and revoicing the students' own explanations with more elaborate forms of language. As Absolum (2006) stated, the students got a "buzz" from being heard and learnt from teacher modelling. The modelling means that teachers ultimately are deemed to have a strong influence on the language used in their classrooms (Anthony & Walshaw, 2007).

Whitney's students were excited about the introduction of new vocabulary and listening to the teacher use these words throughout their workshops. When the students discussed their learning, they realised that they were using their newly learned mathematics words. Whitney increased her use of thinking time and peer discussions before students were asked to share with the class. Kylie began implementing word of the week after the researcher had notified her that S6 commented that she had never heard of the terms multiplication or groups of. During the final week of the research, Whitney had her students sketch and label pictures of the different words they had learnt.

Vocabulary in learning

Both Whitney and Kylie guided their students to use more precise mathematics language, as they explained their thinking. For example, during an improper fractions activity S5 stated, "Each person gets a half and one." Kylie reorganised the sentence, saying, "Each person receives one whole wafer and one-half wafer, so they get one and a half wafers each." She then added, "So that is three halves." The revoicing of such ideas developed a common interpretation and common language to describe what to do and how (Jackson et al., 2012) As a result, S5 went on to use this format in subsequent explanations. Whitney employed the private talk strategy "turn and tell a buddy", which provided each student with the opportunity to share. Whitney remained at her modelling board, preparing for the next phase of the lesson and did not monitor these conversations. Thus, she missed the opportunity to consistently gather information on all her students' mathematical thinking, which, Franke et al. (2009) noted in their research would have guided further instruction and follow-up questions. The teachers expected each student to either share, revoice, or build on others' strategies provided, which motivated the students to actively listen. Rost and Wilson (2013) reiterated that by implementing a strategy such as revoicing, the listener becomes the focal point of the conversation, which requires them to maintain focus and attention to respond accordingly.

Vocabulary development was essential, as it helped the teachers model how to articulate their thinking in mathematically correct ways and the teachers' subsequent use of equipment helped generate talk—linking action to words (Mills, 2018). The research team observed that the participating students were able to use some of the new vocabulary in context of their learning by the end of the three-week study. The importance of correct pronunciation was debated among the team; the students in this research were young and tended to mispronounce many technical words. As noted by the Ministry of Education (2008b), "students will acquire the correct terms if they are used consistently [for example through modelling]" (p. 16), so continual use was essential.

It is important to note that pre-empting misconceptions in language should be considered when developing questions and tasks that reflect the lives of your students. The use of challenging words is important but equally so is ensuring that the students understand and can use these in a variety of contexts before the intended task. Additionally, task questions need to be realistic and appropriate to the students' level of ability. There were several questions the research team had considered to be straightforward for the students. For example, for a question about how much is ¼ of two dozen eggs (paraphrased). The students did not understand what a dozen was and then they could not comprehend why one person would need two dozen eggs. This relates to Chinn's (2017) research, which reported that "many students do not relate maths questions to the same reality as a teacher" (p. 111). Chinn also noted that the students should learn to construct word problems, such as translating symbols to words, to learn how problems are structured and the dual role vocabulary can play.

The importance of correct mathematical language: The conclusion

This study highlighted the importance of developing fractional (and other mathematical) vocabulary as a precursor to developing mathematical talk, and for developing deeper, more connected understandings across all mathematical domains. Talking about mathematics, such as reporting back on procedures and strategies, is different from talking mathematically. This study concluded that the weekly meetings held by the research team assisted in the use of correct mathematical language for both the teachers and the students. Within the weekly meetings, the research team mapped out key words, which assisted the students in understanding the content and concepts. A result of this language focus was the creation of a mini-lesson structure for teaching vocabulary. The teachers connected the vocabulary to action within their lessons and began the journey into using talk more proficiently. There was a shift from demonstrating procedural understanding through avenues such as worksheets, to the students knowing and understanding how and why they reached their answers.

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