# Mathematical Language Development and Talk Types in Computer Supported Collaborative Learning Environments

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In this study we examine the use of cumulative and exploratory talk types in a year 5 computer supported collaborative learning environment. The focus for students in this environment was to participate in mathematical problem solving, with the intention of developing the proficiencies of problem solving and reasoning. Findings suggest that students engaged in exploratory talk may more regularly attempt the use of technical (tier 3) mathematical vocabulary.

## Introduction

The development of mathematical language is essential to student understanding and growth in mathematics; see for example (Austin & Howson, 1979; Morgan, Craig, Schuette, & Wagner, 2014). In this paper we will examine the use of mathematical language by Year 5 students, in the context of a Computer Supported Collaborative Learning (CSCL) environment.

We were interested in the 'talk types' (Mercer & Wegerif, 1999) that would become evident during student online discussion. The three types we looked for in discussion were Mercer and Wegerif's 'disputational talk', 'cumulative talk', and 'exploratory talk'. Our primary intention in this paper is to answer the question; 'will the density of use of Beck, McKeown and Kucan's (2002) tier-three vocabulary (see below) be greater in identified examples of 'exploratory talk' compared with the other two talk types?' A secondary question that we also aim to explore is, 'Is there a relationship between students' (teacher identified) mathematical ability and their use of tier-three mathematical vocabulary?' Finally, we aim to investigate whether the density of tier-three mathematical vocabulary use changed throughout the intervention and also if there were any ability groups (below level, at level or above level) where changes were more obvious.

## Talk Types

Mercer and Wegerif (1999) identified three broad talk types when they analysed many hours of videotaped discussion amongst British primary age students: 'disputational talk', 'cumulative talk' and 'exploratory talk'. Designating and analysing talk types in this way allowed the authors to consider the ways that students use language to collaboratively construct knowledge and problem solve. his approach to the analysis of student discussion since it is prominent within CSCL literature. We rely on Mercer and Wegerif's (1999) definitions for the three talk types in this study:

> **Disputational talk**, which is characterised by disagreement and individualised decision making. There are few attempts to pool resources, or to offer constructive criticism of suggestions. Disputational talk also has some characteristic discourse features – short exchanges consisting of assertions and challenges or counter-assertions.
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> **Cumulative talk**, in which speakers build positively but uncritically on what the other has said. Partners use talk to construct a 'common knowledge' by accumulation. Cumulative discourse is characterised by repetitions, confirmations and elaborations.

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> **Exploratory talk**, in which partners engage critically but constructively with each other's ideas. Statements and suggestions are offered for joint consideration. These may be challenged and counter-challenged, but challenges are justified and alternative hypotheses are offered. Compared with the other two types, in exploratory talk knowledge is made more publicly accountable and reasoning is more visible in the talk (p. 85).

The discourse analysed in this paper occurred in the online environment. That is, it occurred asynchronously in a discussion board. (However we use the term 'utterances' when referring to students' statements.) Like Mercer and Wegerif, we were interested in gaining an understanding of how students jointly construct knowledge. Our interest in identifying and analysing the three talk types stemmed from the author's speculation that CSCL environments designed to foster greater levels of exploratory talk are more likely to result in higher levels of higher order and critical thinking. We hypothesised that given that 'exploratory talk' is represented by talk where public accountability is evident, in addition to reasoning being visible, a greater density of technical mathematical vocabulary may be present when students engage in this talk type.

## Vocabulary - The Three-Tier Framework

Beck, McKeown, and Kucan (2002) established a basic system for the classification of vocabulary. In their system vocabulary is classified as tier-one, tier-two and tier-three. They established these terms as a means to frame teaching and learning in the area of vocabulary development. Their framework has since been appropriated by various researchers for the purposes of understanding aspects of mathematical language development, see for example (Marzano & Simms, 2013).

Tier-one vocabulary encompasses everyday language. These words are the most basic and are used with a high degree of frequency, particularly in spoken language. Tier-one vocabulary includes such words as 'warm', 'cold', 'talk', 'cat', 'dog' etc.

Tier-two vocabulary represents words that are primarily used in written language. They are words with a very high degree of utility. These words are generally utilised by more mature users of language. As a result of their usage primarily in written language, they can be more difficult for students to learn independently. Examples of tier-two vocabulary include, 'proceed', 'following', 'retrospect', 'contradictory' etc.

Tier-three vocabulary includes words with a technical or domain-specific usage. Generally, these words are of a very limited usage, however in the case of this study we see them occurring more frequently because of the mathematical context of the study. They are generally the most difficult words for students to acquire because of the very limited opportunities students have to experiment with them. In the context of mathematics, Tier – three vocabulary would include, for example: 'formula', 'equation', 'symmetry', 'median'.

## Method

The present study took place as part of a project in an Australian suburban primary school over a ten-week period. The first author had previously taught at this school and so was familiar with their curriculum and the students' computer skills.

Participants in the project were 54 Grade 5 students (ranging in age between 10 – 12 years old). There were 26 boys and 28 girls between two classes. Thirty-two percent of the student participants are from a language background other than English (ACARA, 2015). This had implications for this study as working within a CSCL environment places significant demands on students' general literacy abilities. The 54 students were placed in 10 mixed ability groups within the online space. These groups were created on the basis of teacher judgement (students were classified as either below level, at level or above level in mathematics). Teachers classified students on the basis of a series of tests they had conducted, assessing the students' level of procedural and algorithmic fluency and general understanding across key areas of mathematics.

Over the ten weeks in which the unit was delivered students collaboratively solved and/or investigated nine mathematical problems incorporating aspects of each of the content strands of the Australian Curriculum; namely, Number and Algebra, Statistics and Probability and Measurement and Geometry (ACARA, 2014).

Through a one-to-one netbook program every student had their own access to Microsoft Windows so online collaboration generally took place at the students' homes. This required an internet connection so if students did not have internet access at home, they were given the opportunity at lunch times to access the internet in their classroom.

Students were expected to engage in iterative online discourse where they would build on each other's ideas. This is a principal goal of collaborative mathematical problem solving. No online facilitator took part in the CSCL. This decision was taken in order to avoid discussion and communication between students being stifled by an 'expert'.

However the participants did receive support. Each week for the first 7 weeks, prior to the students commencing work on each online problem, an hour of standard classroom discussion was facilitated by the first author of this paper. This time was spent with the class performing three basic tasks: discussing expectations of behaviour, and appropriate approaches to collaboration within the online space; reviewing the previous week's solutions and discussing challenges and successes that students perceived; explaining, reading through and discussing the following week's problem. In weeks 8 and 9 a different pedagogical approach was taken. The level of support was greatly reduced, no discussion of the problems took place and students were asked to solve the problems in their class time but only through working in the CSCL environment.

Analysis of data for this paper was undertaken using qualitative data analysis software NVivo (2014) and was based on two forms of coding. Firstly, all online discussion within each of the ten small groups was coded in terms of talk type. For this analysis one of the three talk types (cumulative, exploratory or disputational) was identified for each discussion, for each group, for each problem. As indicated by Mercer and Wegerif (1999), often this meant that whilst a predominant talk-type was identifiable aspects of the others were also present. In these cases we coded according to the one we believed was *most* in evidence. When disagreement within a group occurred in a manner that moved the group forward in their thinking we chose to classify these episodes as 'exploratory' talk rather than 'disputational' talk. We believe that the lack of disputational talk may be a result of regular teacher led classroom discussions about constructive modes of online communication. Secondly, all online discussion was coded for examples of tier-three mathematical vocabulary. This coding is undertaken at the word level. After coding the two respective approaches were cross-tabulated to detect patterns and associations.

## Results and Discussion

Figure 1 shows an example illustrative of discussion from the online message board coded as exploratory talk with tier-three mathematical vocabulary bolded. The discussion in Figure 1 is provided verbatim (with pseudonyms) from the online space. In this example students worked on a problem where they were required to make a conjecture about whether cats' names or dogs' names are generally longer. The students researched a number of the most common cats' names and dogs' names; calculated the mean, median and mode of these data, graphed results using Microsoft Excel and discussed their results.

Interestingly, the only two talk types that we detected were 'cumulative' and 'exploratory'. In this example of exploratory talk we see the students attempting to decide upon appropriate mathematical vocabulary to describe the three common measures of central tendency. One student offers the word 'maintain' as a possibility. Eventually though, they are able to arrive at the conclusion that the words 'mean', 'median' and 'mode' are the words that they have been seeking to find. This suggests that students' vocabulary may benefit from the co-negotiation of definitions, trialling and experimentation with new terms that the context of this setting allows.

| | |
|---|---|
| Sunny | I think dogs and cats are the same number of letters because in my **graph** it came up with 8 fives and eight fives each.<br>So that my Information<br>Please reply<br>Thanks guys |
| Sienna | Hi Sunny, where is your **graph**? |
| Sienna | Hi everyone, i have done the exel spread sheet and the names that i have got are feamale and male. i am neally compleated. |
| Holly | Hey guys what do you do after you have writen down all the names and numbers? |
| Sienna | hi everyone. What are the three words that we have to do. They are the M words. What are they? |
| Sunny | Same I forgot about those m words I think one was maintain.<br>I am not sure about if it is right. Please reply under<br>Thanks guys |
| Sunny | Guys I know the m words they are **mean**, **mode** and **median**.<br>I just remembered today. I hope this helps you in you **bar graph**, **column graph** and lastly **line graph** etc. Please reply if you are on edmodo.<br>Thanks guys<br>And see you tommorow |

*Figure 1.* Example of discussion coded as exploratory talk.

*Figure 2* shows an example from the online discussion where cumulative talk is apparent. This discussion is again taken from a small group of students attempting to collaboratively solve the previously described 'Pet Names' problem. In this example we see Annie positioning herself as 'leader' within the group. She repeatedly rephrases her desire for suggestions or agreements related to whether she should provide information about the various pet names. No constructive criticism is present, however eventually we see some 'common knowledge' emerging. In this excerpt of discussion we see no tier-three mathematical vocabulary. The group did not present any analysis of their pet names.

| | |
|---|---|
| Annie | hey guys do we need to do male and female cats names if you do please post |
| Kevin | do you what me to rshoq |
| Annie | what is rshoq? |
| Kevin | that mans resuch |
| Annie | no i was thinking i have already done the female and the male cat names and they are french names is that alright with you guys |
| Annie | and you spell research like this. |
| Sheldon | hi |
| Annie | hi just tell me if you guys want to know the names and i will tell you |
| Annie | i will tell you anyway the female names are: |
| | Sassy Misty Princess Samantha Kitty Puss Fluffy Molly Daisy Ginger |
| | Midnight Precious Maggie Lucy Cleo Whiskers Chloe Sophie Lily Coco |
| Annie | And my male names are: |
| | Max Sam Tigger Tiger Sooty Smokey Lucky Patch Simba Smudge Oreo Milo Oscar Oliver Buddy Boots Harley Gizmo Charlie Toby |

*Figure 2.* Example of discussion coded as cumulative talk.

Table 1 shows the number of examples of talk types identified and the number of examples of tier-three mathematical vocabulary. The dominant talk type throughout all discussion during the ten weeks of data collection was cumulative talk. Forty-nine examples of cumulative talk were identified, whilst only 27 examples of exploratory talk were identified. Across the data we see an average of between 7 and 8 mathematical tier-3 words used during examples of cumulative discussions, whilst we see between 10 and 11 examples of this type of vocabulary used in examples of exploratory talk. This indicates that students engaged in exploratory talk were more likely to use tier-three vocabulary than when they are engaged in cumulative talk.

Table 1
*Tier 3 Vocabulary use in Cumulative and Exploratory talk*

| Talk Type | Tier-three Vocabulary Used within Talk Types | Identified examples of Talk Type | Average No. Tier-three Vocabulary per Example |
|---|---|---|---|
| Cumulative Talk | 361 | 49 | 7.4 |
| Exploratory Talk | 284 | 27 | 10.5 |

Table 2 shows the density of tier-three mathematical vocabulary use by differing ability levels of students. With the exception of the ‘at level’ boys a possible association can be seen between the density of mathematical tier-three vocabulary use and the student ability level. One possible explanation for the lower than expected use of tier-three vocabulary use in this group is that 7 of the 11 students in this group had a Language Background Other than English compared with 17 out of 54 overall.

Table 2
*Density of Tier three Vocabulary use in Student Utterances*

| | No. Of Students | Tier-three Vocabulary Use | Total No. of Utterances | Tier-three Vocabulary Use per Utterance |
|---|---|---|---|---|
| Above Level Boys | 5 | 129 | 198 | 0.65 |
| Above Level Girls | 3 | 78 | 96 | 0.81 |
| At Level Boys | 11 | 77 | 301 | 0.26 |
| At Level Girls | 12 | 183 | 350 | 0.52 |
| Below Level Boys | 7 | 35 | 96 | 0.42 |
| Below level Girls | 9 | 128 | 308 | 0.42 |

Table 3 shows the density of mathematical tier-three vocabulary use throughout the study. There does not appear to be any clear evidence of progressive growth in students' use of mathematical tier-three vocabulary throughout the period. However each problem offered different opportunities. We have also indicated rates of online participation of the ten small groups throughout the period. We see that in weeks 2 and weeks 7 the fewest number of groups participated in online discussion. These weeks also correspond with the lowest number of tier-three mathematical terms used. It is possible to conjecture, that in these two weeks students found it more difficult to engage with the tasks. Even though there was a classroom introduction, including explicit discussion of the required mathematical language the mathematical content required was new and also difficult for some students. For example, in week 7, when they undertook the Pet Names problem, students were required to calculate a central measure (mean, median and mode). The development of skills and understanding in this area of statistics does not appear in the Australian Curriculum (ACARA, 2014) until year 7.

It is also worth considering the change in pedagogical approach that took place in the final 2 weeks of the intervention. The classroom based support and facilitation that the students had benefited from, for the previous 7 weeks was withdrawn in the final two weeks for the purpose of gaining some understanding of whether students could transfer any of the learning that had occurred in the previous weeks without the same high level of support. Taking this into account, the average number of tier-three mathematical terms used per group (with weeks 2 and 7 removed) in the period of high support was 9.9 and in the final weeks without support it was 7.4. Our hypothesis that students should be able to transfer their learning after having received sustained support for the previous 7 weeks appears to be invalid. It is important to consider though the particular area of learning that we are assessing in this context. For each of the weeks before the final 2, the classroom facilitator (the first author of this paper), would introduce the new vocabulary and facilitate an extensive discussion and co-negotiation of these terms with students. Students were being 'pre-loaded' with the tier-three mathematical vocabulary required for the problem they would be discussing in the online environment before they were asked to collaborate. Naturally, they were able to better utilise this vocabulary, having been extensively prepared. As there was no specific mathematical content focus over the period of the intervention, each week a new and different set of vocabulary was required of the students. When the classroom support was taken away, so was the students' opportunity to familiarise themselves and become somewhat comfortable with vocabulary that would be of high utility to them in the online space in that week.

Table 3
*Density of Tier three Vocabulary use throughout Intervention*

| Week | Examples of Tier-Three Vocabulary | Number of Groups Participating in Online Discussion | Average Number of Tier-Three words per (participating) group |
|---|---|---|---|
| Week 1 | 68 | 9 | 7.6 |
| Week 2 | 19 | 6 | 3.2 |
| Week 3 | 93 | 9 | 10.3 |
| Week 4 | 129 | 9 | 14.3 |
| Week 5 | 108 | 10 | 10.8 |
| Week 6 | 64 | 10 | 6.4 |
| Week 7 | 25 | 7 | 3.6 |
| Week 8 | 85 | 10 | 8.5 |
| Week 9 | 57 | 9 | 6.3 |

Our final analysis allowed us some understanding of if there was any significant difference in the growth in density of tier-three mathematical vocabulary use amongst the ability groups. Weeks 2 and 7 were removed from calculations.

Again, we do not believe that any the three groups showed clear progression in density of use of tier-three mathematical vocabulary over the period. However, some observations are possible. Firstly, all three groups on average used fewer tier-three mathematical words without classroom support than with support. The ‘above level’ group used 3.6 (per student, per problem) with support and 3.0 without. The ‘at level’ students used 1.6 with support and 1.2 without support and the ‘below level’ students used 1.5 with support and 1.1 without support. It appears that the ‘above level’ students made the greatest gains when provided support and equally their rate of use of these mathematical terms decreased the most of all three groups (whilst still using a greater number of these words than the remaining groups) when support was removed. The average density of tier-three vocabulary use between the ‘at level’ and ‘below level’ students appears very similar both with and without support (in fact the change of 0.4 that was evident without support was identical). This however, must be considered alongside the marked difference in density of tier-three mathematical vocabulary detected between ‘at level’ boys and girls, which we have attributed partially to the high level of LBOTE students in the boys group. Implications include the importance of deliberately teaching mathematical vocabulary and providing opportunities for students to see the value of its use.

## Implications

These observations lead to a number of implications for teaching and further research. We hypothesise that if an intervention was replicated over the same period where a single mathematical content area remained the focus, a theorised growth in the density of student tier-three mathematical vocabulary may occur. We also believe that whilst no clear evidence of growth in student use of tier-three mathematical vocabulary is present, other areas of learning may have made clearer growth and student learning may have transferred from the period in which they received great support to the period of support being removed. These areas include the mathematical proficiencies of problem solving and reasoning, critical thinking and the level to which students engage in genuinely collaborative learning. Applying a more fine-grained approach to the coding and analysis of the talk-types, whereby each individual student utterance in the online space becomes the unit of analysis may prove to help investigate these matters.**Error! Reference source not found.**

The data indicate that students will use tier-three mathematical vocabulary more regularly when engaged in exploratory talk than when engaged in cumulative talk. We have also shown that cumulative talk is likely to be the dominant talk type, given the conditions described. We suggest that it may be beneficial to specifically encourage the engagement of students in exploratory talk in order to prompt them to more regularly experiment with newly acquired vocabulary. Explicitly teaching students about the three talk types and discussing their various attributes and characteristics, including why exploratory talk might be the most productive talk type, may promote this. Such teaching would include an explanation of the importance of building a repertoire of technical mathematical vocabulary. It is envisaged that this may result in groups 'self-regulating' their discussion and being aware of when talk had become less productive.

Additionally, data in this study suggests that a relationship exists between student levels of procedural mathematical achievement (as classified by their teacher) and the density of tier-three mathematical vocabulary use. Our data shows, that students classified, as 'below level' less regularly attempted the use of this type of vocabulary than their peers classified as 'above level'. Furthermore, data suggests that LBOTE students are less likely to attempt this high level vocabulary. Further research would be required to test the hypothesis that a targeted approach to the teaching of tier-three mathematical vocabulary may lead to improved results in procedural assessments of mathematical ability.

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