

Using Concept Cartoons and Argumentative Writing Frames in Mathematical Word Problem Solving

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Abstract

The value of introducing concept cartoons and argumentative writing frames in South African schools within the current curriculum to promote discussion and argumentation is reported in this article. The concept cartoons used in the study reported here were not meant to be humorous in the classroom but were designed to provoke discussion and stimulate mathematical thinking. In traditional mathematics textbooks, students are required to make meaning out of word problems through symbolically described situations, whereas, through cartoons, students are presented with intelligent space to symbolic descriptions out of meaningful situations. The writing frames consisted of skeleton outlines that helped learners use generic structures and language features of recount, report, procedure, explanation, exposition and argumentation. It is against this background that the study discussed in this article used a phenomenographic approach to probe how students experience understanding and constructing of new knowledge when they solve mathematical word problems. Thus, the goal of this phenomenographic study was to allow students to be aware of contradictions in their own reasoning and become more open to alternative ideas as they reflect on their views and understandings of the real world experiences when they engage in word problem solving. Data was gathered through field notes and students' written work over a period of six weeks. The findings demonstrated that writing frames not only served a purpose of stimulating mathematical discussion and thinking in the classroom, but also supported students' abilities to write appropriately for a particular task. Furthermore, writing frames improved students' level or quality of arguments when they engaged in word problem solving in the classroom.

Keywords: language; problem-solving; multilingual classrooms; sense-making; discussion technique

1. Introduction

In mathematics education studies language has been conceived and examined in a number of ways including the nature of mathematical talk or discussion and argumentation in the classroom. In fact, the discourse practices entailed in the learning of mathematics, and the challenges and opportunities within linguistically and culturally diverse mathematics classrooms. Mathematics teachers are faced with loads of pedagogical challenges that should be employed for a quality teaching and learning mathematics to take place. Mathematics classrooms are characterised by traditional and machedanical way of teaching mathematics that reflects teacher dominance during mathematics talk and discussion. There are few instances where learners are encouraged to construct their own knowledge and learning through mathematical talk and argumentation techniques. In other words, learners are seldomly provided with an intelligent space to communicate and argue about what they learn, and as a consequence, they do not participate in a negotiation of meaning in what they are taught. It is against this background that the study reported in this article allows students to be aware of contradictions in their own reasoning and become more open to alternative ideas as they reflect on their views and understandings of the real world experiences when they engage in word problem solving.

2. Literature review

This section looks at discussion and dialogue as a teaching technique in mathematics classrooms, a framework for categorizing the types of instruments used to assess learning style, as well as prior researches on learning style. Furthermore, it describes literature related to studies in argumentation and talk in general. Different perspectives on classroom interactional pedagogy and discursive psychology are outlined.

2.1 Argumentation and discussion in mathematics classrooms

There Argumentation in classroom contexts encompasses a process where learners make a claim, provide suitable evidence to justify it, and defend the claim logically until a meaningful decision has been reached (Webb, Williams & Meiring, 2008). The use of discussion as a tool to increase reasoning has gained emphasis in classrooms worldwide, consistent with earlier reports (Yore, Bisanz & Hand, 2003). Discussion, however, requires scaffolding and structure in order to support learning (Norris & Phillips, 2003).

Wood (2002) found variation in students' ways of seeing and reasoning, and these were assigned in the first place to the particular differences established in classrooms early in the year pertaining *when* and *how to contribute* to mathematical discussions and *what to do as a listener*, consistent with findings reported by a number of other researchers (e.g., Dekker & Elshout-Mohr, 2004; Ding, Li, Piccolo & Kulm, 2007; Gillies & Boyle, 2006). Moreover, participation obligations put boundaries around the opportunities for students to share their ideas and to engage in mathematical practices (Ding et al., 2007; Fuchs et al., 1997).

2.1.1 Toulmin model and questions of context

Factors Toulmin's (1958) outlines the double nature of his model for argumentation. On one hand, Toulmin develops a field in variant model applicable to most fields of argument (such as law, mathematics, science, ethics, and "everyday" topics). It contains six interrelated elements:

- a *claim* or the conclusion to be argued for (p. 96);
- *data* or "the facts we appeal to as a foundation for the claim" (p. 97);
- a *warrant* or a "hypothetical" statement that bridges the data and claim and "authorise[s]" the claim drawn from the data (p. 98);
- *qualifier(s)* or a word such as "necessarily," "probably," and "presumably" that indicates how strong a warrant entitles the claim to be (p. 100-101);
- *rebuttal(s)* or the "circumstances in which the general authority of the warrant would have to be set aside" (p. 101); and
- *backing* or field dependent statements that support the warrant linking the data and claim (p. 103-107).

Textbook writers such as McMeniman (1999) have offered discourse community as a replacement for field. However, Harris (1997) has criticized the term as a naive phrase, one that emphasizes constructs that people share, but minimizes the serious conflicts that are also present in human interactions. Porter (1992) likewise has argued that a discourse community is only very temporary, best witnessed by its forums (such as publications) in which participants have left traces of their former interactions.

Goodwin and Duranti (1992) perhaps summarize the problem best when they suggest that a single, precise, technical definition of context may not be practicable. Drawing on Ochs' (1979) work, they list several broad categories of contextual attributes, each with a list of possible components:

- setting, or the social and spatial framework within which encounters are situated;
- behavioural environment, such as body language;
- language as context, in which talk itself both invokes context and provides context for other talk; and
- extra-situational context, such as background knowledge and discursive rules.

2.1.2 Toulminian studies

Much research on Toulminian models favours his stable definitions of context over accounting for the participants' understandings of the contexts they co-construct. Several theorists (e.g., Crammond, 1997, 1998; Gasper & George, 1997) are primarily interested in developing a better abstract description of argumentation or reasoning, and so they avoid questions of context for questions of representation. They may offer different, specific examples of arguments, but their applications of Toulminian models are generally from a single viewpoint - their own (Naylor, Downing, & Keogh, 2001).

In addition, researchers (e.g., Bugallo-Rodriguez, & Duschl, 1997; Carlsen & Hall, 1997; Chinn & Anderson, 1998) often adopt the model as a static lens for examining arguments in conversations and written texts. Even though they may alter Toulmin's original model for their analyses, they tend to construe these adaptations as stable sets of criteria for coding argumentative utterances.

Most Toulminian studies do not address several key issues which are important for teachers using Toulminian models: how interpretations of the model are dynamic; how students' changing constructions of their contexts define for them what momentarily counts as, for example, a claim; and how these understandings affect their applications of Toulminian terms to their writing. Specialised, limited use of Toulminian models are found in studies (Connor, 1990; Connor & Lauer, 1988; Thornburg, 1991) that have been primarily quantitative and evaluative.

Issues of interest to mathematics educators, such as, knowing, can be examined from the perspective of participants in interaction, rather than as underlying cognitive processes which can be used to explain what people do and say (Edwards, 1997). As Edwards and Potter (1992) acknowledge, this is not to say that people explicitly talk about these things. As Sacks showed, these patterns of interaction arise through the social actions of the participants; actions which bring about the on-going organisation of their talk (see Sacks, 1987). For discursive psychology, the social action through which interaction is organised takes precedence over other aspects of interaction, so that the psychological structures and functions of language became shaped by language's primary social functions (Edwards, 1997).

Edwards and Potter (1992) suggest that such actions might include describing and reporting interesting events, making plans and arrangements, coordinating actions, accounting for errors and absences, accusing, excusing and blaming and refusing invitations. These researchers argue that in mathematics classrooms, such actions might also include describing, explaining, justifying, conjecturing, refuting or having an idea.

Talk is about more than its surface content. Every utterance, for example, also constructs the identity and reflects the interests of the speaker, who may present themselves as, loud or polite, knowledgeable or uncertain, biased or neutral. Each utterance, therefore, reflects the partiality or interest of the speaker (Antaki, 1994). Amongst empirical studies of foreign language attainment, a focus on recycling in local classroom communities can be found in the work of Rampton (1999) who indicated how foreign language teaching is recycled in peer group interactions and participation among adolescents as substantial resources in performance-based identity work. Rampton (2002) points out the role of recurrent routines or rituals in classroom life. Researchers (e.g. Kanagy, 1999; Lunsford, 2002) agree that daily classroom routines provide frameworks for young learners' participation in classroom conversations that go beyond their present level of linguistic competence.

2.2 *Dialogue and discourse practices*

Factors A prominent body of empirical and theoretical findings demonstrates the good outcomes of participating in mathematical dialogue in the classroom (e.g., Fraivillig, Murphy, & Fuson, 1999; Goos, 2004; Kazemi & Franke, 2004; Lampert & Blunk, 1998; Mercer, 2000; Sfard & Kieran, 2001). What these researchers have demonstrated is that effective and quality instructional practices demand students' mathematical talk.

Quality teaching, then, is a joint enterprise, founded on material, systems, human and emotional support, as well as on the collaborative efforts of teachers to make a difference for all learners (Coburn, 2005). In making a difference through classroom discourse, teachers shift students' cognitive attention toward making sense of their mathematical experiences, rather than limiting their focus to procedural rules. According to Yackel and Cobb (1996), students become less engaged in solutions to problems than in the reasoning and thinking that lead to those solutions. Through the patterns of interaction and discourse created in the classroom students develop a mathematical disposition—*ascribing meaningfulness to one another's attempts to make sense of the world. Learning about other ways to think about ideas, to reflect, and to clarify and modify thinking is fundamental to moving learning forward?* Carpenter, Franke, and Levi (2003) maintain that the very nature of mathematics presupposes that students cannot learn mathematics with understanding without engaging in discussion and argumentation. More talk in classrooms does not necessarily enhance student understanding. Better understanding is dependent on particular pedagogical approaches, purposefully focused on developing a discourse culture that elicits clarification and produces consensus within the classroom community.

A variety of situations might arise in which the outcome is not fully realized. For example, a number of studies have reported that some students, more than others, appear to thrive in whole-class discussions. In their respective research, Baxter, Woodward, and Olson (2001) and Ball (1993) found that highly articulate students tend to dominate classroom discussions. Typically, low academic achievers remain passive; when they do participate visibly, their contributions are comparatively weaker, and their ideas sometimes muddled. Nevertheless, pedagogical practices that create opportunities for students to explain their thinking and to engage fully in dialogue have been reported in research undertaken by Steinberg, Empson and Carpenter (2004). In a study from their Cognitively Guided Instruction Project, classroom discussion was central to a sustained change in students' conceptual understanding.

Honouring students' contributions is an inclusive pedagogical strategy. Yackel and Cobb (1996) found that

classroom teachers who facilitate student participation, elicit student contributions and invite students to listen to one another, respect one another and themselves, accept different viewpoints, and engage in an exchange of thinking and perspectives exemplify the hallmarks of sound pedagogical practice.

Teaching for inclusion ensures that participation in classroom discussion is safe for all students. Lubienski (2002), as teacher-researcher, focused on the inclusive aspects of classroom dialogue when she compared the learning experiences of students of diverse socioeconomic status (SES) in a seventh-grade classroom. She reported that higher SES students believed that the patterns of interaction and discourse established in the classroom helped them learn other ways of thinking about ideas.

The discussions helped them reflect, clarify, and modify their own thinking and construct convincing arguments. However, in Lubienski's study, the lower SES students were reluctant to contribute, stating that the wide range of ideas contributed to the discussions confused their efforts to produce correct answers. Their difficulty in distinguishing between mathematically appropriate solutions and nonsensical solutions influenced their decisions to give up trying. Pedagogy, in Lubienski's analysis, tended to privilege the ways of being and doing of high-SES students. In a similar way, Jones' (1991) study showed that the discursive skills and systems knowledge that are characteristic of high-SES families align them favourably with the pedagogy that is operationalised within school settings.

2.3 Concept cartoons

The A cartoon is a graphical media that can either be in the form of a single picture or a series of pictures as in the form of a comic strip, captioned or non-captioned, that are printed in magazines, newspapers and more currently in books (Wai Bing & Hong, 2003). Cartoons are visual tools which combine exaggeratedly drawn characters with dialogues related to everyday real-life contexts in a humorous and satirical mode (Keogh & Naylor, 2000; Stephenson & Warwick, 2002; Coll, 2005). Numerous methods are being developed in order to promote the construction of knowledge. One of these methods is concept cartoons (Keogh & Naylor, 1999) and numerous studies in literature relate to the use of cartoons in science and mathematics education (Uğurel & Morali, 2006; Kabapınar, 2005). In this study, mathematical concept cartoons were used to stimulate discussion and argumentation that is high in quality when students solve mathematical problems in the classrooms.

Webb et al. (2008) suggested that there is value of introducing concept cartoons and argumentation writing frames in South African schools within the current curriculum. In regular textbooks, students are required to make meaning out of word problems through symbolically described situations, whereas, through cartoons, researchers (Lesh & Doerr, 2003) want learners to make symbolic descriptions out of meaningful situations. The concept cartoons, which are cartoon-style drawings showing different characters arguing about everyday situations, are not meant to be humorous, but are designed to provoke discussion and stimulate thinking (Webb et al., 2008).

According to Webb (2010), cartoons which consist of simple drawings and minimal text can empower the participants in the group discussion such that they do not have to 'own' the misconceptions displayed. She points out that cartoons represent visual situations in familiar contexts and use everyday language so that learner participation is maximized, particularly for those who are English language learners.

As noted earlier, Webb et al. (2008) conducted a study in primary classrooms of the Eastern Cape province of South Africa and reported positive improvement in the learners' use of exploratory talk when concept cartoons were used as a trigger. However, they caution practitioners that the process takes time and that teachers must have a sound knowledge of what constitutes genuine discussion, argumentation and exploratory talk before they can carry out these strategies in the classroom.

The teaching approach of using concept cartoons, as suggested by Keogh and Naylor (1999), has a direct and immediate impact in the classroom. They seemed to promote a purposeful approach to practical work – a hands-on and minds-on approach. Wai Bing and Hong (2003) point out that concept cartoons are intended as a starting point to stimulate discussion and for eliciting ideas from the learners. They claim that to illustrate this point, students can be provided with an illustration and questions that require them to consider their thoughts, feeling and form opinions about the situation portrayed. The questions asked consist of: *What do you see?* (facts); *What do you think?* (opinions); and *What do you feel?* (feelings). This makes it an extremely valuable exercise to use with groups because it encourages open discussion (Wai Bing & Hong, 2003).

The cartoons used in this study fit the descriptions discussed in this section, and were merely used to stimulate discussion in the classroom during word problem-solving. As such, the cartoons chosen were rich in mathematics content and discourse, which afforded learners with the opportunity to use their everyday-life knowledge to solve word

problems that are taken from everyday life examples presented in an argumentative manner.

3. Research methodology

The study is framed by a phenomenographic study in education research, which proposes that the ultimate goal of teachers is to assist their students in developing conceptions that are consistent with those of experts in different areas, such as mathematics. However, it may not be a case that students may have multiple (or different) and alternative conceptions for a phenomenon which may not reflect those of experts in the field. Hence, Marton's (1986) claims that "a careful account of the different ways that people think about a phenomena may help uncover conditions that ease the transition from one-way of thinking to a qualitative better view of reality" (p. 33).

3.1 Participants

40 Grade 9 learners from a multilingual mathematics classroom participated in the study reported in this article over a period of six weeks. The average age was 15.8 years ranging from 15 to 17 years old. The school is located within a semi-urban area and serves learners from middle class families.

3.2 Instrument

For the purposes of this study, a word problem test, concept cartoons and argumentative writing frames were used to collect data. The test was used to have an insight into learners' ways of solving word problems and gauge their problem solving abilities against the use of writing frames and concept cartoons. Concept cartoons were used to trigger discussion during word problem solving processes. Writing frames assisted in and supported students' writing abilities and guide their mathematical thinking when arguing about word problem solving. Data collection and analysis in this study proceeded together throughout the period of study.

3.3 Procedure

The purpose of discussion was to help learners engage in talk through sharing, seeking and constructing their own knowledge when solving mathematical word problems. The discussions took the form of dialogue and talk (formal and informal) in both English and the learners' home language. The researcher used concept cartoons as a stimulus or trigger, to initiate and practise the skills required for the development of talk that is high in quality and sound in quantity. In promoting argumentation, learners are expected to disagree and/or agree with one another, providing verbal and written evidence to back up their claims. The introduction of argumentation writing frames assisted learners' mathematical writing and level or quality of arguments between teacher and learners, and between learners themselves, when they engage in problem-solving of word problems.

3.4 Design type

In this study, the introducing discussion and argumentative writing frames on problem-solving abilities of grade 9 second language learners were explored. The study focused on writing to learn and solve word problems, discussion and argumentation. Concept cartoons in mathematics were used as triggers to stimulate discussion when they solve problems. The purpose of introducing discussion was to help learners seek, share and construct knowledge when engaging in word problem-solving. In promoting discussion, learners were expected to disagree with one another, engage critically on issues and build positively on what others have said.

The study then focused on writing to learn and solve word problems, and introducing argumentation in mathematics multilingual classrooms. In order to achieve this, writing frames were used to help support learners' ability to write appropriately for a particular task, guide their mathematical thinking and argue to learn mathematical word problems. These writing frames consisted of skeleton outlines that helped learners use the generic structures and language features of recount, report, procedure, explanation, exposition and argumentation.

4. Findings and discussion

4.1 Discussion and argumentation in the classroom

For learners, discussion, debate and critique are all learned strategies. Sfard and Kieran (2001) emphasise that "the art of communicating has to be taught" (p. 70). As such, experimental learners were afforded appropriate time and space for exploring ideas and making connections (Stein, Grover, & Henningsen, 1996) between classroom mathematics and out-of-school mathematical knowledge and a sustained press for explanation, meaning, and understanding (Fraivillig et al., 1999), during the use of concept cartoons and writing frames. The overall results of the study support Carpenter et al. (2003) notion that the very nature of mathematics presupposes that students cannot learn mathematics with understanding without engaging in discussion and argumentation. It appears that in the experimental classrooms observed after the intervention, mathematical discussions and thinking were greatly enhanced by the pedagogical practices that allowed learners to engage in argumentation (Empson, 2003; Goos, 2004). In doing so, learners were not only in a position to discuss classroom activities and solve word problems, but they were involved in taking and defending a particular position against the claims of other learners (O'Connor & Michaels, 1996). They pointed out that this teaching process depends on the skilful orchestration of classroom discussion by the teacher. In particular, teachers in the experimental group showed signs of improvement over time, and had begun to understand how to promote discussion in mathematics multilingual classrooms, via the use of the concept cartoon as a stimulus. However, as Ball (1993) pointed out, highly articulate students displayed a tendency to dominate classroom discussions and, as such, the management of classroom discussion appeared to be vital if one is to promote conceptual understanding via this technique (Steinberg, Empson, & Carpenter, 2004).

Writing frames (or sentence starters) assisted learners to present their responses and findings in a structured and written form. Data also revealed that instruction that addressed aspects of learners' writing (such as writing frames) seemed also to address learners' understanding of word problem-solving. Learners' writing appeared to be beneficial to mathematics teachers as well (Drake & Amspaugh, 1994). In fact, written explanations of the learners' problem-solving process allow the teacher to understand and assess the learner's thinking and comprehension (Freitag, 2005). As such, the writing frames provided by the study served as an effective tool for word problem-solving and seemed to promote and improve writing in mathematics multilingual classrooms.

Before the use of concept cartoons and writing frames, the pattern of utterances and/or mathematical discourse in experimental classrooms imitated Mercer's (1995) Initiation-Response-Feedback (IRF) process, also known as triadic dialogue (Lemke, 1990). However, it was also evident that the quality of discussions and arguments in some of the experimental classrooms improved over time. Data generated from the observations during the use of concept cartoons and writing frames showed that teachers' attempts at initiating discussion, in the form of a question or task which predicts the learner response, were successful in most cases. In actual fact, a fair number of learner responses produced the information that made it possible for the teacher, in turn, to evaluate the response in terms of its closeness to the expected answer (Mehan, 1985; Mercer, 1995).

What was lacking in these classrooms was the ability for the teacher to realise more precise understanding of ways in which to follow up opportunities specifically for the learning of mathematical language and the language used in mathematics. This particular observation mirrors what Krashen (1982) and Long (1983) reported in their studies. These researchers observed that even though classroom discussions were used in their studies, the effectiveness of those classroom discussions was limited because it was the teacher who initiated what to be discussed, and decided who provides a response, after which the teacher either commends or condemns. In so doing, the teacher resolves when to put an end to the discussion, which was also evident in teachers' responses to the interview protocols used in the study.

4.2 Classroom interactions

The teaching approaches and strategies promoted discussion and argumentation in the classroom. The classroom atmosphere provided opportunities for learners to engage in dialogue, where they could agree to disagree in order to reach a common understanding. Forms of interactions in this classroom followed a narration and two-way question and answer approaches characterised by inquiry learning. The classroom was embedded with mathematical and social discourses that reflected both the culture of the learners' backgrounds and that of their classroom. The teacher's actions in the classroom showed a domain of discourse closely associated with learners' cultures having the same assumptions, values, and linguistic domain. The teacher's perspective on bilingual mathematics learners encouraged acquisition of

vocabulary, and did not reflect high levels of construction of knowledge and meaning. There were instances where interactions in this classroom took the form of teacher initiated discussions, typified by teachers' frequent use of inauthentic initiating question turns. The follow-up turns by either the teacher or learners somewhat happened during classroom discourse but were of low quality. The interactions that took place within this classroom were found to have highly ritualised components that are not explicitly taught, but are embedded within the classroom culture. Although the teacher occupied the largest percentage of talking time in her lesson, what she did was to enable the learners to engage in dialogue. This dialogue took place between the teacher and certain individual learners. Learners were not confident that they could argue a case and challenge the teachers. The teacher issued a lot of instructions about what the learners were to do and modelled what was to be done. She struggled to take firm comparison of the interactions during her lesson. The unsuccessful interactions in this classroom indicated scant understanding and agreement of the rules of engagement between the teacher and learners with a view to active and positive contributions to classroom discussions.

5. Conclusion

The introduction of argumentation writing frames appeared to have a role in assisting learners' mathematical writing skills and a level or quality of arguments between teacher and learners, and between learners themselves, when they engage in problem-solving of word problems. Writing frames (or sentence starters) seemed to assist learners to present their responses and findings in a structured and written form. Data also revealed that instruction that addressed aspects of learners' writing (such as writing frames) seemed also to address learners' understanding of word problem-solving. It is therefore recommended that the introduction of argumentative writing frames and discussion as a technique be integrated within the pedagogical strategies in the teaching and learning of word problems in South African classroom settings in order to enhance quality teaching of problem solving.

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