The Mathematics Talk of a Secondary School Teacher of Mathematics and Physics

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Studies have been conducted in the broad area of language in mathematics teaching, but the research in this paper investigated the language used by a teacher in her physics and mathematics courses. Several commonalities and differences of this teacher's talk when teaching the two subjects were identified and are presented here. The style of her talk varied from the casual to the formal depending on which course she was teaching.

Teaching and learning mathematics relies as much on the language of the speakers and their style as it does the mathematical skill of the instructor. Basson (2002) and others (e.g., Kinney, 1990) have claimed that mathematics and science are interrelated fields of thought. Not only do students and teachers of mathematics need to talk in class about mathematics, but also students and teachers of science need to talk about mathematics. Furthermore, the teaching of mathematics and science could benefit from being integrated (Stuessy, 2003).

Before one can embark on teaching these two distinct (albeit interrelated) fields together as integrated courses of study, more must be known about the kinds and styles of talk that occur within mathematics and physics teaching. The study presented here investigated the language genres of one teacher as she taught a beginning algebra course and a beginning physics course.

A brief background and literature review about language genres and discourse in the teaching of mathematics will be presented, followed by a rationale for the quasi-ethnographic methodology used in the study. The results and conclusions of the study are then presented through a critical discussion.

Background and Review of Literature

Language and discourse have been the topic of study within mathematics education for a number of years (Ellerton & Clarkson, 1996). It has been the case, however, that study and research reports labelled under a "language" heading have been diverse. The aspect of language and discourse that has been examined here involves the conceptual notion of language genre (Wallace, 2004; Wallace & Ellerton, 2004). Language can be seen as a means of communicating and can be used to support the development of understanding and learning. Based on this notion and the ideas of Sfard (2000, 2001), Halliday (1993) and Lemke (1989, 1990) the conceptual notion of language genre has been developed and explored.

A teacher's tools necessarily include talking. But is all talk the same? Teachers and students learn to interact with one another by learning to communicate. There tends to be a certain style and form to this communication; one that develops over time (Bickmore-Brand, 1997; Ellerton & Clements, 1991; Hasan, 1996b; Lemke, 1989). Learning to "talk mathematics" or "talk physics" involves, therefore, not only the linguistic register, but also these characteristic ways of talking within the culture of the discipline-based classroom. Therefore, a language genre is a form and style of communicating that is negotiated and

developed within a particular discourse community. These ways of communicating can be via written, verbal, and non-verbal forms.

Communication, in general, and classroom communication, in particular, includes several modes, such as verbal utterances, written texts, and physical gestures in social contexts (Roth & Lawless, 2002). Any type or mode of communication can be initiated by teachers or students and if these become systematised, either consciously or subconsciously, they can be incorporated into language genre.

Wittgenstein (2001 [1945, 1949]) claimed that in any discourse, mathematical or otherwise, language games or rules exist. It is the case that individuals communicate, and thus participate in discourse without having the rules explicitly stated. It is in this sense that these rules take on a normative quality (Sfard, 2000).

The notion of language genre was developed from several fields of study, notably mathematics education, science education, and linguistics. Lemke (1982; 1989), for example, has conceptualised physics as a way of talking science in the sense that it personalises the physics, and helps to avoid regarding physics as an independent and external body of knowledge. Students' participation in classroom discourse is affected by their social and cultural contexts and by the function of the discourse. Coming to "talk mathematics" is shaped by the function or purpose of the discourse and by the social and cultural contexts and situations in which it is developed. Words do not innately hold meaning; rather, meaning is derived from the social interaction of talking.

Bakhtin's (1986 [1952-1953]) essay describing speech genre has been influential for much of the genre literature (Halliday & Martin, 1993; Hasan, 1996b; Hicks, 1995). Hasan (among others) has often quoted Bakhtin's definition of speech genre. It was instrumental in the development of language genre:

> Language is realized in the form of individual concrete utterances (oral and written) by participants in the various areas of human activity. These utterances reflect the specific conditions and goals of each such area not only through their content (thematic) and linguistic style, that is, the selection of lexical, phraseological, and grammatical resources of the language, but above all through their compositional structure (Hasan, 1996a, pp. 167-168).

Content, style, and compositional structure are defining characteristics of Bakhtin's speech genre. Hasan (1996b) continued to explain Bakthin's notion: "Each separate utterance is individual, of course, but each sphere in which language is used develops its own relatively stable types of these utterances. These we may call speech genres" (pp. 167-168). Such genre embrace "the author's conception of the audience and his own community" and are arbitrated by the customs of the genre itself (Hasan, 1996a, p. 52, emphasis original). Language genres are developed through socially negotiated situations and become relatively stable for a given cultural context. In particular, language genres have particular styles, content, and grammatical composition while maintaining patterns of interaction between the discourse participants.

Research Design and Methodology

The methodology of this study was both qualitative and ethnographic. Qualitative data were collected in order to establish a basis for interpreting the language patterns in the teacher's discourse and the resulting language genres of the teacher. The inductive and interpretive nature of qualitative studies requires that the researcher remain faithful to the participants' views. (Maykut & Morehouse, 1994). To accomplish this task, the researcher was in daily contact with the teacher before and after each classroom observation.

The study was considered ethnographic because it was an in-depth examination concerned with the social and cultural aspects of its participants in their natural environment (Erickson, 1986; Pirie, 1998). For the purpose of this study, the environment was defined by two secondary school classrooms, and the participants were the students and their teacher. The focus of this paper is on the commonalities and difference in the teacher's talk in the mathematics classroom and her talk in the physics classroom.

One teacher volunteered to participate in the semester-long research project. She was chosen because of her knowledge of and teaching in both mathematics and physics. She was observed on a daily basis in both her algebra and physics classes. The teacher prepared and delivered all lectures and lessons. Outside tutorials were also conducted by the teacher, but were not included as part of the study.

The teacher had been teaching secondary school mathematics and physics for 7.5 years. Her school is located in the heart of an urban area in the Midwestern USA. The demographics of the school, however, show relatively little racial and ethnic diversity. In the 2003-2004 academic year, the school's enrolment was 1554 students and comprised of African American (3.3%), Asian (0.6%), Caucasian (91.6%), Hispanic (2.4%), Multiracial (1.9%), and Native American (0.3%). The socioeconomic makeup for the students, on the other hand included, included low and middle income households, with over 30% of the student-body qualifying for *subsidised lunches*.

Data consisted of daily observations of classroom activities and lessons, daily briefings (informal interviews) with the teachers, and formal interviews with the teacher and the researcher. Video and audio recordings and written notes were collected for all data sources. Hundreds of hours of video were recorded, digitized and edited into an electronic format, viewed and analysed through several phases.

The analysis of this qualitative data followed a systematic iterative process through the use of guiding themes in several phases as reported by Cobb and Whitenack (1996). Ongoing analysis was conducted in phases throughout the study to help focus future data collection and analysis. The ongoing analysis began with the daily review of field notes, classroom observation protocols, and daily lesson video. Review of field notes and memos, as part of an ethnographic study, were critical to understanding the data (Howard, 1995). Once patterns were identified in the data through the first analysis, the second phase of analysis was started, which focused on providing rich descriptions to these patterns.

Presentation and Discussion of Algebra Talk and Physics Talk

Regardless of the class that she was teaching (algebra or physics), the teacher attended to the meaning of mathematical concepts and processes, but the talk differed in these classes. Differences were noted not only in terminology, but also in style, content, grammatical structure, and participation by the teacher and the students. This leads to the belief that there are subgenres of mathematics talk and physics talk. For this study the language genres found in the algebra class are called algebra talk, while the language genres found in the physics class are referred to as physics talk. Throughout this section the main characteristics of the teacher's algebra talk and the teacher's physics talk are presented and discussed.

The patterns identified in the data during the iterative analysis process highlighted several features of the teacher's talk. These features are represented in Tables 1 and 2 and show the characteristics common in the teacher's talk in both physics and algebra classes. In particular, Table 1 shows the similarities in the teacher's talk in the algebra classroom

and her talk in the physics classroom. Entries in Table 2, presented later in the paper, show that there were differences between the teacher's algebra talk and physics talk. The presentation and discussion of the data will be organized around these two summaries.

Commonalities

The content of the teacher's physics talk relied on physics concepts and mathematical concepts and processes, which in most cases were also components of mathematics talk. The teacher's physics talk, therefore, shared several characteristics with her algebra talk, most notably when she was performing calculations. In particular, the shared characteristics were the use of long and interconnected utterances, the use of linguistic links between curricular content, the use of context as a motivator for the curricular content, the use of informal language for mathematical manipulations, and the use of an entertaining presentation style.

Table 1
Teacher Talk Summary: Commonalities

Characteristics
Long interconnected utterances
Linguistic links between previous and new content
Context as a motivator for the study of physics and algebra
Informal language for mathematical manipulations
Organized nature of the discipline
Entertaining presentation style

The deliberately long interconnected utterances occurred daily in both the algebra and physics classes. For example, the teacher made this utterance in her algebra course:

> Teacher: And what we were doing with lines, last chapter, was taking a rule, like y equals three x plus one, and trying to match up x coordinates with y coordinates based on that rule. And so what I want to do is work through this problem like we would have on the test or on any of the homework that we were doing in chapter five. So when you have directions like graph this guy and they give you a rule, they give you a function like this what we did was pick some x values and I always recommended picking nice easy ones, like negative one, zero, positive one, but it doesn't matter which x values you pick. The only reason that I recommend picking small ones is that we are going to have to graph them and so it would be really miserable to have to graph an x coordinate of twenty-five. so we will stay close to the origin. So if I use negative one for the x value in this rule, what y value will it be? … negative two, if I put in a negative one I get a negative three [circles the 3x term with her hand as she says this] from this term, add one I get negative two

These utterances were long, due, in part, to the sense-making that the teacher employed by noting certain connections, and used everyday and informal contexts.

The teacher wanted to ensure that the lessons were organized to go beyond basic knowledge of terms. The goal, therefore, was to have students participate in lessons where the content was presented within the larger curricular framework of the discipline. In particular, the teacher, in this study, situated the day's lesson within what would be taught in a few days time and what had already been taught.

Context, or related everyday and informal situations, set the stage for many of the lessons, which was evident in the talk. The teacher's talk with contextual situations often relied on metaphors to produce meaning and to make connections. Highlighting the

curricular framework, the use of connections between disciplines (such as mathematics and science), and context also contributed to the length and interconnectedness of the teacher's utterances. For example, a common context for the vectors is "tug-of-war,"

> Teacher: Now, for any given object there are many, many forces acting on it in most cases, so in most instances that we are going to take a look at there are going to be multiple forces going on here, all the forces acting together, so think in terms of a tug of war. So if you have one end of the rope, your friend has the other end of the rope and you pull on it whoever is pulling the hardest is going to win.

Informal language was a critical feature of the teacher's talk in both algebra and physics. In the first excerpt, the teacher used the informal description "tip-top" to describe the vertex of the parabola. In the second excerpt, the teacher has introduced the mathematical ideas of slope and linear equations.

> Teacher (Physics): The ones we were working with last time started at this tip-top and we only did half the parabola, because we were starting out with zero vertical velocity. Today we are going to have the upward part of it as well, so we are going to be looking at that.

> Teacher (Algebra): So the two characteristics of a line that make it unique, are slope and a point. If someone gives me how steep a line is and a point, I can narrow it down exactly and know exactly which line they are talking about.

She also used informal verbs like "get rid of" when performing mathematical operations.

Mrs. Arc's pattern of talk indicated that teaching mathematics and physics should make use of the possible cases or outcomes of a particular topic. Therefore, the talk was organised around the mathematical and scientific content and the ways in which the teacher saw the interconnections within and between the two subjects. This was intended to reinforce to students that mathematics and science are detailed and interconnected (at least within algebra and within physics) and that the interconnections are important in understanding the larger picture.

The teacher talk tried to be entertaining and the material was presented in a lively manner in both algebra and physics. The teacher's tone of voice was generally jovial and warm. The nature of the talk suggested to the students that both mathematics and physics were useful and interesting, and that they, therefore, deserved the students' close attention during lessons and homework.

Differences

The primary differences between the teacher's algebra talk and her physics talk are shown in Table 2. These differences were evidence of the differing instructional design of the courses. The purpose of the utterances in both classes was either to convey meaning or to generate meaning. Other differences were apparent in the ways informal language and gestures were used by the teacher.

Even though both teacher algebra talk and teacher physics talk generally shared the attribute of informal language, talk in both algebra and physics manifested this attribute in different ways. The algebra talk often incorporated informal language to help students to make sense of the *terminology*. This was accomplished through analysing root words and literal meanings. In contrast, physics talk often used informal language or non-technical language to make sense of *concepts*. In this way physics talk was more likely to generate meaning from a situation familiar to the students and relevant to physics, whereas algebra talk conveyed meaning from natural language instruction. Therefore, the teacher's

mathematics talk was focused on the procedures more than on any underlying conceptual understanding. Algebra talk presented mathematics; physics talk developed ideas.

Table 2
Teacher Talk Summary: Differences

Characteristics	
Physics Talk	Algebra Talk
Generate meaning for scientific phenomena	Convey meaning for procedures and concepts
Questions addressing scientific processes and concepts	Questions focused on procedures
Use of informal language combined with formal definitions	Use of informal language to provide motivation for the meaning of certain terminology
Use of gestures to illustrate talk and focus student attention	Use of gestures to focus attention during talk
Mathematics as calculations	
Mathematics as analytical and interpretive tool	
Use of demonstrations and drawings to help "tell" a story	
Inherent appeal and value of physics	

The extent to which the use of informal language was a help or a hindrance for the students is unclear. Other studies have noted that the use of informal language may change the mathematical meaning of statements by placing the mathematics into a different context (Mitchell, 2001) and that the use of natural language meanings may be a further detriment to formal education (Roth & Duit, 2003). The meanings of natural language may not correspond to the mathematical meanings of terminology or may contradict the mathematical meanings. The influence of natural or informal language on student understanding was not the focus of this study, and the data collected in this study could not be applied to any conclusions about student understanding.

> Teacher "*f* equals *m a*, so any force, is a mass times an acceleration, whether it is friction or a weight, just your general old push or pull any kind of a force can be represented by mass times acceleration, in the case of weight the acceleration just happened to be gravity. So it is perfectly legitimate for me to make that replacement. This frictional force is going to take a mass and accelerate it, so I get my *ma*. Now, a handy thing here, mass and mass over here same side of the equal sign [Written on board: ~~*m*~~*a* = ~~*m*~~*g*], they are both factors. If I divide both sides by mass, they are going to drop out.

Physics talk focused on developing meaning for the concepts through activities and discussions. Physics talk, therefore, relied on actions from physical situations though which students were expected to develop understanding. These actions were accompanied by talk that focused on mathematical calculations and analyses.

Algebra talk, on the other hand, relied on a procedural genre. Marks and Mousley (1990) noted that the recounting of methods as a procedural genre was similar to a narrative genre (i.e., recounting of events). Algebra talk had a procedural and narrative

nature, while physics talk was more descriptive of individual concepts and was more explanatory than was algebra talk. The questions posed by the teacher about the nature of physics not only moved the discourse forward, but the questions also demonstrated the exploratory nature of the teacher's physics talk. It was not unusual, therefore, for the physics students to investigate or explore the problems, which was not the case with the algebra students.

Conclusion

Physics talk as it was exhibited by this one teacher over the course of the semester took on attributes associated with the purpose or goal of the discourse. Therefore, the function of the utterances framed the genre characteristics. For example, teacher talk in the physics class involved the use of grammatical structures that served to present information in varied forms to generate meaning. Moreover, the content of physics and mathematics played key roles in the attributes of the language genres. Mathematics content is seen as more rigid, and this rigidity was, therefore, evident in the talk. Physics, however, is more flexible and active as was evident in physics talk.

Algebra talk, as it was evidenced over the course of the semester, stressed the highly organized nature of mathematics. The teacher's talk assumed several linguistic and other attributes associated with the purpose or goal of the discourse. Talk in the algebra class involved the use of grammatical structures that served to present information in rigid forms. The rigidity was noted in the way that meaning was conveyed and procedural focus.

Physics talk tended to investigate concepts as a means of developing understanding, whereas algebra talk was limited to discussion of procedures. Burton (1988) pointed out that students need to see algebraic language as a means of conveying meaning. Clearly algebra talk in the current study conveyed procedures, but did not convey relational mathematical meaning. In general, physics talk did accomplish the goal of attending to meaning as far as the physics topics were concerned. The case was different for algebra talk in physics classes, which still attended to procedures.

The important implication is the development and presentation of the conceptual notion of language genre. The language genres found in this teacher's classroom present an interesting backdrop for further study. Moreover, through the identification of the language genres of this teacher and the characteristics of her talk, transitions between these language genres have been identified and are being analysed (Bower & Ellerton, 2005).

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