

“Give Me One Reason Why This Is True”:  
A Multimodal Investigation of the Strategies Used by University Teachers  
of Mathematics to Elicit Responses from Students

by

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### **Abstract**

This study aims to broaden the current understanding of undergraduate university mathematics teaching by conducting a multimodal analysis of video-recorded segments of classroom teaching by an experienced professor and a less experienced Teaching Assistant (TA). The study focuses on the participants' use of discursive strategies and multimodal features including gestures, gaze, and facial expressions, as they are used to elicit responses from students and promote participation in the classroom. The analysis is conducted through the qualitative multimodal thematic coding of video-recorded segments, and audio transcripts, and with the quantization of the participants' strategies used to elicit student responses. Findings show that despite variance in the teaching location, educational backgrounds, and levels of experience of the participants, the discursive and multimodal strategies that they used during teaching are remarkably similar; in other words, the participants use the same genre of teaching undergraduate mathematics. Findings also reveal subtle differences between the teaching practices of the experienced professor and less experienced TA. Conclusions present undergraduate mathematics teaching as a complex, multimodal, and wholly interactive genre of teaching.

Keywords: Discourse, Genre, Gesture, Mathematics, Multimodality, Pedagogy

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## Glossary of Terms

<b>Beats:</b> up and down, back and forth flicks of the hand which commonly correspond with rhythm of speech.....	27
<b>Commentary and metacommentary:</b> when performing a chalk talk lecture, mathematics teachers provide a running commentary in which they verbalize everything they write on the board. Metacommentary occurs when they talk <i>about</i> what they write on the board.....	22
<b>Communities of Practice (CoP):</b> Discourse communities formed by people who engage in a process of collective learning in a domain of shared goals, values, and beliefs. The central unit of analysis in the situated leaning perspective.....	19
<b>Deictic gestures:</b> pointing gestures .....	27
<b>Discourse communities:</b> socio-rhetorical networks that form in order to work towards sets of common goals.....	18
<b>Discourse ensemble:</b> gesture and speech employed together by a speaker as partners in a single rhetorical enterprise.....	26
<b>Genre:</b> this study uses a definition provided by Artemeva and Fox (2010, 2011; Fox & Artemeva, 2011) of genre as "constellations" (Campbell & Jamieson, 1979) of overtly recognized rhetorical conventions <i>and</i> tacit and improvisational strategies, triggered by the interaction between an individual's socialization and an organization (Schryer, 2000; Schryer & Spoel, 2005) .....	21
<b>Hedge:</b> a word that conveys imprecision or uncertainty often used to lessen the force of what is said.....	63

<b>Higher-level actions:</b> defined by Norris (2004) as communicative modes “bracketed by openings and closings and made up of a multiplicity of chained lower-level actions” (p.11).....	37
<b>Hold:</b> the shape of the gesture is held briefly.....	26
<b>Iconic gestures:</b> gestures that present images of concrete entities and/or actions.....	27
<b>Interlocutor:</b> an individual involved in a conversation or 'conversation partner' .....	32
<b>Legitimate Peripheral Participation (LPP):</b> an analytical perspective on learning which suggests a novice begins learning at the periphery of an institution by participating in simple tasks at first (which are legitimate in that they are not designed specifically for the novice to learn), but which gradually increase over time in engagement and complexity (Lave & Wenger, 1991) .....	17
<b>Lower-level actions:</b> defined by Norris (2004) as the smallest interactional meaning units.....	37
<b>Metaphoric gestures:</b> gestures that present images of the abstract.....	27
<b>Multimodal text:</b> a text created by the combination of image, sound, gesture, movement and writing or print, communicated through paper, the screen, face to face meetings, or performative space .....	24
<b>Open Hand Prone (OHP) gestures:</b> a family of gestures in which the palm of the open hand faces down or away from the speaker. This family shares the semantic theme of stopping or interrupting a line of action (physical, communicative, or mental) that is in progress. ....	28
<b>Open Hand Prone ‘Vertical Palm’ OHP(VP) gesture:</b> the hand is held with the palm facing vertically away from the speaker. OHP(VP) indicates a wish that either the	

action of the speaker be halted, the interlocutor's action be halted, or what is being done jointly be halted.....	30
<b>Open Hand Prone Horizontal Palm OHP(ZP) gesture:</b> the palm is placed horizontally and faces downwards. OHP(ZP) indicates a desire for an action being done by external circumstances (rather than something the speaker can, or seeks to control) be halted.....	30
<b>Open Hand Supine (OHS) gestures:</b> a family of gestures in which the palm of the open hand faces up. This family of gestures has in common the feature of offering or giving, or showing readiness to receive something, whether a concrete item, or the content of what is being said.....	28
<b>Open Hand Supine with Lateral Movement OHS(PL) gesture:</b> a gesture in which the hands are held facing palm up and with lateral movement away from the speaker's midline or backwards until behind the speaker's vertical median. Almost always executed with both hands PL is used to imply non-intervention.....	32
<b>Open hand Supine Palm Addressed OHS(PA) gesture:</b> a palm up gesture which occurs when gesturing towards something (either a person or object). When used in pointing, the PA gesture is used to 'present' the object to the audience as something to be inspected for some quality the speaker wishes to draw attention to. When directed at an individual, OHS(PA) is often used to acknowledge something said by the interlocutor or indicates what another has said is correct. When used in coordination with a question PA is often used to obtain something specific from the interlocutor .....	32
<b>Open Hand Supine Palm Presentation OHS(PP) gesture:</b> a gesture conducted by extending the supine forearm with palm facing up within the immediate frontal space	

of the speaker and ‘presented’ or ‘displayed’ but not moved as if to indicate something. PP is typically used in coordination with a speaker introducing something he or she is about to say, or during an explanation, comment, or clarification of something the speaker has just said.....	31
<b>Pause:</b> here a pause is considered to be a silence spanning no less than 0.6 seconds.....	48
<b>Pointing gestures:</b> gestures that are linear in nature and often held in position briefly once the body part doing the pointing has reached its furthest extent. Often used to indicate specific objects, locations, or directions.....	28
<b>Pointing with the Index Finger Extended (IFE):</b> pointing with the hand using an extended index finger. IFE is most likely to be used when a speaker singles out an object which is to be attended to as a particular individual object. ....	29
<b>Pointing with the Open Hand (OH):</b> pointing with the hand while all fingers are extended. OH pointing is often used when the object being indicated is not itself the primary focus or topic of the discourse but is related. ....	29
<b>Preparation phase:</b> the beginning of the movement of the hand or hands from the actor's rest position.....	26
<b>Quantitizing:</b> here quantitizing refers to the conversion of qualitative data into numerical codes that can be processed statistically (e.g., Dornyei, 2007).....	40
<b>Questions:</b> sentences addressed to the listener which ask for an expression of fact, opinion, belief etc.....	43
<b>Question, clarification:</b> used to facilitate the instructors’ understanding of student responses either because the initial response was inaudible or because the instructor requires more information from the student .....	45

<b>Question, checking:</b> or 'audience check', a question posed at the audience usually paired with a turn to the audience or 'pan-gaze' and a pause, used for the purpose of monitoring.....	47
<b>Question, self-directed:</b> questions posed by the speaker, not necessarily to an interlocutor, and then immediately responded to by the speaker.....	46
<b>Recovery:</b> the final stage of a gesture when the stroke and any post stroke hold is released and the speaker returns to the rest position.....	26
<b>Rest Position (RP):</b> the position of the speaker when no gesture is being made .....	26
<b>Strategies:</b> the discursive and multimodal practices used by the participants in order to teach mathematics.....	19
<b>Stroke:</b> the 'apex' of the gesture when the shape is manifested with the greatest clarity.....	26
<b>Teacher Persona:</b> the character assumed and enacted by an instructor during teaching (can create a welcoming and inclusive atmosphere or a distanced rational-scientific atmosphere).....	38
<b>Time-stamping:</b> (in transcribing data) the insertion of timed break-points between speaker turns enabling the synchronization of the video clips with the transcripts.....	36
<b>Unit of analysis:</b> identifies the level at which the phenomena of interest occurs (Geisler, 2004). Here the unit of analysis for analyzing gestures is the stroke and hold 'nucleus' of the gestural excursion.....	29
<b>Utterance:</b> defined by Bakhtin (1986) as "a link in the chain of speech communication" (p.91). This study expands this definition by incorporating Kendon's notion of utterance as "any ensemble of action that counts for others as an attempt by an actor to 'give' information of some sort" (2010, p. 7) .....	30

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### **List of Symbols**

Underline (      ) - represents the Open Hand Prone (Horizontal Palm) Gesture as it coincides with the spoken discourse

Dash (//) - represents 'beats' in the gesture

Bolding (bold) - represents a hold in the gesture

## **Chapter 1: Introduction**

Investigation into university pedagogy is becoming increasingly significant due to unprecedented and fundamental changes in higher education (Redden, 2009). This study aims to investigate instructor strategies used to elicit student responses and interaction in the undergraduate mathematics classroom. By analyzing the discursive strategies and multimodal features employed by an experienced professor and a less experienced Teaching Assistant (TA) while engaged in teaching, this study intends to broaden the current understanding of university mathematics lecturing as a complex and wholly interactive style of teaching.

Recent research in college and university trends has described the current context of higher education as one of tremendous growth and increased globalization (Association of Universities and Colleges of Canada, 2011). The Association of Universities and Colleges Canada (2007) states that, over the next 10 years, Canadian universities will need to replace an additional 21,000 faculty on the brink of retirement; faculty numbers will also need to grow to facilitate undergraduate enrolment increases. To satisfy these hiring requirements, new faculty (including recent PhD students) will need to be trained in pedagogy. These trends of institutional expansion and globalization are occurring simultaneously with recent advancements in technology (Redden, 2009). The meeting of increased growth, global interconnectedness, and new technologies has created a push towards a preference for online learning and away from face-to-face teaching (Trenholm, Alcock, & Robinson, 2012). To meet the increasing demand for training new faculty and

to fully understand the implications of increased online learning, research into interactive teaching practices is particularly pressing.

In mathematics, e-lectures and various kinds of other online learning forums are becoming more common (Trenholm, Alcock, & Robinson, 2012). For example, Cretchley (2005) has observed that developing educational technologies provide a host of new opportunities and that online stimuli are replacing the role of teacher, the effects of which are likely being felt most keenly at the tertiary level. This shift has been supported by those who criticize the way mathematics is traditionally taught in universities (e.g., Gordon, 2008; Greenberg & Williams, 2008).

Traditional mathematics teaching practices have been described by some as a ‘transmission model’ of teaching (Barnes, 1992; Yoon, Kensington-Miller, Sneddon, & Bartholomew, 2011), in which students sit passively listening to the instructor talk, unengaged in any authentic mathematics actively. Yusof and Tall (1998) describe the traditional methods of teaching mathematics at university as leading to a “deficit model” of rote-learning material to pass examinations (p.1). Gerofsky (2010) also mentions the passivity of mathematics students and describes traditional mathematics lectures as “bleak” and “disembodied” and in need of serious reform. Other bodies of research, however, point to the value of mathematics lecturing suggesting that mathematics lectures provide necessary modeling, communication, and motivation to students at the undergraduate level (Pritchard, 2010). A study by Rodd (2003) suggests that the mathematics lecture theatre is a site for “awe and wonder”, where something marvelous

and inspiring can happen (p.15). One may wonder how such contrasting views can surface in research surrounding a particular discipline. Pritchard (2010) suggests that such hostility towards mathematics teaching practices may reflect a widespread reluctance amongst educational researchers to recognize that different disciplines must be treated differently, stressing that the push to replace mathematics lecturing with more modern approaches without appropriate research may prove harmful to students (p.610).

Indeed, only very recently has there been empirical research which aims to analyze and describe the teaching practices of university mathematics instructors (e.g., Artemeva & Fox, 2010; Artemeva & Fox, 2011; Speer, Smith, & Horvath, 2010), while fewer still provide a multimodal analysis of such teaching practices (e.g., Fox & Artemeva, 2011). Furthermore, empirical research focusing on the role played by teachers' gestures as they interact with students in mathematics teaching is equally limited, and focuses primarily on levels K-12 (e.g., Alibali & Nathan, 2012; Goldin-Meadow, Kim, & Singer, 1999; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). There does not seem to be any available research to date which offers a multimodal examination of the teaching practices of university mathematics instructors as they interact with students.

This study intends to lay the groundwork for filling these gaps by conducting a fine-grained, multimodal analysis of university mathematics teacher's practices as they attempt to elicit responses from students and promote participation in the classroom. Furthermore, this study aims to accumulate new information about how novices come to learn these teaching practices, thus intending to provide reference for the potential future

development of training materials necessary during the current institutional climate of growth and expansion.

The theoretical framework for this study has its roots in Rhetorical Genre Studies (RGS), a school of thought that defines 'genre' as social action (Miller, 1984) or as "typified ways of acting within recurrent situations, and as cultural artifacts that can tell us things about how a particular culture configures situations and ways of acting" (Bawarshi & Reiff, 2010, p. 78). This framework is enhanced by Lave and Wenger's (1991) situated learning perspective and Legitimate Peripheral Participation (LPP). The situated learning perspective views learning and knowing as social, experienced-based, and context specific; LPP is an analytical perspective on learning which suggests a novice begins learning at the periphery of an institution by participating in simple tasks at first (which are legitimate in that they are not designed specifically for the novice to learn), but which gradually increase over time in engagement and complexity (Lave & Wenger, 1991). As demonstrated by Artemeva (2008), theories of RGS and situated learning are compatible and complementary (pp.173-174).

As previously mentioned, this current study adopts a multimodal approach to analysis. A multimodal text is described here as comprised of the combination of image, sound (speech), gaze, movement and writing as communicated within a performative space. Multimodal theory, Bearne (2009) explains, takes into account non-verbal elements of communication such as movement, image and sound, alongside written and spoken language.

Further, this study particularly focuses on the hand movements, or gestures, used by university mathematics instructors while they are engaged in teaching. There has been extensive research on the relationship between gesture and mathematical understanding (e.g., Arzarello & Edwards, 2005; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Roth & Lawless, 2002). A growing body of research also suggests that teachers' gestures can help to facilitate students' comprehension and retention of mathematical material (e.g., Alibali & Nathan, 2012; Goldin-Meadow, Kim, & Singer, 1999; Roth, 2001). The majority of research surrounding gestures in teaching and learning makes use of McNeill's (1985; 1992) taxonomy of gesture and focus largely on iconic gestures (gestures that present images of concrete entities and/or actions) and metaphoric gestures (gestures that present images of the abstract) (McNeill, 2005, pp.38-41) and their role in explaining abstract concepts. It does not appear that much research has investigated the role that more subtle interactive gestures play when used in teaching mathematics. In order to shed light on this underexplored aspect of mathematics pedagogy the analytical framework of this study incorporates gesture theory as described by Kendon (2004) in addition to the theories already discussed.

To understand more about the teaching practices of university mathematics instructors, and the process involved in learning these practices by novice teachers, this study examines video-recordings of two teachers of university mathematics, a less experienced TA and a very experienced professor, using qualitative thematic multimodal coding

assisted by QSR International's NVivo 10 software and the multifaceted theoretical and analytical framework described above, to answer the following research questions:

- 1) How do instructors attempt to elicit responses and promote participation from students in an undergraduate mathematics lecture?
  
- 2) Is there any difference between the teaching practices of a less experienced TA and a very experienced professor while instructing undergraduate mathematics classes?

Before answering these questions, I provide a detailed description and discussion of the theories and research used to inform the theoretical and analytic frameworks of this study. This is followed by a description of the methods used to conduct the analysis. The findings of this analysis are then presented in two parts: first, I present findings related to the strategies used by the participants to elicit responses from students and promote participation in the classroom ('strategies' are defined here as the discursive and multimodal practices used by the participants in order to teach mathematics), and also provide insight into the similarities observed in the participants' enactment of mathematics teaching. Second, I describe the observations regarding any differences exhibited by the participants while teaching. These findings are discussed in the following section in light of the theoretical framework presented in Chapter 2. Conclusions and implications of this study are then presented, followed by an account of this study's limitations and suggestions for future research.

## **Chapter 2: Theoretical and Analytical Framework**

### **Rhetorical Genre Studies (RGS)**

The term ‘genre’, traditionally used to describe and categorize various literary text types, has come to take on new meaning outside the world of literature (Freedman & Medway, 1994). Venturing outside the initial notion of genre as the classification of literary texts, rhetoric studies first expanded the meaning to encompass non-literary texts of writing and speaking; a move enriched by Bakhtin (1986) who described speech genres as “relatively stable types” (p.60) of utterances used by individuals to participate in social spheres.

Bakhtin describes an utterance as “a link in the chain of speech communication” (p.91).

Therefore, according to Bakhtin, every utterance is created in *response* to other utterances which precede it.

From this initial expansion came an increased focus on the production of written genres and the process by which such texts came to be (e.g. Elbow, 1973; Emig, 1971; Flower & Hayes, 1981). This focus, although valuable at the time neglected to take into account the social aspects of writing composition. Bakhtin’s (1986) view of the social embeddedness of oral and written genres was central to the understanding of speech and writing as a response to social situations. This view of speech and writing as a response to broader social contexts would give rise to the current understanding of genre as fundamentally a social activity, one that perceives knowledge as socially constructed in response to communal needs, goals, and contexts (Freedman & Medway, 1994). Furthermore, Freedman and Medway (1994) state that current notions of genre not only recognize that genres can be “characterized by regularities in textual form and substance” but also that

these regularities are seen as being derived “from the similarity in the social action undertaken” (p.2).

The notion of genre as ‘social action’ (Miller, 1984) marked the beginning of the school of thought known as Rhetorical Genre Studies (RGS). Miller’s (1984; 1994) research moved beyond the understanding of genre as defined by its regularities in textual features and expanded it towards the view of genre as typified rhetorical actions created in response to recurrent social situations. This definition encompasses not only the substance and form of genres, but also the motive and context of their creation (Freedman & Medway, 1994).

Reflecting on Bakhtin’s (1986) discussion of generic stability, Schryer (1993) further revised the definition of genre to be understood as fluid and changing, “stabilized-for-now or stabilized-enough sites of social and ideological action” (p. 108). Schryer (1995) went on to introduce the concept of genre as a verb, suggesting we ‘genre’ our way through life in response to the social situations with which we are presented and surrounded. Further, Schryer (2000) incorporates the notion of genre as ‘constellations’ (Campbell & Jamieson, 1979) of rhetorical conventions comprised of tacit and improvisational strategies; a view which Artemeva (2008) suggests, allows for the viewing of genres as “sites of tensions between creativity and convention that may allow for individual expression, as both constraining and enabling” (p. 22). This view of genre as stable yet flexible highlights the idea that RGS sees genres as comprised of typified similarities of rhetorical actions that remain malleable to some extent. That is, an agent is

constrained by her genre in that there are typified norms she must abide by in order to meet the needs of the situation, but can improvise effectively in so far as she understands fully the broader purpose (the social action) and context (the audience), of her craft<sup>1</sup>.

From the reconceptualization of genre as social action, the investigation into the intricacies of written and spoken genre, and the process of their production within broader social contexts began to develop. The value of examining the process of how genres are learned through the lens of RGS became evident with a growing body of research on the development of genre knowledge in a variety of contexts. The contexts include academic writing in elementary (e.g., Larson & Maier, 2000), secondary (e.g., Smidt, 2002; Beck, 2008), and post-secondary (e.g., Giltrow, 2002; Parkin, 2009) education; professional atmospheres with particular interest in genres sets and systems (e.g., Paré, 2000; Paré & Smart, 1994) and identity university-to-workplace transition (e.g., Dias, Freedman, Medway, & Paré, 1999; Dias & Paré, 2000). More recently genre research has begun to focus on the complex enactments of genres of pedagogy (Artemeva & Fox, 2010, 2011; Bawarshi & Reiff, 2010; Fox & Artemeva, 2011). Although the most appropriate method for teaching and learning genres has been cause for much debate

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<sup>1</sup>To temporarily abandon the world of writing, take for instance the art of tie-dyeing, a practice involving the application of dye to fabric. Within this craft there is remarkable flexibility involving the scrunching, bunching, and knot-tying of textiles. There is flexibility in the dyeing process as well: single or multicolour, bold application or faint, dipping, drizzling, or splattering. Furthermore, the artist can use tools: elastic bands are most common, but some tie-dyists (perhaps those that are more experienced) may choose to improvise by introducing paint brushes or stamps to apply the dye. The practice of tie-dyeing seems to be entirely carefree, unrestrained and haphazard, does it not? But take away the knots, take away the manipulation of fabric, and the product is just a coloured shirt. Take away the colourful dye, and the product is unlikely to satisfy its audience. Although there is remarkable flexibility, there are overtly recognized constraints as well.

(Freedman, 2008), the RGS school of thought maintains that genres need not be explicitly taught, but rather, are learned through involvement, that full genre knowledge becomes possible only through performance (Freedman, 1994, p. 206).

### **CoP and Situated Learning**

As previously mentioned RGS has proved a powerful tool when applied to the study of academic and workplace genres, as noted in the literature (e.g., Dias & Paré. 2000; Dias, Freedman, Medway, & Pare, 1999; Giltrow, 2002; Paré & Smart, 1994), however, combining RGS with additional theories of genre learning allows for the concepts of identity formation and genre learning to be further explored and expanded. Theories of Legitimate Peripheral Participation (LPP) and situated learning (e.g. Lave, 1991; Lave & Wenger, 1991; Wenger, 1998) are based on the view that learning is a social process comprised of and individual being an active participant in the practices of social communities (Wenger, 1998). Smith (2003, 2009) describes LPP as the process in which a newcomer becomes incorporated into a CoP. “Initially” Smith explains, “people have to join communities and learn at the periphery. The things they are involved in, the tasks they do may be less key to the community than others” (para. 1). These tasks, although less “key” than other tasks being worked on by perhaps more experienced members of the community, are nonetheless, legitimate in that they are not designed specifically for the newcomer to learn (Lave & Wenger, 1991). CoP act as the central unit of analysis in LLP and the situated learning perspective.

Wenger (1998; 2006) defines CoP as being formed by people who engage in a process of collective learning in a domain of shared goals, values, and beliefs. This domain is not necessarily a physical domain, Wenger (2006) explains, but rather a shared domain of interest and human endeavor. Through time and interaction the members of this domain, while engaged in a process of shared learning, values, and goals, establish a CoP. In CoP novices begin learning at the periphery; they become acculturated by working on authentic activities, gradually moving towards the full participation state. The ‘oldtimers’, as described by Lave (1991), are those that have become fully acculturated into the CoP, and have mastered its genres. As shown by Artemeva (2008) RGS and theories of situated learning and CoP when used together, function as a valuable tool for examining the process of genre learning.

For the purpose of this study the CoP that I refer to is the community of university mathematics teachers. Theories of situated learning and CoP will help to inform this study by offering further insight into similarities and differences in the performance of the genre as enacted by the less experienced TA, and the very experienced professor, as described in Chapter 1.

### **Chalk talk: A global pedagogical genre**

Noticing trends of globalization and internationalization within disciplines of higher education, Artemeva and Fox (2010, 2011) have set out to investigate whether there are any similarities in the way undergraduate mathematics is taught across global and local contexts. They define global context as the teaching of mathematics in university

classrooms around the world, while local contexts refer to “a unique classroom within cultural, institutional, national, social, or nested contexts” (p.346). The aim of their research has been to delve deeper into the understanding of academic literacy and effective teaching through the investigation of the relationships between global and local CoPs of university mathematics teachers.

Artemeva and Fox (2011) define genre as “constellations” (Campbell & Jamieson, 1979) of overtly recognized rhetorical conventions *and* tacit and improvisational strategies, triggered by the interaction between an individual’s socialization and an organization (Schryer,2000; Schryer & Spoel, 2005) (p.348). This highlights the nature of genres as stabilized, yet allowing for flexibility while pointing to a genre’s ability to shape and be shaped by the social agents who use them. The organization to which Artemeva and Fox refer is a discipline in a university embedded within a larger cultural-historical context. RGS facilitates their study by offering a lens through which to examine the regularities of the genre, as well as subtle differences.

In order to understand the complexities of the genre and how they function across global and local contexts, Artemeva and Fox developed a ‘distinctive profile of regularities’ (Paré & Smart, 1994) which comprise the production and consumption of the genre. Using a modified grounded theory approach (e.g., Charmaz, 2006) they began analyzing the writings, sayings, and doings of 50 teachers of undergraduate mathematics lecture classes in 10 universities using video recorded and audio-recorded lectures, audio-recorded interviews, observational field notes, and collections of written artifacts. The

participants of their study differed across linguistic and cultural backgrounds as well as in level of experience (novices and experienced professors). This analysis led to the identification of typified and recurrent elements of the genre, as well as local and individual differences. What Artemeva and Fox (2010, 2011) found was that across all the observed local contexts, mathematics teachers enacted the same teaching genre through speaking aloud while writing on the board, moving, gesturing etc. They found that as the participants of their study performed this genre of teaching, they engaged in the recurring practice of writing on the chalkboard while verbalizing what they wrote, and then turning and talking about what they had written. Artemeva and Fox (2010, 2011) identified this typified recurring practice of teaching undergraduate mathematics as ‘chalk talk’.

Artemeva and Fox found a variety of elements in the enactment of chalk talk which recur across all observed contexts. These elements include use of mathematical commentary (mathematics teachers provide a running commentary in which they verbalize everything they write on the board) and metacommentary (occurs when they talk *about* what they write on the board), use of the chalkboard and notes, positioning themselves in relation to the class and chalk board, as well as typified and recurring types of gestures and expressions. Differences too were noticed based on individual enactment and local contexts (e.g., Artemeva & Fox (2010, 2011); Fox & Artemeva, 2011) noticed differences in culturally defined perceptions of teacher’s notes and classroom interaction). Of these rhetorical conventions, this study investigates and expands on the areas of

metacommentary, gestures, and classroom interaction within the enactment of the chalk talk genre, in two mathematics classrooms.

In a follow-up study, Fox and Artemeva (2011) “present evidence of the inherent multimodality of chalk talk” (p.85), as well as the “cinematic aspects and the embodied nature of the genre” (p.96). Fox and Artemeva base their method of multimodal analysis on a framework proposed by Norris (2004) for the examination of video-recorded data of two instructors engaged in chalk talk. In addition to the rhetorical conventions that were observed reoccurring across contexts in their previous study (Artemeva & Fox, 2010, 2011), Fox and Artemeva (2011) describe elements of the teacher’s body positioning and focus common across all video-recordings. Artemeva and Fox were also able to draw conclusions from their study regarding differences in genre use by novices and experienced professors. As mentioned above, RGS sees genre learning as achieved by novices “only while being immersed within a specific situational context that produces and is reproduced by the genre” (Artemeva & Fox, 2011, p. 86). This view has powerful implications for understanding more about the observed differences which surface between novices and experienced agents while engaged in genre enactment.

### **Novices and veterans learning genres of CoP**

Prior to Artemeva and Fox (2010, 2011; Fox & Artemeva, 2011), several RGS theorists have combined RGS and situated learning perspective in order to study the process of genre learning as it shapes the identities and experiences of novices and veterans alike. For example, Schryer and her collaborators (1994; Schryer & Spoel, 2005; Spafford,

Schryer, Mian, & Lingard, 2006) have explored the induction process of novices in the workplace by studying medical students. Their work examining the professional genre of medical case presentations by medical students (Spafford, Schryer, Mian, & Lingard, 2006), suggests first, that the enactment of professional genres conveys to novices ways of speaking, thinking, perceiving, and behaving that will shape their future identities as professionals. Secondly, Schryer's work makes the suggestion that medical case presentations are a kind of 'hybrid' genre. This hybrid genre she suggests is situated between school and workplace genres that she names 'apprenticeship genres' in which medical students slip between roles of learners and care providers. Schryer's longitudinal research of medical students' enactment of professional genres speaks to the gradual, but also highly participatory nature of the university-to-workplace transition and acculturation into a professional CoP.

Paré (2000) provides another example of research which highlights the phenomenon of social agents being shaped by, and shaping genres. Paré's research examines the powerful role that genre production plays in shaping the professional identities of newcomers struggling to negotiate the clash between the ideologies of their institutions and their sense of selves. Paré investigated this phenomenon by examining the work of a group of women, Inuit social workers, as they engaged in the professional genre of recordkeeping. By engaging in this written genre the social workers had to grapple with their identity as Inuit women, when preparing records for the consumption of white authorities. As a result of this internal struggle, the Inuit social workers kept less-detailed records than the institution found desirable. Paré's findings stressed the ideological power professional

genres have to both create and control one's identity, he suggests "learning to participate in workplace genres means learning one's professional location in the power relations of institutional life (p. 69). Both Schryer's and Paré's work exhibit the complex realities of newcomer induction through participation in workplace genres and their professional communities, while also pointing to the impact this induction has on identity formation.

Much as RGS has informed previous studies on the chalk talk genre (Artemeva & Fox, 2011; Fox & Artemeva 2011) RGS allows this study to examine the genre of chalk talk in-depth for a holistic understanding of the similarities, and also differences which comprise its enactment. Also, as demonstrated by recent research in genre learning (e.g., Artemeva, 2008; Spafford, Schryer, Mian, & Lingard, 2006), the careful examination of genre enactment, when done through the lens of RGS and situated learning perspectives, allows for a deeper understanding of the socialization and identity formation of experienced and less experienced social agents.

### **Multimodality and Gesture Theory**

As previously mentioned, multimodal theory takes into account other modes of communication, such as images, gestures, and sound, alongside written and spoken language. A multimodal text, Bearne (2009) explains, is created by the combination of image, sound (including speech and music), gesture and movement and writing or print, communicated through paper, the screen, face to face meetings, or performative space (pp. 240-241). The data in this study present a complex multimodal text comprised of speech, movement, gesture and gaze, and writing, enacted simultaneously within the

performative space of the undergraduate classroom. The value of a multimodal analysis lies in the ‘holistic view’ which is taken when a researcher expands investigation beyond the text. Kress and van Leeuwen (2006) articulate this point by suggesting that the meanings that can be realized in language and visual communication overlap; “some things can be ‘said’ either visually or verbally, others only visually, others only verbally” (p. 2).

In order to examine the visual and verbal communicative features in conversation, Kendon (2004) has used digital video technology to assemble large corpora of data for the analysis of gesture-in-use. Kendon notes that multimodal analysis of video data has become much less cumbersome and expensive since the development of technology which facilitates the assembly of large collections of such specimens (p. 226). With these corpora, Kendon has conducted a study allowing for the classification and deduction of semantic and pragmatic functions of these forms in use. As mentioned in Chapter 1, this classification acts as a framework for the gestural analysis component of this study.

Above, the value of multimodal analysis was discussed with respect to the holistic view that can be obtained when all modes of communication are considered as they overlap with speech or text. In fact, it is possible to take this a step further and suggest that to analyze speech, when isolated and divorced from its accompanying gestures, is to examine but one side of the coin. McNeill (1985) argues that gestures and speech share a computational stage (are part of the same psychological structure), meaning that “sentences and gestures develop internally together as psychological performances”

(p.350). McNeill's work suggests an argument can be put forth that gestures reveal a stage deep within the speaking process in which two kind of thinking are being coordinated: imagistic, and syntactic. Kendon's (2004) work supports McNeill's thoughts on the 'co-expressiveness' of speech and gesture but suggests, however, that creating an utterance that uses both modes of expression is something that the speaker achieves. An utterance is defined by Kendon as "any ensemble of action that counts for others as an attempt by an actor to 'give' information of some sort" (2010, p.7). Kendon suggests that when "gestures and speech are employed together as partners in a single rhetorical enterprise" the speaker works to create an 'ensemble' of meaning (p.127). Kendon explains that the discovery that speakers use variations in how the speech and gesture of their discourses are organized supports this concept:

These variations in how the speech and gesturing are organized in relation to one another suggest that speakers continuously adjust one utterance component to the other. This is why we prefer to say that the semantically coherent gesture-speech *ensemble* is a speaker *achievement*. The relationship between the gestural component in the utterance does not seem well understood as a simple causal relationship, where the one is dependent on the other in some kind of unchanging way. Speakers rather, can control these two components and can orchestrate them differently, according to the situation. ( p. 127)

Kendon describes gestures as having one or more phases which make up the 'movement excursion' (the sequence of bodily movement which makes up the gesture). The first phase is known as the preparation phase when the hand or hands begin to move from the

actor's rest position (the position of the speaker when no gesture is being made) towards the apex of the gesture. This apex, which follows the preparation phase, when the movement's 'shape' is manifested with the greatest clarity, is referred to as the stroke.

Following the stroke there is sometimes a hold which occurs when the shape of the gesture is held briefly before the final stage known as the recovery. The stroke and any post-stroke hold are referred to by Kendon (2004) as the "nucleus" of the gesture phrase and are thought to be the part of the excursion which "carries the expression or meaning of the gesture" (p. 112). The stroke and hold 'nucleus' of the participants' excursions will act as the unit of analysis in this study (a unit of analysis is defined by Geisler (2004) as that which "identifies the level at which the phenomena of interest occurs" (p.29)). Some observations will also be made in regards to the participants rest positions.

The taxonomy of gestures proposed by McNeill (1992, McNeill & Levy, 1982) is now used as the base for most work concerned with the role gestures play in educational issues (e.g., Goldin-Meadow, Kim, & Singer, 1999; Gerofsky, 2010; Kelly, Barr, Church, & Lynch, 1999). In his work, McNeill (2005) suggests that there are four basic types of gestures. This quartet of gestures includes beats (up and down, back and forth 'flicks' of the hand which commonly correspond with rhythm of speech), deictic gestures (pointing), iconic gestures, and metaphoric gestures. The majority of research on the role of gestures in mathematics cognition places emphasis largely on the illustrating roles of iconic, metaphoric, and deictic gesturing and their role in understanding abstract concepts (e.g., Alibali & Nathan, 2012; Arzarello & Edwards, 2005; Roth, 2001; Roth & Lawless,

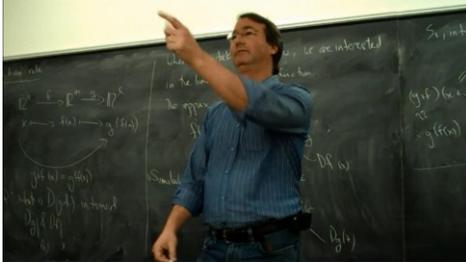
2002). This study, however, focuses on non-pictorial hand movements which Bavelas and colleagues have named ‘interactive gestures’, which generally consist of movements of the fingers and palms towards the addressee (Bavelas, Chovil, Coates, & Roe, 1995; Bavelas, Hagen, & Lane, 1989; Bavelas, Chovil, Lawrie, & Wade, 1992).

Bavelas et al. describe interactive gestures as simple, non-pictorial gestures which serve to regulate the coordination of speaking turns, to seek a request or response, or to acknowledge understanding. I have chosen to use Kendon’s taxonomy of gestures (2004) as my analytical framework because, although Bavelas’s research focuses on interaction, the framework she proposes is context based and would require a multimodal analysis of the students’ as well as the instructors’ gestures which falls beyond the limited scope of this study. Kendon’s categorization, based on hand formation, not only allows for a detailed analysis of the instructors’ use of gestures, it covers a much broader range of gestures and their functions in conversation.

Pointing is defined by Kendon (2004) as having a certain characteristic movement pattern in which the body part carrying out the pointing is moved in a well-defined path, towards a specific target. The movement is commonly linear in nature and often held in position briefly once the body part doing the pointing has reached its furthest extent. Pointing gestures are regarded as indicating an object, location, or direction within a physical space shared by the speaker and interlocutor, or a space constructed by the speakers own actions. Similarly, the objects, locations, or direction being referred to may be visible within the shared space, out of sight of the hearer and speaker (as when a speaker points

beyond the walls of a house to indicate a location or direction), or the object being pointed to may be abstract and constructed by the speaker's narration (p. 200). Kendon's study of pointing concludes that the form of pointing adopted by the speaker is systematically related to the way the object being referred to is presented in the speaker's discourse.

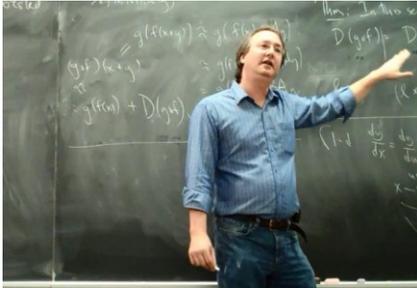
Pointing with the Index Finger Extended (IFE) (Figure 1) is most likely to be used when a speaker singles out an object which is to be attended to as a particular individual object. Typically the speaker when pointing with IFE will use an explicitly deictic word such as 'here', 'there', 'this', 'that', etc.



*Figure 1.* Pointing with Index Finger Extended (IFE). This figure illustrates the professor attempting to elicit a response by pointing at a student using IFE.

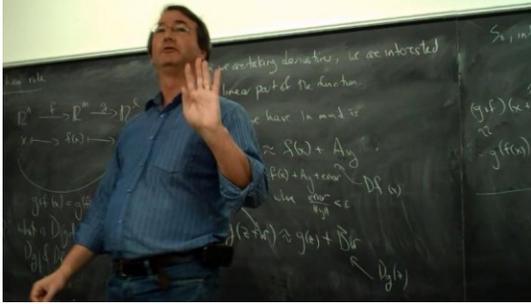
Kendon sees a clear contrast between pointing with the Open Hand (OH) (Figure 2) versus pointing with IFE. In Kendon's study all cases when OH is used in pointing the object being indicated is not itself the primary focus or topic of the discourse but is

something that is related to the topic and explicit deictic words are less commonly used in the associated speech.



*Figure 2.* Pointing with the Open Hand (OH). This figure illustrates the professor pointing at the chalkboard with OH.

All gestures in the Open Hand Prone (OHP) or ‘palm down’ family consist of gestures where the palm of the hand faces down or away from the speaker. This family shares the semantic theme of stopping or interrupting a line of action (physical, communicative, or mental) that is in progress. This family can be divided into two groups: OHP ‘Vertical Palm’ (VP) (Figure 3), when the hand is held with the palm facing vertically away from the speaker. OHP(VP) indicates a wish that either the action of the speaker be halted, the interlocutor’s action be halted, or what is being done jointly be halted. Interestingly, Kendon (2004) has suggested that where the hand is placed when performing this gesture allows the actor to specify whose action he or she wishes to halt (p. 255).



*Figure 3.* Open Hand Prone (OHP) Palm Vertical (VP). This figure illustrates the professor using OHP(VP) while engaging in mathematical explanation.

OHP Horizontal Palm (ZP) (Figure 4), when the palm is placed horizontally and faces downwards, still indicates the desire that a line of action be halted, however this gesture suggests that the halting is being done by external circumstances rather than something the speaker can, or seeks to control. Kendon has observed the use of this gesture in several contexts which apply to this study: 1) When reference is made to circumstances in which no further action is necessary, as when a statement is made that is deemed complete or sufficient, requiring no further inquiry or comment 2) When statements are made which are universal, for which no exception is possible 3) When an extreme assessment is made, whether positive or negative.

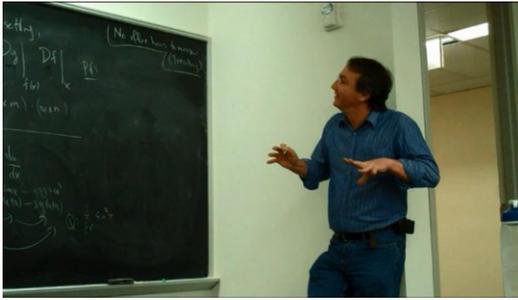
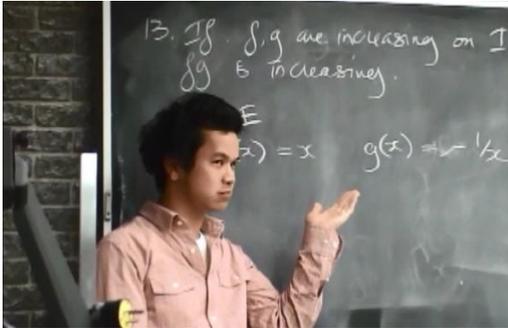


Figure 4. Open Hand Prone (OHP) Palm Horizontal (ZP). This figure illustrates the professor using OHP(ZP) while engaging in mathematical explanation.

The Open Hand Supine (OHS) or ‘palm up’ family includes gestures in which the palm of the hand faces upwards. This family of gestures has in common the feature of offering or giving, or showing readiness to receive something, whether a concrete item, or the content of what is being said (Kendon, 2004, p. 264). Gestures in the OHS family can also be used in pointing.

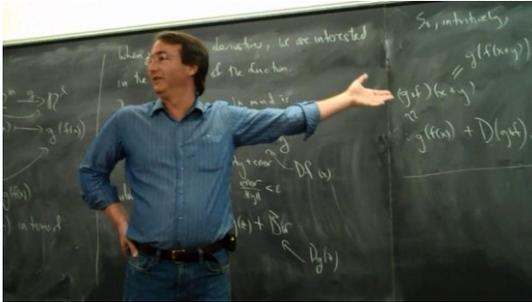
This family of gestures can be divided into three sub-groupings: Palm Presentation (PP), Palm Addressed (PA), and Palm with Lateral Movement (PL). Palm Presentation (PP) (Figure 5) gestures are conducted by extending the supine forearm with palm facing up within the immediate frontal space of the speaker and ‘presented’ or ‘displayed’ but not moved as if to indicate something. PP gestures are commonly one handed and often combined with a slight lowering of the hand followed by a hold (p. 264). Kendon describes this gesture as typically being used in coordination with a speaker introducing something he or she is about to say, or during an explanation, comment, or clarification of something the speaker has just said. PP gestures have been observed in the following

discursive contexts: 1) When explaining the meaning of a term phrase 2) When expounding the premises or conditions for understanding something 3) When describing the circumstances that provide the setting for a narrative 4) When providing a conclusion or a summary with regard to something that has just been said.



*Figure 5.* Open Hand Supine (OHS), Palm Presentation (PP). This figure illustrates the TA presenting an equation to the students using OHS(PP).

Palm Addressed (PA) (Figure 6) is a palm up gesture which occurs when gesturing towards something (either a person or object). When used in pointing, the PA gesture is used to ‘present’ the object to the audience as something to be inspected for some quality the speaker wishes to draw attention to. When directed at an individual, OHS(PA) is often used to acknowledge another as a source of something said or indicates what another has said is correct. Kendon also suggests that the PA gesture is used when something specific is indicated that the speaker desires to obtain from the interlocutor. Kendon (2004) refers to this as the ‘question’ context of use of this gesture.



*Figure 6.* Open Hand Supine (OHS), Palm Addressed (PA). This figure illustrates the professor gesturing to the chalkboard using OHS(PA).

The gesture OHS with Lateral Movement (PL) (Figure 7) is almost always executed with both hands. The hands are held facing palm up and moved with laterally away from the speaker's midline or backwards until behind the speaker's vertical median. Kendon suggests that this gesture is used to imply non-intervention and has identified its use in the following contexts: 1) When expressing an unwillingness or inability to intervene in something 2) When admitting, accepting, or claiming something is obvious, about which nothing further needs to be said 3) When asking a question but having no expectation an answer will be, or can be, forthcoming from someone else 4) When saying something 'could be so' without making any position with regard to it 5) When indicating that the other is free to do something.



*Figure 7.* Open Hand Supine (OHS), with Lateral Movement (PL). This figure illustrates the professor while engaged in the OHS(PL) gesture.

### **Chapter 3: Methods**

This qualitative study examines video recordings of instructors engaged in the performance of a chalk talk lecture. The data used for the study were originally collected by Artemeva and Fox within the framework of the original large-scale international study of the chalk talk genre (see 2010, 2011; Fox & Artemeva, 2011). Permission to use the data was obtained from the primary researchers.

#### **Ethics Approval**

The ethics approval for the overall study (Artemeva & Fox, 2010, 2011; Fox & Artemeva, 2011) was originally granted by the Carleton University Research Ethics Board in 2007 and has been renewed annually (the latest renewal dated August 2013). Informed Consent has been obtained from all study participants, including the participants in my study.

**Participants**

The participants of this study are two male university mathematics instructors who are native speakers of English. The participants of this study include an experienced professor with decades of teaching experience and a PhD student (a teaching assistant [TA]) with seven years of teaching experience at the time the data for this study were collected. Both educational and the majority of professional experience of these participants occurred in North America: the teaching assistant was educated and was teaching in Canada at the time of the recording; the experienced professor was educated and was teaching in the United States at the time of the recording.

**Research Site**

Both instructors were video-recorded while teaching in their first language at the undergraduate post-secondary level, in early 2000s at Canadian (TA) and American (Professor) Universities. The TA was leading a problem solving session, while the professor was delivering a lecture.

**Data**

The video-data for this study were extracted from video-recorded sessions of the participants engaged in mathematics teaching which were initially gathered for Artemeva and Fox's (2010, 2011) study on the chalk talk genre. From these sessions, all instances in which the participants were visible, audible and attempting to elicit feedback and participation from the students were isolated and transcribed. Due to the limited size and scope of this MA study, approximately four minutes of footage from each participant

were selected to be analyzed. Four minutes of footage allowed me to observe a variety of recurrent features of the genre, and to make note of distinct differences. The final footage that was chosen ensured that both participants were engaged in actions that were of a comparable nature (points in the teaching in which the participants were writing questions or equations on the board and attempting to have their students solve problems, or prove theorems). Video data can be obtained from the author.

### **Qualitative Multimodal Coding**

The segments of the video recordings were time-stamped (the insertion of timed break-points between speaker turns) enabling the synchronization of the video clips with the transcripts. The video segments and transcripts were then uploaded into QSR International's NVivo 10 (2012) software (a computer application designed for qualitative data analysis of rich, text-based or multimodal data). NVivo software has been used to organize video data during the implementation of various qualitative and multimodal research projects (cf. Crowley, Harre, & Tagg, 2002; Seror, 2005; Walsh, 2003).

Qualitative multimodal thematic coding was used in order to examine aspects of the 'chalk talk' genre from the theoretical perspective of Rhetorical Genre Studies (RGS), specifically, instances in which mathematics lecturers attempted to elicit feedback and participation from the students in the audience. This approach is similar to Norris's (2004) multimodal interactional analysis in that it provides a holistic analysis where "the

importance of each mode in a real-time interaction is integrated exclusive of the presupposition that any one mode is inherently more important than another” (p.112).

Norris’s (2004) proposed framework also is concerned with gestures, particularly beats and diexis as ‘lower-level actions’ which she suggests are used to structure the “foregrounding and backgrounding of higher level communicative actions that the participant engages in simultaneously” (p.114). Norris defines lower-level actions as “the smallest interactional meaning unit” and higher-level actions as communicative modes “bracketed by openings and closings and made up of a multiplicity of chained lower-level actions” (p.11). Examples of lower-level actions would be gestures or words, and examples of higher-level actions would be greetings, or commands. The analytical approach used in this study similarly acknowledges lower-level actions such as gestures and facial expressions as playing an invaluable role in higher-level communicative actions like eliciting responses; my approach differs, however, in the application of codes to lower-level actions in order to establish themes of higher-level functions which were previously established by researchers of the chalk talk genre.

As mentioned in earlier sections, Artemeva and Fox (2010, 2011) discovered an array of rhetorical conventions in the enactment of the chalk talk genre which repeated across global contexts, as well as a variety of individual and local differences. Artemeva and Fox (2010) began their study of the chalk talk genre using a modified, or constructivist, grounded theory approach (e.g. Charmaz, 2006) in order to analyze the data and establish a thematic tree of recurring themes (see Appendix A for a relevant part of original tree).

Because the initial chalk talk study was of an emergent nature, the thematic tree was left open for expansion pending further investigation. Therefore, the coding tree first established and expanded by Artemeva and Fox (2010, 2011; Fox & Artemeva, 2011) acts as a “start list” (Geisler, 2004), or a list of “possible categories that may be relevant to coding” (p. 60), for this study. The tree was revised, as suggested by Giesler (2004), adding new categories (applying codes and adding new codes) and dimensions upon the discovery of new, conceptually independent features not yet included in the coding scheme (see Appendix B for revised tree). The discovery of new ‘lower-level’ features led to the creation of new codes, which were then added to already established themes or grouped together (when appropriate) in order to establish new dimensions of the tree. This method is described by Geisler (2004) as “nested-coding”; that is, lower-level codes were grouped together into higher-level codes in order to provide a holistic multimodal analysis. Once developed, the same tree was used for all coding in this study.

Four primary codes establish the overarching theme of Teacher Persona which is defined by Artemeva and Fox (2010) as “the character they [teachers] played as they taught” which can create a welcoming and inclusive atmosphere or range to a distanced rational-scientific atmosphere (p. 177). These codes which make up the theme of the Teacher Persona are Language, Metastructure, Awareness of Students, and Embodiment. Within Language, the participants’ lexical production was coded for a variety of qualities such as, for example, questions, answers, and commands. Metastructure housed qualities involved in pedagogical practices and mathematical explanation. Under Awareness of Students aspects of the way the instructor engages with the students are documented, for

example the level of power sharing involved in the lecture. Embodiment contained coding that relates to how an instructor uses his body during a lecture. Coding in this theme encompassed gaze (what the instructor was looking at), stance (posture and rest positions), and gesture (hand movements). Although there is a wide variety of the gestures described by Kendon (2004) visible in the data, as described in Chapter 2, this study is limited to the investigation of the participants' use of two gesture families of the open hand: Open Hand Prone (palm down), and Open Hand Supine (palm up) as well as pointing gestures used during instances of interaction with students.

The video samples were coded for discursive as well as multimodal features. Textual or 'verbalized' features were coded using segment transcripts. Sections of text were highlighted and codes were applied using NVivo 10's transcripts feature (see Figure 8).

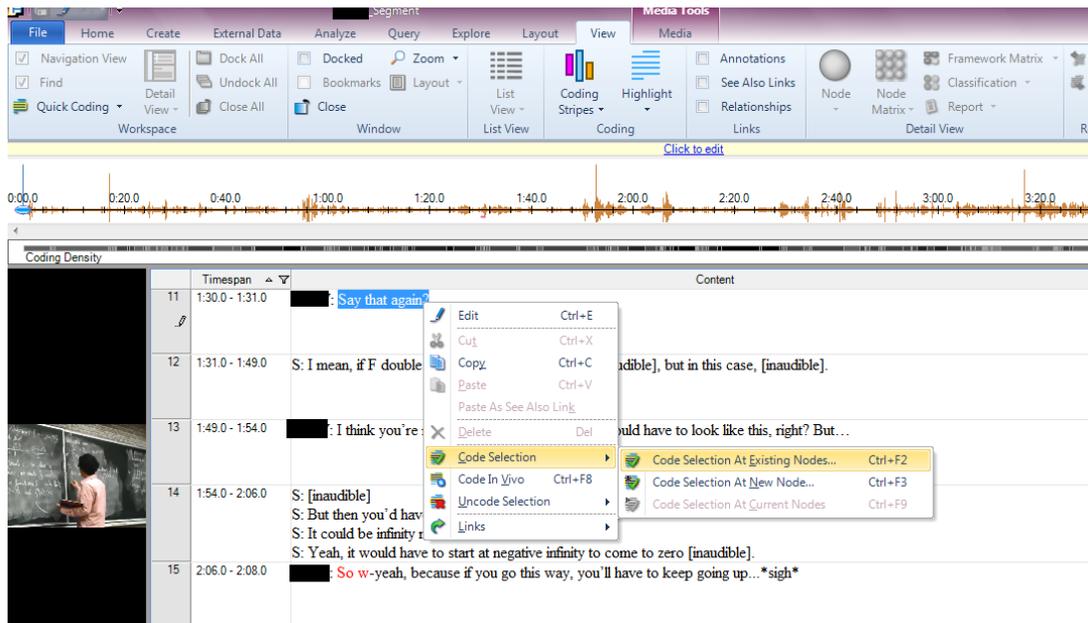
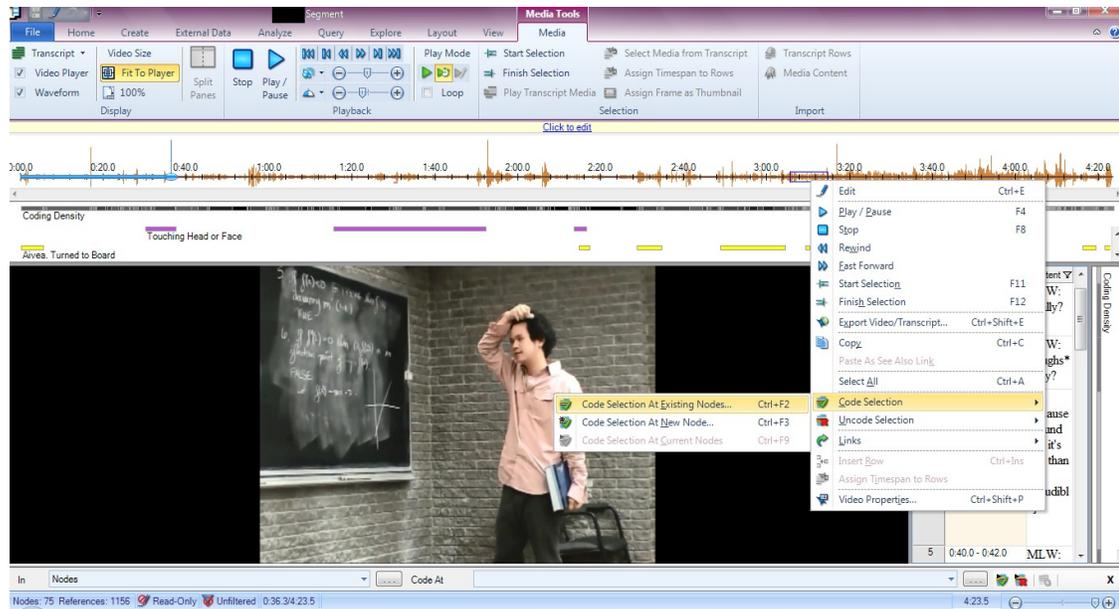


Figure 8. An example of multimodal textual coding using QSR International's NVivo 10 software; Transcripts feature.

Nonverbal and gestural features were coded using the video data. The video data were slowed down and segments of the video clips were highlighted and coded using NVivo 10's media feature (see Figure 9).



*Figure 9.* An example of multimodal video coding using QSR International's NVivo 10 software; Media feature.

**Quantitizing.** Although Dornyei (2007) suggests that qualitative data are not gathered for the purpose of being directly counted, he goes on to say that subsequent analysis can define categories through which certain aspects of qualitative data can be quantified (p. 38). Dornyei describes the technique of ‘quantitizing’ as involving the conversion of qualitative data into numerical codes that can be further processed statistically, a process used by qualitative researchers who wish to produce numerical tabulations of certain aspects of their data in order to achieve a ‘thick’ description. Therefore, in addition to the

descriptive observations drawn from this qualitative multimodal thematic approach to coding, this study also benefits from the tabulation of results allowing for the categorization and comparison of findings needed for a robust and holistic analysis of the data.

As mentioned above, the ‘verbal’ data were coded using transcripts (i.e. textual coding), allowing for the tabulation of ‘instances’ (i.e. each time a feature occurs) of certain discursive features. All other non-verbal and gestural features were coded using the video data allowing for the tabulation of instances, as well as an accurate account of the percentage of segment covered (referred to as ‘coverage’). This method of coding allowed for a good understanding of how multimodal features occur together (co-occur) in the data, however, only the video data coding allowed for an accurate account of coverage. For this reason all results are provided in ‘instances’, with percentages allotted only to nonverbal and multimodal features when presented in Chapter 4.

#### **Chapter 4: Findings**

This section presents the findings of this study in two parts. The first provides observations of how the participants elicited responses and promoted participation from the students in the class, and highlights the similarities which exist in the teaching practices of the participants. These observations are illustrated using examples from either the TA or the professor. Examples from both participants are used, however, in several cases the strategies under discussion were observed being used by only one of the participants (usually the professor rather than the TA). For this reason, there is unequal

representation of the two participants within the examples. The second section provides observations regarding the subtle differences which exist between the TA and the professor as university teachers of mathematics. The significance of these findings is discussed further in Chapter 5.

### **Eliciting Responses and Promoting Participation**

Communication between students and instructor involves a multifaceted performance comprised of a symphony of verbal and non-verbal actions which may seem, to anyone immersed within the genre, as commonplace, or remain unnoticed at the conscious level; but which, in fact, constitute an extremely complex discursive accomplishment.

Observations show that the participants engage in a number of important discursive and pragmatic strategies involving their speech, gestures, and focus in order to elicit responses from students. A number of the following findings are in agreement with the recurrent features of the chalk talk genre already identified by Artemeva and Fox (2010, 2011; Fox and Artemeva, 2011); many, however, provide additional insight and support to chalk talk as a complex, stabilized, and inherently interactive pedagogical genre.

Because so many of these communicative elements co-occur within any given moment of the participants' performance, a sequential discussion can be challenging. For this reason, this section begins with a detailed example of one such event. Additionally, a multimodal table is used to present this occurrence in further detail (see Appendix C) in order to illustrate the simultaneous and multifaceted nature of meaning-making within the chalk talk genre.

*The Professor writes a formula on the chalkboard holding a set of notes in one hand. He finishes the formula and turns to the class.*

*Professor: Ok, so let's prove this. So, how are you gonna prove this?*

*During a substantial (9.4 second) pause he walks to the table in front of him, puts down the notes, wipes the chalk off his fingers onto the back of his jeans and picks up a can of Pepsi. He smiles slightly, glances up at the audience then down at his notes. He places his left hand on his hip. As he takes a sip of Pepsi with his right hand, he looks across the audience of students. He walks back to the table, puts down his Pepsi, picks up a piece of chalk and crosses his hands in front of him. He looks again from one side of the room to the other. His stance and expression seem to convey that he will wait until someone comes forth. He bounces his shoulders up and down several times and as his smile fades he issues a command to the students.*

*Professor: \*Bouncing slightly\* Give me one reason why this is true.*

*He waits again, and seeing no response he expands the parameters of the command.*

*Professor: You can use two if you need to but if you can do it in one...*

*As he says these words he lifts his hand and extends his index finger slightly upwards. He continues to look across the room for signs of students' willingness to come forward.*

*Seeing again no response he presses together his lips and furrows his brow, he reaches both hands out in front of him as if desperately wanting to receive something:*

*Professor: But, you know, what's your intuition? Why should this be true?*

*He breaks his stance and puts his right hand out in front of him in a stopping motion, a hint is given:*

*Professor: I keep telling you folks- Don't try to find a proof, understand why it's true...*

*As he says the word 'understand', he spreads his hands again and parts them on either side of his body as if he were holding something quite substantial. As he finishes his sentence he brings his hands to center and dips his palms as if to pour the contents onto a page in front of him:*

*Professor: and write down that understanding.*

*He points out into the audience and calls a student's name. She answers him. She shyly mumbles her answer with the intonation of a question. He puts his hand to his ear:*

*Professor: Sorry?*

*She responds again, and the answer is incorrect. He goes back to the board, and re-explains the task.*

*Figure 10.* Example 1, the professor attempting to elicit student responses

The example provided in Figure 10 spans just over 48 seconds, within this time, the professor engages in a variety of discursive strategies including four questions and one command, all while deploying a variety of gestures and other nonverbal cues urging the students to participate (see Appendix C for a detailed description of gestures and nonverbal cues). There are other factors at play as well: elements of authority and power sharing, facial expressions and eye contact all come together to monitor the students' understanding and to maintain their attention. How does one begin to tease apart the fabric of these interactions in order to examine their make-up? This section discusses in succession the observations made surrounding the discursive strategies and multimodal features exhibited by the participants while attempting to elicit responses and encourage participation from students in the audience.

**Discursive strategies.** This section presents observations of how discursive actions such as questions, pauses, commands, and further explanation are used by the participants in order to elicit responses and promote participation from students.

**Questions.** Observations show that both participants most commonly use questions (sentences addressed to the listener which ask for an expression of fact, opinion, belief etc.) to elicit responses from students in the audience. The TA asks a total of 15 questions and receives responses 8/15 times. The Professor asks a total of 13 questions and receives responses 5/13 times (see Table 1 for complete question/response breakdown).

Table 1

*Discursive Strategy/Student Response Breakdown*

Response/Strategy – TA & Professor							
Questions:	TA strategy Instances	Student Response to TA strategy	Student Response/TA Strategy instances	Prof strategy instances	Student Response to Prof strategy	Student Response/Prof Strategy	Total response/total strategy
Clarification	5	4	4/5	2	2	2/2	6/7
Checking	4	2	2/4	3	0	0/3	2/7
Mathematical	3	1	1/3	8	3	3/8	4/11
Self-directed	3	1	1/3	0	0	0	1/3
Total Questions	15	8	8/15	13	5	5/13	13/28
Mathematical explanation	2	0	0/2	11	2	2/11	2/13

Commands	0	0	0	2	0	0/2	0/2
Total Discursive Strategy	17	8	8/17	13	7	7/13	26/28
<sup>2</sup> Self initiated questions	NA	11	NA	0	NA	0	37/28

The participants appear to use questions to perform several different functions. Questions are posed to the audience in order to promote participation. This is demonstrated in Figure 10: the initial question posed by the professor (*How are you gonna prove this?*) acts as the first of several attempts to engage the students in a two-way discourse. Both participants are constantly trying to engage the students in problem solving activities by asking questions related to the tasks at hand; in doing so, they attempt to promote participation and are also given the opportunity to gauge student understanding as the class unfolds.

Questions also seem to be used by the participants in order to facilitate mathematical explanation and understanding. The most common questions to receive responses are those that seek clarification from the students. In Figure 10, the professor holds his hand to his ear and asks “*sorry?*” which prompts the student to repeat her answer. The TA asks five questions for the purpose of clarification and receives responses 4/5 times. The professor asks two questions for the purpose of clarification and receives responses 2/2 times (see Table 1). ‘Clarification’ questions facilitate the instructors’ understanding of

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<sup>2</sup> In this study self-initiated student responses are not considered to be a result of any particular discursive strategy, therefore, certain values are considered Not Applicable (NA)

student responses either because the initial response was inaudible, as in the example shown in Figure 10, or because the instructor requires more information from the student (see Figure 11).

*Student: Matrix properties.*

*Professor: Matrix property. What do you mean?*

*Student: I mean that due to like matrix multiplication you should be able to show that.*

*Figure 11.* Example 2, the professor asking a ‘clarification question’.

In this case, the professor wanted more information from the student in order to clarify for himself the student’s line of thought.

Questions can also be used during mathematical explanation to help clarify a concept. For example, in example 3 (Figure 12) the students and the TA are trying to decide whether a mathematical statement is true or false. The students put forward a few different responses and the TA seems stumped. He appears to be trying to make sense of the problem for the class and seemingly himself as well. He walks towards a graph on the board and points with his index finger drawing a path upwards (see Figure 12).

*Student1: I think [inaudible] could be greater than zero.*

*Student3: I would say true.*

*TA: So, wait, what does this have to be?*

*He then immediately answers.*

*TA: This has to be concave up and decreasing. So what does that look like? It looks like this.*

*He points with his index finger at the board and traces the trajectory of the graph.*

*Student1: [inaudible]*

*TA: Say that again?*

*Student1: I mean, if  $F$  double prime of  $X$  is less than zero [inaudible], but in this case, [inaudible].*

*TA: I think you're right, but I don't actually... It would have to look like this, right?*

*But...*

*Student2: But then you'd have to...*

*Student3: It could be infinity minus.*

*Student1: Yeah, it would have to start at negative infinity to come to zero [inaudible].*

*TA: So w-yeah, because if you go this way, you'll have to keep going up, right?*

*He points with his index finger at the board and then traces the trajectory up towards the ceiling and holds it there briefly.*

*Figure 12.* Example 3, the TA using self-directed questions during mathematical explanation.

In the example shown in Figure 12 the TA begins by asking a question (*what does this have to be?*) and then immediately provides the answer (*concave up and decreasing*), he then repeats this action with a different question (*So what does that look like*) and then immediately answers by tracing along the equations trajectory along the graph with his finger (*It looks like this*). These types of questions are referred to here as ‘self-directed’

questions. Although these questions are not necessarily posed directly to the students, they nonetheless result in student responses. The TA asks three self-directed questions and receives a response 1/3 times (See Table 1).

Another type of question commonly observed in the data is ‘checking’ (described by Artemeva & Fox (2011) as an ‘audience check’). In the previous example (Figure 12), the TA ‘checks’ with the class twice by asking “*right?*”. Checking commonly occurs after mathematical explanation and appears to perform a monitoring function; it can be paired with a pan-gaze, and is typically followed by a pause (see Figure 13).

*Professor: Right. So I mean what we said here, you know –if this is the proof. We just have to justify the steps. The point is that the err... If we think of  $F$  and  $G$  as linear functions plus an error, then, because we're only interested in first derivatives, we're only interested in the linear parts. The errors won't matter. Okay?*

*\*Pause, pan-gaze\**

*Professor: That's our intuition is that I can ignore the difference between this squiggly equality and a real equality for the purposes of working out this Jacobian.*

*Student: When does it become significant?*

*Figure 13.* Example 4, the professor using a question in coordination with a ‘pan-gaze’ to monitor student understanding.

Checking, and the pause that typically follows it, allows students the opportunity to ask questions and seek clarification from the instructor. Checking also provides a means for

the instructor to monitor the students' engagement in order to ensure the class is following in the discussion. The TA asks four checking questions and receives responses 2/4 times (see Table 1). The professor asks three checking questions and receives no immediate response; however, from the example shown in Figure 13, it is evident that a student question follows shortly after an instance of checking. Furthermore, it should be mentioned that, for reasons of privacy, the student audience is not visible in the video data, and as a result, any nonverbal responses cannot be accounted for; the students in the audience may well be providing non-verbal assurance of their understanding during these instances of checking such as, for example, head nodding or shaking.

***Pausing.*** A 'pause' in this study is described as a silence spanning no less than 0.6 seconds (the smallest pause captured within the coding). Although pausing is described here as a discursive strategy, it is also considered a nonverbal behaviour. Pausing seems to play an important role in student-instructor interaction for a number of reasons. As mentioned above, pauses commonly follow questions and are used during instances of checking providing students time to respond and interject (this type of pause is often described as 'wait time'). The data shows that 7/26 total student responses and 1/3 of student questions occur directly following a pause (see Table 2). Pausing is also used by the professor for emphasizing certain points during mathematical explanation.

Table 2

*Student Questions*

Student Questions
-------------------

	TA Lecture	Prof Lecture	Total
Following: Pause	0	1	1
Mathematical explanation	0	1	1
Clarification questions	1	0	1
Total student questions	1	2	3

As I discuss below, context and body language appear to have a significant impact on how the instructors create meaning. In the case of pausing, there are several instances in which the participants' non-verbal behaviors, when followed by a pause, seem to communicate to the audience that a question is being posed (Figure 14).

*The TA finishes writing an equation on the board. He steps back and looks at it. He turns slowly to the class and partially closes the textbook he is holding in both hands.*

*\*Pause\* (.67 sec)*

*Student: False.*

*TA: Really? \*laughs\* Why?*

*Student: Because I found that...*

*Figure 14.* Example 5, the TA using a pause in coordination with a shift in focus (from board to audience) in order to elicit a response.

The situational context, paired with the TA's shift of focus from the board to the class, combined with the .67 second pause, turns the entire event into an implied question. This action successfully elicits a response from the audience despite the absence of instructor verbiage. This example, and as already illustrated by the professor in Figure 10,

demonstrates that pauses, when combined with particular stances and gestures, can be used as a powerful interactive tool (the use of stance and gestures is discussed further in the following subsection).

**Commands.** A variety of other discursive approaches in addition to questions have been observed in-use by the participants. As illustrated in Figure 10, the professor poses a question to the class (*How are you gonna prove this?*) followed by a substantial pause (9.4 sec). When this discursive action fails to elicit a response, the professor makes another attempt by issuing a command (*Give me one reason why this is true*) followed again by a pause (2.4 sec). When still no response is heard, the professor softens the command with the addition of the modal auxiliary verb ‘can’ and by widening its parameters (*You **can** [use two if you need to] but if you **can** do it in one...*). The professor issues a total of two commands (see Table 1) to the class and although they do not result in responses (0/3), it does make clear the instructor’s intentions and may help prompt the students to respond. In both cases, when the professor issues a command, it is followed by an additional comment or tag questions, likely to lessen the potential for perceived severity or intimidation.

**Further explanation.** Throughout the data it becomes evident that in all cases when an instructor feels that there is some confusion with the material on the part of the students (made known through a lack of student response, incorrect responses, student questions or requests for clarification), the instructor provides further explanation. The explanation may be regarded by the instructor as a ‘hint’ as seen in Figure 10 (*I keep*

*telling you folks- Don't try to find a proof, understand why it's true and write down that understanding) and again in the example in Figure 15.*

*Student1: I mean that due to like matrix multiplication you should be able to show that*

*Professor: Well...due to matrix multiplication...*

*Professor: Well I mean we need to...so but you still have to... So, if you like, I said prove this formula. If you don't want to prove it you can derive the Jacobian of the composition for me and you're allowed to know the Jacobian of G and the Jacobian of F. And I tell you it is exactly what you would expect if the functions themselves were linear.*

*Professor: \*pause\**

*Professor: Okay-.*

*Student1: So are you...?*

*Professor: Yes that's a hint.*

Figure 15. Example 6, the professor providing further explanation as a 'hint'.

The example in Figure 15 is a continuation of the transcript used in example provided in Figure 11, in which a response is given that the professor wishes the student to expand on (*Matrix properties*). The professor asks for clarification (*What do you mean?*). When the student does expand on his answer, the professor considers the response and seems to feel it is less than satisfactory. The professor, rather than deeming the response incorrect, launches in to further explanation which he then refers to as a hint. The professor will often evaluate an answer as correct by exclaiming 'Right!' when a student displays

understanding. When a student misses the mark, however, or when no student responds surface, the professor provides further explanation.

**Multimodal features.** This sub-section presents observations of the multimodal features used by the participants to elicit responses and promote student participation.

***Focus and gaze.*** Determining the participant's focus in this study involves the consideration of gaze (eye focus) and body orientation (turn). Turning focus towards students seems to be a strategy used by both the TA and the professor when attempting to elicit student responses. In all cases when the professor is attempting to elicit participation from students, his focus is on the audience (body turned to class, gaze directed at student(s)). Although the TA focuses primarily on the board (see Table 3), in all cases, when asking a question posed at the students, he turns his gaze to the class. When the TA is asking self-directed questions, he is focused on the board. It is the act of the TA turning his body and gaze towards the class that seems to imply his desire for a response. This is illustrated in Figure 14 when the TA's focus turns to the students and is followed by a pause; while he is facing the board during a pause, it appears as though he is considering for himself the equation he has written, only when he turns his body to the class does the pause seem to imply a request for a response. The participants also turn their focus to the class during all instances of checking.

Table 3

*Focus and Gaze*

Focus and Gaze				
	TA Instances	TA Coverage	Professor Instances	Professor Coverage
Body facing board	11	22.54%	2	4.30%
Body facing class with head turned to chalkboard	0	0	8	4.04%
Body facing students	7	19.51%	14	53.75%
Gaze at chalk board	19	63.72%	18	17.83%
Gaze at specific student	11	18.79%	16	15.50%
Pan-gaze	8	11.99%	13	41.07%
Gaze on students while asking questions/Total questions asked	12/13	NA	13/13	NA

The participants' gaze seems particularly important during what is described here as a 'pan-gaze'; when a participant's gaze moves from one side of the audience to the other. Both participants conduct pan-gazes throughout the recorded segments. The pan-gaze occurs most frequently when an instructor is awaiting a response from students (as demonstrated in Figure 10) and while 'checking'. The TA engages in a pan-gaze a total

of eight times (11.99% coverage), four of which occur while awaiting student participation and one occurs while checking. The professor conducts a pan-gaze 13 times (41.07% coverage), five of which occur while awaiting student participation and three occur while checking.

***Gestures.*** Findings suggest that there are a variety of gestures and stances (body posture and positioning) which seem to play a role in eliciting responses from students. These include but are not limited to pointing (with the index finger and open hand), gestures of the open hand (prone and supine), and rest positions (hands on hips, and hands crossed in front). Research suggests that some individuals gesture more than others (Kendon, 2004; Merryman & Bronson, 2009) and for this reason, a comparison of gesture use between participants is not considered to be fruitful. Although this may be true in a general sense, because the participants of this study are performing the same genre, in a comparable local context, comparative observations appear more relevant than in other contexts. The professor gestures much more than the TA (the TA engages in 22 instances of gesturing (17.76% coverage) and the professor engages in 64 instances of gesturing (52.04% coverage)) and so, in many cases throughout this section only the professor is referred to for the sole reason that the TA was not observed partaking in a wide variety of gesturing.

***Pointing.*** There are several instances in the data when pointing is used to elicit student responses. Most commonly, participants would point with IFE at a specific

student and the student would provide a response. The TA points one time with IFE directed at a specific student (see Table 4) and he too is met with a response.

Table 4

*TA's use of Pointing Gestures*

Pointing - TA				
	Select student for response	Student response elicited	Pointing at board	Total
Point IFE	1	1	8	9
Point OHP	0		0	0

The professor points with IFE directed at a specific student two times throughout the recorded segment (see Table 5), each time he is met with a response.

Table 5

*Professor's use of Pointing Gestures*

Pointing - Professor				
	Select student for response	Student response elicited	During mathematical explanation	Total
Point IFE	2	2	1	3
Point OHP	0		10	10

When the TA performs the IFE gesture, it is to have a specific response repeated out of several responses uttered, whereas in the case of the professor, the IFE gesture seems to give the student permission to speak. This difference in gestural meaning likely has to do

with the difference in the degree of power held by the TA versus that held by the professor which is discussed further in the following sections.

OHP can also be used in pointing. The professor points using OHP a total of ten times during mathematical explanation (see Table 5). This is similar to Kendon’s (2004) observation that when a participant is pointing with the open hand at an object, it is not the object that is of the primary focus, but rather something related to the topics being discussed (for example, the parameters for understanding an equation rather than the equation itself).

*Open Hand Prone- Vertical Palm and Horizontal Palm.* The professor employs the OHP(VP) gesture once during the recorded segment (see Table 6).

Table 6

*Professor's use of Open Hand Prone Gestures*

OHP- Professor				
	Asking question	Halting line of thought	During mathematical explanation	Total
OHP Pointing	0	0	10	10
OHP (VP)	0	1	0	1
OHP (ZP)	2	0	6	8

In this instance he uses both hands to deliver the gesture while issuing the statement ‘*don’t try to find a proof*’ described in Figure 10. This gesture appears to be

complementing the word ‘*don't*’ and stressing the professor’s desire for the students to halt their line of thinking that they should ‘*try to find a proof*’. Although this gesture itself does not seem to assist in eliciting responses directly, much like pointing with OHP it is used to help shape the mathematical explanation, or in this case ‘hint’, being provided by the professor, thereby playing an important role in promoting participation.

OHP(ZP) is used a total of eight times by the professor (see Table 6). This gesture is used for the most part during mathematical explanation (6/8 instances). But OHP(ZP) gesture is used twice, and is most pronounced, when the professor is attempting to elicit responses from the audience, by asking a question (Figure 16).

*Professor: So, yes if if ***pause***(1.3sec) /G/ and F/ are linear/ ***pause***(1.3sec) then this is true ***pause***(2.8sec)*

*Professor: What if they're not linear?*

*Professor: Then why is it true?*

Figure 16. Example 7, the professor using OHP(ZP) in coordination with a question.

Underline (\_\_\_) - represents the Open Hand Prone (Horizontal Palm) Gesture as it coincides with the spoken discourse

Dash (//) - represents ‘beats’ in the gesture

Bolding (**bold**) - font represents a hold in the gesture

When the professor begins this statement (Figure 16) (*So, yes*), he is already in the preparation phase (Kendon, 2004) of the gesture. He brings his hands up tightly and rapidly, palms facing down in front of him high at chest level, and then vigorously throws them down to his waistline for the word “*if*”. While doing this he brings his shoulders upwards towards his ears and then drops them with his hands. During the first pause he brings his hands, still palms facing down back up to his midline, and holds them there. During the pause he prepares for the next beat of the gesture, bringing his shoulders up again and raising his hands slightly. When he utters the word “*G*” he drops his shoulders and hands down again. With each word that follows he brings both hands up and down in the OHP(ZP) gesture. When the statement “*then this is true*” is uttered, the professor sweeps his hands outwards away from his midsection, hands held in the OHP(ZP) position while paused and conducting a pan-gaze of the audience. He holds his hands apart and with palms facing down throughout the pause. While uttering the question “*What if they’re not linear?*”, he draws his hands up again to his center and sweeps them out to his sides before letting his hands come to rest. The class begins to talk amongst themselves as he repeats the question “*Then why is it true?*”. He repeats the questions more quietly than the first time it is asked and looks around the class for someone ready to answer.

There are a few elements at play here which seem to be aimed at promoting participation. In the initial statement made by the professor (Figure 16), it seems clear that the OHP(ZP) gesture is being used to convey the notion that the statement being uttered (*yes if /\*pause\*(1.3sec) /G/ and F/ are linear/\*pause\*(1.3sec) then this is true*

*\*pause\*(2.8sec)* is complete, requiring no further action. The sweeping away motion which is conducted when the statement “*then this is true*” is uttered seems to further imply that discussion of that aspect of the scenario is done, as though the professor ‘clears it from the table’. When the question is posed to the class “*What if they're not linear?*”, and the professor once again performs the OHP(ZP) with both hands, lifting them up and dropping them, as if he is pushing the question out and away from him for the students to answer. When the professor ‘pushes’ the question away from himself, it seems to imply that he will no longer be engaging with it, that it is now up to the students to think about. This echoes Kendon’s (2004) observation that the OHP(ZP) gesture can be used to mean a statement is complete, requiring no further action on the part of the speaker. The students, likely impacted by the discourse ensemble, begin to talk amongst themselves about the question.

*Open Hand Supine- Palm Addressed, Palm Presentation, and Lateral Movement.*

The OHS gesture seems especially important in the participants’ attempts to evoke responses from the students in the audience. Because this family of gestures is thought to carry the meaning of giving and receiving, it makes sense that it would be employed when instructors are presenting questions to the students, or attempting to receive responses. Both the TA (see Table 7) and the professor (see Table 8) use gestures of the OHS family.

The professor uses the OHS (PA) gesture a total of six times throughout the recording (see Table 8); one instances occurs during mathematical explanation, one instance occurs

while the professor is asking a question, three instances occur while acknowledging what a student has said is correct, and one instance occurs while ‘checking’.

Table 7

*TA's use of Open Hand Supine (OHS) Gestures*

OHS- TA		
	Presenting a question	Total
OHS(PP)	1	1

Table 8

*Professor's use of Open Hand Supine (OHS) Gestures*

OHS-Professor							
	Asking Question	Checking	Acknowledging correctness	Offering an alternative	Issuing a command	Mathematical explanation	Total
OHS(PA)	1	1	3	0	0	1	6
OHS(PP)	0	0	0	1	0	5	6
OHS(PL)	0		0		1	2	3

According to Kendon (2004), OHS(PA) can be used during conversation to acknowledge an interlocutor as the source of something or to indicate what an interlocutor has said is correct. The professor uses OHS(PA) in this way three times. The most notable and pronounced instance in which this gesture is used to elicit responses from students, however, occurs during the discourse provided in Figure 10:

Professor: *But, you know, just what's your intuition? / Why/ should/ this be true?*

During the preparation phase of this gesture the professor is uttering the words “*you know, just*”, he furrows his brow and purses his lips. He brings both hands up to either side of his shoulders, palms facing in, and spreads his fingers apart while lowering his whole body slightly. As he performs this discourse ensemble, one is given the impression that the professor is fully engaged in the desire for the students to respond, as though he is trying to draw something out from the audience. As he says “*what’s your intuition*” he moves his hands out in front of him and towards the audience (palms still facing in and spreading his fingers further). The word “*Why*” is stressed, the professor brings both hands in towards him and out again, repeating this movement three times throughout the remainder of the utterance.

The OHS(PA) gesture, when used in such an animated way, gives the impression that the professor is completely consumed with the want to receive a response from the students. The professor is constantly looking around the class at his students while engaged in this appeal, and after he has issued a hint, the students begin to come forward with responses. This supports Kendon’s (2004) claim that in the ‘question’ context, this gesture can be used to mean something specific has been indicated that the speaker desires to obtain from the interlocutor.

Both the TA and the professor display OHS(PP). The professor uses the OHS(PP) gesture primarily during mathematical explanation (5/6 instances) when presenting advice or instruction to the students in the audience. This agrees with Kendon’s (2004) suggestion

that OHS(PP) can be used when a speaker is explaining the meaning of a term or phrase, or when expounding the premises or conditions for understanding something. The professor also uses it once to present an alternative approach to the students (see Figure 17).

*Professor: So but you still have to... So, if you like, I said prove this formula. If you don't want to prove it you can derive the Jacobian of the composition for me and you're allowed to know the Jacobian of G and the Jacobian of F.*

*Professor: And I tell you it is exactly what you would expect if the functions themselves were linear*

*Figure 17.* Example 8, the professor using OHS(PP) while presenting an alternative to the students.

In this example the professor is referring to instructions he had given earlier (*Let's prove this. How are you gonna prove this? Tell me in one sentence why it's true*). After receiving two inadequate responses, he presents to the students this alternative (*So, if you like... you can derive the Jacobian of the composition for me and you're allowed to know the Jacobian of G and the Jacobian of F*). In this case the OHS(PP) gesture is serving to 'present' an alternative approach to the initial instructions which the students seemed to struggle with.

The TA uses OHS(PP) in only one instance (Table 7). He uses the gesture to elicit a response from the students by presenting an equation to them (Figure 18).

*The TA writes an equation on the chalkboard and turns to the class. Moving his left hand from his cheek he places it under the equation and looks quizzically at the students, raising his eyebrows. He lowers his hand slightly and holds it in position-*

*TA: \*pause\*(2.1sec)*

*When he is met with no response he breaks his pose, drops his hand, laughs and verbalizes the question*

*TA: Do you believe this one? You don't believe this one?*

*Figure 18.* Example 9, the TA using OHS(PP) to present a question to the students.

In this example, the TA seems to be using the OHS(PP) gesture in lieu of an introduction. This would complement Kendon's (2004) claim that the OHS(PP) is typically being used in coordination with a speaker introducing something he or she is about to say. Although the gesture matches OHS(PP) in form, another interpretation could be that it is playing the role of OHS(PA) in order to 'present' the object to the audience as something to be inspected for some quality the speaker wishes to draw attention to (i.e., true or false). In any case, the gesture is being deployed for the purpose of eliciting a response from the students.

The professor uses OHS (PL) a total of three times during the recording (see Table 8).

The majority of instances occur (2/3), during mathematical explanation; however, one

instance occurs while trying to elicit responses from students by issuing a command (Figure 19).

*Student1: When does it become significant?*

*Professor: Ah well we have to find out. When it- when would it... Okay so the question is when does it become significant? Answer it!*

*Professor: When will the error become significant?*

*Student2: Whenever Y is large*

*Figure 19.* Example 10, the professor using OHS(PL) while issuing a command.

In this example a student asks the professor a question. The professor begins to answer it, but then repeats the questions to the class and commands the students to answer it. When the professor exclaims “*Answer it!*”, he throws his hands forward then laterally backwards and away from his midsection with palms up in the OHS(PL) gesture. As described by Kendon (2004) OHS(PL) can be used when a speaker expresses unwillingness or inability to intervene in something, or when the speaker indicates that the other is free to do something. In this case it is most likely being used to express the professor’s unwillingness to intervene in the student’s query, leaving it to the other students in the audience to answer. This gesture could also be interpreted as the professor offering-up the question to the class implying that the audience is free to answer it. When uttering the question “*When will the error become significant?*”, the professor engages in the same OHP(ZP) gestures described in Figure 16, as if pushing the question towards the

audience in a sweeping motion. This sweeping gesture contributes to the impression that the professor is refusing to engage with the question, thereby insisting that the students respond to it.

**Similarities in participants' use of discursive strategies and multimodal features.**

Observations of the participants' teaching practices show a significant number of similarities in their performance, discursively as well as multimodally. Both participants ask questions in order to interact with students (Table 1). The questions asked by the TA and the professor are remarkably similar and limited to questions about the subject at hand (mathematical), clarification, and checking questions. Both the TA and the professor engage in mathematical explanation and pause after asking questions and while checking. The participants both shift their focus from board to students as they move from writing on the board to providing explanation, and asking questions. While explaining and monitoring during their performance, their eyes move in the same fashion; focusing on the board, or down at their notes/textbook, and at specific students or across the audience in a pan-gaze. Although the professor gestures more than the TA, both participants engage in similar types of gesturing; they both point at students using IFE to prompt a response, and at the board during explanation. Also, both the participants were observed using OHS gestures in order to 'present' questions to the students. The similarities in the participants' discourse, movement, and gestures, are present in the higher-level actions of their teaching practices, as well as lower-level actions, some of

which are so discrete (eye movements, for example) their discovery may have gone unnoticed if not for the fine-grained nature of this study's analytical framework.

### **Observed Differences Between Teaching Assistant and Professor**

Similarly to Artemeva and Fox's observations (2011; Fox & Artemeva, 2011), in addition to the striking similarities in the performance of the chalk talk genre, some differences between the TA and the professor were observed. These differences are grouped into two sub-sections: Formality and Power Sharing which include observations of the degree to which the participants present themselves as formal or informal, and power sharing or power centric, and Lecturing Style which provides observation about the participants' use of mathematical explanation, questions, and checking.

**Formality and power sharing.** The most visible differences between the TA and the professor is the level of formality they exhibit as lecturers, and the degree of power sharing that they present during their performance. The TA is less formal and engages in more power sharing than the professor. The TA displays several elements which convey informality. His attire appears informal: an untucked shirt, unbuttoned sleeves, and partially unbuttoned front. The TA exhibits nonverbal behaviours which can be perceived as informal. He is often observed touching his head or face (6 instances, 22.58% coverage), making puzzled faces, and sighing as if he were thinking or 'stumped' on a question. He is observed lightly kicking the wall (one instance), flicking chalk (one instance), and using humour/laughing (9 instances, 13.66%). He also adopts an informal stance (Table 9): when in a rest position his arm is at his side or with chalk partially

engaged and holds the textbook in the other hand for the majority of the segment (1 instance, 75.52% coverage), yet only references it once (1 instance, 0.98% coverage). His casual appearance and informal actions appear to create a less authoritative teacher persona and seem to lessen the social distance between himself and the students.

Table 9

*TA's use of Textbook and Rest Positions*

TA's use of Textbook and Rest Positions					
	Asking question	Facing board, thinking	Listening	Total instances	Total coverage
Arms at side holding textbook	3	3	2	8	
Chalk partially engaged holding textbook	0	2	0	2	
Holding Textbook				1	75.52%
Referencing Textbook				1	0.98%

The professor exhibits more formality during the recorded segments. He appears more formal in his attire; a fully buttoned up, tucked-in shirt with rolled up sleeves. The professor writes questions on the board and then poses questions and commands to the students with great confidence. His rest positions also seem more authoritative in nature; for instance, when the professor is paused waiting for a student response he is more likely to stand in a rest position with his hands on his hips, or his hands crossed in front than with his arms at his side. When listening to a student or during mathematical explanation, he is more likely to stand with his arms at his side (Table 10). When the professor is standing with his hands on his hips, or with his hands crossed in front, he seems to be

putting more pressure on students to answer than when occupying a rest position with his arms at his side. He leaves his notes on the desk and walks to the desk to reference them. His more formal approach to lecturing seems to create a more authoritative teacher persona, and there seems to be more social distance between the students and the professor. This is demonstrated by the students tendency to await the professors permission to respond (usually given with an IFE gesture), whereas the students shout out their answers to the TA and do not wait for permission to speak.

Table 10

*Professor's use of Notes and Rest Positions*

Rest Position- Professor					
	Waiting for response	Mathematical explanation	Listening	Total instances	Total coverage
Hands on Hips	2	1	0	3	
Hands Crossed in Front	4	0	2	6	
Arms at side	1	2	2	5	
Holding Notes				1	2.97%
Referencing Notes				2	0.1%

The TA engages in more power sharing than the professor. This power sharing is displayed in a variety of ways. Firstly, he uses a variety of hedges, conveying imprecision or uncertainty or lessening the force of what is said, such as the expression ‘I think...’ (two instances) and the modal verb ‘could’ as in ‘you could probably...’ (two instances). Secondly, the TA never issues commands and rarely pressures the students to respond. The TA also exhibits power-sharing by checking with the students if what he has said or

written is correct, as in Figure 12 (*It would have to look like this, right?, you'll have to keep going up, right?*). This discursive approach may contribute to the TA seeming as though he is, at times, lacking confidence, as does his tendency to hold the textbook without referring to it. Also important to note is the TA's tendency to display what seems to be unintentional power sharing; he does this by appearing stumped, engaging in self-talk (Figure 12), or by self-proclaiming a lack of knowledge about a problem (Figure 20).

*TA: Yeah, I think it's false*

*He walks up to the chalkboard and writes FALSE and then steps back while continuing to face the board.*

*TA: Umm, you know what? You could probably...*

*He scrunches up his face and runs his hand along the ridge of the chalkboard. He pauses and twists his body before lightly kicking the wall. He leans forward and flicks the chalk along the ridge of the chalkboard.*

*TA: You could probably uh, use the mean value theorem*

*He lifts chalk brush in the air, and holds it up beside his head. He then turns to face the class and wrinkles his nose up to look displeased. He begins to laugh as he erases the board and turns his head again to the class.*

*TA: \*Laughs\* Ah, T.A.s making stuff up.*

*TA: \*Laughs\**

*He walks to the board and writes the three dots of an ellipsis indicating an unfinished thought following "False ... " and then writes the number marking the next question. He laughs and turns his head again to the class.*

*TA: \*Laughs\* Unsatisfactory*

*Figure 20.* Example 11, the TA self-proclaiming a lack of knowledge.

In this example the prominence of hedges observed in the TA's discourse becomes obvious (*Umm you know what?, You could probably(x2), uh*), as does the occasional uncertainty he displays during mathematical explanation (*TAs making stuff up, Unsatisfactory*). His casual nature is also displayed by his frequent laughter, funny faces, fidgeting, and stance (lightly kicking the wall, twisting his body, leaning forward to flick chalk). Interestingly, although the TA seems unconfident in his mathematical knowledge at times, and works together with the students to solve equations, when a student is confused, the TA does step into a 'masterful' role and confidently provides mathematical explanation (Figure 21).

*TA: You believe this one? You don't believe this one?*

*Student: I don't get it.*

*TA: Well, these are both increasing, right? This is obviously increasing. Do you know what this looks like? This is increasing. If the derivative is one over...*

*Figure 21.* Example 12, the TA providing mathematical explanation.

In this example the TA poses a question to the students and presumably (not seen on the video), a student signals to him that she is experiencing uncertainty. The TA seeks

clarification from her, inquiring if her uncertainty is in the “truth” of the equation (*You don't believe this one?*). When the student makes her uncertainty known, without judgment or negative evaluation, the TA launches into further explanation, monitoring her understanding along the way (*right?, Do you know what this looks like?*). A glimpse of his mathematical confidence can be sensed by the use of the word “*obviously*” (*This is obviously increasing*). This observation suggests that perhaps the TA's ‘uncertainty’ is, in fact, an element of his informal teaching style.

The professor appears to exhibit less power sharing and seems more power centric. There are no instances of hedging as is observed in the TA's speech. The professor employs a different type of modality which is seen as giving permission (*you can, you're allowed to, don't try to*) (Biber, Conrad, & Leech, 2002, pp. 174-180). During mathematical explanation the professor expresses an air of confidence, never asking students if what he has said or written is correct, and never expressing uncertainty about his mathematical knowledge. The professor issues commands to the students and when posing questions to the students he is persistent, using gestures, repetition, and stance to encourage students to respond. The stances used by the professor when awaiting student responses (hands on hips, crossed in front) also serve to exert his power over the class. These stances give the impression that he will not continue the lecture until a response is put forth. The professor is never seen as apparently unintentionally power sharing.

**Lecturing style: Mathematical explanation, questions, and checking.** The TA's lecturing style, as previously mentioned, appears less formal and involves more

power sharing than is exhibited by the professor. The TA takes the approach of writing questions on the board and solving them together with the students (a difference which could be attributed, in part, to the fact that the TA leads a problem solving session, while the professor is lecturing). The TA engages in less mathematical explanation (two instances) than the professor and asks fewer mathematical questions (three instances) (Table 11).

Table 11

*Discursive Strategies, Comparative Breakdown*

Discursive Strategies		
Questions:	TA	Professor
Mathematical	3	8
Self-directed	3	0
Total Questions	15	13
Mathematical explanation	2	11
Commands	0	2
Repetition student responses/Total student answers	4/19	7/7
Repetition student questions/Total student questions	0/1	1/2
Direct evaluation of student answers	0	3

The TA seldom repeats student questions and answers aloud (4/19 total student responses, 0/1 questions) and does not proclaim the answers correct or incorrect.

Similarly, when a student asks a question he does not repeat the question aloud but simply tries to provide an answer. The TA also engages in longer pauses than the professor. Although both participants engage in relatively the same number of pauses, the TA pauses for more than twice as long as the professor (Table 12).

Table 12

*Pausing, Comparative Breakdown*

Pausing		
	TA	Professor
Total instances	11	13
Total coverage	34.45%	15.81%

The professor's seemingly more formal approach also involves writing questions on the board, but he does not attempt to solve the problems with the students, rather, he constantly urges the students to answer independently. The professor engages in many instances of mathematical explanation (11 instances) and asks many mathematical questions (eight instances) (see Table 11). When a student answers a question, the professor routinely repeats the answer aloud (repeats 7/7 total student responses). In the event of a correct response, the professor will exclaim that the answer is correct (three instances), and use the answer to advance the explanation. When a student asks a question, the professor will typically repeat the question, but does not attempt to provide an answer, rather, he will rephrase it as a question for the students to answer (Figure 19). The professor routinely engages in checking to ensure the class is following along by asking 'ok?' usually coinciding with a pan-gaze.

Furthermore, the TA spends more time focused on the chalkboard, while the professor spends more time focused on the class (see Table 13). The TA turns his body to face the class a total of seven times (facing class 19.51% coverage), he turns his body to face the board 11 times (facing board 22.54% coverage). The TA's gaze is directed at the chalk

board for the majority of the recorded segment (19 instances, 63.72% coverage), he focuses on specific students 11 times (18.79% coverage), and engages in a ‘pan-gaze’ eight times (11.99% coverage).

Table 13

*Focus & Gaze, Comparative Breakdown*

Focus & Gaze				
	TA Instances	TA Coverage	Professor Instances	Professor Coverage
Body facing board	11	22.54%	2	4.30%
Body facing class with head turned to board	0	0	8	4.04%
Body facing students	7	19.51%	14	53.75%
Gaze at board	19	63.72%	18	17.83%
Gaze at specific student	11	18.79%	16	15.50%
Pan-gaze	8	11.99%	13	41.07%

The Professor keeps his body turned towards the class for the majority of the recorded segment (14 instances, facing class 53.75% coverage). He turns his body to face the chalkboard only two times (facing board 4.30% coverage). When he does need to look at the chalkboard, he rarely turns his back to the class, rather, he remains turned to the class with his head facing the board (8 instances, 4.04% coverage). The professor directs his gaze at the chalkboard 18 times (17.83% coverage), he focuses on specific students 16

times (15.50% coverage), and engages in a pan-gaze 13 times (41.07% coverage).

Although the TA spends more time focused on the chalkboard while the professor spends more time focused on the students, the TA is met with significantly more student responses (19 instances) than the professor (seven instances).

The findings of this study confirm that the chalk talk genre (cf. Artemeva & Fox, 2011; Fox & Artemeva, 2011) is performed by the participants in a way that is remarkably similar across contexts. Both participants use a variety of the same discursive and multimodal strategies in order to elicit responses from students and promote participation in the classroom. It does seem evident though, there are certain differences, particularly in formality, power sharing, and lecture style between the performances of the less experienced TA, and the very experienced professor.

## **Chapter 5: Discussion**

This study has revealed a variety of typified and recurrent elements enacted by the participants during their performance of the chalk talk genre, in addition to the characteristics already described and discussed in previous studies (Artemeva & Fox, 2010, 2011; Fox & Artemeva, 2011). By conducting an in-depth analysis of the co-occurring elements of metadiscourse, movement, gestures, and student interaction, this study demonstrates that features of the genre recur across contexts even on a minute level. Observations show that there exist remarkable similarities in the teaching practices of the TA and the professor both discursively and multimodally. Several subtle differences also exist between the ways in which the less experienced TA and the very

experienced professor conduct themselves while performing a chalk talk lecture. This section discusses the relevance of these findings in light of the theoretical framework that has been presented and will be further illustrated using past and current research in student engagement and pedagogy in order to answer the research questions:

- 1) How do instructors attempt to elicit responses and promote participation from students in an undergraduate mathematics lecture?
- 2) Is there any difference between the teaching practices of a less experienced TA and a very experienced professor while instructing undergraduate mathematics classes?

In addition to answering these questions, this section provides observations regarding the inherent interactive nature of the chalk talk lecture.

### **Eliciting Responses and Promoting Participation**

During the performance of a chalk talk lecture, participants attempt to elicit responses and promote participation from students by using a variety of discursive strategies which are combined and performed concurrently with a range of complex, multimodal features.

These discursive strategies and multimodal features include:

- **Asking questions** about what they have written on the board, as well performing audience checks, asking for clarification, using self-directed questions, and repeating questions and answers.

- **Providing further explanation** when no response is heard or when students have ‘missed the mark’.
- **Pausing** before and after asking questions, during instances of checking, while listening to students and briefly after student responses.
- **Issuing commands** which are followed by other discursive strategies.
- **Avoiding negative evaluation** of student responses.
- **Shifting focus** from board to students to signal the desire for a response
- **Gaze** participants use a directed gaze when attempting to elicit a response from a specific student, or a pan-gaze when attempting to promote participation from the audience and while checking
- **Gesturing** using the Index Finger Extending when pointing at a specific student; using the Open Hand Prone (Horizontal Palm) and gestures of the Open Hand Supine family when attempting to promote participation from the group

**Discursive strategies.** The findings of this study show that in order to elicit responses, the participants engage in a running commentary (often referred to here as mathematical explanation) and then turn to the class and talk about what they have written (metacommentary). The majority of discursive features used by the participants in order to elicit responses from students occur in and around their metacommentary.

The discursive features used by participants to elicit responses from students include, firstly, asking questions. Both participants appear to pose mathematical questions to the students in order to promote participation in the classroom, engage students in a two-way

discourse, and monitor understanding. The professor was observed using ample repetition during his performance of the chalk talk genre. He was observed repeating not only questions about the subject matter but also repeating student questions and student responses aloud for the students to hear. Sometimes when a student asked a question, the professor was observed repeating the question, and then reposing it for the students to answer.

Speer, Smith III, and Horvath (2010), in a study of collegiate mathematics teaching, explain that teacher questions are used to engage students in the teachers' presentation as well as to reveal aspects of students' thinking. They also suggest that questions serve to guide the teacher's decisions such as "should I move on because they understand, or back up a bit?" (p. 109). This observation supports the notion that questions are used by the participants not only to engage students in the lecture, but also to monitor their understanding. Checking questions, or conducting 'audience checks', were also used by the participants for the purpose of monitoring. Although checking did not always result in verbal responses from the students, it did allow students the opportunity to ask questions. Speer, Smith, and Horvath's work speaks to the nature of the explicit 'checking' questions that were observed being used by the participants. Although it is difficult to assume the participants' intentions when asking questions of a mathematical nature, questions such as "*Right?*", "*Okay?*", and "*Do you believe this one?*" clearly serve to monitor student understanding.

Clarification questions were also used by the participants to elicit student responses.

When a response was inaudible, or when the participants needed more information about a student's line of thought, they asked clarification questions; clarification questions were most likely to receive a response from students.

The TA used self-directed questions during mathematical explanation, in coordination with checking questions. These were the only questions which were posed by the participants while not focused on the students. Although these self-directed questions were not necessarily directed at the students, they nonetheless were met with student responses. A study by Hall and Smotrova (2013) of a different pedagogical genre in teaching English as a Second Language (ESL), suggests teacher self-talk makes visible for students the teacher's position as a struggling instructor allowing them to imagine the teacher to be more like themselves. The authors have observed that self-talk appears to engender cooperative participation in the form of self-initiated emphatic responses from students. The TA received 11 self-initiated student responses during the recorded segment, whereas the professor, who did not ask any self-directed questions, did not receive any self-initiated responses. This may suggest that self-directed questions, although not explicitly directed at students, is one way that participation is promoted in a chalk talk lecture.

Pausing also seems to be a strategy used by the participants to elicit responses from students. Both participants pause after asking questions, and when checking. In certain cases pausing, in coordination with a shift of focus from board to audience, seemed to

imply non-verbally to the students that a response was desired. Speer, Smith, and Horvath (2010) note that wait time, and instructor reaction/evaluation are important components of teacher questioning. They go on to state that wait time influences students' sense of the teacher and the teacher's expectations for the students (p. 109). Another study (Budd Rowe, 1986) conducted in a different context (elementary through college classes, mostly in science and literature) illustrates the importance of pausing in eliciting student responses and promoting classroom participation. Budd Rowe describes major outcomes of nearly 20 years of her research on pausing and wait time. She found that longer wait times following questions (ideally spanning more than three seconds) amounted in a significant increase in frequency and length of student responses. Additionally, Budd Rowe's work found that the use of longer wait times after questions caused the variety of students who voluntarily participate in classroom discourse to increase, while instances of students 'failing to respond' decreased. Budd Rowe's research also suggest longer wait times following student responses. According to Budd Rowe, a longer wait time provided after student responses results in further elaboration and increased student to student exchanges. Many of the pauses that my study's participants engage in span much longer than three seconds; in the example provided in Figure 10 the professor pauses for 9.4 seconds, and the TA in one instance pauses for 11 seconds.

It should also be noted that the professor, when pausing and awaiting student responses, uses a specific stance as his rest position. When the professor is attempting to elicit responses he most commonly stands with his hands on his hips, or with his hands crossed

in front. These stances seem to project the professor's authority over the class while conveying the impression that he will not continue the lecture until a response is given.

Finally, the professor attempts twice to elicit responses from the audience using commands. These commands are not met by responses, however, but do seem to make clear the instructor's intentions and may help encourage the students to respond. In one instance the command is quickly rephrased as a question. In another instance command is followed by a pause, and when no response is heard, the professor broadens the parameters of the command followed by further explanation (Figure 10). In this study, it seems as though commands are used to elicit feedback only in coordination with other discursive strategies.

The findings show that further explanation or 'hinting' is another discursive strategy used by the participants to elicit student responses. Speer, Smith, and Horvath's (2010) study may help to explain the role this strategy plays in student-instructor interaction. When attempting to elicit a response and receiving none (as is the case in Figure 10), or when receiving a response which is incorrect (Figure 15) the instructor is made aware that he may need to 'back up a bit' and offer further explanation, or a 'hint'.

The participants' strategies of 'backing up a bit', or providing further explanation when reacting to student responses which 'miss the mark' may also play an important role in promoting participation in the classroom. Speer, Smith, and Horvath (2010) state that teachers must weigh a range of considerations when reacting to student responses and

that their reactions carry evaluative content in regards to whether the response was taken as right or wrong, or valued or not. They suggest that when reacting to student responses, teachers commonly a) request further clarification, b) seek a second opinion from another student, or c) evaluate the response directly or indirectly (p. 110). Both the TA and the professor seem to avoid negative evaluations of student responses. In several cases, when met with a less-than-satisfactory answer, the participants will seek clarification (Figure 11, Figure 14) in an attempt to glean more information about the students' line of thought. Only the professor is observed evaluating responses directly, and only when the answer is correct and the evaluation is positive (e.g., "*Right!*"). When an answer is incorrect, the participants evaluate it indirectly by refining or reposing the question, or by issuing further explanation. To further illustrate this phenomenon, a study conducted by Sime (2006), in the context of a language learning classroom, discussed adult students' need to feel comfortable with classmates and within their learning environment to participate without fear of being ridiculed or dismissed (p. 222). Avoiding the use of negative evaluations of student responses likely helps the participants establish learning environments in which students feel comfortable participating without risk of dismissal or embarrassment. As will be shown in the following subsection, teachers' multimodal features can also play an important role in establishing a participatory classroom environment.

**Multimodal features.** The participants use a variety of multimodal features in coordination with discursive strategies in order to elicit responses from the students and

promote participation in the classroom. Once again, these multimodal features are strikingly similar in both participants' enactment of the chalk talk genre.

Both participants use focus and gaze in order to elicit responses from the students. In all cases when participants desire a response from the students, they turn their body (or at very least their head) and direct their gaze towards the audience. When desiring a response from a single student, or when listening to a response, they direct their gaze at a specific student. When asking checking questions, or when attempting to elicit responses or promote participation from the students as a whole, the participants engage in pan-gazing.

In the context of the language learning classroom, Sime (2006) notes the role that gestures and other non-verbal behaviours play organizationally as well as emotionally in the classroom. Adult ESL students in Sime's study mention the use of gaze and focus in teachers' monitoring, saying that the teachers would turn and look from student to student to show that they were being monitored. Another student that Sime interviewed mentioned that if the student 'looked up' at the teacher during this monitoring sequence while the rest of the class was working, it meant that the student needed help. Sime's findings show that learners interpret teachers' actions holistically and that the participants of Sime's study perceived themselves as reacting constantly to the teachers' nonverbal behaviours in a way that furthered their learning and preserved classroom cohesion (p. 224). Much like the teachers described in Sime's study, in the context of a chalk talk

lecture both the TA and the professor constantly used focus and gaze to monitor student engagement and understanding.

A variety of hand gestures are also used very explicitly to elicit responses from the students. For instance, pointing with IFE is used to elicit student responses from specific students, seemingly either by granting permission to speak, or singling out a response from many put forth. This echoes Kendon's (2004) observation that IFE is most likely to be used when a speaker singles out a specific individual which is to be attended to (pp.205-207). Both participants are observed pointing at a specific student using IFE, each occurrence of the gesture when used in this context is met with a response. Sime's (2006) study also mentions the language teachers' ability to control classroom interactions through the use of pointing. Adults ESL students in Sime's study noted that the teachers would use pointing to lead classroom activities and control turn-taking, saying explicitly that if the teacher pointed at you, it meant they were required to answer. This example illustrates the role that pointing can play in eliciting student responses.

OHP(ZP) is used to elicit responses while asking questions. When used in this context, the professor seems to be 'pushing' the questions towards students. This context is similar to Kendon's observation that OHP(ZP) is used when reference is made to circumstances in which no further action is necessary (p.255), however, in these cases it seems as though the professor is implying that no further action is necessary on *his* part, and it is now the students turn to engage.

OHS gestures, which Kendon (2004) describes as a gesture family of ‘offering’, ‘presenting’, and showing ‘readiness to receive’ (p.273), are also used by the participants to promote participation. Most notably, OHS (PA) which Kendon suggests when directed towards an interlocutor is used by the speaker to indicate that he or she expects to receive something (p.272). The professor uses the PA gesture while attempting to elicit responses by combining this gesture with questions about the subject matter (see Figure 10 and Appendix C for a detailed example of this phenomenon). OHS (PP) gestures are used by the participants to promote participation by ‘presenting’ questions to students, or ‘offering’ alternative strategies for problem solving. OHS(PL), Kendon (2004) suggests, can be used to express an unwillingness or inability to intervene, or implies the listener is ‘free to act’ (p.275). The professor seems to use the gesture in this context when attempting to elicit responses from the students by issuing a command. When the OHS(PL) is used in coordination with a command, it seems to imply the professor’s unwillingness to intervene, leaving the students free to respond.

Pointing as well as OHP and OHS gestures seem to be used throughout mathematical explanation as well as when the participants are explicitly attempting to elicit responses and promote participation. Although these gestures are not used explicitly to suggest the offering, or presenting of questions, the ‘shifting’ of turn-taking, or the desire to receive responses they do none-the-less serve interactive functions. The gestures used by the participants during explanation may help to shape commentary and metacommentary, suggest enthusiasm, or acknowledge students’ contribution thereby playing an important role in promoting participation.

Sime's (2006) study of the significance of nonverbal cues in language teaching describes an instance when an instructor reacts to a student's correct response by smiling and pointing to him with an open hand. A student in the study describes the event in the following way:

She indicates Ronaldo with her hand and smiles at him to show to the rest of the group that he has a good answer. So everybody has now a feeling that if you give a good answer you will be appreciated and that makes you feel self-confident (p. 221)

The professor in my study engages in a very similar discourse ensemble when acknowledging what a student has said is correct by gesturing towards them using OHS(PA), a function of the gesture observed in Kendon's (2004) research. This speaks to the benefit of a supportive learning environment and the emotional impact that gestures and other nonverbal cues can have on students.

The findings make apparent that interactive gestures are frequently used by the participants in order to control speaking turns and promote participation by seeking and requesting responses. The participants also use interactive gestures to acknowledge contributions and check understanding, and to guide students' line of thinking while problem solving. These findings agree with past research which explored the nature of interactive gesturing (Bevelas, Chovil, Coates, & Roe, 1995; Kendon, 2004; McNeill, 1985; 1992; Roth, 2001). Additionally, the participants' full involvement of their bodies in the lecture process, particularly the passion and enthusiasm that is evident in the professor's performance, could prove important for maintaining student engagement.

Studies in various educational contexts showed that nonverbal behavior helped to convey to students their teachers' enthusiasm and positive stance during a lesson (e.g., Ambady & Rosenthal, 1993; Sime, 2006; Tin, 2009).

### **Similarities in Genre Enactment**

The participants of this study were not only observed performing all the same genre characteristics as described by Artemeva and Fox (2010, 1011; Fox and Artemeva, 2011), they engaged in remarkably similar discursive strategies and multimodal features when attempting to elicit responses from students. Having magnified and expanded on several of the aforementioned genre characteristic included commentary and metacommentary, asking questions, and moving in space, findings reveal typified and recurrent features present at even a minute level. Despite variance in teaching location, educational backgrounds, and levels of experience, participants used largely the same discursive strategies in order to elicit responses and promote participation from students. The only exception to this is the use of self-directed speech by the TA, and the use of commands by the professor, both of which may be related to level of experience or genre mastery.

Furthermore, both participants engage in largely the same non-verbal behaviors to interact with students. Similarities in nonverbal behaviors include the same use of eye-movements while listening, checking, and eliciting; and the same shifts in focus when desiring a response. Finally, both participants use relatively the same gestures when attempting to elicit responses and during mathematical explanation. Both participants engage in pointing at the board during instances of explanation, and at students in order

to elicit responses. Finally, both participants use gestures of the OHS in order to ‘present’ questions to the students. These rhetorical similarities reveal the typified, recurrent and inherently multimodal nature of the chalk talk genre even when scrutinized to the microlevel of eye movements, hand, and body positioning.

### **Observed Differences between Teaching Assistant and Professor**

Although the participants’ enactment of the chalk talk genre is comprised of a complex intertwining of typified and recurrent rhetorical conventions there also appear to be a variety of subtle differences between the ways the less experienced TA and the very experienced professor perform the genre. These differences include:

- **Level of formality:** the TA conveys a less formal teaching style than the professor.
- **Degree of power sharing:** the TA engages in more power sharing while the professor appears more power-centric.
- **Degree of confidence conveyed:** the TA seems less confident than the professor during his performance of the genre.
- **Primary focus:** the TA’s primary focus seems to be on the chalkboard while the professor’s primary focus appears to be on the students.
- **Degree of control over student responses:** the TA does not attempt to control student responses while the professor has full control of student responses.

As discussed in the theoretical framework of this study, Lave and Wenger (1991) define CoP as being formed by people who engage in a process of collective learning in a

domain of shared goals, values, and beliefs. In CoP novices begin learning at the periphery as described in LPP; they become acculturated by working on authentic activities, gradually moving towards the full participation state. The participants of this study are members of the CoP of university mathematics teachers. The TA, although not a true novice, is still situated closer to the periphery than the professor who has decades of experience (an “oldtimer” in the CoP). Although the TA is engaged in complex and legitimate tasks of teaching and genre production, he is still learning within the CoP, moving towards full participation and genre mastery. Previous research on the chalk talk genre (Artemeva & Fox, 2011) indicates some differences in genre enactment attributable to individual and cultural variance; elements such as formality, power-sharing, confidence, and audience control, on the other hand, may be also related to experience.

Observations in this study show noticeable variance between the level of formality and degree of power sharing exhibited by the participants. Lowe and Pugh (2007) conducted a study within a school setting of 30 teaching assistants enrolled in a BA (Hons) Education course in order to understand more about the participants’ perception of power within their position as TAs. Lowe and Pugh suggested that TAs’ conception of power is embedded in the structure of the institution and therefore is closely linked with the ‘head teacher’. TAs in Lowe and Pugh’s study indicated that they did not perceive themselves to have power because of the lack of status associated with the role of TA. Many TAs in the study also identified lack of qualifications as a reason why they did not have power. Furthermore, these TAs saw the head teacher as the most powerful person in the school due to factors such as position and expertise. Lowe and Plugh’s study may help to explain

why the TA in my study used such a high degree of power sharing (both seemingly intentionally and unintentionally) within his performance of a chalk talk lecture, and also supports the notion that many of the differences displayed by the TA may have to do with the degree of participation within the CoP.

Observations in my study show the TA focused primarily on the chalkboard while the professor focused primarily on the students. This finding supports observations made by Fox and Artemeva (2011) which suggest that “novice professors are much more likely to orient themselves towards the board for a high percentage of the lecture time” (p.96). Focusing primarily on the chalkboard without attempting to control student responses further portrayed the TA as ‘on the same level’ as the students. The professor was primarily focused on the class, constantly monitoring students’ understanding while pressuring them to engage and participate. Although the professor seemed to be putting more effort into urging the students to respond (by using more interactive gestures, repetition, and by asking more mathematical questions), the TA received more than twice the number of responses. This phenomenon could be the result of the TA engaging in longer pauses, or using self-talk which may help to elicit self-initiated responses from students as previously discussed, however, another explanation could be the TAs lack of control over student responses.

Although the TA’s approach results in a highly participatory environment, controlling student responses may at times be important for a number of reasons. In Artemeva and Fox’s (2011) study, a Russian-Israeli professor comments on the outspoken nature of

Israeli students during lectures. The professor acknowledged that student responses are incredibly valuable in order to understand that students are learning, however, he went on to say that these students were so outspoken that if he did not control the flow of questions, the lecture could not move forward. This example speaks to the very important role that student interaction plays in undergraduate mathematics teaching, but also highlights the need for instructors to have some degree of control over student responses.

Furthermore, the method of selecting respondents using pointing, used by the professor in my study, has the potential to allow equal opportunity participation for quiet, timid, or underrepresented students (students who make up the minority in the mathematics community). For example, Rodd and Bartholomew (2006) conducted a longitudinal study of a group of women attending undergraduate mathematics lectures. They observed that although female enrollment in mathematics programs was on the rise, women were still very much the minority.

Rodd and Bartholomew also found that although the women in the study did participate, they were less likely to provide self-initiated responses and speak up with questions than their male peers. Observations such as these suggest yet another reason why it may be important for instructors to attempt to control student responses. Granted, to have control over student responses likely requires some level of power-centricity which perhaps the less experienced TA has yet to acquire.

**The interactive nature of chalk talk**

One of the most evident findings of this study is that at no point are the participants seen as disengaged from their students. In a chalk talk lecture instructors and students appear to be engaged in a continuous dialogue of talking, writing, and gesturing. Even while instructors' backs are turned they continue to clarify, reflect, and write a shared dialogue between student and instructor. While instructors are focused on the students, they are constantly monitoring, gesturing, eliciting, asking, responding, and explaining.

Cretchley (2005) conducted a study investigating why undergraduate students attend mathematics lectures. Students listed such reasons as “to ask questions and hear what others ask” (para. 18) as a primary reason for attending lectures. Cretchely's findings demonstrate the value that students find in the question/answer aspect of mathematics lecturing, and provide support for the interactive nature of traditional chalk talk lectures. To further illustrate this point, a recent study by Tin (2009) examined instructional features of language learning classrooms found to be “most interesting” (p.117) by post-graduate students. Results showed that the lecturing style of all lectures said to be ‘most interesting’ were interactive, dialogic, and participatory. Tin describes ‘interactive lecture’ as a “classroom learning event primarily controlled and led by a lecturer and including subject input from the lecturer but also including varying degrees and types of oral participation by students” (p. 124). This definition of an interactive lecture describes the type of teaching environment developed by the participants of this study.

As previously mentioned, there have been claims that traditional university mathematics lecturing uses a ‘transmission’ model of teaching in which students act as passive recipients of the subject matter, unengaged and unable to participate (e.g. Barnes, 1992; Yoon, Kensington-Miller, Sneddon, & Bartholomew, 2011); and also that the genre of teaching is static and disembodied, somehow kept separate from all physicality and emotion (Gerofsky, 2010). The observations presented in this study directly refute these claims highlighting the dynamic, multimodal, and wholly interactive nature of the chalk talk genre.

### **Chapter 6: Conclusions and Implications**

This study has shown that university mathematics teachers use a complex interweaving of discursive strategies and nonverbal behaviours, including gestures, to elicit responses, and promote participation from students. Discursive strategies include asking questions, pausing, issuing commands, and providing further explanation, or ‘hints’. Questions appeared to be used for several functions, namely to engage the students, seek clarification, and to monitor student understanding. The participants also seemed to promote participation by using discursive strategies which helped to establish a supportive and highly participatory environment. For instance, the participants were careful not to react with negative evaluations of student responses which were incorrect and instead would offer further explanation.

Multimodal features also seem to play an important role in eliciting student responses.

The participants used gaze, focus, stance, and a variety of interactive gestures in order to

elicit student responses and promote participation. Nonverbal features such as focus and gaze were used to elicit responses from students, particularly at times when the participants conducted a shift in their focus from the chalk board to the students; turning towards students seemed to act as a powerful nonverbal signal used to request participation. Focus and gaze, especially a ‘pan’ gaze, combined with pauses and ‘audience checks’ were used to monitor students’ understanding and engagement. These instances of ‘checking’ allowed the opportunity for students to ask questions about the topic at hand.

Gestures used to elicit student responses included pointing, and two gesture families of the open hand (OHP and OHS). Pointing with IFE was used to single out students to respond, while pointing with the open hand served to acknowledge student contributions. Gestures of OHP were used to shape mathematical explanation or ‘push’ questions towards students. Gestures of OHS were used to present questions to students, or to show a ‘readiness to receive’ responses. In some cases OHP and OHS gestures were used to express the participant’s unwillingness to intervene, leaving the responsibility to respond on the students.

Furthermore, observations point to the ‘co-expressiveness’ (McNeill, 1985, 1992) of speech and gesture as inseparable facets of communication. This study highlights the need for multimodal analysis in studies of lecture pedagogy. As stated by Fox and Artemeva (2011), “when only talk and writing are addressed in research, much of the actual pedagogical value of the chalk talk lecture is missed” (p.97).

Not only does this study point to the value of multimodal analysis in pedagogical research, its findings support and expand on Artemeva and Fox's (2010, 2011; Fox & Artemeva, 2011) discovery of the chalk talk genre as "constellations of overtly recognized rhetorical conventions *and* tacit and improvisational strategies, triggered by the interaction between an individual's socialization and an organization" (Artemeva & Fox, 2011, pp. 348-349). The participants' performance of the chalk talk genre encompasses all of the genre characteristics described by Artemeva and Fox (2010, 2011; Fox & Artemeva, 2011) as well as additional more subtle elements made visible only by this fine-grained multimodal analysis. These findings demonstrate that even when scrutinized to a minute level, the participants are engaged in a typified intricate genre performance of interweaving, recurrent, rhetorical actions which cannot be teased apart. The similarities that are evident throughout this study provide further support that chalk talk is a complex genre of university mathematics pedagogy which spans local and global contexts. Observations also show, however, that there are slight variations between the ways the very experienced professor and the less experienced TA perform the genre.

Although the TA is not a true novice (over seven years of teaching experience), he is nonetheless situated closer to the periphery of the CoP than the very experienced professor who has decades of experience performing the chalk talk genre. The TA exhibited a variety of differences in his performance which could be attributed to his less experienced position in the CoP.

The TA seems slightly less confident in his performance; he fidgets and grips the textbook, he shows uncertainty, and ‘clowns around’. He does not attempt to exert power over the students or control the students’ responses. The TA’s performance is more ‘subdued’ in that he engages in less mathematic explanations, asks fewer questions, and is less animated than the professor. He presents himself as on the same level as the students and teaches by working and thinking *with* them to solve problems. He keeps his focus on the chalkboard letting the students’ responses wash over him as they guide him in participatory problem solving. Interestingly, he does demonstrate his advanced mathematical knowledge, and more formal teaching persona, when a student asks for help (Figure 21). This could suggest that his uncertainty is but an element of his teaching style, and in fact, his method of student-guided participatory problem solving could be a tactic used to engage students in active learning.

The very experienced professor has fully mastered enactment of the chalk talk genre. His formal lecture style, and ‘student focused’ approach exude confidence and passion for the performance. He exercises power over the class by using a combination of discursive and gestural moves to urge, even pressure students to engage with him. While waiting for students to respond he uses an authoritative stance, facing the class with hands on hips, or hands folded in front combined with pan-gazes and facial expressions suggesting that he is willing to wait until a response is provided. While attempting to elicit responses, he uses repetition, commands, and his entire body to *urge* the students to respond. During mathematical explanation he is lively and animated, controlling student responses and

line of thought with his hands, speech, and movement. He *embodies* the math, and with rapt attention on the students, he strives to convey it to them.

When examined through the lens of RGS and theories of situated learning these differences can lead to the insight into how novices become acculturated into the CoP of university mathematics teaching, and how this socialization process affects genre production. This study comes at a time when the need to hire new university faculty is pressing (AUCC, 2009); the insights provided here could prove valuable for the production of training materials designed for newcomers to the world of university mathematics teaching.

Contrary to claims made about the ‘bleak’ and disembodied’ nature of mathematics pedagogy (Gerofsky, 2010), this study has provided insight into chalk talk as a complex, multimodal, and wholly interactive genre of teaching. The findings of this study stress the importance of face-to-face teaching in terms of monitoring student understanding, promoting student interaction and engagement, and ensuring equal participation within a supportive learning environment. These findings are particularly significant for institutions of higher education to consider during the present climate of growing class sizes and advancing technology which has provided support for increased online learning. As stated by Trenholm, Alcock, and Robinson (2012) “students’ use of e-lectures in mathematics may, in fact, encourage rote learning; e-lectures allow students to remove themselves from an obvious community of practice and thus miss out on valuable human interaction that may help correct such approaches to [rote] learning” (p. 712).

### **Limitations and Suggestions for Future Research**

Limitations of this study include a limited sample size and analytical scope. Due to researcher's time constraints this study included observations of only two participants, one of whom was, although less experienced than the other, not a true novice. This study would have benefitted from a larger sample size comprised of participants ranging from true novices to very experienced professors. Furthermore, although a deep multimodal analysis of the data was conducted, due to the limited nature of this study only a partial analysis of the participants' gestures could be conducted (interactive gestures limited to pointing, two families of the open hand, and rest positions). A complete analysis of all the participants' gestures *and* facial expressions would have been ideal.

Suggestions for future research include conducting multimodal analyses of full chalk talk lectures involving a complete investigation of representational as well as interactive gestures. Also, in order to understand more about the interactive nature of the chalk talk genre, multimodal research is required which examines a larger sample size, ideally examining the teachers as well as the students. Finally, in order to learn more about the acculturation of novices into the chalk talk genre, future research would benefit from a longitudinal study examining true novices as they move from the periphery towards a fully situated position within the CoP of university mathematics teachers.

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## Appendix A

### Enactment of the Genre System (Artemeva & Fox, Raw Data)

#### C. TEACHER PERSONA

##### Ci. LANGUAGE

**Cib. Repetition:** *this node refers to how repetition is used in the lecture.*

**Cic. Pauses:** *this node refers to how pauses are used in the lecture.*

**Cid. Rhetorical Questions (RQ):** *this node refers to how a professor uses rhetorical questions throughout the lecture.*

**Cie. Questions and Answers (Q & A):** *this node refers to how questions are answered (professor and student rapport).*

##### Cih. Richness of the Discourse

**Ciha. Formality:** *this node refers to how professors make use of formalities.*

**Cihb. Humour and Irony:** *this node refers to how professors use humour and irony in their lectures.*

**Cihe: Discourse of the Discipline**

**(Language):** *this node refers to all*

*references made to discourse of the discipline.*

*Cihg: **Rhetorical Informality:** this node refers to all instances of rhetorical informality.*

**Cii. META-STRUCTURE**

*This node refers to all comments made regarding a professor's organization of the lecture.*

**Ciia. Housekeeping/Announcements:** *this node refers to how Professors make announcements and other housekeeping items in their lecture.*

**Ciib. Pedagogical:** *this node refers to how the Professor organizes the lecture.*

**Ciiba. Positive-Supportive:** *this node refers to all pedagogical references in a positive and supportive nature/standpoint.*

**Ciibb. Negative-Distancing:** *this node refers to all pedagogical references which are from a negative- distancing standpoint.*

**Ciicb. Mathematical Explanation:** *This node refers to all references made to mathematical explanation.*

**Ciii. AWARENESS OF STUDENTS**

**Ciiib. Equality and Power Sharing:** *this node refers to how power sharing is observed in the classroom setting.*

**Ciiiba. Power Centric:** *this node refers to how a Professor is power centric in the lecture.*

**Ciiibb. Power Sharing:** *this node refers to how a Professor shares the power in the lecture.*

**Ciiibba. Voluntary Power Sharing:** *this node refers to all instances of power sharing, on a volunteer basis.*

**Ciiibbb. Involuntary Power Sharing:** *this node refers to all instances of power sharing, on an involuntary basis.*

**Civ. EMBODIMENT**

**Civa. Gaze:** *this node refers to a professor's 'look' or 'glance'*

**Civb. Arms:** *this node refers to a professor's use of their arms.*

**Civc. Head:** *this node refers to a professor's head movements.*

**Civd. Action:** *this node refers to other actions.*

**Cive. Body:** *this node refers to a professor's overall body language.*

**Civf. Formality:** *this node refers to the level of formality (or informality) a Professor uses in a lecture.*

*Civfa. Formal:* **Formal:** *this node refers to any comments made regarding how a Professor uses a level of formality in the lecture.*

*Civfb. Informal:* **Informal:** *this node refers to any comments made regarding how a Professor uses informal ways of teaching.*

Appendix B

Adapted Coding Tree (adapted from Artemeva & Fox)

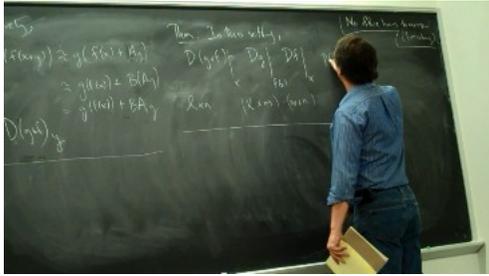
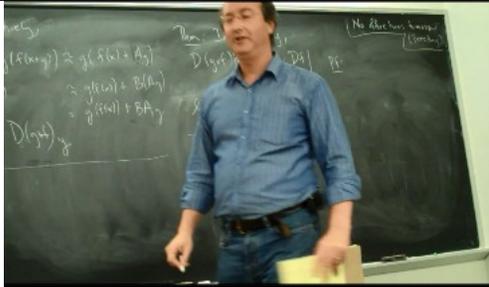
Name	Sources	References	
A.TEACHER PERSONA	2	624	
Ai.LANGUAGE	2	187	
Aia.Lexical Richness	2	8	
Aib.Repetition	2	41	
Aic.Pauses	2	23	
Aie.Questions and Answers	2	64	
Aiea.Lecturer Question	2	24	
Aieaa.Rhetorical Questions	0	0	
Aieab.Asking for Clarification	2	6	
Aieac.QuestionAnswer pair	1	2	
Aiead.Checking	2	4	
Aieb.Student Question	2	5	
Aiec.Lecturer Answer	2	4	
Aieca.Answer own Question	1	1	
Aiecb.Answer Student Question	1	1	
Aied.Student Answer	2	18	
Aiee.Repetition of Student Question	1	2	
Aief.Repetition of Student Answer	2	11	
Aif.Commands	1	3	
Aig.Richness of Discourse	2	45	
Aiga.Formality	0	0	
Aigb.Informality	2	12	
Aigc.Discourse of Discipline	2	20	
Aigd.Linguistic Sequential Markers	1	3	
Aige.Humour and Irony	2	10	
Aiega.Laughter	2	5	
Aih.Softeners	1	3	
Aii.META STRUCTURE	2	35	
Aii.a.HousekeepingAnnouncements	0	0	
Aii.b.Pedagogical	2	22	
Aii.ba.Positive-Supportive	2	22	
Aii.bb.Negative-Distancing	0	0	
Aii.c.Other	2	13	
Aii.ca.Researcher's Presence	0	0	
Aii.cb.Mathematical Explanation	2	13	
Aiii.AWARENESS OF STUDENTS	2	104	
Aiii.a.Respect	2	28	
Aiii.aa.Devaluing	1	2	
Aiii.ab.Valuing	2	26	
Aiii.b.Equality and Power Sharing	2	45	
Aiii.ba.Power Centric	2	15	
Aiii.bb.Power Sharing	2	30	
Aiii.bba.Voluntary Power Sharing	2	23	
Aiii.bbb.Involuntary Power Sharing	2	7	
Aiii.c.Empathy	2	11	
Aiii.ca.Empathetic	2	8	
Aiii.cb.Distant	1	3	
Aiii.d.Inclusiveness	2	20	
Aiii.da.Including	2	20	
Aiii.db.Excluding	0	0	
Aiv.EMBODIMENT	2	298	
Aiv.a.Gaze	2	88	
Aiv.aa'.Pan' Gaze	2	21	
Aiv.ab.Directed Gaze	2	67	

Aivaba. Directed Gaze at Chalk Board	2	37	Yellow
Aivabb. Directed Gaze at Other	2	4	Yellow
Aivabc. Directed Gaze at Student	2	26	Yellow
Aivb. Gestures	2	133	Magenta
Aivba. Pointing	2	59	Green
Directed	2	30	Yellow
Aivbaa. Pointing at Board	2	23	Orange
Aivbab. Pointing at Student	2	4	Orange
Aivbac. Pointing at Other	2	3	Orange
Index Finger Extended	2	13	Yellow
IFE Neutral	1	3	Orange
IFE Prone	2	9	Orange
Open Hand	1	10	Yellow
OH Prone	1	10	Orange
OH Supine	0	0	Orange
With Chalk Only	1	6	Yellow
Aivbb. Enactment	1	1	Green
Aivbc. Hand Bunch	1	3	Green
Aivbd. Hand to Ear	1	1	Green
Aivbe. Modelling	2	4	Green
Aivbf. Open Hand Prone	2	10	Green
Aivbfa. Horizontal Palm	2	9	Yellow
Aivbfb. Vertical Palm	1	1	Yellow
Aivbg. Open Hand Supine	2	18	Green
Aivbga. Lateral Movement	1	3	Yellow
Aivbgb. Palm Addressed	1	6	Yellow
Aivbgc. Palm Presentation	2	9	Yellow
Aivbh. Rest Position	2	24	Green
Aivbha. Arms at Side	2	14	Yellow
Aivbhb. Chalk Partially Engaged (Fist)	1	1	Yellow
Aivbhc. Hands Crossed Front	1	6	Yellow
Aivbhd. Hands on Hips	1	3	Yellow
Aivbi. Touching Head or Face	1	6	Green
Aivbj. Other (Unclassified)	2	7	Green
Aivbja. Index Finger Up 'One'	1	1	Yellow
Aivbjb. Raised Fist	1	2	Yellow
Aivbjc. Rolling Hand 'etc.'	1	1	Yellow
Aivc.Body	2	77	Magenta
Aivca. Turned to Board	2	13	Green
Aivcb. Turned to Board Facing Class	0	0	Green
Aivcc. Half Turn	2	23	Green
Aivcd. Turned to Class Facing Board	1	8	Green
Aivce. Turned to Class	2	21	Green
Aivcf. Writing on Board	2	11	Magenta
Aivog. Erasing Board	1	1	Magenta

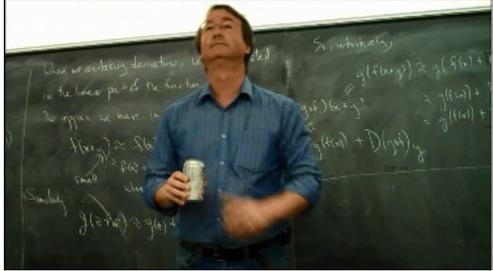
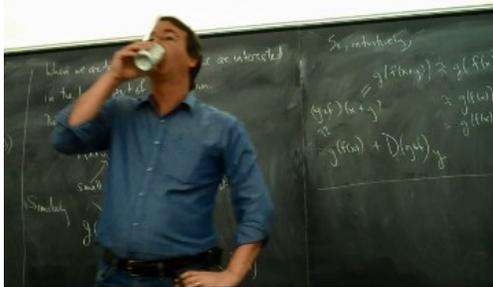
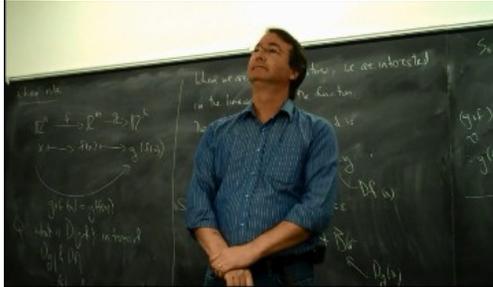
Running Head: Give me one reason why this is true

### Appendix C

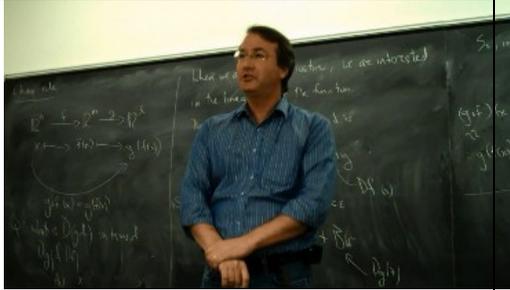
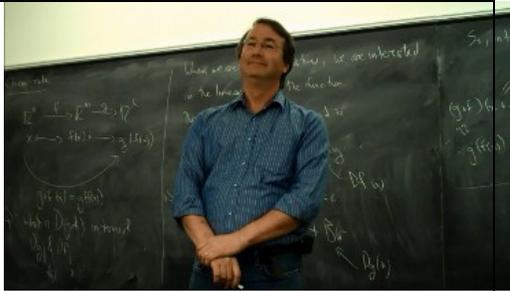
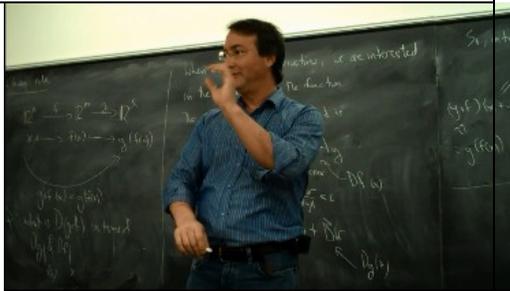
**Multimodal Table (Further Illustrating Figure 10)**

Time stamp	Speaker	Verbiage	Hand gestures	Stance, gaze, facial expression	Notes	Image
0:01.0 - 0:05.0	Prof	Okay. So- let's prove this.  Pause (2.2 sec)	None	Turned to board, focus on board	Writing on the board  Holding chalk in left hand, notes in right hand	
0:05.0 - 0:07.6	Prof	So how are you going to prove this?	None	Turns to face students, focus on desk then up at students	Walking towards desk, places notes on desk	

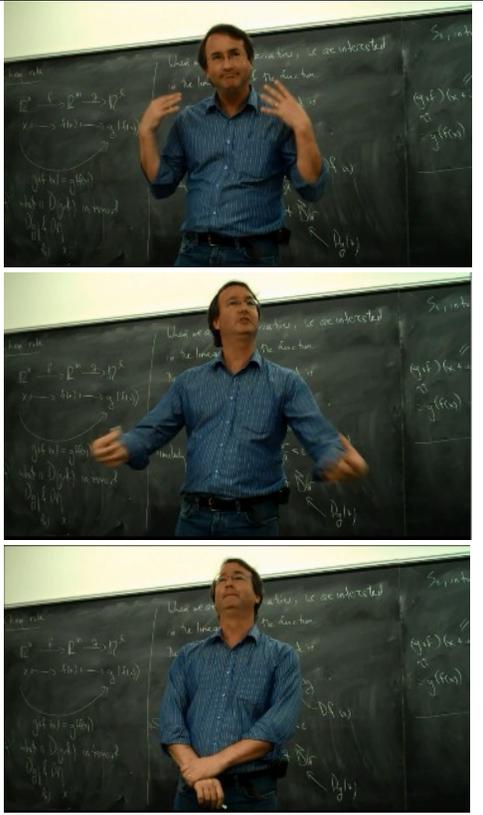
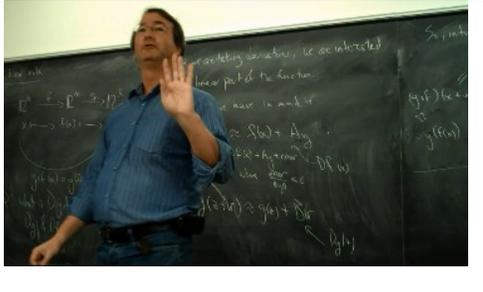
Running Head: Give me one reason why this is true

0:7.6-0:11.3	Prof	Pause (9.4 sec)	None	Facing students, focus on students, Smiles slightly	Wipes chalk off finger onto jeans, picks up pepsi	
0:11.3 - 0:14.0	Prof	Pause (9.4 sec continued)	Places left hand on hip (RP)	Pan gaze across audience, sips while maintaining gaze, pan gaze across audience	Lift pepsi with right hand, sips pepsi, steps forward replaces pepsi on desk	
0:14.0 - 0:17.0	Prof	Pause (9.4 sec continued)	Hands crossed in front (RP)	Pan gaze across audience, bouncing shoulders slightly	Wipes right hand on jeans, picks up chalk with left hand, switches chalk to right hand, back to RP	

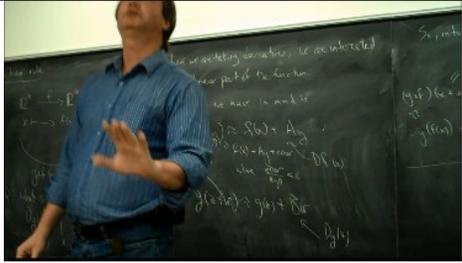
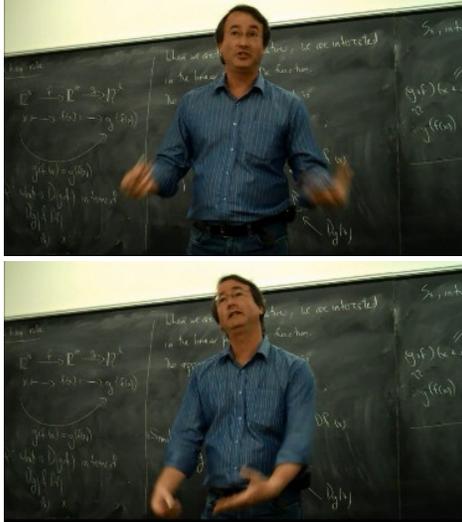
Running Head: Give me one reason why this is true

0:17.0 - 0:21.2	Prof	Tell me in one sentence why it's true.	Hands crossed in front (RP)	Facing class, focus on class, bending at knees, bouncing torso and shoulders up and down with each word	None	
0:20.7 - 0:22.6	Prof	Pause (1.9 sec)	Hands crossed in front (RP)	Facing class, focus on class, smiling slightly	None	
0:22.6 - 0:25.0	Prof	You can use two if you need to but if you can do it in one.	From RP, lifts left hand, hand bunch, hold, returns to RP	Facing class, focus on class, smiling slightly	Apex of gesture coincides with word 'one'	

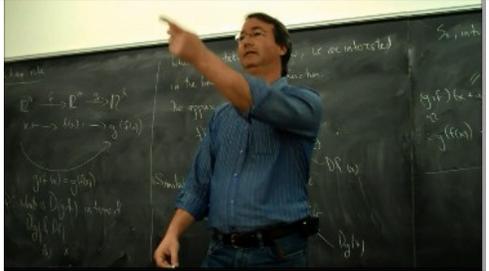
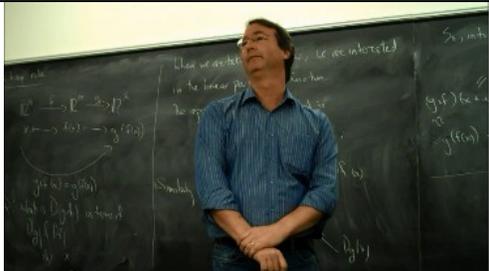
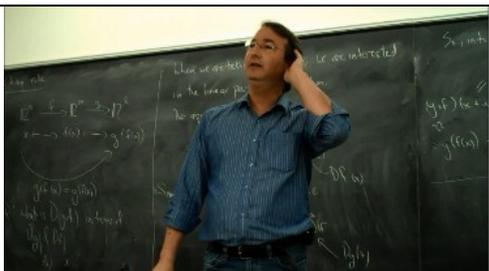
Running Head: Give me one reason why this is true

<p>0:25.0 - 0:28.8</p>	<p>Prof</p>	<p>But, you know, what's your intuition? Why should this be true?</p>	<p>From hands crossed in front RP reaches out both hands into OHS(PA), extends and retracts hands bouncing slightly, three strokes , returns to RP</p>	<p>Facing class, focus on class, furrowed brow, pursed lips</p>	<p>Apex at 'intuition', 'why', 'should'</p>	
<p>0:28.8 - 0:34.1</p>	<p>Prof</p>	<p>I keeping telling you folks you know don't try to find a proof.</p>	<p>From hands crossed in front RP, raises hand OHP(VP), lowers to OHP(ZP), four strokes</p>	<p>Facing class, focus on class</p>	<p>Apex of stroke 'don't', 'try', 'find', 'proof'</p>	

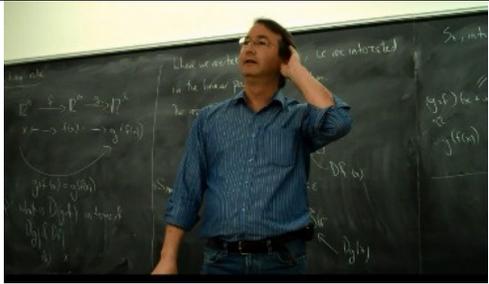
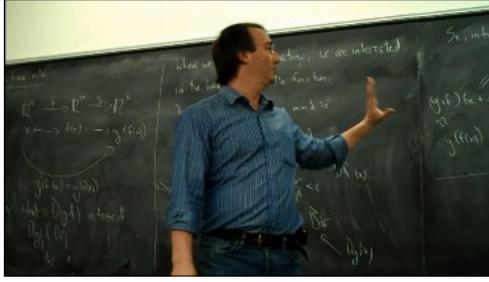
Running Head: Give me one reason why this is true

						
<p>0:34.1 - 0:36.1</p>	<p>Prof</p>	<p>Understand why it's true and then write down that understanding.</p>	<p>Both hands raised to either side, OHS(PA), widening hands which each stroke (two strokes), third stroke raises both hands up and tips palms forward as if to pour contents of hands onto imaginary surface in front</p>	<p>Facing class, focus on class, raised eyebrows</p>	<p>Apex of first two strokes on 'understand', 'why'  Apex of second gesture 'write down'</p>	

Running Head: Give me one reason why this is true

0:36.1 - 0:37.2	Prof	[Student Name]?	Points at student with IFE	Facing class, focus on specific student	None	
0:37.2 - 0:37.7	Student	[Inaudible]	Return to hands crossed in front RP	Facing class, focus on specific student	Listening	
0:37.7 - 0:38.8	Prof	Sorry?	From RP brings left hand to ear, holds	Facing class, focus on specific student		

Running Head: Give me one reason why this is true

0:38.8 - 0:39.7	Student	Chain rule.	Holds hand to ear	Facing class, focus on specific student	Listening	
0:39.7 - 0:41.5	Prof	Well that's what we're - this is the chain rule (class laughter)	Points with OH to board,	First turned to class focus on board then turns to board, focus on board, walks to board, writes 'Chain Rule'	First turns only head to board referencing board, hesitates, then upon uttering 'this is' turns whole body and walks towards board	
0:41.5 - 0:48.4	Prof	and we're trying to prove it.	Hands in front, parts them slightly	Turns back to students, focus on student, eyebrow raised	Slight part of hands at 'prove'	