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A quantitative multimodal discourse analysis of teaching and learning in a web-conferencing environment – The efficacy of student-centred learning designs

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ABSTRACT

This paper presents a quantitative approach to multimodal discourse analysis for analyzing online collaborative learning. The coding framework draws together the fields of systemic functional linguistics and Activity Theory to analyze interactions between collaborative-, content- and technology-related discourse. The approach is used to examine how the task subject matter, the activity design, and the choice of interface affected interaction and collaboration for a computing course conducted in a web-conferencing environment. The analysis revealed the critical impact of activity design on the amount and type of discourse that transpired. Student-centred designs resulted in over six times more student discourse as compared to teacher-centred designs and created a learning environment where students took greater ownership over the tasks and contributed more to the content-based discussion. The paper also incorporates a rationale for the approach to coding and a reflection on its efficacy for discourse analysis in technology-based learning environments.

1. Introduction

Studying computer-mediated communication facilitates understanding of communication patterns, forms, functions, conventions and subtexts, which can in turn engender an understanding of how people derive meaning within such contexts (Naidu & Jarvela, 2006). Recent emphasis in technology-based learning has shifted from a focus on more passive and individual learning of content to explore more student-centred and collaborative approaches to learning (Conole, 2007). However the use of networked technologies to enable collaborative learning provides no guarantee of improved outcomes, prompting the need for research to understand the factors that underpin their effective use (Naidu & Jarvela, 2006; Suthers, 2006).

Many contemporary online learning environments afford multimodal collaboration. For instance, web-conferencing systems such as Adobe Connect Meeting (Adobe Systems Inc., 2009), Elluminate Live (Elluminate Inc., 2009) and Wimba Classroom (Wimba Inc., 2009) offer a wide array of modalities for facilitating interaction and co-construction of knowledge, making these rich environments for studying collaborative learning. In such environments a multimodal discourse analysis methodology is useful in order to account for the multiple channels of communication being used. Analyzing a subset of collaborative modalities can lead to an incomplete understanding of how meaning is being made (Jewitt, 2006).

However there is a sparse literature about how multimodal collaborative learning environments are being used to facilitate learning. For instance, a search of the ERIC database as at 26th of August 2009 returned 31 references with the term "web-conferencing" in any field. However all but four of these were using the term to refer to more generic online collaboration (for instance using discussion boards) or only tangentially referred to the use of fully fledged web-conferencing systems. Only one of these papers proposed any recommendations for the way in which such systems are operated (Reushle & Loch, 2008). None of the articles had applied a systematic approach to researching the interactions of web-conferencing participants.

This study utilizes a quantitative multimodal discourse analysis approach to investigate the following research question:

How do the interface design, task type and activity design influence the amount and type of collaboration that occurs during learning episodes conducted in a web-conferencing environment?

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By performing intertextual analysis between individual learning episodes, global results and learning design results were able to be derived. The quantitative approach provides a more objective means to detect and quantify cause-and-effect relationships, which can be used to complement established interpretivist multimodal discourse analysis approaches (Jewitt, 2006; Kress, Jewitt, Ogborn, & Tsatsarelis, 2001). The coding framework that will be demonstrated uniquely integrates Engeström's (1987) Activity Theory framework with Halliday's (1985) systemic functional linguistics.

2. Background literature

2.1. Student-centred collaborative learning in online environments

The multimodal discourse analysis that will be described in this paper provides a means for examining the effect of more student-centred and collaborative pedagogies. The lack of interaction that online students have with their peers and teachers in distance courses is considered one of the major downsides of distance education (Perez Cereijo, 2001) and can significantly impact upon students' satisfaction rating of their online courses (Chang & Smith, 2008). Increasing the level of student interaction in online learning environments has been found to positively affect student achievement (Gao, 2001; La Pointe & Gunawarndena, 2004; Stavredes, 2002).

Reeves, Herrington, and Oliver (2004) present a compelling vision for online collaborative learning, whereby learners enrolled in a common unit of study work together through the online medium to solve complex problems and complete authentic tasks. They believe that by being able to collaboratively solve authentic tasks online "the learning outcomes accomplished by these learners will be of the highest order, including improved problem solving abilities, enhanced communication skills, continuing intellectual curiosity, and robust mental models of complex processes inherent to the performance contexts in which their new learning will be applied" (Reeves et al., 2004, p. 53). Student-centred collaborative learning can foster more independent and creative thinking skills at the same time as it develops collaborative learning capabilities (Luan, Bakar, & Hong, 2006). For this and other reasons several educators claim there is a critical need for online instructors to shift from the traditional teacher-centred mode of online teaching to a more learner-centred teaching style (Barrett, Bower, & Donovan, 2007; McCombs & Vakili, 2005; Reeves et al., 2004).

Implementing student-centred as opposed to teacher-centred approaches has been found to affect the nature of discourse that transpires. Wu and Huang (2007) found that in teacher-centred classes the majority of questions were asked by the teacher and students usually engaged in simple question-and-answer and initiation–response–evaluation (IRE) sequences. In student-centred classes, students more frequently described their ideas about the subject matter, provided information to their group members, and engaged in question-and-answer sessions between themselves (Wu & Huang, 2007). Evidence suggests that such student initiated questioning can result in greater comprehension, better links to prior knowledge and more flexible thinking skills (King, 1994; Lampert, 1990). Using multimodal discourse analysis to study learning and teaching that is mediated through a web-conferencing system provides the opportunity to examine whether these discursive patterns replicate in the online environment, and whether other new patterns emerge.

Educators' beliefs about learning have been found to influence the extent to which they design for student-centred learning, and changing personal theories about the value of student-centred learning and the role of technology is a direct way to bring about educational reform (Churchill, 2006). Novice educators indicate a need for greater guidance on how to implement online collaborative learning (Koo, 2008). The multimodal discourse analysis applied in this study provides hard evidence to inform personal theories about student-centred collaborative learning and insight into its implementation.

2.2. An Activity Theory perspective

Activity Theory (Engeström, 1987) is a powerful framework for the design and development of technology-based learning environments because its assumptions are consonant with the ideas of constructivism, situated learning, distributed cognition and everyday cognition (Jonassen & Rohrer-Murphy, 1999). The framework provides a useful lens through which to study intersubjective learning in distance educational contexts, because it focuses upon the relationships that exist among those involved in an activity (Greenhow & Belbas, 2007).

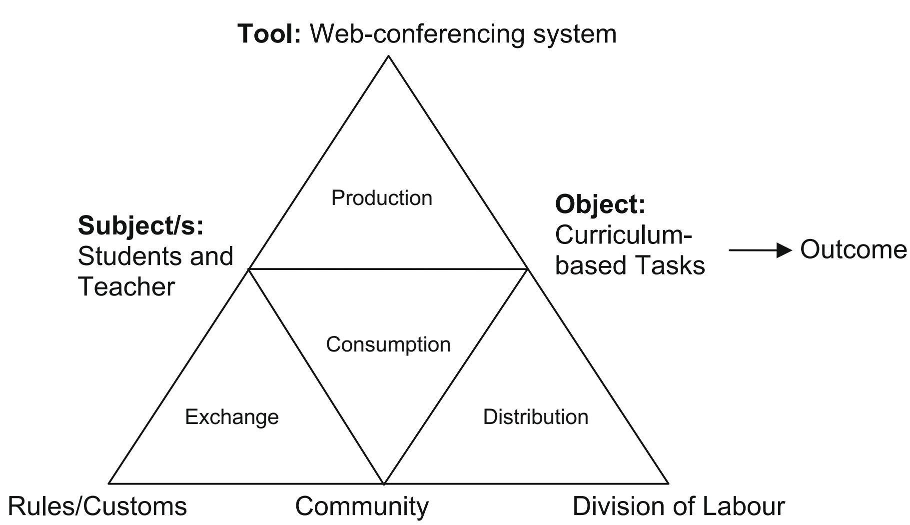

Fig. 1. Engeström's (1987) Activity Theory framework as applied to this study.

Engeström's (1987) Activity Theory framework considers how people (subjects), interact with objects via mediating tools in order to effect outcomes. This is done in the context of a community with its own set of rules and approaches to division of labour. Fig. 1 represents these components in the context of this study.

The primary focus in activity systems analysis (particularly when analyzing learning) is the top triangle of the model that encompasses the Tool/s, Subject/s and Object/s (Jonassen, 2002; Jonassen & Rohrer-Murphy, 1999). Known as the "production" sub-system, these three interacting components lead to the accomplishment of the activity outcomes. This study focuses upon how the components of the Production sub-system interrelate, i.e., the web-conferencing environment, the participants, and the object of study.

2.3. Multimodal discourse analysis

Multimodal discourse analysis is an increasingly important technique for analyzing contemporary learning contexts because it attends to the multiplicity of modes of communication that may be active (Kress et al., 2001). In contrast to single channel discourse analysis techniques where one mode of communication is considered (as is the case with text-chat transcripts), multimodal discourse analysis allows all modes of communication to incorporate into an analysis (Jewitt, 2006). Where many channels of communication are being used, only analyzing a subset suffers the risk of leaving out much of what is being communicated which can potentially result in incomplete or inaccurate conclusions (Jewitt, 2006; Norris, 2004).

Multimodal discourse analysis draws upon systemic functional linguistics to deconstruct the types of meaning that occur within the communications that transpire (Jewitt, 2006). Types of meaning including the following:

- *interpersonal* – meaning relating to interaction between speaker and addressee(s),
- *ideational* – construing the world around us and inside us, and
- *textual* – concerned with the creation of a text (outlined in Matthiessen & Halliday, 1997).

As resources these interpersonal, ideational and textual elements form a system of meaning making that allow texts to be formed through the discursive flow they enable (Halliday, 1998).

Modalities can represent all three types of meaning (Jewitt, 2006). For instance, in the visual mode ideational meaning is purveyed using narrative representations (that show the unfolding of actions, events, or processes of change) or conceptual representations (that relay the generalized, categorical and stable characteristics of elements). The visual mode can be used to deliver interpersonal meaning by depicting relationships between viewers. Finally, the placement of elements in a composition can effect the information value they have in the context, influencing the textual meaning (Jewitt, 2006).

It should be noted that multimodal discourse analysis is a developing field and that while some excellent qualitative research has been performed in this area (Baldry & Thibault, 2006; Jewitt, 2006; Kress et al., 2001) this study extends and adapts previous approaches to conduct a large scale quantitative analysis of teaching and learning in an online multi-modal environment. This quantitative approach provides a means of performing intertextual analysis on a more objective basis.

The multimodal discourse analysis technique will be demonstrated by using it to investigate learning design in a web-conferencing environment. The term 'learning design' is used to describe the "learners and a space where they act with tools and devices to collect and interpret information through a process of interaction with others" (Oliver, Harper, Wills, Agostinho, & Hedberg, 2007, p. 65). Three components of learning design form the independent variables for this study:

- *Technology design* – the design of the interface of the mediating technology (tool).
- (inter)*Activity design* – how participants are expected to interact during the learning episode (the degree of collaboration between subjects).
- *Task design* – the curriculum matter within the particular learning domain, both content knowledge and processes addressed (object of study).

These three aspects of the learning design are used to investigate how the design of the interface, activity and task influence collaboration in a web-conferencing environment. These three components relate (respectively) to the tool, subject and object of Engeström's (1987) Activity Theory framework, as well as the textual, intersubjective and ideational components of systemic functional linguistics (Halliday, 1985).

2.4. Designing the coding frame

A wide variety of literature relating to content and discourse analysis was reviewed in an attempt to find the most appropriate approach to coding the data, including Henri's (1992) approach to content analysis of discussion forums and Gunawardena, Lowe, and Andersons' Interaction Analysis Model (1997). However these models and many others like them had been designed for analysis of discussion forums and were inadequate to capture aspects of the discourse relating to:

(1) coordinating activity between participants and
(2) using the collaborative technology.

The more flexible and dynamic nature of the web-conferencing environment as compared to single mode discussion boards meant that discourse needed to be devoted to deciding how to use the collaborative technology to collaborate, and to coordinating who should perform different operations. As such, a coding scheme was developed based on Activity Theory and systemic functional linguistics to capture whether discussion related to the mediating technology, coordinating activity between people or the curriculum-based content. These three elements were operationalized as follows:

(1) *Technology* – discourse regarding the tools of the collaborative platform (web-conferencing environment).
(2) (inter)*Activity* – discourse relating to coordinating interactions between people; what has/is/should be done and by whom.
(3) *Content* – curriculum-based discourse about subject matter, relating to the learning of an idea in the learning domain.

Identifying Technology, (inter)Activity and Content as the three aspects by which the subject matter of discourse is differentiated aligns directly with Production sub-system of the Activity Theory framework; the Technology discourse relates to the tools (web-conferencing affordances) being used, the (inter)Activity discussion relates to how the subjects (people) are coordinating operations with one another, the Content conversation relates to the object (curriculum matter) being addressed. Discourse on these levels leads to the learning outcomes (goals) being achieved.

The Technology, (inter)Activity and Content classifications also correspond to the types of meaning identified by systemic functional linguistics and used in previous qualitative multimodal discourse analyses such as that by Jewitt (2006). Discourse relating to Technology is explicating the textual nature of the discourse – how the text is being structured and formed using the web-conferencing environment. Discourse relating to (inter)Activity explicates the interpersonal nature of the text – how it relates to others. Discourse relating to content explicates the ideational intention of the text – focusing on learning concepts about the world.

Interactions between these categories were also included because an initial analysis of the data revealed that sentences often address more than one of these aspects at once (and that these intersections were potentially the most interesting aspects of the textual discourse). Thus the coding system was adjusted to allow for all combinations of Content, Activity and Technology being explicitly emphasised in the discourse.

As well as investigating the subject of the discourse, the coding scheme was designed to incorporate a dimension focusing upon patterns of interaction in the web-conferencing environment. Capturing information relating to the nature of collaboration between participants is an aspect that was not emphasised in many other popular coding systems. The interaction coding layer recorded whether participant contributions were a statement or a question, whether they were independently initiated or responsive, and in the cases where they were responsive whether it was in response to statement, question or action.

Another critical intention of the multimodal discourse analysis was to examine ways in which participants leveraged the affordances offered in multi-modal environments to facilitate collaboration and share representations. Thus the coding scheme was designed to code all actions according to the modality that was used to make them. For instance contributions to the whiteboard, writing text in shared note-pods, and broadcasting the desktop were all coded as separate types of actions, whether participant comments were made using text-chat or audio were all differentiated in the coding system, meaning that the modality of all contributions could be analyzed.

The coding frame outlined in the next section operationalizes this multimodal discourse analysis approach. The coding scheme has been designed to be sufficiently broad so as to be easily understood and applied to a range of technology-based learning contexts at the same time as it captures aspects relevant to collaborative learning in multimodal learning environments.

3. Method

3.1. The context

This study analyzed the in-class contributions and interactions of 26 students enrolled across three semesters of an online Graduate course in Information Technology at Macquarie University. Students were graduates from disciplines other than computing who wished to extend their Information Technology knowledge and skills. Of these students eleven were enrolled in 2005 Semester 2, eleven in 2006 Semester 1, and four in 2006 Semester 2. Students varied in age from 25 through to 56 years old, and all were proficient in the language of instruction (English). Of the 26 students, 9 were female and 17 were male.

The subject of the course being analyzed was introductory programming, which introduced students to the fundamental syntax, semantics and logic of writing computer programs (using Java). Before class each week students were to attempt some tutorial questions (by reference to the text-book) and practical exercises (using the BlueJ Integrated Development Environment to write small computer programs). Then in the weekly two-hour synchronous online class the students and teacher used the web-conferencing environment to discuss the solutions and attempt in-class activities relating to the introductory computer programming concepts being learnt.

The particular web-conferencing system used in this study was the Adobe Acrobat Connect platform (Adobe Systems Inc., 2009) which provided the following facilities through any Flash enabled web browser:

- General Presentation Delivery – PowerPoint presentations, general documents.
- Screen-sharing – entire desktop or single window, with remote control capabilities.
- Webcam and VoIP – multiple bandwidth settings, ability to stream.
- Text-chat – capacity to send to all or selected individuals.
- Whiteboard – various colours/fonts/transparency levels, document overlay, etc.
- File Upload/Download – selected from computer or content library.
- Polling – allowing questions to be composed and participants to vote.
- Attendee List – including status indicator ('fine', 'slower', etc.).
- Notepad – for text contributions such instructions, collaborative authoring, etc.

The web-conferencing system also afforded several flexibilities including the ability to adjust the access control of participants to tools, the ability to toggle between pre-defined layouts during learning episodes, and the capacity to create new layouts by dragging, dropping and resizing the tools they wish to use while the learning activity is being undertaken. This allows layouts to be redesigned to meet the collaborative requirements of the learning activity, either in advance or dynamically during a learning episode. Finally, all sessions have the capacity to be recorded, which enabled the data for this study to be collected.

As the method to be demonstrated is novel, its rationale and mechanics are described in some detail below in order to allow researchers to evaluate it and, if deemed appropriate, apply it in other contexts. Firstly, the approach to categorising the three independent variables (the interface design, the interactivity design, and the task design) is described.

3.2. Categorizing the technology design

There are several areas of the literature that could be used to inform the categorization of technology (interface) designs. In particular, a large body of empirical research on Human Computer Interaction reveals how interfaces can be effectively designed to not only support individuals to form schema (Cheng & Beaumont, 2004; Demetriadis, Karoulis, & Pombortsis, 1999; Sedig, Klawe, & Westrom, 2001), but also support the co-construction of knowledge between learners (Hollan, Hutchins, & Kirsh, 2000; Luff et al., 2003; Vu, Hanley, Strybel, & Proctor, 2000). The extent to which individual or collaborative concept formation is supported by an interface design depends on how the affordances of a learning technology are applied (Suthers, 2006; Yoon, Ho, & Hedberg, 2005). For instance, in the case of the web-conferencing environment, the screen broadcasting tool can be used by the teacher to enact a transmissive approach to instruction, whereas providing groups of students with access to text-chat, Voice Over IP and whiteboard spaces enables them to engage more collaboratively with tasks.

The range of possible tools that can be utilised in the web-conferencing environment and the flexibility with which they can be resized makes categorising interface designs problematic. In order to simplify the categorization process interfaces in this study were classified as belonging to one of two categories:

(1) *Presentational* – interface designs where only the teacher had access to the majority of tools.
(2) *Collaborative* – interface designs created to allow student access to most if not all of the tools in the environment so that they may collaboratively construct understanding.

3.3. Categorizing the (inter)activity design

Task ownership is a critical feature of any learning activity, and one that distinguishes one learning design from another (Kirschner, Strijbos, & Kreijins, 2004). The level of task ownership determines the mode of interaction between the teacher and students. Clark (2005) identifies three such types of activity designs for e-learning:

(1) *Teacher-centred (receptive)* – information delivery approaches, where the lecturer communicates a stream of information to students. Magliaro, Lockee, and Burton (2005) propose that such transmissive approaches are more useful for students with little or no understanding about a particular topic.
(2) *Teacher-led (directive)* – these approaches use a deductive instructional approach. Small chunks of content, examples or demonstrations, may be presented, followed by periods of student activity such as practice or question answering. Feedback and interaction between the teacher and student occurs. Laurillard (2002) provides a comprehensive explication of such an approach in her Conversational Framework for teaching using technology at tertiary level.
(3) *Student-centred (guided discovery)* – more inductive learning environments in which learners complete a series of goal-related tasks. Collaborative learning approaches are based on this approach, whereby student-to-student flow of concept forming discourse is central and the teacher adopts a more facilitory role. There is a solid support for such approaches from a broad spectrum of educational literature (Bandura, 1977; Jonassen, Lee, Yang, & Laffey, 2005; Mayer, 2005; Suthers, 2006; Waite, Jackson, Diwan, & Leonardi, 2004).

The three categories are not presented as an unequivocal categorical system; for instance students can comment in teacher-centred learning episodes just as the teacher can interject during student-centred activities. However observing where ownership for the activity resides (with the teacher, teacher leading students, or centred upon the students) provides a common vocabulary for discussing approaches to in-class interaction and differentiating between the types of activity designs that are applied.

3.4. Categorizing the task design

Different types of tasks may be represented differently in web-conferencing environments, and the capacity to distinguishing between types of content allows their differential effect on learning to be considered. Anderson and Krathwohl's (2001) taxonomy of learning, teaching and assessing present a 'knowledge' dimension for classifying the sort of content being addressed in educational tasks:

(1) *Factual (declarative) knowledge* – discrete pieces of elementary information, required if people are to be acquainted with a discipline and solve problems within it.
(2) *Procedural knowledge* – the skills to perform processes, to execute algorithms and to know the criteria for their appropriate application.
(3) *Conceptual knowledge* – interrelated representations of more complex knowledge forms, including schemas, categorization hierarchies, and explanations.(Anderson & Krathwohl, 2001, pp. 27–29)

Anderson and Krathwohl (2001) also present a metacognitive knowledge category, but because no explicitly metacognitive tasks were presented to students in this study it does not feature as a category in this analysis. As well, the 'cognitive process' dimension of Anderson and Krathwohls' (2001) framework has not been incorporated into this research as it relates more to the way in which individual students attempt to learn concepts rather than the object of study.

3.5. Sampling learning tasks

The final sample selected for this analysis included a set of eight common learning tasks across the three iterations of the course, resulting in 24 learning episodes being analyzed. The learning episodes represented a variety of task types (declarative, procedural, and conceptual), activity designs (teacher-centred, teacher-led and student-centred) and interface designs (presentational and collaborative) as represented in Table 1.

These tasks were selected on the basis of being of some typicality, but also providing potential for learning about pertinent phenomena occurring in the data (in accordance with Stake, 1994). The approximately six-hour lesson time across 24 learning episodes provided a dataset that was both sufficient to address the research questions and of adequate magnitude so that statistical tests could be meaningfully conducted (as recommended by Herring, 2004). Note that interaction effects were not being measured in this study so that while a variety of interface, activity and task design combinations were analyzed it was not necessary to include every possible combination of these in the sample. It should also be noted that in four of the Iteration 2 learning episodes students split into two group-work rooms, resulting in two extra transcriptions for that iteration of the task. Even though group-work was attempted in Iteration 3 no extra transcriptions were required because there were only three students completing the course (all group-work could be conducted in the main room).

The identical task, interface, and activity design was applied for all three iterations in Topic 1 to act as a mechanism for calibration between semesters. Statistical tests found no significant difference in the type of discourse contributed by the teacher across semesters, $\chi^2(8, N = 204) = 8.96$, $p = 0.35$, or by students across different semesters, $\chi^2(4, N = 75) = 1.59$, $p = 0.84$, providing grounds for amalgamating the datasets from the three iterations for the purposes of analysis. Qualitative observations of the similar types of discourse and interactions that resulted from the same learning designs also supported the view that the different student cohorts did not unduly influence the types of collaboration that transpired (see Bower, 2008).

3.6. Multimodal discourse analysis coding frame

For the purposes of this study, the following definitions have been used to distinguish between textual discourse and actions:

- Textual discourse – any written or spoken contribution to the web-conferencing environment as part of a discussion, in effect, “what is said”. This relates to the use of words to engage in discourse.

Table 1
Summary of the 24 learning episodes sampled for the multimodal discourse analysis.

Learning episode	Task description	Task type	Interface design	Activity design	# Students	Episode duration (mins)
Topic 01 Iteration 1	Debug cube program	Debugging (procedural)	Presentational	Teacher-led programming	9	7
Topic 01 Iteration 2	Debug cube program	Debugging (procedural)	Presentational	Teacher-led programming	11	6.25
Topic 01 Iteration 3	Debug cube program	Debugging (procedural)	Presentational	Teacher-led programming	2	10.5
Topic 02 Iteration 1	Distinguish program features	Identification (declarative)	Presentational	Teacher-led question response	8	7.25
Topic 02 Iteration 2	Distinguish program features	Identification (declarative)	Collaborative	Student-centred tutorial group-work	8	27.25
Topic 02 Iteration 3	Distinguish program features	Identification (declarative)	Collaborative	Student-centred tutorial group-work	3	27.5
Topic 03 Iteration 1	Write SoftDrinkCan program	Meet design spec. (procedural)	Presentational	Teacher-led programming	8	18.5
Topic 03 Iteration 2	Write SoftDrinkCan program	Meet design spec. (procedural)	Collaborative	Student-centred group programming	9	19
Topic 03 Iteration 3	Write SoftDrinkCan program	Meet design spec. (procedural)	Presentational	Teacher-led programming	3	17
Topic 04 Iteration 1	Applet comprehension questions	Comprehension (conceptual)	Presentational	Teacher-led question response	9	8.75
Topic 04 Iteration 2	Applet comprehension questions	Comprehension (conceptual)	Collaborative	Student-centred tutorial group-work	8	17.25
Topic 04 Iteration 3	Applet comprehension questions	Comprehension (conceptual)	Collaborative	Student-centred tutorial group-work	3	7
Topic 09 Iteration 1	Shallow versus deep copies	Comprehension (conceptual)	Collaborative	Teacher-centred whiteboard presentation	9	11.75
Topic 09 Iteration 2	Shallow versus deep copies	Comprehension (conceptual)	Collaborative	Teacher-centred whiteboard presentation	7	8.5
Topic 09 Iteration 3	Shallow versus deep copies	Comprehension (conceptual)	Collaborative	Student-centred whiteboard activity	4	6.75
Topic 10 Iteration 1	Radio-button to ComboBox	Meet design spec. (procedural)	Presentational	Teacher-led programming	8	21.5
Topic 10 Iteration 2	Radio-button to ComboBox	Meet design spec. (procedural)	Collaborative	Student-centred group programming	7	32.75
Topic 10 Iteration 3	Radio-button to ComboBox	Meet design spec. (procedural)	Collaborative	Student-centred group programming	3	36
Topic 11 Iteration 1	Nested loop array output	Prediction (conceptual)	Presentational	Teacher-centred presentation	9	4.5
Topic 11 Iteration 2	Nested loop array output	Prediction (conceptual)	Presentational	Teacher-centred presentation	6	10.5
Topic 11 Iteration 3	Nested loop array output	Prediction (conceptual)	Collaborative	Teacher-Led whiteboard activity	2	27.75
Topic 12 Iteration 1	Adjust file reader	Meet design spec. (procedural)	Presentational	Teacher-centred presentation	9	5
Topic 12 Iteration 2	Adjust file reader	Meet design spec. (procedural)	Collaborative	Teacher-led whiteboard activity	7	11.5
Topic 12 Iteration 3	Adjust file reader	Meet design spec. (procedural)	Collaborative	Teacher-led group programming	3	6.75
Totals						356.5

- Actions – any recorded contribution to the web-conferencing environment that is non-textual, such as clicking on buttons, drawing on the whiteboard, modelling programming, and so on.

All textual discourse has been classified by its *subject* and its *interactive nature*. All *actions* were classified by the media through which they occurred and were sometimes further categorised by the collaborative function they performed.

3.7. Segmenting and coding textual discourse and actions

Strijbos, Martens, Prins, and Jochems (2006) argue for care in defining units of analysis in order to improve the validity and reliability of conclusions drawn from content analysis studies. The 'sentence' was selected as the unit of analysis in this study because:

(a) it is fine-grained, providing greater frequencies through which to determine patterns of collaboration,
(b) its boundaries are often defined by the participants, allowing the data to remain more pristine than if the researcher were to define the 'units of meaning', and
(c) its size is more consistent than the 'unit of meaning' approach and less exposed to unreliable segmentation issues such as unit boundary overlap (Strijbos et al., 2006).

All textual discourse in this study was either contributed in spoken form using the Voice Over IP audio facilities or by typing text into a text field area such as a notes pod or text-chat tool. Because the contributor determined the bounds of a text-chat sentence the problem of determining the demarcation points was in most instances resolved. In some (very few) cases participants would include two sentences in a single text-chat entry separated by punctuation. For these text-chat contributions, end of sentence punctuation (such as a "full stop", "question mark", or "exclamation mark") was considered to denote the end of a sentence, just as a capital letter denoted the beginning of a new sentence. In cases where audio contribution sentence boundaries were ambiguous, sentences breaks were made. This prevented the subject of discourse contributions from running into each another, thus allowing for less ambiguous categorization of sentences under the coding scheme. All textual-discourse contributions were classified as to their Subject–Interaction profile.

The purpose of coding the subject of textual discourse was to determine the extent to which the discussion in the web-conferencing environment related to the actual task-based curriculum of the course (Content), coordinating interactions between people (Activity), working with the collaborative platform (Technology), or a combination of these. The following three questions provided guidance in coding the subject of discourse for a sentence:

(1) Does the sentence relate to curriculum-based concepts? (Content)
(2) Does the sentence relate to who should be doing what and/or when? (Activity)
(3) Does the sentence relate to the use of the collaborative software? (Technology)

Note that the answer may be yes to more than one of these questions, or no to all. All codes were applied in context in order to categorize each utterance according to its semantic intention. For instance, a student response of "yes" was classified as to its Content-Activity-Technology profile based upon the utterance to which it is responding. If students were asked whether they knew which group they were in and they responded "yes", it would be categorised as an Activity statement, whereas if they were asked whether the Java programming language is case-sensitive their response of "yes" would be a Content statement.

Table 2 provides some examples of each of the possible Subject categories of sentences, as well as some associated commentary to help clarify the category boundaries. For a more complete explanation of category definitions, see Bower (2008).

Every textual-discourse contribution (written and speech) was also coded according to its interactive nature in order to determine collaborative patterns that occurred in the environment. Discourse was classified as either a statement or question so as to be able to analyze whether particular learning designs or pedagogical strategies led to more questions being posed or answered. Statements were considered to be those comments that did not generally invite response whereas questions indicated to others that responses were required, thus impacting on the expectation to interact. Where a question was rhetorical, it was coded as a statement. All textual discourse sentences were also coded as to whether they were independently initiated or responsive. If they were responsive, the contribution to which they were responding was noted, either a Question, Statement, or non-discursive contribution (Action). This categorization scheme resulted in an eight point coding system for nature of interactions:

(1) Independent Question.
(2) Independent Statement.
(3) Question Response to an Action.
(4) Question Response to a Question.
(5) Question Response to a Statement.
(6) Statement Response to an Action.
(7) Statement Response to a Question.
(8) Statement Response to a Statement.

For the purposes of this study only comments that were responding directly to a specific action or comment were considered to be a 'response'. As well, questions and statements to one's own contributions were not considered to be responsive.

Finally, all actions recorded in the transcripts were classified into the following categories:

(1) adjusting the virtual classroom interface to better facilitate communication,
(2) broadcasting a document with questions, answers or content,
(3) highlighting text with the cursor to emphasize,

Table 2
Subject of textual discourse coding definitions.

Subject category	Brief definition	Examples
Activity	Activity discourse explicitly relates to what will be done and/or by whom in the current learning situation, in an attempt to coordinate activity between people. This also relates to setting up the task	*"Let's have a look at task number 3."* *"So in a moment I'm going to ask you all to give me your ideas."*
Content	Content sentences relate to curriculum-based subject matter, i.e. the content being learned	*"What is the problem with this piece of code?"* *"When I tried a value of 10 it didn't work."*
Technology	Technology sentences explicitly relate to the functionality and properties of the virtual classroom web-conferencing system. Note that they do not relate to other technologies concurrently being used as these are not categorised as the tool for mediating collaboration	*"So when we're using the notes pod we can all scroll to different points"* *"The screen-share can take a while to come through depending on your bandwidth."*
Activity-Content	Activity-Content sentences relate to who should perform a task during collaborative problem solving and contributions that coordinate curriculum-based discussions between people. This includes when the teacher explicitly asks students to provide a response to a content based questions	*"You need to change the variable name"* *"Can anyone tell me if a Company belongs to the list of parameters in this program."*
Activity-Technology	Activity-Technology sentences relate to how the web-conferencing tools can be used to coordinate activity between people	*"People can just copy and paste their solutions directly onto the whiteboard."* *"Could the first three students on the attendee list use the left-hand note-pod"*
Content-Technology	Content-Technology sentences relate to using technologies to address content	*"You can see I'm using the pointer tool to highlight the instance field declarations in this program."* *"So could we use another box on the whiteboard to represent the second value in the array?"*
Activity-Content-Technology	Activity-Content-Technology sentences relating to how to use the technology to perform an activity while demonstrating content based knowledge	*"So in the chat window can you all be discussing what you think the difference between an instance field and a local variable is."* *"Can everyone can scroll right to the bottom of the notes pod and let me know when you've found the createControlPanel method."*
Other – *General sentiments and attitudes regarding a task*	These involve personal expressions of feelings or subjective judgments, not specifically related to explicitly discussing an aspect of content, activity, or technology	*"Yeah, I really enjoyed that exercise."* *"Thank you for your positive energy and excellent questions."*
Other – *Personal, unrelated, or unclassifiable discussion*	These do not relate to teaching, coordinating activity or technology – off task textual discourse. This includes all sentences that were unable to be classified into any other category.	*"Nice desktop pattern."* *"Hmmm, ok, whoops"*

(4) moving information between resources and pods,
(5) moving of people between layouts and rooms,
(6) note-pod non-textual-discourse contributions (such as deleting text),
(7) recording the online session,
(8) screen-sharing to model programming processes,
(9) unrelated operations (such as setting up the next task), and
(10) whiteboard operations (such as drawing a line, adding a label, or moving a shape).

These categories not only differentiated the type of action being performed but also implicitly and immediately indicated the modality being used.

The meaning unit for all actions was any distinct semantic collaborative contribution involving some component of spatial selection. For instance, clicking on the share screen button within the virtual classroom environment, drawing a rectangle on a whiteboard, or pasting a line of computer code into a program were all distinct actions.

3.8. Measuring reliability – objectivity of coding scheme application

Generally speaking there are two reliability issues inherent in content analysis research – the demarcation (segmentation) of units within the sequence of materials, and then the corresponding coding of those units (Bauer, 2000, p. 143). A second rater was used to gauge the consistency with which the coding methods were applied. A traditional percentage agreement approach to measuring inter-rater reliability was chosen over the Kappa statistic approach due to limitations of the Kappa statistic proposed by some researchers (Gwet, 2002; Uebersax, 2002).

To provide dataset upon which measures of inter-rater reliability could be drawn, four learning episodes from the sample of 24 were selected. The episodes were selected so that a range of topics, iterations, task types, interface designs, activity designs, and modalities were represented, as outlined in Table 3.

In order to provide a measure of *segmentation reliability* the demarcation of sentences applied by the transcriber was compared to demarcation performed by the researcher. A "disagreement" in segmentation was recorded every time the transcriber and researcher marked a different end of "sentence" position (i.e. one person felt a sentence had been completed and the other did not), and an "agreement" in segmentation was when the transcriber and researcher agreed on the end of a sentence position. For the transcripts analyzed there were 134 agreements and 30 disagreements, leading to an overall segmentation agreement of 81.7%. This is acceptable according to Strijbos et al. (2006). Note that Topic 9 Iteration 3 was not included in this analysis because it was transcribed by the researcher.

In order to calculate measures of coding reliability a second rater familiar with technology-based learning and the coding of transcripts was employed to code the four transcripts identified for inter-rater reliability analysis. This rater was provided with the codebook and

Table 3
Learning episodes used for inter-rater reliability measurements.

‘Topic – Iteration	Task description	Task type	Interface design	Activity design	Modality
Topic 1 Iteration 2	Debug cube program	Procedural	Presentational	Teacher-led	Screen-sharing
Topic 9 Iteration 3	Shallow versus deep copies	Conceptual	Collaborative	Student-centred	Communal whiteboard
Topic 11 Iteration 1	Nested loop array output	Conceptual	Presentational	Teacher-centred	Document broadcast
Topic 12 Iteration 3	Adjust file reader	Procedural	Collaborative	Student-centred	Communal note-pod

instructions about the coding process. Both the Subject of textual discourse and the Nature of Interaction were coded. Four transcripts were coded and percentage agreement calculated using the formula:

$$Percentage\ Agreement = \frac{Sentences\ Coded\ Identically}{Number\ of\ Sentences\ Coded}$$

This resulted in a percentage agreement for the Subject of textual discourse in the four transcripts of 80.2%, and a percentage agreement for the Nature of Interaction of 82.3%. These once again indicate an acceptable level of agreement between raters for reliability of coding purposes (Strijbos et al., 2006).

4. Results

The multimodal discourse analysis enabled results to be produced on several levels, including:

(1) Within learning episode results – findings relating to collaborations within a learning episode based on the learning design that was implemented.
(2) Global results – summaries of the entire dataset that serve to characterize teaching and learning collaborations across all 24 learning episodes.
(3) Learning design results – results stemming from considering how the dimensions of variation (interface, task type and activity design) effected collaborations.

A summary of the data and results for the first Iteration of Topic 10 is presented below in order to exemplify the within learning episode analysis process. It has been selected because it is of some typicality in so far as illustrating how the teacher and students may contribute to a learning episode and utilise the web-conferencing technology. Global results relating to the subject of discourse, the nature of interactions, and the modalities used are reported after the Topic 10 exemplar, to demonstrate how the multimodal discourse analysis could provide a characterisation of the entire sample and illuminate differences between teacher and student discourse and activity. Finally, results regarding how learning designs affected discourse in the web-conferencing environment are drawn in order to demonstrate how the methodology can be used to determine significant cause-and-effect relationships in the data. In the latter analysis careful attention is dedicated to aspects of validity (particularly in relation to the existence of intervening variables) and the appropriateness of analysing the effect of independent variables is either justified or refuted.

4.1. Within episode results – an example from Iteration 1 of Topic 10

The task analyzed for the three episodes in Topic 10 was a procedural exercise requiring students to write a computer program that met the following design specification:

> “Adjust the program your wrote in the pre-class activities that changed the background colour of a panel using radio-buttons so that it now changes the colour using a dropdown menu.”

In Iteration 1 a presentational interface was used incorporating the standard desktop sharing tool as the major component of the window. The teacher was the only person with permissions to operate the desktop sharing tool, and students could only contribute to the activity using he text-chat pod at the bottom of the interface (see Fig. 2). The teacher broadcasted his desktop containing the Integrated Development Environment (IDE) and prompted students for suggestions about how to change the program so that it uses a dropdown menu instead of radio-buttons. This constituted a teacher-led activity design. There were eight students participating in the learning episode.

The teacher performed most of the actions in this 21.5 min episode, contributing 60 separate recorded instances of teacher modelling programming actions and four instances of the teacher highlighting text to provide emphasis. All 126 of the teacher textual-discourse contributions were made using audio. The majority of the teachers’ comments related directly to Content (77 out of 126 textual-discourse contributions, see Table 4) indicating that the teacher played a significant knowledge bearing role in this episode. Note that for ease of interpretation table cells representing counts of between 1 and 4 occurrences have been marked with a light colour, while cells with countsof 5 or more have been coloured in a darker shade.

Thirty of the 126 teacher textual-discourse contributions related in some way to coordinating activity (see Table 4). It was noted that many of the 12 Activity statements that the teacher contributed occurred at the beginning of the task. These were to set the expectation for activity during the learning episode and to describe how students should be engaging in this task. The teacher also made 18 Activity-Content statements throughout the task. Once again a large proportion of these occurred at the beginning of the learning activity. These contributions establish how the class should interact with the content (for example, ‘‘And what we’re going to do is turn the code that we have into a dropdown menu”).

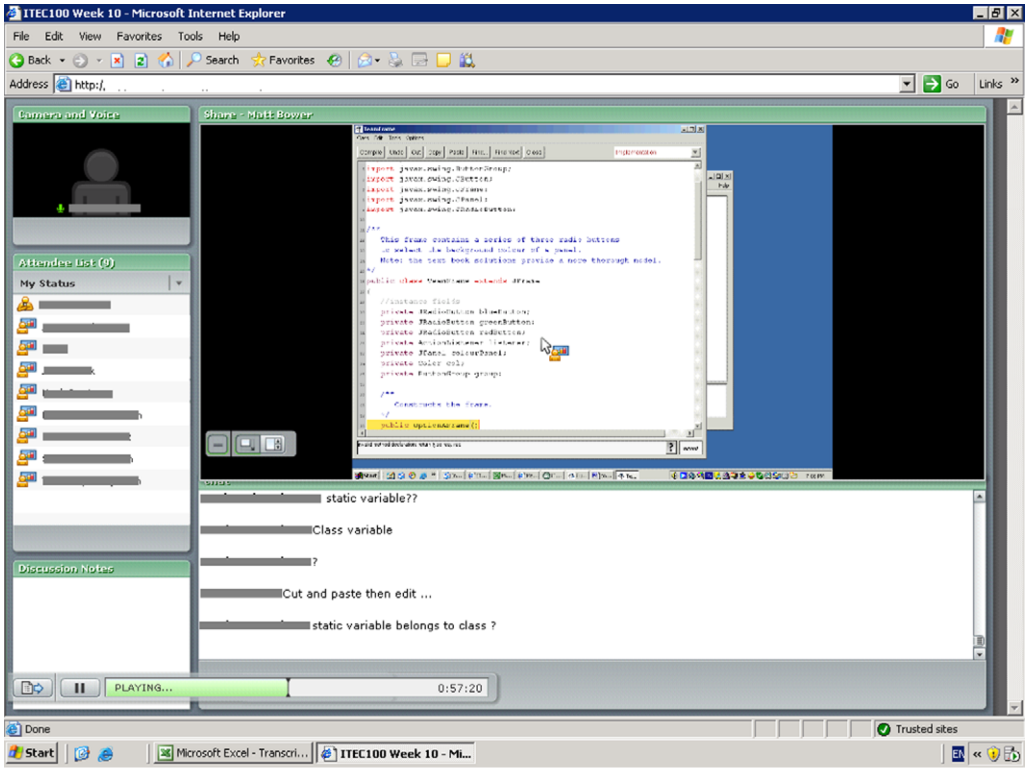

Fig. 2. Interface design for Topic 10 Iteration 1 showing a screen-share of the IDE used by the teacher (top right), the text-chat area used by students (bottom right), a notes area (bottom left) and the attendee list (middle-left).

Students only communicated using text-chat, contributing a total of 64 textual-discourse contributions using this means. The teacher-led activity design whereby the teacher prompted students for suggestions about what to do next resulted in students being less directive in discussing the curriculum matter; most of the Content comments made by students were Statement Responses to Questions (19 out of 36, see Table 5). Students also make 10 Activity-Content statements (see Table 5) which related to providing the teacher with explicit directions about the steps that should be performed to solve the problem, such as "add the panel".

However, the design that was implemented did not render students entirely passive; they did have some space to direct learning. Students made three Independent Questions and eight Independent Statements all relating specifically to Content (see Table 5). In many cases this caused the teacher to adopt a more responsive role; 37 of the 126 textual-discourse contributions made by the teacher were responses to student questions or statements (see Table 4).

No difficulties with the communication approaches were experienced during this learning episode, and as such no Technology or Technology-related discourse contributions were recorded by either the teacher or students (see Tables 4 and 5). This is atypical in the entire

Table 4
Topic 10 Iteration 1 Subject–Interaction counts for TEACHER textual discourse during learning episode.

	Independent question	Independent statement	Question response to question	Question response to statement	Statement response to question	Statement response to statement	Question response to action	Statement response to action	Totals
Content	16	36	1	2	7	13	0	2	77
Activity	1	8	0	0	3	0	0	0	12
Technology	0	0	0	0	0	0	0	0	0
Activity-Content	2	9	0	1	0	6	0	0	18
Activity-Technology	0	0	0	0	0	0	0	0	0
Activity-Content-Tech.	0	0	0	0	0	0	0	0	0
Content-Technology	0	0	0	0	0	0	0	0	0
Task sentiments/attitudes	3	7	0	0	0	4	0	1	15
Unrelated/unclassifiable	1	2	0	0	0	0	0	1	4
Totals	23	62	1	3	10	23	0	4	126

Table 5
Topic 10 Iteration 1 Subject–Interaction counts for STUDENT textual discourse during learning episode.

	Independent question	Independent statement	Question response to question	Question response to statement	Statement response to question	Statement response to statement	Question response to action	Statement response to action	Totals
Content	3	8	3	1	19	2	0	0	36
Activity	3	2	0	0	1	1	0	1	8
Technology	0	0	0	0	0	0	0	0	0
Activity-Content	0	6	0	0	2	2	0	0	10
Activity-Technology	0	0	0	0	0	0	0	0	0
Activity-Content-Tech.	0	0	0	0	0	0	0	0	0
Content-Technology	0	0	0	0	0	0	0	0	0
Task sentiments/ attitudes	0	5	0	0	4	1	0	0	10
Unrelated/ unclassifiable	0	0	0	0	0	0	0	0	0
Totals	6	21	3	1	26	6	0	1	64

dataset analyzed, and occurred in part because by Topic 10 both the teacher and students were familiar with the mode of interaction associated with the teacher-led programming approach.

The teacher-led activity design appeared effective in allowing the teacher to demonstrate how to adjust programs and articulate logic relating to the task. The process of debugging code could be demonstrated, with the class able to offer debugging suggestions at each obstacle. On the basis of a similar analysis conducted across all 24 learning episodes, global results were derived and quantitative analyses performed.

4.2. Global results

The ability to construct global results allows the nature of teaching and learning using the multimodal collaborative environment to be characterised across the entire dataset. In terms of the 24 web-conferencing episodes being analyzed a total of 2241 teacher textual-discourse contributions and 1584 student textual-discourse contributions were coded in the transcripts. This equates to the teacher contributing 58.6% of comments students contributing 41.4% of comments during the learning episodes. Note that the proportion of teacher versus student textual discourse within individual episodes varies greatly around these amounts.

4.2.1. Subject of textual discourse results

The proportion of teacher textual-discourse contributions and student textual-discourse contributions classified by Subject category across all 24 learning episodes are represented in Fig. 3. Having proportions of discourse types allows statistical tests to be conducted to determine whether there were differences in the subject of teacher and student discourse. A Chi-square test for homogeneity of teacher and student proportions of Subject textual discourse types revealed a significant difference between the overall proportions of teacher and student contributions, χ^2 (8, N = 3825) = 60.34, $p < 0.001$.

Individual Subject categories could then be analyzed using two-population proportion equivalence tests to determine which categories of teacher and student discourse were significantly different. A Bonferroni adjusted significance level of $\alpha = 0.05/9 = 0.00556$ to account for the nine categories of Subject textual discourse types being examined. The results of this analysis are presented in Table 6.

Qualitative analysis of the learning episodes could then be used to provide explanations for the significant differences between the proportion of teacher and student contributions in some categories:

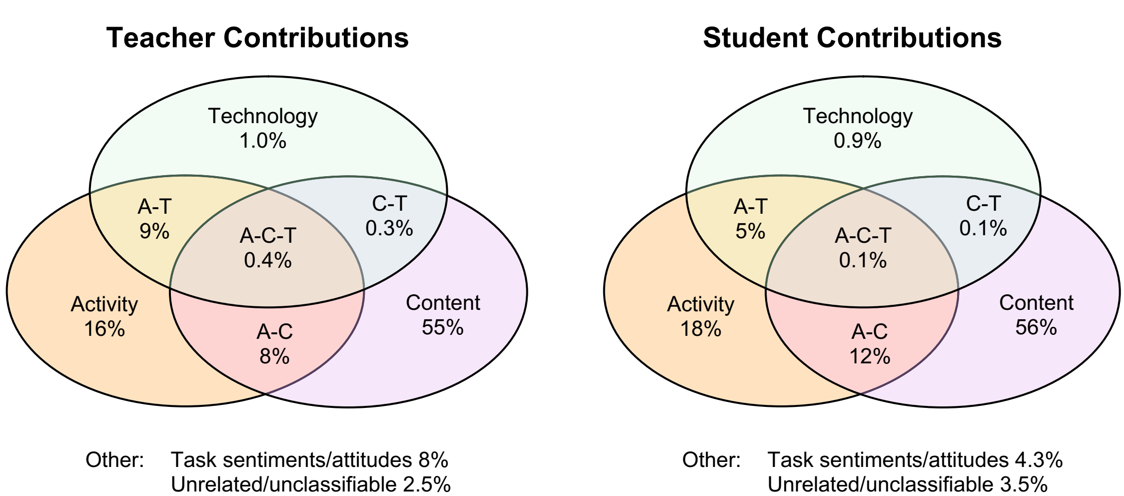

Fig. 3. Proportion of textual discourse by subject across all episodes for the teacher (2241 contributions) and students (1584 contributions).

Table 6
Tests for homogeneity of teacher and student textual discourse by subject category.

Subject	*Z*-value	*P*-value
Content	0.417	0.687
Activity	1.844	0.065
Technology	0.108	0.914
Activity-Content	3.870	<0.001*
Activity-Technology	4.087	<0.001*
Activity-Content-Tech.	2.179	0.029
Content-Technology	1.458	0.145
Task sentiments/attitudes	4.486	<0.001*
Unrelated/unclassifiable	1.678	0.093

* Indicates a significant result at $\alpha = 0.00556$.

- The larger proportion of Activity-Content contributions by students compared with the teacher (12% as opposed to 8%) could be explained by the group-work activities they undertook – when collaboratively solving problems students not only need to discuss what is to be done but also by whom.
- The greater proportion of Activity-Technology contributions by the teacher compared with students (9% as opposed to 5%) could be explained by the need for task instructions to establish how the technology was to be used, as well as the need to guide and troubleshoot during activities.
- The larger proportion of task-related sentiments and attitude contributions by the teacher as compared to students (8% as opposed to 4.3%) could be explained by the proactive teacher attempt to establish an encouraging learning environment and engender a positive attitude towards computing studies.

4.2.2. Nature of Interaction results

The coding framework was also able to characterize the types of interactions that occurred in the web-conferencing environment. The percentage of the 2241 teacher textual-discourse contributions and 1584 student textual-discourse contributions classified by Nature of Interaction across all 24 learning episodes are represented in Table 7.

Once again two-population equivalence tests could be performed to detect differences in the proportion of interaction types for teachers and students. A Chi-square test for homogeneity of teacher and student proportions of textual discourse classified by interaction types revealed a significant difference, χ^2 (7, $N = 3825$) = 699, $p < 0.001$. Individual interaction categories were once again analyzed to determine significant differences between teacher and student discourse with a Bonferroni adjusted significance level of $\alpha = 0.05/8 = 0.00625$ used to account for the eight categories of interaction textual discourse types being examined. The results of this analysis are represented in Table 8.

Again, qualitative analysis of the episodes was able to identify reasons for the above differences in the proportion of interaction types for teacher versus student contributions:

- The larger proportion of Independent Statement contributions by the teacher compared with students (55.2% as opposed to 25.4%) could be explained by the instructive and directive role often assumed by the teacher.
- The greater proportion of Statement response to Question contributions by the students as compared to the teacher (35.7% as opposed to 6.1%) can be explained by the large number of responses students provided during teacher-led question-response sequences.
- The greater proportion of Question response to Question contributions by the students as compared to the teacher (2.5% as opposed to 0.5%) could be explained by the need for students to clarify understanding relating to questions posed in-class, both concepts being discussed and the meaning of a particular question.
- The larger proportion of Question response to Statement contributions by the students as compared to the teacher (4.3% as opposed to 1.8%) could be explained by the need for students to clarify the meaning of both content related discussions as well as those relating to task instructions.

The frequency of each of the non-textual-discourse contributions (Actions) provided a characterisation of how the technology was used to mediate collaboration and learning. The actions by the teacher and students across all learning episodes are represented in Table 9 below.

The results indicate usage patterns that occurred, and qualitative analysis could then be performed to interpret them. The teacher played a relatively active role in the learning episodes analyzed, with 598 actions compared to students' 284 (see Table 9). The way in which the teacher usually assumed a managerial role over the technology is represented by the 35 instances of adjusting the virtual classroom interface to better facilitate communication compared to 16 by students (see Table 9). As well, the often instructive role of the teacher

Table 7
Teacher and student proportions of textual discourse by interaction type.

Grand totals	Independent Question (%)	Independent Statement (%)	Question response to question (%)	Question response to statement (%)	Statement response to question (%)	Statement response to statement (%)	Question response to action (%)	Statement response to action (%)	Totals (%)
Teacher	13.5	55.2	0.5	1.8	6.1	18.0	0.1	4.7	100.0
Students	10.9	25.4	2.5	4.3	35.7	17.8	0.4	3.0	100.0

is evidenced by the relatively large number of actions relating to screen-share modelling programming, broadcasting documents with questions or answers or content, and emphasizing by highlighting text with cursor as compared to students (a total of 426 such teacher actions as opposed to 76 by students).

The use of collaborative learning designs in some episodes led to a large number of student non-textual-discourse contributions to note-pods as they collaboratively wrote solutions to problems (113 by students compared to 10 by the teacher). This is the only action in the virtual classroom where student contributions outnumbered teacher contributions (except for moving between layouts and rooms, which is to be expected because there were always several students and only one teacher). Students made contributions to the whiteboards and moved information between resources and pods, however equivalent teacher actions outnumbered student actions in a ratio of almost two to one.

The discourse and activity measures provided by the framework serve to portray the entire dataset. However this multimodal discourse analysis approach can also be used to compare and contrast sets of lessons based on independent variables.

4.3. Learning design results

For the analysis of the web-conferencing environment the following variables were identified ex-ante:

(1) Task type (declarative, procedural, conceptual).
(2) Technology design (presentational, collaborative).
(3) Activity design (teacher-centred, teacher-led, student-centred).

However, based on extended observation of the learning episodes during the coding process concerns arose over the internal validity of performing quantitative analysis along the task type and technology design dimensions. In some episodes the effect of the task type (declarative, procedural, or conceptual) and interface design (presentational, collaborative) was overshadowed by the activity design. For instance, a teacher-led approach adopted in Iteration 3 resulted in substantially different discourse to the teacher-centred approaches of Iteration 1 and Iteration 2 even though the same task was being addressed. The transmissive (teacher-centred) approach to instruction adopted in Topic 9 Iteration 1 entirely overshadowed any effect upon discourse that may have been achieved by the collaborative interface design. Thus the potential to conduct valid statistical analysis along the task type or technology design dimensions was to this extent questionable. From the review and analysis of the 24 learning episodes it did however appear that activity designs were a direct causal influence on collaborations. For this reason only statistical analysis along the activity design dimension will be demonstrated.

Before commencing the statistical analysis of the learning episodes it was necessary to perform standardizations so that the five teacher-centred, eleven teacher-led and eight student-centred activity designs represented in Table 1 could be compared on a consistent basis. Standardizations were performed on the following levels:

(1) duration of learning episodes and
(2) number of students in each learning episode.

Table 8
Tests for homogeneity of teacher and student textual discourse by interaction category.

Nature of interaction	*Z*-value	*P*-value
Independent Question	2.400	0.016
Independent Statement	18.383	<0.001*
Question response to question	5.117	<0.001*
Question response to statement	4.612	<0.001*
Statement response to question	23.300	<0.001*
Statement response to statement	0.178	0.858
Question response to action	2.217	0.027
Statement response to action	2.680	0.007

* Indicates a significant result at $\alpha = 0.00625$.

Table 9
Summary of teacher and student actions (all episodes).

Action	Teacher	Student
Adjusting VC interface to better facilitate communication	35	16
Broadcasting documents with Qs or As or content	17	0
Highlighting text with cursor to emphasize	76	2
Moving information between resources and pods	21	12
Moving of people between layouts and rooms	28	34
Note-pods non-textual-discourse contributions	10	113
Recording the online session	6	0
Screen-share to model programming processes	332	74
Unrelated operations	15	0
Whiteboard operations	58	33
Total	598	284

Table 10
Average rates of teacher and per-student textual discourse per minute for different activity designs.

	Teacher-centred	Teacher-led	Student-centred
Teacher	6.0936	8.6068	5.0969
Per-student	0.1607	0.5858	1.1538

If learning episodes were not standardized based on their duration, longer episodes could not be compared to shorter episodes in terms of their Subject–Interaction profile. To account for this the teacher and student Subject–Interaction matrices were divided by the duration in minutes to determine a rate of contribution per minute for each of the cells. As well, student Subject–Interaction matrices were divided by the number of students to derive per-student contributions per minute for each of the matrix cells. Measuring student contributions per person per minute as opposed to total student contributions per minute accounts for biases to contribution rates caused by having more students in one learning episode than another, thus allowing for more accurate comparison and contrast of episodes. As well, measuring per person activity allows the measurement of individual involvement in each learning episode.

The resulting average teacher and per-student textual-discourse contributions per minute for episodes of each type of activity design are represented in Table 10. Note that rates of contribution are unweighted by duration, meaning that the longer of the 24 episodes did not count for more in these calculated averages than shorter episodes. The differences between the rates are represented graphically in Fig. 4.

These rates of discourse per minute could then be statistically analyzed to determine whether there were significant differences between the overall rates of contribution for different types of activities designs for either the teacher or the students. One-way analysis of variance on the mean rate of teacher contribution for the three activity designs (teacher-centred, teacher-led, and student-centred) revealed a significant difference between the rates, $F(2, 21) = 11.52$, $p < 0.001$. As well, an equivalent test of per-student rates of textual discourse also indicated significant difference between activity designs $F(2, 21) = 9.20$, $p = 0.001$. In order to determine where these differences between activity designs lay, two-tailed t-tests were conducted on the three permutations of activity design pairs. With a Bonferroni adjusted significance level of 0.05/3 = 1.67%, the following teacher results were observed:

- a significantly larger average rate of teacher contribution for learning episodes that applied the teacher-led activity design as compared to the teacher-centred activity design, $t(14) = -3.779$, $p = 0.002$ and
- a significantly larger average rate of teacher contribution for learning episodes that applied the teacher-led activity design as opposed to the student-centred activity design $t(17) = 4.267$, d.f. = 17, $p < 0.001$.

The fact that there was no significant difference between the average of the rates of teacher textual-discourse contributions for the teacher-centred and student-centred activity designs was surprising, with $t(11) = 0.951$, $p = 0.362$. However later analysis reveals that there was a significant difference in the type of discourse, namely that under student-centred activity designs the Subject–Interaction profile of the teacher's discourse is less content based and relates more to managing activity and technology than in the teacher-centred design.

As well, the average rates of teacher textual-discourse contribution for the teacher-led activity design was higher than the rates for the teacher-centred rate, which defied expectations (as one would expect there to be more teacher sentences per minute if the teacher was adopting a predominantly transmissive approach). Quantitative and qualitative analysis revealed that this was because the teacher was using more long winded sentences to explain content in the teacher-centred designs, and also because in teacher-led designs there was a greater kinetic energy resulting from the conversational nature of the episodes.

Equivalent analysis of the per-student textual discourse rates at the same 1.67% significance level yielded the following results:

- a significant difference between the average rate of per-student contribution for the teacher-centred and teacher-led activity designs, $t(14) = -2.762$, $p = 0.015$, with a 265% larger rate of per-student contributions for the teacher-led design,
- a significant difference between the average rate of per-student contribution for the teacher-centred and student-centred activity designs $t(11) = -3.565$, $p = 0.004$, with a 618% larger rate of per-student contributions for the student-centred design, and
- borderline significant difference between the average rate of per-student contribution for the teacher-led and student-centred activity designs $t(17) = -2.646$, $p = 0.017$, with the teacher-led rate once again being larger. (Note that this is a borderline result with only a 0.003 difference between the critical p-value and that of the test statistic.)

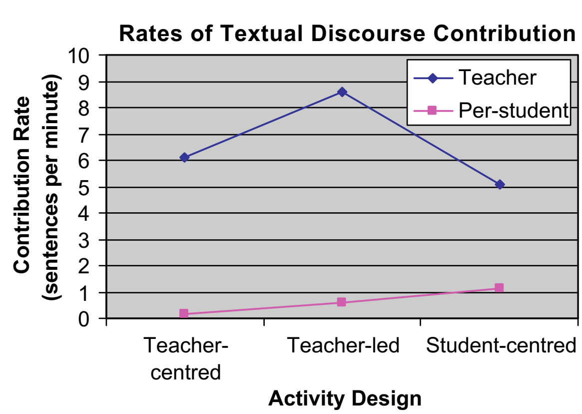

Fig. 4. Rates of teacher and per-student textual discourse by activity design.

Thus the analytic approach availed by performing the standardisations not only uncovered significant differences in contribution rates under different activity designs, but provided a measure of those differences. Perhaps more interestingly the process could also be applied to each of the coding categories in order to determine whether certain activity designs tended to have significantly higher or lower rates of a particular type of discourse.

Individual Subject and interaction category contribution rates for teachers and students were analyzed in an attempt to determine whether these differences in contribution rates could be attributed to a particular type of discourse. In order to improve the reliability of the analysis, only Subject types relating to learning with average rates of teacher textual-discourse contribution per episode of five or greater (i.e. 120 contributions across the 24 learning episodes) were considered for analysis. Once again all statistical tests used Bonferroni adjusted significance levels to account for the large number of comparisons being drawn. The following effects were detected:

(1) There was a significantly lower mean rate of teacher Content textual-discourse contribution per minute for the student-centred as opposed to the teacher-led activity design with respective averages of 1.736 and 5.978 sentences per minute, $t(17) = 6.485$, $p < 0.001$. This illustrates the teacher delegation of responsibility for Content discussions to the students for the student-centred design.
(2) There was a significantly higher mean rate of per-student Content textual-discourse contribution for the student-centred as opposed to the teacher-centred activity designs with respective averages of 0.648 and 0.090 sentences per minute, $t(11) = -4.816$, $p < 0.001$. This indicates the increase in student ownership over content in the student-centred as opposed to teacher-centred activity designs.
(3) There was a borderline significantly lower mean rate of per-student Content textual-discourse contribution for the teacher-centred versus teacher-led activity designs with respective averages of 0.090 and 0.437 sentences per minute, $t(14) = -3.261$, $p = 0.006$. Once again, the teacher-centred activity design inhibits the rate of student Content textual-discourse contribution.
(4) There was a significantly higher mean rate of teacher Independent Questions for the teacher-led as opposed to student-centred activity design with respective averages of 1.347 and 0.647 sentences per minute, $t(17) = 3.278$, $p = 0.004$. In the teacher-led activity design the teacher attempts to involve students by positing questions, whereas in the student-centred activity design there is less need because students are automatically involved by the nature of the task.
(5) There was a significantly higher mean rate of teacher Independent Statements for the teacher-led as opposed to student-centred activity type with respective averages of 4.360 and 2.726 sentences per minute, $t(17) = 3.316$, $p = 0.004$. In the student-centred activity design the teacher does not need to make as many directive and instructive comments.
(6) There was a significantly lower mean rate of per-student Statement Response to Questions for the teacher-centred as opposed to student-centred activity types with respective averages of 0.090 and 0.346 sentences per minute, $t(11) = -3.82$, $p = 0.003$. Students are seldom responding to questions in the teacher-centred activity design, whereas in the student-centred design they have the chance to respond to the questions of both the teacher and each other.

The results of performing the quantitative analysis above should be considered in light of the following qualifications:

- In each learning episode there was a range of affecting factors (such as student virtual classroom competencies, the specific details of the teacher implementation, the particular students involved in the learning episode and so on) that impact upon collaborations and thus comprise part of the error in this analysis.
- The sample is only a small subset of learning episodes in three different teaching semesters, by one teacher in one subject, and as such cannot be considered representative of all activity designs. The external reliability of extrapolating these results to other educational contexts needs to be carefully considered.

5. Discussion

The quantitative multimodal discourse framework enables a profile of individual learning episodes to be developed, that can then be used to compare and contrast lessons conducted in multimodal learning environments. The approach also allows global results to portrayed and quantitative analysis to be performed in an attempt to measure the impact of independent variables upon collaboration. Significant results signaled important features of the data that could then be scrutinized using qualitative observation.

5.1. Findings in this study

In this study of web-conference based lessons the multimodal discourse analysis technique enabled significant differences between the collaborative behaviors of the teacher and students to be detected. Across the whole dataset the teacher made significantly more Activity-related comments (see Table 6). Qualitative observation revealed that this was due to attempts by the teacher to provide collaborative guidance. The teacher also made a significantly larger proportion of Independent Statements by virtue of an often transmissive approach to instruction (55.2% compared to 25.4% by students, see Tables 7 and 8). As well, the teacher tended to dominate the management of the collaborative technology (see Table 9). On the other hand students made a relatively larger proportion of Statement response to Questions (35.7% compared to 6.1% by the teacher, see Tables 7 and 8) which qualitative analysis revealed was a result of making numerous replies to questions posed both by the teacher and other students. Thus across the entire corpus of learning episodes the teacher played a more directive role.

The multimodal discourse analysis technique allowed the significant influence of activity design (either teacher-centred, teacher-led, or student-centred) upon collaboration to be quantified. Levels of student discourse increased as less teacher-dominated activity designs were applied, with the student-centred activity design resulting in a more than six times larger rate of per-student contributions than for the teacher-centred design and more than two-and-a-half times than under teacher-led design (see Table 10). The level of teacher discourse also varied by the type of activity design, with the significantly less sentences contributed in the student-centred activity design as compared to the teacher-led activity design (5.1 sentences per minute as opposed to 8.6 sentences per minute, see Table 10). Thus the multimodal discourse analysis was able to provide a measure of the extra participation afforded by the movement from teacher-centred to more student-centred approaches, which has in turn been shown to improve student performance (Gao, 2001; La Pointe & Gunawarndena, 2004; Stavredes, 2002) and satisfaction (Chang & Smith, 2008).

Perhaps more interestingly the approach illuminated the different types of discourse that resulted from different activity designs. The student-centred activity design led to significantly higher rates of content-related contribution by students and significantly lower rates of content contribution by the teacher. This trend should inform online teachers that they need to consider student-led strategies if a student focus on the content is to be encouraged. As well, the movement towards more student-centred activity designs led to significantly lower rates of independently initiated teacher statements and questions and consequently less student statements responding to questions. This represents a replication of the more student initiated contribution patterns that have been observed under student-centred approaches in face-to-face environments (Wu & Huang, 2007).

5.2. Reflection upon the technique

The multimodal discourse analysis technique enables all the channels of communication to be captured and analyzed in order to better describe and understand phenomena in multimodal learning environments. It provides an instrument for framing analysis and identifying cause-and-effect relationships. The view it offers draws attention to patterns in the data which can then be analyzed from a qualitative perspective. The coding framework also addresses the question of where the discourse in multi-channel collaborative environments is directed – either towards the mediating technology, coordinating activity or the content itself. This is important because if educators ultimately intend students to focus on the to-be-learned material then understanding the amount and nature of ancillary discourse caused by operating in an online environment is critical.

The coding framework integrates the previously disjoint fields of Activity Theory (Engeström, 1987) framework with systemic functional linguistics (Halliday, 1985). As well, whereas Activity Theory had previously considered the participants, tools and content as separate components of an activity system, the coding framework applied in this study emphasised the intrinsically inseparable and overlapping nature of these elements. This was particularly evidenced by the considerable proportion of teacher and student discourse coded in the Activity-Content and Activity-Technology categories (see Fig. 3), even with a unit of analysis as fine-grained as the 'sentence'.

The coding framework also includes a layer that attends to the nature of interactions between people, which not only allows cause-and-effect relationships amongst collaborative acts to be detected, but also for this layer to be analyzed in conjunction with the subject of discussion. This enables discursive profiles of learning episodes to be established, and objective intertextual analysis to be conducted. The multimodal discourse analysis approach can also be used to objectively compare and contrast individual learning episodes (Bower, 2009).

The multimodal discourse analysis approach also opens up a range of opportunities for future research, such the application of the framework to analyze discourse and activity in a range of other learning domains and using other multimodal technologies. There is also the potential for more detailed and descriptive approaches to representing results of the coding framework (for instance, graphical time sequence diagrams of discourse and actions), which may allow previously unforeseen patterns of collaboration to be revealed.

6. Conclusion

In this implementation the multimodal discourse analysis approach provided a quantification of the extra contribution afforded by adopting student-centred learning designs in the web-conferencing environment, with a more than six fold increase in contribution as compared to teacher-centred approaches. Given that student interaction in online learning environments has been found to positively affect student achievement (Gao, 2001; La Pointe & Gunawarndena, 2004; Stavredes, 2002) and satisfaction (Chang & Smith, 2008), the study provides compelling evidence to support the calls that have been made for more learner-centred modes of online teaching (Barrett et al., 2007; McCombs & Vakili, 2005; Reeves et al., 2004).

The multimodal discourse analysis also enabled patterns in the nature of discourse to be detected, with more student-centred approaches resulting in more student discussion specifically related to the content and less student responses to teacher questions. Such student initiated and content focused environments have been shown to result in greater understanding (King, 1994; Lampert, 1990). Thus by changing the patterns of discourse to be less responsive and more student-directed the analysis indicates that student-centred online approaches can improve the quality of learning by changing the underlying nature of the environment in a similar manner to that which has been observed in face-to-face contexts (Wu & Huang, 2007).

Many of today's online educational environments use multimodal technologies to facilitate more dynamic and interactive learning. These require new analytic approaches in order to better understand how activity is facilitated and meaning is co-constructed in such environments. Quantitative multimodal discourse analysis provides a range of descriptive statistics that portray teacher and student use of these multimodal learning environments. The subject of discourse, the interactive nature of collaboration, and the different modalities used to perform actions are able to be deconstructed in order to characterize the nature of teaching and learning using multi-channel contribution-based technologies. The objective analysis afforded by the approach provides a suitable complement to the more descriptive multimodal discourse analysis techniques that analyze how modalities instantaneously combine to co-construct meaning. It is intended that the multimodal discourse analysis methodology applied in this study can provide a useful tool for analyzing collaboration in other multimodal technology-based learning contexts.

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