A proposed model of a visual interaction analysis graph for studying educational interactions and their impact on learning within a technology enhanced learning environment

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Abstract

Enhancing educational interactions in collaborative learning within Technology Enhanced Learning Environments (TELE) is a popular approach to engage students in active learning within the Higher education sector globally. These entail providing educational interaction episodes at various time points of a teaching/learning session. Analyses of interactions can explore whether improving student collaborations and interactions do indeed have an impact on learning. Few empirical studies on interaction analyses have been conducted in the context of Technology Enhanced classrooms in Higher education. Tools used currently for analyses of video data of educational interactions yield reports that are either too technical or do not, in themselves, give feedback on the impact of student interactions on learning. In this project, while studying collaborative learning within a Technology Enhanced practical lab, a simple model of an "Interaction Timeline Graph" was developed to sequentially analyse educational interactions over time, so that teachers and students alike might understand these. Content analyses of widely-used video analysis software applications was done. This led to some elements of these software applications to be incorporated in this new model. To further analyze educational impacts of these interactions, elements of a learning framework applied specifically to Technology Enhanced Learning lab have been coded and then incorporated into a further innovative detailed model of the "Visual Interaction and Learning Sequence Graph". Such a model of "Visual Interaction and Learning Sequence Graph" includes three critical segments of colour coded educational interactions in a sequential timeline as well as their representative snapshots along with each of its learning element. While studying learning in a technology enhanced classroom setting, it has much potential in its use, as interactions can be directly related to learning outcomes and summative grades. As this "Visual Interaction and Learning Sequence Graph" is simple and graphic, it can be used as a feedback tool for both the learner as well for facilitators on the effectiveness of interactions. When compared with grades, this model could also be used to expand academic analytics in identifying types of interaction that successful students engage in and those that may influence increased learning effectiveness and higher student performance.

Keywords

Educational interaction analyses; TELE; Interaction quality; Interaction graph; Mapping learning frameworks

Introduction

Education in the later 20th and in the 21st centuries has seen a continued focus on developing practices that move from teacher-centred to more student-centred learning approaches. Collaborative learning is one of the direct ways used to develop interaction in student-centred learning processes. Interactions can be defined as "reciprocal events that require at least two objects and two actions. Interactions occur when these objects and events mutually influence one another" (Wagner, 1994, p.8). Approaches that harbour interactivity in learning include peer teaching, peer collaboration and active learning. In a context of classroom learning, interaction can refer to a whole series of physical, psychological and educational relationships that participants, sharing the same environment, develop among themselves with a dynamic character (Cremmers & Tillema, 1988).

Within such a learning environment, Bender (2003) illustrated how technology can further facilitate learner-centred activities. Computer technology in education permits students to interact meaningfully with ideas and learn generatively (Cohen et al., 1994). Kear et al. (2004) suggested three uses of information and communication technology (ICT) - to support a resource-based learning approach, to participate in virtual communication and to promote an active approach to learning. Some (for example, Watkins, 2010 in Shepherd, 2010 cited in Passey, 2011), have advocated such approaches to deeper learning.

Even when learning technology has proven to be effective (as assessed by global measures), individual differences in the way students interact with the technology, facilitators, content and peers can help explain why some students gain more from collaborative learning than others. Thus, differences revealed by tracing educational interactions and the evaluation of these interactions on their learning might be useful for identifying those who have engaged effectively, to internalize the content and be able to demonstrate learning outcomes.

Interaction has its roots in constructivism, an epistemological framework (Piaget & Inhelder, 1971) that argues that knowledge and meaning are generated from an interaction between human experiences and their ideas. Over the past decades, a number of learning theories have evolved about the relationships between interactions, their educational benefits, social learning processes and the learning community in general. Collaborative learning research has paid close attention to the study of students' interactions during peer-based work, analyzing and identifying cognitive advantages of joint activity (Dillenbourg et al., 1996). In this context, Kendon (1990) stressed the need to identify the patterns and natural sequences of interaction whenever people enter each other's presence such as a collaborative learning environment. "Behavior consists of pattern in time. Investigations of behavior deal with sequences that, in contrast to bodily characteristics, are not always visible" (Ebel-Eibelsfeld, 1970, cited in Magnusson, 1997).

Based on a new paradigm that interaction is both the means and the end of education as we strive to educate global citizens, interaction can be considered a defining characteristic of education. This construct follows from Garrison and Shale (1990) who defined all forms of education as essentially interactions between content, students, and teachers. In today's world of technology-enhanced learning (TEL), technology, as a tool, when added to such a framework, leads to further complex interactions. This is later explored in this paper in a proposed model of learner interaction involving not just learners, contents and teachers but also technology.

The theoretical framework of such a four pronged approach (i.e. content, students, teachers and technology) can be found in the constructs of socio-cultural theory, specifically the one that proposes Activity Theory (Nardi, 1996) for representing the activities of groups where technology plays a role as mediator. Within this theory, an analysis model is proposed for identifying and representing the human and artificial elements (interactions) involved in joint tasks (Engeström, 1987). Collaborative and active learning, as happens in professional medical education, realizes contemporary approaches of situated cognition and a social construction of knowledge (Lave & Wenger, 1991). Thus, evaluation of the impact of such learning processes would logically involve their mapping within these cognitive and social knowledge construction domains.

A gap in the literature

A key to understanding learning in a collaborative TELE lies in understanding the rich interaction between individuals (Dillenbourg, 1999). To improve the quality of educational practices, there has been recent interest amongst educators in studying teaching and learning processes, using more general methodologies concerned with recording and analysis of teacher and student behaviours as they occur in the actual classroom situation. Multimedia tools (e.g. digital video technology) allow researchers to preserve the original complexity of data, while enabling them to analyze the data in comprehensive units (Brugmann & Kita, 1995). A number of video analysis software applications are available that can qualitatively and quantitatively analyze elements of digital video recordings of educational interactions. However, such methods provide data in forms that are often difficult to interpret, and are mainly in the realms of the educational researcher. The data are neither self-evident to the facilitator or student nor are they linked to any taxonomies of learning so that specific impacts on such learning can be evaluated.

A key goal for research is, therefore, the development of a simple graphical tool to measure and depict the quantity and quality of educational interactions and map them onto a learning framework. Reviewing different existing models of interaction analysis tools used in different business, behaviour and educational sciences provides us with ideas that allow us to arrive at a model of visual interaction analyses that can evaluate the impact of these interactions within a learning framework. Key questions to ask in this context are: How can video of educational interactions in TELE be analyzed and interpreted easily by students and teachers through a simple graphical model? How can learning frameworks be incorporated within this model to evaluate more specifically such educational interactions?

Reviewing video analysis software

Studying interaction is important, not just in educational research. Psychology, infant and child development, animal behaviour, marketing and usability studies all use methods to measure behaviour/interaction. The commonest methods to gather such interaction data is a systematic observation of behaviour/interaction as it unfolds sequentially in time and then is recorded in digital video. These data are then fed into a video analysis software application that can record, code and analyze such behaviour/interactions.

In addressing the first research question, a comprehensive literature search and a content analysis of video analysis software applications and other models were initially undertaken. The search terms used included *video# or *digital video# and *graphical analyses# and *interaction# or *effect# (* denotes a wild card within the same stem, while # denotes a truncation of terms). From the literature search, reliable and widely researched video analysis tools (both statistical and graphical) were identified and are described and discussed briefly here.

OBSERVER

This is a widely used and versatile software application for the collection, analysis, presentation and management of observational data and has been employed in research (Cadée, 2002) for recording and undertaking interaction analyses of various types of human behaviour. It yields reports that incorporate objective and quantitative data (Noldus, 2001). However, it does not include the specific pattern detection methods that are considered particularly useful for educational research.

VIDEOSEARCH

This is a Macintosh multimedia research tool that facilitates analysis of qualitative data by coding excerpts of videotaped material into precise user-defined categories of student activity (Harrington & Knibb, 1999). It can be used in a situated learning environment. The advantage is that a unique function or role can be tagged to the task. However, neither is the timeline analysis present nor is there any graphical report of the analyses.

THEME

Theme (Magnusson, 2000) is a professional software application for detecting hidden behavioural patterns. An advantage of this application is that it generally works independently of the behavioural unit and has applications in behavioural, educational (Koch & Zumbach, 2002) or in sports science research.

The main advantage of THEME is that the analyses can be conducted in a differentiated and flexible manner, enabling the researcher to uncover hidden patterns of dynamic interaction that one might miss without the multimedia support. It allows flexible handling of the coding process: verbal and nonverbal patterns can be analyzed either in one coding process or sequentially and can then be computed in an integrative manner. Categories that have been forgotten earlier or that prove to be superfluous can easily be added or dropped during the coding process. This leaves the researcher more exploratory freedom in addition to several different ways to approach the analysis (Koch & Zumbach, 2002). There are two features of this software application that are worth noting. Firstly, it can incorporate, at one time, a multitude of interaction coding. Further, what makes it unique from most other analysis models is the powerful algorithm that can generate graphical output of the interactions over time. However, the graphical output is neither easy to understand for a student or a teacher nor graphical in its true sense.

Interaction Diagrams

In the field of unified machine language, interaction diagrams are designed to let developers and customers view a software application from a different perspective and to varying degrees of abstraction commonly created in visual modelling tools. These tools model the behaviour of user cases by describing the ways groups of objects interact to collaborate in the behaviour, displaying the time sequence of the objects participating in the interaction (Fowler, 2004). Though these diagrams and analyses are extensively used in market research and management process studies, they do not give an in-depth representation of the behaviour. However, their simplistic and graphical nature to depict interactions and their being easily understood by any user are advantages that must be taken into consideration when emulating this as a model.

Video analysis software adapted to monitor specific medical education environments

Principles and features of the interaction analyses listed above were identified, and using a coding of the educational interactions, a simple model, an interaction graph for sequential analyses of educational interaction within TELE, was developed. A collaborative learning environment within TELE was chosen for studying the educational interactions and formulating this model. Over the last few years the School of Medicine in Monash University Sunway Campus has incorporated technology enhanced collaborative small group learning sessions as a common pedagogical approach to enhance active learning through an innovative technology enhanced anatomy learning lab (EPLARC). It combines elements (pedagogy, space and technology) of a next-generation learning space (Radcliff, 2009) as well as using medical and anatomy resources.

Within this EPLARC, during practical sessions, student groups are encouraged to discuss structured anatomy practical tasks. Student groups use content from books, models, plastinated (dried siliconised) cadaveric specimens, technology as Computer Assisted Learning (CAL) applications and web resources (within the EPLARC) and interact with other learners (group members) in solving the practical tasks and present their learning outcomes to the whole class. Lecturers facilitate these presentations and gives feedback. Through these active learning processes, a large cohort of students is thus expected to attain a deeper learning of knowledge (identification of body structures), skills (body surface marking and clinical examination) and attitude (presentation and communications) following Bloom's domains of learning objectives (Bloom, 1956).

This is an example of a "Smart" classroom. These classrooms are increasingly being adopted to engage students in active learning. With the inclusion of technology as well as lecturer facilitation within such collaborative learning pedagogy, these learning environments are, however, extremely challenging for objective educational impact studies. In order to study the complex educational interactions between the learner (L), facilitator (F), content (C) or technology (T) within a TELE such as the EPLARC, the interactions within student groups are categorized (and coded) into small units of consecutive interactions. A number of types of interactions were found and coded: learner-content (LC), learner-learner (LL), learner-facilitator (LF), and learner-technology (LT) besides the more complex interactions like LCT, LFT, and LFCT. Such coding and categorization of complex interactions logically led to their sequential analysis (Tójar, 1996) to discover specific patterns in the interactions as the practical session progressed.

Based on the exemplars of the reports of visual analysis software applications like VIDEOSEARCH and OBSERVER, a simple model for studying interactions was derived and used in a research study. The THEME software application created a simple line diagram for the graphical representation of the sequence of interactions. This feature, along with duration of each interaction (proportionate to the width of the graph), was incorporated into this model to yield a simple "Interaction Time Graph" (ITG) where interactions were depicted temporally, plotted sequentially (see Figure 2, Segment 1).

A major shortcoming of the visual analysis software applications (e.g. the graphical interaction pattern of THEME) was the absence of a visual representation of the overview of the interactions at a glance. It thus lacked being informative as a feedback tool for facilitators and students. To overcome this, snapshots of the video, representative of the major events during a learner interaction episode, were incorporated within the ITG to make it graphical so that it could be readily understood by facilitator and students (see Figure 2, Segment 2). Through these sequential graphs, interactions could be quantitatively (e.g. by duration, or frequencies) and to some extent qualitatively (e.g. by types) analyzed. This is a novel method of ontology to study how interaction patterns are occurring over time, while an active learning session is progressing and how it has an effect on learning. Hence, the ITG, if computerized for use in a collaborative environment, can act as a valuable tool to monitor group learning.

A learning framework integrated with interaction analyses

This simple model, however, did not incorporate ways to evaluate impact on student learning. To answer the second research question, a learning framework based on TELE was chosen (Passey, 2011). This learning framework, initially created as a simple model to evaluate ICT uses (Passey & Rogers, 2004, p.26, cited in Passey 2006, p.145, Figure 1), was based on a conception of three learning stages (Child, 1973) - of internalization (attention, sensory engagement, etc.), internal cognitive processes (analysis, evaluation, creativity, concept formation, etc.) and externalization (speaking, writing, reporting, etc). Passey further "created a more detailed framework (to identify the impacts more specifically)" based upon cognitive aspects of learning (Passey, 2006). This was modified later, to develop a learning framework that integrated five main aspects of learning (Passey, 2011), shown in Figure 1, categorized using the following outline criteria:

- Megacognitive – transfer of learning both within and across subjects; deep, wider, real and authentic learning (Bransford et al., 2000; Vygotsky, 1978).
- Cognitive – sensory stimuli for learner engagement, information handling, and demonstration of use of acquired learning (Bloom, 1956; Child, 1973; Gardner, 1991; DES, 2006).
- Metacognitive – adoption of learning strategies, knowledge transfer between scenarios (Presseisen, 2001).
- Social – interactions with others within classroom environments and the forms of interaction that allow a learner to access or use information, as well as to share it, or to work co-operatively with others (Pask, 1975; Vygotsky, 1978; Lave & Wenger, 1991).
- Societal – selection of or focus on information based upon clinical, societal or a wider relevance or longer-term interest (Lipman, 1995; McFarlane, 1997; Moseley et al., 2005).

If this learning framework is applied as it stands in the context of collaborative learning in medical education, some categories would include elements that do not relate readily to medical learning activities and outcomes. Thus, a modification of the detailed learning framework is suggested and is shown in Figure 1. Some of the learning categories, designed to accommodate school pupils' learning, were modified to a minor extent to better encompass university student learning activities (e.g. omission of the sensory stimulus of music in internalization). A simple code for depicting each of these learning aspects was designed – a two/three letter code denoting (a) the process or cognitive activity (e.g. Sensory Stimulus=S) and (b) denoting the learning outcomes (e.g. Visual=V). Thus, a Visual Stimulus in an educational interaction e.g. when studying an atlas picture would be depicted as a LC interaction (learner-content) and would be tagged with a SV learning category (see Figure 1). The complete elements, applicable in the context of TELE based on uses of cognitive and social tools, were modified, coded and were then incorporated into a detailed model called the "Visual Interaction and Learning Sequence Graph" (VILSG).

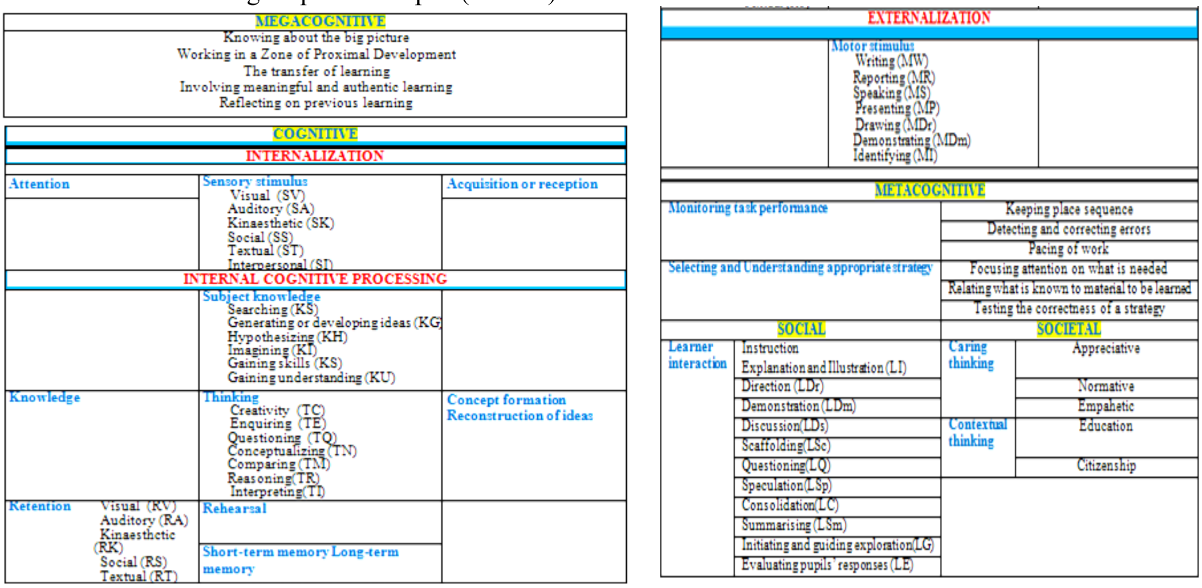

Figure 1: A more detailed learning framework to evaluate uses of ICT, modified to include codes for specific learning processes (Adapted from Passey, 2011, p.46-47, Figure 38).

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As the new VILSG model (shown in Figure 2) was developed within the context of the practical collaborative learning and presentation session, most of the "externalization" motor learning categories (Speaking, Demonstrating, Presenting, etc.) are applicable (e.g. MS, MDm, MP). However, it is to be emphasized that this model could be applied more generically to other types of complex learning activity and could be similarly tagged based on these principles. This model, like that of the THEME, has flexibility allowing the adding/dropping of learning categories during the coding process and in retrospective analyses.

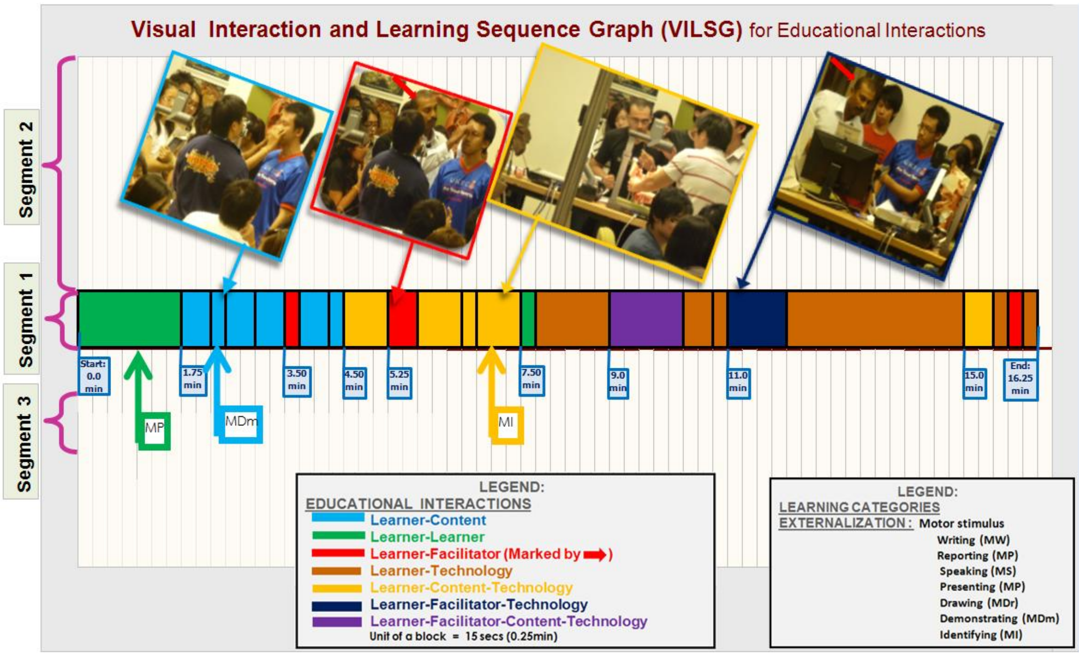

Figure 2: Model of Visual Interaction and Learning Sequence Graph (VILSG)

The segments are described as follows:
Segment 1: Interaction Time Graph (ITG) of sequential educational interactions with their duration.
Segment 2: Representative snapshots of interactions - a visual map of the context of these interactions.
Segment 3: Tagging of educational interactions with learning aspects.

Conclusion and implications for using the VILSG model

There is growing evidence concerning the value of increasing the amount of interactivity for enhancing learning. The process of intellectually interacting with content results in changes in the learner's understanding, perspective or cognition. Learner-content interaction has been considered as a defining characteristic of education with LF, LT and LL being key elements in active learning (Chickering & Gamson, 1987; Chickering & Ehrmann, 1996).

In developing ways to answer research questions about forms of learner interactions, a simple graphical model showing forms and levels of educational interactions has been developed and is described here. The approach used has characterized graphically interactions in TELE when students are engaged in collaborative active learning activities. The coding and analyses of the interactions used provide a process-oriented qualitative description of a mediated group activity that can be subsequently analysed from three perspectives: (i) a visual graphical aid for both the facilitator and the learner regarding group performance in reference to other groups; (ii) temporal relationships of interactions as a learning session progresses; and (iii) classifying educational interactions in terms of learning frameworks based on cognitive and social dimensions developed by Passey (2011).

A comparative case analysis was used to detail features of the most widely used software applications or tools of interaction analysis. The most important thing that is lacking is the mapping of learning categories within a recognizable framework. Analyses of educational interaction per se would not be as useful if the learning impacts of this were not evaluated. Hence, a model of a learning framework suggested by Passey (2011) was adopted to explore detailed learning aspects.

Based on this learning framework and on the framework of the simple “Interaction Timeline Graph (ITG)”, from the data of a small project, a visual interaction timeline graph mapped with learning categories was innovatively developed and named the “Visual Interaction and Learning Sequence Graph (VILSG)”. Using this VILSG technique, digital video data of educational interactions within a TELE can be coded both for the type of interactions as well as forms of learning categories. It can also be used to provide feedback on the effectiveness of students’ time spent in each element of their interactions. With snapshots and graphical representations of each of the interactions, VILSG is also able to provide feedback to both students and teachers with regard to which interactions are linked to the learning of knowledge, skills or attitude.

Similar to what Passey (2006), in his analyses of ICT uses on the impact on learning presented, it is anticipated that the VILSG model will help in quantitative analyses and evaluations of impacts of educational interactions on practical skill learning in subjects including science, technology, engineering and mathematics(STEM), medicine and health education. When compared with subject grades, this model could be used to expand academic analytics, allowing types of interaction that successful students engage in, but those who are less successful do not, that may influence or be linked to increased learning effectiveness and higher student performance. It will provide a more detailed view of the whole process of learning. For example, the LC interaction can imply different contents, and when this is mapped with ‘SV’ code, it will be possible to see a picture of the learning activity that would be quite different from that when a student is reading a book or text (‘ST’code).

From initial developments, it is clear that a novel VILSG can positively contribute towards the growing body of evaluation methods to measure interactions in the TEL environment and can provide a positive contribution to educational research in TEL. Collaboration with computer scientists in developing an algorithm based upon this model will enable further steps to be taken in developing a wider form of this model. In-depth studies with samples in different disciplines using TELE will inject more rigour into the validation of this model. Student and teacher perception studies on the use of such models used as a feedback tool will be useful in the long term for acceptance and further modifications of this model in professional practice.

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