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Synchronous collaboration competencies in web-conferencing environments – their impact on the learning process

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Based on a three-semester design-based research study examining learning and teaching in a web-conferencing environment, this article identifies types of synchronous collaboration competencies and reveals their influence on learning processes. Four levels of online collaborative competencies were observed – operational, interactional, managerial, and design. The relative importance of students and teachers possessing the different levels of competencies depended on the degree of interactivity in the learning designs being applied. Both misunderstandings and misuses impacted on learning and collaborative processes, with misuses occurring more persistently throughout semesters than misunderstandings. The distinction between developing students' technical skills and their collaborative capabilities is drawn. Strategies for developing each are recommended.

Keywords: web conferencing; technology; collaboration; competencies; capabilities; skills

Context

The use of web conferencing to provide a more interactive learning experience for distance students is becoming more widespread. For instance, a survey of the AACE EdITLib database by the author found that 22 of the 24 papers focusing on web conferencing in learning and teaching were written since 2007. The synchronous voice, text-chat, note-taking, whiteboard, and screen-sharing functionalities provided by systems such as Adobe Connect (Adobe Systems Inc., 2010), Elluminate Live (Elluminate Inc., 2010), and WebEx (Cisco Systems Inc., 2010) provide a powerful suite of tools with which to present information, model processes, and share concepts.

However, using tools such as web-conferencing to facilitate learning and teaching is more complex than for asynchronous online learning. Firstly, there are several tools to master; secondly, different tools need to be selected depending on communication requirements; thirdly, the affordances of tools in combination requires consideration; and fourthly, decisions about how to use tools often need to be made in real time. Failure to understand one subtle feature of a tool or its use can have a crippling impact on the learning episode, amplifying the importance that users have developed technical and collaborative competencies in synchronous multimodal learning environments.

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At the same time, the multimodal affordances of web-conferencing systems provide the opportunity to apply less transmissive and more active distance learning pedagogies. Increasing student involvement in online environments is a direct means to improving learning outcomes (Britain, 2007). For instance, Laurillard (2002) has advocated the need for discursive interaction between the teacher and students so that the teacher can better understand learner needs and adjust the direction of the lesson accordingly. Jonassen, Lee, Yang, and Laffey (2005) emphasised the importance of applying collaborative learning approaches to provide students with the opportunity to engage in knowledge construction processes. However, these sorts of pedagogies require an increased level of collaborative competency, in terms of being able to operate the technology and being able to interact effectively.

This article draws on a three-semester design-based research study to identify the sort of synchronous collaboration competencies required in multimodal learning environments and elucidate their impacts on the learning and teaching process.

Background

The importance of technological and collaborative competencies

Leading international education bodies emphasise the crucial need for technological and collaborative competencies (International Society for Technology in Education [ISTE], 2007a; Partnership for 21st Century Skills [P21], Association for Career and Technical Education [ACTE], & National Association of State Directors Career Technical Education Consortium [NASDCTEC], 2010). The ISTE (2007a) defines a range of educational technology standards for students, which include the ability to:

- use technology effectively and productively
- communicate and collaborate
- conduct research and use information
- think critically, solve problems, and make decisions
- demonstrate creativity and innovation
- be ethical digital citizens.

For the purposes of this article, technological competencies are defined as ‘performance standards relating to the operation of a technology in order to achieve an intended outcome’ and collaborative competencies are defined as ‘standards of interaction with other members of a group that contribute to the collective solving of a problem or completion of a task.’ Technological and collaborative competencies are particularly important, as they open up gateways to achieving the other four competencies for students outlined by the ISTE (2007a) above. The ISTE (2007b) also defines standards for teachers, which include the capacity to develop digital-age learning experiences and facilitate student learning and creativity. As students are provided with more responsibility for learning processes it is possible that they may also require some of these competencies.

The P21 – a leading and influential international organisation for the modernisation of education – emphasises the importance of moving beyond the three Rs to the four Cs (P21, 2009). Communication, collaboration, critical thinking, and creativity are argued as essential in order for students to participate in contemporary society and remain competitive in the global workplace (P21, 2009; P21 et al., 2010). Technological proficiencies are seen as not only as valuable skills in their own right but also as a matter of accessibility in so far as technological capabilities provide students with a means to learn (P21 et al., 2010). Accordingly, they argue the crucial need for teachers to have students use technology as tools for productivity, communication, and creativity through the curriculum (P21 et al., 2010).

Other research supports the educational imperative for developing students' technological capabilities. Technology can act as a medium for the development of critical thinking and analytic abilities, even in lower ability students (Santavenere, 2003). Understanding how to operate the mediating technology can significantly increase students' ability to acquire the to-be-learnt subject matter concepts (Clarke, Ayres, & Sweller, 2005). Students with greater levels of comfort with technology who have participated in technology-mediated courses report significantly greater levels of satisfaction with the course (Rodriguez, Ooms, Montanez, & Yan, 2005).

The technological competencies of students can impact on their ability to learn the underlying subject matter being taught through technology. An experiment by Clarke et al. (2005) found that students with low-level spreadsheet capabilities learned mathematics more effectively if they learnt prerequisite spreadsheet skills prior to attempting mathematical tasks. Extrapolated to the current context, the cognitive load caused by having to learn and operate the collaborative technologies may reduce the cognitive resources available to learn the curriculum. Thus, developing students' technological competencies as well as those of teachers may be critical to engaging effective learning in the web-conferencing environment.

Attempts have been made to define specific technological competencies for the modern era. Eisenberg and Johnson (2002) suggested a six-stage framework for conceptualising students' technological skills based on the ability to (1) define tasks, (2) seek information, (3) locate and access information, (4) use information, (5) synthesise information, and (6) evaluate information, using a range of synchronous and asynchronous technologies such as forums, instant messaging, spreadsheets as well as other online and desktop software. Although examples are proposed for how the framework might be used (Eisenberg, 2001), it is not examined in context so that there is no empirical evidence to demonstrate how these skills do or do not impact on students' learning process.

Collier, Weinburgh, and Rivera (2004) described a framework for assessing the technological capabilities of pre-service teachers that includes their ability to use operating systems, word processing, spreadsheets, databases, graphics, the Internet, email, photo and video technologies. Incorporating these technologies into a pre-service teacher education program led to significant increases in teachers' self-reported technological ability and in their perceived importance of technology for learning and teaching (Collier et al., 2004). However, once again the skills are not examined at the level of the actual learning episode so it is not possible to understand how competencies affect activity. Furthermore, the framework does not address higher-level technological capabilities such as managing group processes and designing environments to facilitate collaboration.

Coordinating activity in technology-based environments contains inherent difficulties above and beyond those experienced in face-to-face contexts. Neale, Carroll, and Rosson (2004, p. 115) defined distributed process loss as the amount of coordination that is required to manage the main work of interest when operating remotely; for instance, clarifying what team members are doing and how they should proceed. They noted that distributed process loss can be much more costly than when coordinating face-to-face, identifying that at times it can be ‘so costly, in fact, that groups often do not recover from its effects’ (Neale et al., 2004, p. 117). Their two-year analysis of an online collaborative system showed how the use of collaborative technologies fractured the contextual information critical to the collaborative process, and that this effect increased as students attempted more tightly coupled interactions, that is, those where more frequent interaction was required. Neale et al. proposed that it is only if the proper levels of communication and coordination are supported, that groups can achieve common ground and acquire activity awareness critical for effective functioning.

The idea that increased levels of interactive complexity require heightened levels of online collaborative competencies is supported by other models for coordinating online learning (Salmon, 2000). Critically, organisations emphasising the importance of technological and collaborative competencies do not see the development of these competencies as disjointed pursuits, but rather as synergistically and intrinsically related (ISTE, 2007a; P21, 2009). For instance, in order to engage in web-conference-based learning requires the capacity to use the technology to synchronously collaborate with other participants, which for the purposes of this paper will be defined as ‘synchronous collaboration competencies’.

Learning and teaching using web conferencing

Recently a great deal of literature has emerged examining learning and teaching using web conferencing. Many of these papers simply describe general features and uses of web-conferencing software (Fuest, 2007; Keir & Elizondo, 2010; Premchaiswadi & Tungkasthan, 2007; Regazzoni, Bonesana, Djaékov, & Mattiuz, 2007). Others report on the user experience (Bower & Hellstén, 2010; Wang, 2008) or compare the features of different synchronous multimodal tools (Karabulut & Correia, 2008).

Some studies extend on this to recommend pedagogical strategies for learning and teaching in web-conferencing environments, including self-assessment questionnaires and polls (Abourbih & Witham, 2007), techniques for facilitating turn-taking (Suggs, Myers, & Dennen, 2010), and teacher-guided collaborative problem-solving approaches (Bower, 2008b). Web-conferencing tools such as those that enable online presentations, video, screen-sharing, sharing of resources, polling, and chat can be used to enhance online engagement (Chapman & Wiessner, 2008), and research has indicated that such increased levels of interaction in web-conferencing environments correlate with student satisfaction with online classes (Kuo & Walker, 2010).

The use of web conferencing in tertiary education has been shown to positively correlate with course satisfaction (Huang & McConnell, 2010), and to be generally positively received by students (Boudreau, 2009; Ramirez, 2006). The use of web conferencing to supplement traditional language education approaches has resulted in significantly higher assessment marks (Charbonneau-Gowdy & Cechova, 2009), and improvement in the quality of learning experience for computer science students (Bower, 2009; Coffey, 2009–2010).

Studies investigating the influence of technological and collaborative competencies on learning and teaching using web conferencing identify how technological training was important for participants but provide little detail of the sorts of competencies that were required (Chivers & Luca, 2010; Kreher, 2008; Reushle & Loch, 2008). Garonce and Santos (2010) defined a range of roles adopted in a web-conferencing environment, including educational, social, management, and technical. Although they described the extent to which teachers played these roles, they made only passing reference to how the collaborative competencies of the teacher influenced learning and did not discuss student competencies. In fact throughout the literature it is difficult to find a systematic empirical study of how the collaborative competencies of students and teachers affect learning in any online environment, let alone multimodal synchronous online environments.

This study examines the types of student and teacher synchronous collaboration competencies that are required when learning and teaching using a web-conferencing system, as well as their influence on the learning process.

Method

Data collection and analysis in this study followed a design-based research process. Design-based research (also called development research, design research, and design experimentation) methods integrate design and empirical research methods with an aim to develop models and an understanding of learning in naturalistic intentional learning environments (Tabak, 2004, p. 226). The design-based research process utilises iterative cycles of theory-based analysis, design, and testing in order to derive principles for the creation of effective learning environments (Reeves & Hedberg, 2003). Design-based research was selected because of its ability to be applied in authentic settings, its emphasis on both successes and failures to inform practice, and its orientation towards practical learning design solutions (as outlined by Herrington, Reeves, & Oliver, 2010). The study took place from Semester 2 of 2005 to Semester 2 of 2006.

The deliberate refinements to pedagogy that occurred across the three semesters can be summarised as follows:

- **Iteration 1**: instructive approaches primarily using the default interface designs of the web-conferencing system (this iteration offered a baseline for analysis).
- **Iteration 2**: use of collaborative spaces to facilitate more student-centred learning, with activities and interfaces purposefully designed to engage greater student involvement (for instance, designing an interface that contained areas for groups of students to collaboratively write a computer program).
- **Iteration 3**: refinements to the designs and pedagogical strategies used in iteration 2, with pervasive use of audio and more flexible adjustment of the interface to meet evolving collaborative and cognitive requirements of lessons (such as spontaneously integrating whiteboards if spatial concepts were being discussed or increasing the size of pods if they were to become the main focus of the learning episode).

The subject being taught in each of the classes was introductory computer programming as part of an Introduction to Software Development unit. Participants were students enrolled in the subject as well as the teacher (who was also the principal researcher). There were 26 students who enrolled across the three semesters involved in this study, of whom 20 completed the unit. Of the 20 students, 10 were enrolled in Semester 2 of 2005; 7 in Semester 1 of 2006; and 3 in Semester 2 of 2006. This decline in enrolments across semesters was commensurate with other computing subjects at Macquarie University and other universities generally (Cassel, McGettrick, Guzdial, & Roberts, 2007). Of the 26 students, 9 were female and 17 were male.

The Adobe Connect Meeting platform (Adobe Systems Inc., 2010) was used to provide the virtual classroom (see Figure 1). The platform includes the following facilities:

- Presentation delivery – presentation of PowerPoint slides and FlashPaper files
- Screen-sharing – broadcast of single window or entire desktop
- VoIP and Webcam – enables transmission of audio and video between users
- Text-chat – capacity to send text messages to all or selected individuals
- Whiteboard – drawing using various colours, fonts, and transparency levels
- File upload/download – sharing of files from users' computers
- Polling – allowing questions to be composed and participants to vote
- Attendee list – participant names (includes status indicator such as fine, slower)
- Notepad – for text contributions such as instructions and collaborative authoring.

By default the attendee names are shown in a panel on the left-hand side of the screen, and the meeting host (or super-user) can spontaneously adjust the access control of presenters and participants to each of the tools. Each of these tools (or pods) can be instantly resized, drag-and-dropped, created, or deleted. As well, a room can have several pre-designed layouts, which can be selected by hosts via tabs at the bottom of the screen. Finally, all sessions have the capacity to be recorded.

To familiarise themselves with the web-conferencing system students spent approximately 30 minutes in the first lesson using the various tools (text-chat, white-board, polling tool) to introduce themselves to one another. The teacher guided them through explaining their current work context via text-chat, indicating their programming and web-conferencing experience via the polling tool, and using the whiteboard tools to draw a picture of their choosing. The teacher saw this as an effective way to simultaneously develop students' technological competencies and establish a sense of community. The teacher also demonstrated the other features of the web-conferencing

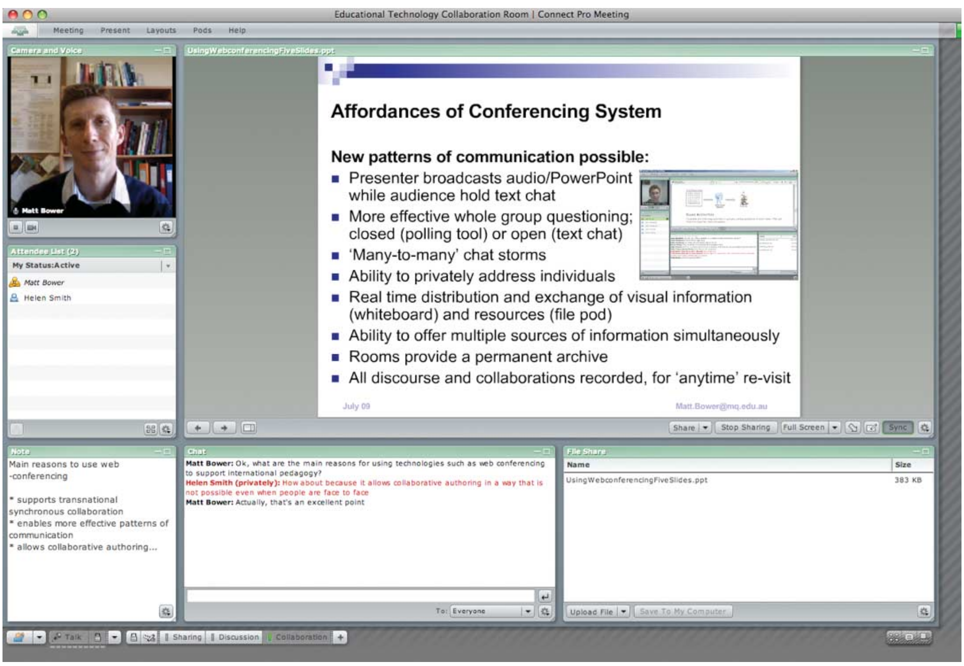

Figure 1. An Adobe Connect Meeting interface, showing (clockwise from top left) camera and voice, share, file-share, chat, note and attendee list pods.

system. The teacher had taught the introductory programming subject using the web-conferencing system on one occasion before the study commenced and so had basic understanding of how to operate the technology. None of the students had any substantial experience with web conferencing before commencing the course.

The data corpus for this study comprised recordings of the 12 two-hour web-conferencing lessons that occurred across each of the three semesters (iterations). Lesson content focused on the tutorial and practical activities prescribed for each week, as well as other in-class extension activities designed to enhance student understanding of the concepts being addressed. This included general comprehension and basic programming tasks relating to topics such as Java syntax and basic object-oriented programming and graphics, through to more challenging topics such as the design of inheritance hierarchies, error handling, and system design. To provide more reliable comparison, the subject matter remained essentially consistent across the three semesters. However, the pedagogical approach varied according to the iterative refinements outlined above.

Data analysis involved the teacher (as participant researcher) reviewing the recordings of each lesson and documenting any observations pertinent to understanding learning and teaching in multimodal synchronous environments. This included all instances where synchronous collaboration competencies impacted on the learning experience, either by affecting the representation of knowledge or the interaction between participants. These observations were archived in a project database so that final conclusions could be cross-referenced back to their primary data source (a summary of the project database is available in Bower, 2008a). The systematic nature of the database not only provided a comprehensive sample upon which to determine the range of effects relating to the synchronous collaboration competencies of both students and the teacher, but also enabled their relative prevalence to be gauged. The analysis also allowed different levels of synchronous collaboration competencies to be observed. Applying different pedagogies across semesters enabled the relationship between synchronous collaboration competencies and the types of activities that students were performing to be scrutinised.

Results

Iteration 1 observations

The teacher's ability to use the web-conferencing technology impacted on the effectiveness of delivery and learning on several occasions in iteration 1. For instance, in the first weeks of iteration 1 the teacher did not know that minimising the web-conferencing browser window while screen-sharing would cause student messages to pop up in mini-bubbles (windows). Thus, to be able to see students' text comments the teacher often had the text-chat visible behind the Integrated Development Environment software being used to write the programs (as shown in Figure 2). This resulted in a double representation of the text-chat pod to students, unnecessarily occupying space that could have been used to broadcast more educationally useful information. This was an example of the teacher not understanding how the technology operated. Other examples of this included the following, with numbers in parentheses indicating the frequency with which the issue arose:

- Not understanding how the different levels of student permissions allow students to access various features of the virtual classroom

- Not understanding the critical effect of the synch button preventing the students from seeing the relevant parts of the solution or inadvertently allowing them to access all of the solutions (4 instances)
- Not being able to provide students with the best advice to improve the view of the screen-share broadcast (3 instances)
- Not understanding how full-screen mode prevents students from making text-chat contributions (2 instances)
- Not being able to advise students on the operation of multiple rooms during a groupwork session
- Not appreciating that different screen sizes may cause more of the tutorial solution document to be revealed than intended.

An understanding of how the features of the web-conferencing software could be applied in different circumstances evolved throughout the semester as the teacher's experience increased.

Another way in which teacher virtual classroom competencies could influence collaboration and learning was when the teacher understood how the web-conferencing system operated but inadvertently misused the technology. Web-conferencing environments are different to face-to-face environments in that settings within the environment affect how others perceive collaborations, in ways that may not be directly observable by the collaborator. For instance, having incorrectly set audio levels is difficult for a user to self-detect but is easily detected by others. Other examples of the teacher misusing the technology despite understanding how it worked include:

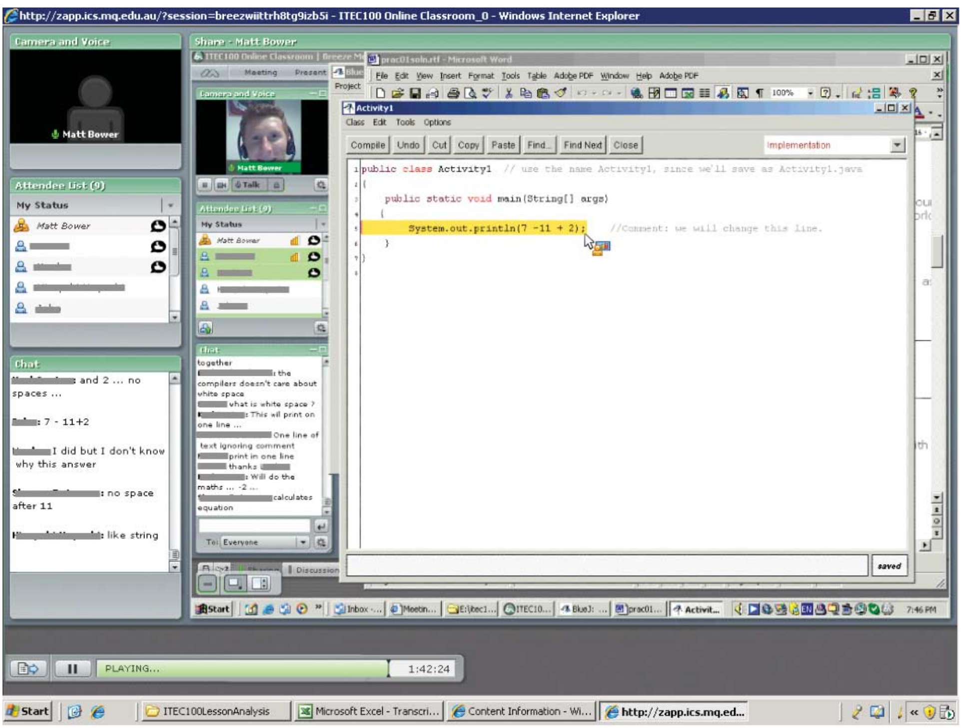

Figure 2. Screenshot of teacher sharing screen twice to overcome technical misconception.

- Accidentally posting private messages instead of public messages through the text-chat
- Forgetting to broadcast the desktop when attempting to perform a screen-sharing presentation (2 instances)
- Forgetting to minimise the web-conferencing browser window during a screen-share so that student text messages appear in pop-up windows
- Not appreciating the impact of the media on collaboration, such as responding to audio technology problems using audio
- Unintentionally leaving the microphone on during mid-lesson breaks (2 instances).

Instances of misusing the interface occurred almost uniformly throughout the iteration, reducing in prevalence more slowly than instances of misunderstanding the interface.

There were also examples of how underdeveloped student competencies affected collaborations in iteration 1. These included:

- Not being aware of how to use the scroll or full-screen button to create a clear view of desktop broadcasts (3 instances)
- Not knowing how to upload files to broadcast documents
- Inadvertently communicating using private text-chat instead of public.

These were far less than for the teacher, due to the fact that students were in most cases recipients of a transmissive pedagogy than contributors to collaborative learning activities.

There were several web-conferencing skills that had not been covered in the introductory lesson that students required later in the semester, and others that were covered during the semester but that students had forgotten. Because students often required reminding of how to use unfamiliar tools at the time of use, the teacher learnt to adopt a gradual and just-in-time approach to developing students' synchronous collaboration competencies.

In iteration 1 there were cases where the teacher implemented some pedagogical tactics to account for the different nature of interacting in the web-conferencing environment, such as:

- Repeating student text-chat using audio to acknowledge and emphasise the points students were raising
- Repeating own audio using text-chat to emphasise a point or to place a marker in the text-chat to assist later review.

These tactics serve as a form of highlighting that demonstrated how modalities may interoperate in order to promote attention and selection.

Iteration 2

Based on observations from iteration 1 indicating low levels of student discourse in more teacher-dominated learning episodes, redesigns in iteration 2 attempted to engage more student-centred learning by redesigning tasks and interfaces for greater collaboration. These more student-centred activities required an increase in the level of synchronous collaboration competencies to be exercised by the teacher. For instance, the teacher was required to manage groupwork sessions and design spaces to promote effective collaboration. This also led to a new range of potential mistakes that the teacher could make and problems that could occur, with examples including:

- Not switching students to the correct layout in their groupwork room (or not instructing students when and how to change layouts)
- Accidentally linking the content of note-pods on two separate layouts and then replacing the contents with the wrong information
- Inadvertently designing a collaborative interface for group programming in which students sharing their screen had no direct way to communicate with their peers (because they could not immediately access text-chat and did not have audio set up).

Student-centred groupwork approaches to learning required students to apply more advanced technological competencies in order to manage collaborations and control tool usage. Student synchronous collaboration competencies impacted on the effectiveness and efficiency of collaborations, with examples including:

- Not understanding how to broadcast the screen (2 instances)
- Not understanding the mechanics of performing a screen-share broadcast and hence making unnecessary screen transitions
- Needing to spend time becoming familiar with how to use the whiteboard
- Asking how they could increase the size of the screen-sharing display (3 instances).

Throughout the semester it became increasingly apparent that for successful collaboration to occur the teacher needed to take responsibility for ensuring students had adequate prerequisite technological competencies. Students acquired some competencies quickly, and this improved the efficiency with which lessons were conducted. For instance, students quickly became familiar with and expert at transitioning between their groupwork rooms and layouts. Other competencies appeared to be more related to practice. Students commented during two of the lessons that practice enabled them to markedly improve the efficiency and effectiveness with which they interacted during groupwork.

Some synchronous collaboration competencies related to strategies to overcome distributed process loss. For instance, students were asked to append their initials to any note-pod contribution in a communal solution space so that the contributor could be easily identified. Such an approach ultimately improved the efficiency of collaborations by obviating the need to discuss who had contributed.

In iteration 2 there were examples of how poor tool choice and directions could negatively impact on collaboration. For example, in week 2 of the semester students were provided with two zip files in a file-share pod so that they could download and compare two computer programs (see Figure 3). A pod allowing them to choose a whiteboard or screen-share was provided in the main area at the top of the layout; however, students were not provided with directions on how they should use the web-conferencing tools to collaborate.

Although there was some discussion recorded in each room's text-chat pod, the large sharing spaces for the whiteboard or screen-share were hardly used (and used

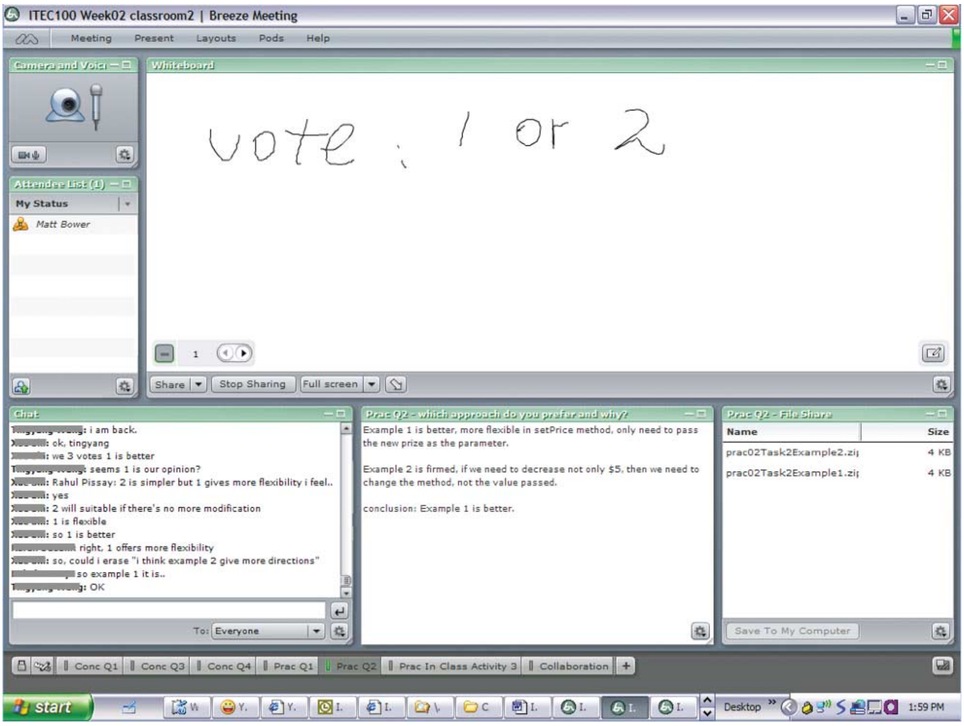

Figure 3. Ineffective groupwork interaction through the interface.

ineffectively) by the two groups. For instance, one student in groupwork room 2 attempted to conduct a vote using the whiteboard, which was a less time-effective approach than using the text-chat (see Figure 3). The fact that students downloaded the two separate code files on their own machine meant there was no common artefact to which they could refer. This process also caused an unnecessary time overhead compared to if the code had been placed in note-pods. The design of the interface and the teacher's management of the learning episode resulted in ineffective collaboration and isolated learning.

On the other hand, using a whiteboard to visually represent conceptual relationships allowed multiple pieces of information to be simultaneously represented and interrelated. For instance, based on student misconceptions of the challenging computing concept of casting, the teacher prepared a diagram that enabled students to visualise how the component knowledge items related to each other (see Figure 4). The write-ability of the whiteboard meant that the teacher and students could embellish the diagram based on the discussion that emerged between them. The teacher prescribed the task itself on a note-pod, providing students with a clear directive and focus. Responses to formative questioning and unsolicited student comments indicated that the tools selected and approach adopted had furthered their understanding of the concept.

During the student use of audio that was trialled in iteration 2 it was noted that establishing audio communications could require some time at the beginning of a lesson or task. This was because there were various settings that needed to be configured and these were idiosyncratic to each user's machine. Problems could occur with

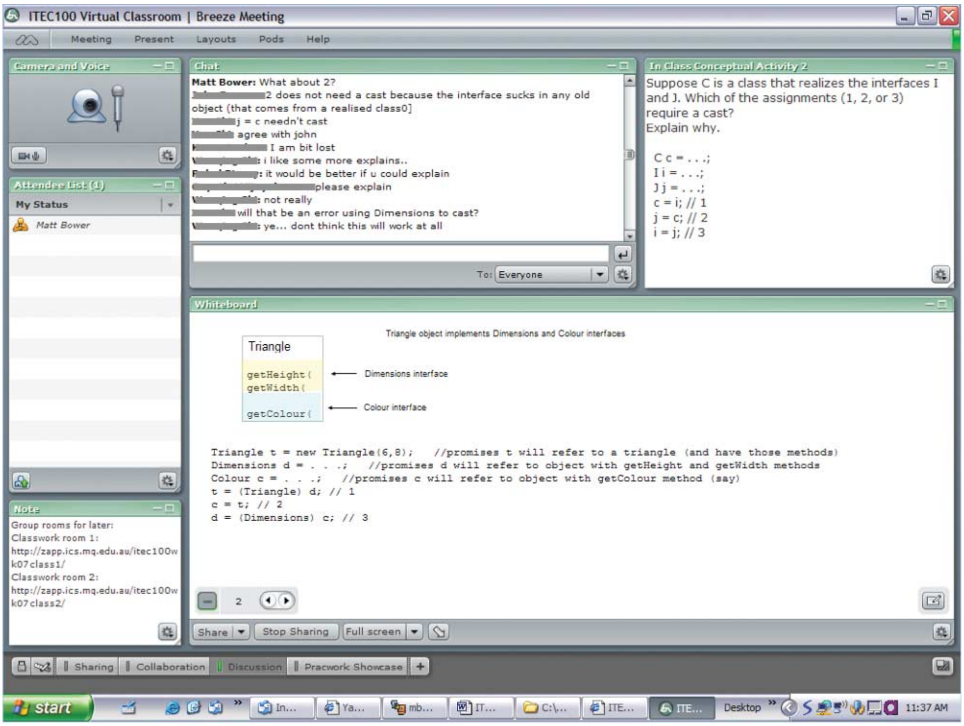

Figure 4. Whiteboard diagram supporting explanation.

the students' audio and microphone settings on their operating system, within the web-conferencing system, or on the hardware itself. The fact that student audio was difficult to set up and coordinate was the main impediment to its not being used more frequently in iteration 2. This is an example of how technical competencies compromised the ability to apply interactive pedagogies. However, once audio facilities were established they enabled more rapid and greater amounts of small-group collaboration to occur than if using text-chat alone. For this reason the strategic decision was made to persist with this approach more determinedly in iteration 3.

Iteration 3

The teacher's synchronous collaboration competencies improved notably between iteration 2 and iteration 3. As the teacher's familiarity with the web-conferencing platform improved, so did the quality and automaticity of advice regarding how students could best use the tools (for instance, how to optimise the screen resolution or collaborate effectively on an activity). At the same time, even in this third iteration there were still occasions where the teacher misused the web-conferencing system; for example, forgetting to broadcast the screen during a programming demonstration. There were also instances where the teacher was still learning about optimal ways to use the web-conferencing system; for instance, the most effective approaches to use audio discussions during full-screen sharing sessions, or how access privileges could allow students to scroll through the document being presented.

Despite the teacher's experience with developing student competencies, student ability to use the web-conferencing system evolved in a similar manner to previous semesters. For instance, there were still repeated enquiries regarding how to enlarge the size of the screen broadcast throughout the semester even though this was explained in advance (reinforcing the appropriateness of just-in-time technical competency development).

The general improvement in the teacher's synchronous collaboration competencies led to an increased capacity to spontaneously redesign the interface to meet arising cognitive and communicative needs of the episode. This included adjusting the position or size of pods within the interface, or incorporating entirely new pods to better suit the type of information being represented. For example, Figure 5 illustrates how the teacher spontaneously added a whiteboard to the interface during a group-programming task to provide remedial instruction about how the coordinates of circle constructor related to the coordinates of the drawing canvas. Students were able to at once see how the code they were writing in the note-pods related to the object they were attempting to represent on the drawing canvas.

The more active nature of the tasks required students to be more advanced users of the web-conferencing system, enabling them to become more capable of making dynamic design decisions. Because they were directly designing from the perspective of the learner, in some cases they applied design reasoning that had not been considered by the teacher. For example, once students had acquired an understanding of the circle placement concept shown in Figure 5, they were invited to make adjustments to the web-conferencing system in a way that best supported completion of their

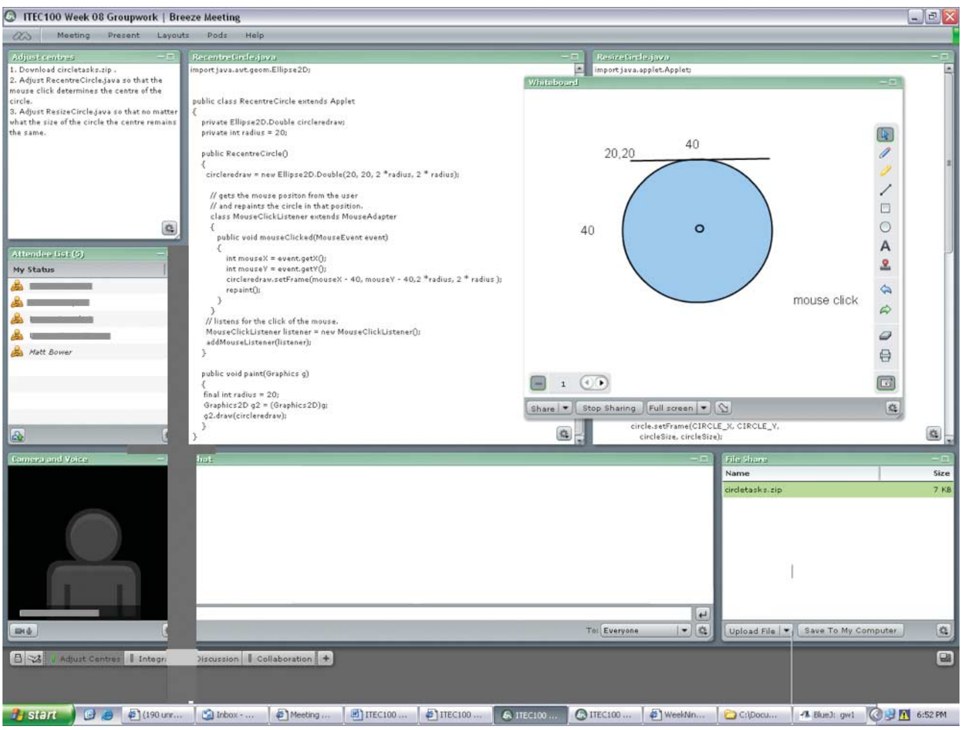

Figure 5. Spontaneous inclusion of a whiteboard to support discussion of visual concepts.

group-programming task. Students chose to extend the solution note-pods to the bottom of the screen so that they covered the text-chat pod. This allowed the programming code to be the main focus of the interface, and removed the text-chat area that had become redundant because students were using audio to collaborate (see Figure 6). Students were then able to complete the programming task with both program files in full view.

The observations above provide a general indication of the different ways in which collaborative competencies could influence learning in this multimodal synchronous learning environment. For a more complete exposition refer to Bower (2008a).

Discussion

A range of different levels of synchronous collaboration competencies were observed during this study:

(1) Operational – the ability to operate the tools and functions of the collaborative technology
(2) Interactional – the ability to effectively interact to perform a task or solve a problem using the technology (including the ability to apply interactional tactics to collaborate effectively)
(3) Managerial – the ability to manage a group or class including providing support on how to use the technology and interact effectively

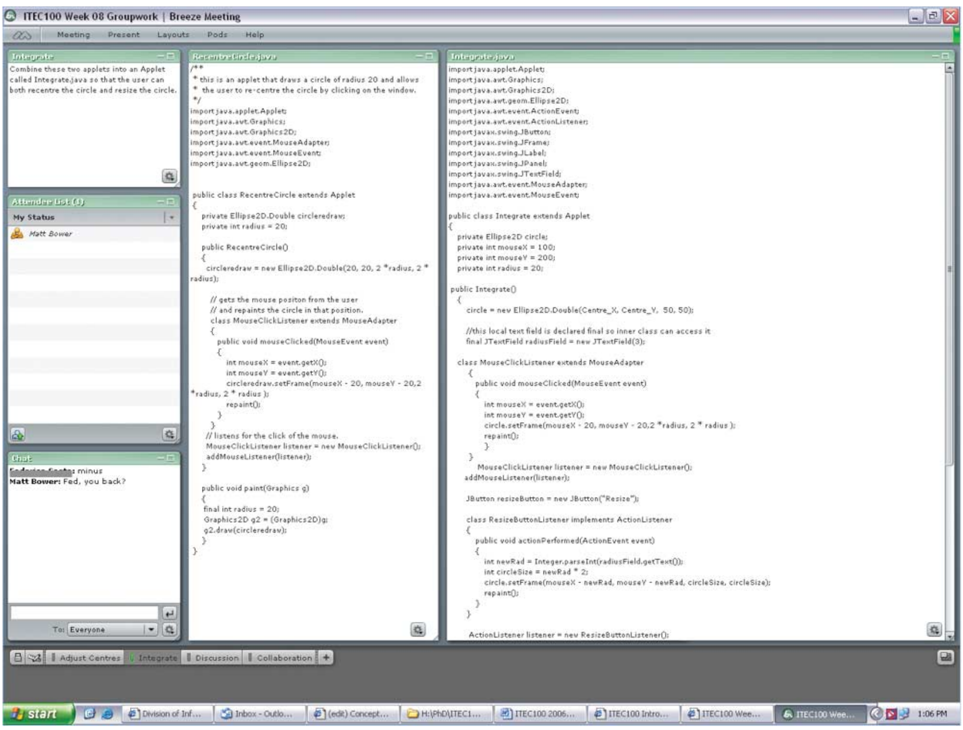

Figure 6. Redesign of interface to meet changing collaborative needs.

(4) Design – the ability to select and organise tools in a way that optimises interaction and best supports activity management (including the ability to dynamically design the environment based on emerging collaborative and cognitive requirements).

Operational competencies were the most easily developed, though they required practice to become familiar. Examples included the ability to contribute to the text-chat, use the whiteboard, upload and download files, and change the screen resolution. Teaching these at the point they were required reduced the risk that students would have forgotten the skills by the time they need them.

Interactive competencies included knowing how to use the tools not only to receive and transmit information, but also to collaborate and co-create. One component of interactive competencies was applying strategies that enabled other users to understand who is manipulating and contributing to the environment when, where, and for what purpose. Examples included appending initials to note-pod contributions, repeating audio using text-chat to prompt for contribution, and using audio to indicate the focus of attention. These interactive strategies helped to overcome distributed process loss by providing people with awareness of others' actions and centre of concentration.

Management competencies occurred at the level of the teacher or groupwork leader. They included clearly prescribing the task and its objectives, designating roles and spaces, reminding group members of how to interact effectively, and troubleshooting technological problems. Failing to attend to these management issues could mean that students conduct unnecessary discourse relating to coordination of activity and using the technology, which in turn could distract them from focusing on the content to be learned. Management competencies were particularly important because their effects were often amplified across the group or class.

Design competencies related to selecting and arranging appropriate tools to satisfy the cognitive and collaborative demands of the learning episode. Designs could be constructed in advance by the teacher, or created during a learning episode by either students or the teacher depending on emerging communicative requirements. Effective design required users to understand the different representational and interactional potentials of different tools. For instance, text-chat affords multi-user contribution of concise factual information; audio in combination with a whiteboard supports exchange of conceptual information; and screen-sharing enables representation of procedural information. Live redesign of the interface required the user not only to understand how to appropriately select and arrange tools according to the emerging cognitive and collaborative requirements of the learning episode, but also to have the confidence to apply those changes in real-time. Importantly, as students become more proficient users of the web-conferencing environment and are granted more control over the learning experience, they can become active participants in the redesign process.

These levels of synchronous collaboration competencies were observed to be hierarchical in nature, with technical competencies required for effective interaction, interactional competencies required for management, and management competencies required in order to be able to effectively design. Observations in this study support the notion that the lower levels of collaborative competencies are more easily mastered than the higher levels. This may be because the higher-level competencies such as managing and designing require the lower-level competencies of operating and interacting.

Deficiencies in synchronous collaboration competencies related to misunderstanding and misuse. Misunderstandings and misuses were observed at all levels of competencies (from operational to design competencies). Some examples of misunderstandings and misuses from this study are outlined in Table 1.

Deficiencies in synchronous collaboration competencies at best resulted in less efficient collaboration and learning, and at worst could lead to a total communication breakdown. Misunderstandings were overcome relatively quickly throughout the semester, whereas misuses were more persistent. Strategies for overcoming student deficiencies in competencies include offering an introductory tutorial session, providing students with the opportunity to use the web-conferencing system outside class

Table 1. Examples of synchronous collaboration competency deficits.

	Misunderstandings	Misuses
Operational	• How the ‘synch’ button affected the view of others • How the screen size and resolution affects others’ view • How to use the scroll or full-screen features to enhance the view • How full-screen mode affected others’ ability to write text-chat messages • How to upload files • How to broadcast documents on the screen • How to use the whiteboard • How to set up and use audio	• Incorrectly setting audio levels (either too soft or loud) • Accidently directing text-chat messages to individuals rather than groups (or vice versa) • Forgetting to broadcast the screen when attempting to demonstrate a computing process • Forgetting to minimise the room to enable student text-chat message windows to appear • Leaving the microphone turned on during breaks
Interactional	• How to interact with others while performing a screen broadcast	• Not making the focus of attention clear (not using audio or pointer tools) • Not identifying own contributions to a collaborative space (either by appending initials to contribution or using audio)
Managerial	• How to explain the screen size features to improve others’ view • How to apply correct permissions to enable groupwork • How to switch others to the correct groupwork room • How to advise on the mechanics of operating multiple rooms during groupwork	• Not being able to explain the most affective way to collaborate using audio • Responding to an audio problem using audio • Not explaining the required skills or modes of operation for a groupwork collaboration
Design	• How information on the different layouts being designed within a groupwork room was interconnected	• Selecting a tool that was inappropriate for the information being shared • Using a cluster of tools prevented students from direct communication • Using a cluster of tools that inhibited efficient collaboration

time, and adopting a just-in-time approach to developing newly required competencies to reduce the risk that students cannot remember the skills.

Many of the problems that occurred during the learning episode related to not understanding the view of others. Unlike in a classroom where the view of others is reasonably consistent and readily interpreted, some of the mediating functionalities such as full-screen mode, synchronise mode, scrolling facilities, permission levels as well as audio settings and screen resolutions mean that the view of other people is not easily anticipated. A potential strategy to help web-conference managers and designers overcome this is to have a second computer running during a web-conferencing session with a ghost user logged in during a lesson. This allows the teacher to observe how changes to settings affect the student view. This may be particularly important in the first weeks of teaching using web conferencing when the teacher has little knowledge with which to anticipate the view of others.

The type of pedagogy applied influenced the type of synchronous collaboration competencies that were required. Under the more transmissive pedagogical approach adopted in the first iteration the teacher required higher levels of competencies relating to broadcasting information, interacting with students, and managing classes (i.e., up to management competence). Students essentially only required the ability to send text-chat messages and receive audio (operational competence). As more active learning approaches were applied in iteration 2 and iteration 3, the teacher required a range of new competencies relating to managing groupwork and designing the environment. Under these more student-centred pedagogies, student learning depended on their ability not only to operate the technology, but also at times to interact, manage, and design.

Although the students' synchronous collaboration competencies had a substantial impact on the learning that transpired, the teacher's synchronous collaboration competencies had a greater impact by virtue of their amplified effect on students. The teacher not only is required to make more advanced use of the interface during learning episodes, but also is ultimately responsible for providing troubleshooting support when students experience technical problems.

All of these issues raised illustrate that teaching effectively in web-conferencing environments is not as simple as directly transferring face-to-face approaches. The affordances of the web-conferencing platform allow a new range of learning designs (pedagogical patterns) to be applied and also impose several constraints that need to be managed. Salmon (2000) noted that introducing technology into teaching and learning without adequate support and training is likely to result in 'meager and unsuccessful' outcomes (p. 55). Given the inherent complexity of teaching using web-conferencing systems it would appear that substantial professional development is appropriate. Development of technical competencies, strategies for overcoming distributed process loss, approaches to managing learning episodes, and how to apply dynamic designs provide suitable foci for web-conferencing teacher education programs.

Conclusion

A range of synchronous collaboration competencies are required for effective learning and teaching in web-conferencing environments. These include operational competence, interactional competence, managerial competence, and design competence. Deficiencies in any of these competencies may be in the form of misunderstandings or misuses, with misunderstandings more readily rectified than misuse behaviours.

The synchronous collaboration competencies required by the teacher and students depend on the type of pedagogies being applied. More teacher-centred pedagogies require the teacher to exercise up to low-level management competencies and students to apply operational competencies. More student-centred pedagogies require the teacher to exercise higher-level management and design capabilities, and students to utilise some management competencies. As students develop confidence in using the web-conferencing system they can also become designers of the learning environment.

Collaborative strategies such as appending initials after note-pod contributions and being explicit about the focus of attention can be used to overcome distributed process loss that would have otherwise been caused by incomplete communication of contextual information. A gradual, just-in-time approach to synchronous collaboration competency development enables students to practise their skills as they are required and reduces the risk that their capabilities are forgotten. In so far as the teacher is ultimately responsible for the management, design, capability development, and pedagogical strategies applied in the web-conferencing environment, they are the major influence on the success of web-conference-based learning episodes.

It is the responsibility of educational institutions to prepare students with the collaborative skills that they will require to participate in society and our increasingly competitive global workforce. As multimodal synchronous communication systems become more prevalent and the functionalities they afford become more sophisticated, the ability to effectively collaborate using such systems will become increasingly important. Operational skills are undoubtedly a prerequisite for efficient online collaboration, but to truly empower our students we need to provide opportunities for them to develop their interactional, managerial, and design capabilities. An understanding of the capabilities and deficits that impact on learning and collaboration will enable teachers to circumvent problems and improve the quality of educational experiences they offer. It is intended that the findings from this study of web conferencing can be used to enhance learning and teaching in other multimodal synchronous learning environments.

Notes on contributor

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