Video-Conferencing for the Mathematics Classroom: Mathematics and Music for Secondary School Students

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Abstract: A group of secondary school students in Singapore participated in a video-conferencing programme conducted by an overseas university on a mathematics enrichment topic. Not only did the students have to attend a lesson taught by an expert, they also had to make short presentations to an audience whom they had never met before. This article describes the video-conferencing programme that linked secondary school students in two countries with a mathematics expert. The perceived benefits and shortcomings of such a technology are also considered with the aim of enabling potential users of video-conferencing to take advantage of the potential to support and enhance teaching and learning.

Introduction

Video-conferencing is an interactive form of real-time technology that can bring individuals or groups in different parts of the world together for a face-to-face communication, enabling all the parties involved to see and hear each other concurrently. A few decades have passed since this technology was first introduced. Yet its introduction in education is only a fairly recent matter. Even then, the use of video-conferencing as a learning tool has tended to focus mainly on higher education (see Schiller & Mitchell, 1993; Andrews & Klease, 1998; Freeman, 1998; Canning, 1999; Sharpe, Hu, Crawford, Gopinathan, Moo, & Wong, 2000; Hu et al., 2001; Peterson, 2004; Wang & Yuen, 2004), but rarely at primary and secondary levels (see Arnold, Cayley, & Griffith, 2002; Gage, 2003; Martin, 2005). However, what is encouraging now is the fact that there seems to be expanding interest in the video-conferencing technology. For instance, there are an increasing number of school districts in the United States implementing such a technology to improve their instructional systems (Kollie, 2005). There are several possible reasons why video-conferencing has recently received greater attention. First, rapid technological development makes its use become increasingly more accessible than ever. Second, the perceived potential of such a technology as a learning tool is also becoming more apparent. This technology can be used, for example, to foster collaborative learning among students located at geographically different sites (Martin, 2005). Additionally, video-conferences with a presentation component can offer a good training ground for students to practise how to report their work effectively to a target audience (Chua, 2005). At this juncture, it may be difficult to appreciate the full potential use of this technology in secondary schools. Therefore, describing,

discussing and critiquing selected video-conferencing programmes may be appropriate and helpful.

A group of Singapore secondary school students participated in a video-conferencing programme conducted by a British university. First, the students attended a lesson which covered the connection between mathematics and music via the use of video-conferencing technology. About a month later, they presented their project work, also via this technology, to a live audience comprising the expert and some British students. The purpose of this article is to gather and report students' feedback about their learning experiences in this video-conferencing programme. Benefits and shortcomings of conducting lessons through the use of video-conferencing technology are also presented. As using such technology as a means for teaching and learning is a relatively new initiative, the findings are important and valuable for school teachers considering participating in such programmes. This article begins with a brief literature review on the use of video-conferencing in education as well as an outline of the video-conferencing programme. A description of the lesson conducted and a discussion of the perceived benefits and shortcomings of video-conferencing as witnessed from this programme then follows.

The Use of Video-Conferencing in Education

Studies in the research literature on the use of video-conferencing in education seem to be limited mainly to institutions of higher education, with relatively few at the primary and secondary levels. At the tertiary level, video-conferencing is typically used for lecturing at multi-campus institutions. One main reason for such use lies in its potential in achieving economies of scale. For instance, it appears more cost effective to combine smaller classes of students across more than one campus into one group to be taught by the same lecturer, thereby reducing the lecturer's need for travel between different campuses (Schiller & Mitchell, 1993). More importantly, students' concerns about equity in assessment and learning are also allayed when the same module on separate campuses is taught by the same lecturer (Freeman, 1998). One use of video-conferencing was reported in an ethnographic case study by Wang and Yuen (2004), where the video-conferences were held solely for cultural exchange purposes for students learning a foreign language. In Singapore, video-conferencing has been used in pre-service teacher education programmes to enable prospective teachers to share ideas, experiences and teaching resources during teaching practice (Sharpe et al., 2000; Hu et al., 2001).

There is evidence in the research literature that using video-conferencing can enhance learning outcomes for students. For instance, Australian first-year undergraduates developed work place competencies such as critical thinking and problem solving skills, which are valued in the job market (Andrews & Klease,

1998). Year 8 British students showed improvement in their mathematical communication skills, both oral and written, after participating in video-conferences (Gage, 2003). In another case study, which involved A-level students from a British school receiving distance lessons from the Liberty Science Centre in the USA, it was noted that learning through video-conferencing enhanced students' motivation and improved their problem solving skills (Martin, 2005). Even so, the potential of video-conferencing at the primary and secondary levels still remains relatively unexamined in the research literature.

MOTIVATE Project: A Singapore Case Study
The Video-conferencing Programme

The video-conferencing programme in which the Singapore students took part is called the *MOTIVATE* project (**M**athematics **O**pportunities **T**hrough **I**nternet, **V**ideo-conferencing **A**nd in**T**eractive **E**ducation). Initiated by the University of Cambridge, this real-time video-conferencing project provides a platform for school-going children of ages 5 to 18 years to be engaged in a direct interaction with expert users of mathematics from whom they get to solve problems and learn about the applications of mathematics in the real world. The project uses multipoint video-conferencing[1] to connect participants from different geographical locations around the world. Its aims are three-fold: to enrich the children's mathematical experience, to broaden their mathematical horizons as well as to provide them with opportunities to work collaboratively on mathematical tasks, and present their work to an outside audience.

A typical *MOTIVATE* video-conference is conducted over two sessions. The first session is an interactive discussion between a particular expert in mathematics and students from the participating schools, lasting normally an hour and a half. To give the participating students a flavour of what to anticipate at the first session, they are expected to complete a preliminary task posted earlier on the *MOTIVATE* website prior to attending this session. The first session usually begins with the experts introducing themselves and talking about their involvement with mathematics in their own fields. They then deliver a lesson on their specialised areas which students will unlikely encounter in school, and set small tasks for them to do. Each video-conference covers a particular mathematics-related topic, ranging widely from Mathematics and Sport, Mazes, and Malaria as an Infectious Disease to The Planets. Time is set aside not only for students to work out the tasks in groups followed by a discussion with the participating expert, but also for them to clarify any doubts that they may have about the topic.

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[1] Multipoint video-conferencing occurs when participants at three or more sites are connected simultaneously for a face-to-face communication.

In between the two video-conferencing sessions, usually a month apart, participating students are asked to do follow-up projects using the details available on the *MOTIVATE* website. During the course of their work they can send their queries to, and have them answered by, the expert participating in the video-conference. At the second session, some students from each participating school are encouraged to make short presentations on their project work. After each presentation, these students are expected to field questions from the expert and other schools' students. When the presentations and questions are completed, the expert summarises the work done by the students and suggests to them some ideas on how to extend their project work.

The school and students

In 2004, 26 Secondary Three students from a Singapore school participated in one of the *MOTIVATE* video-conferences. Coming from a mixed-gender school with a student population of about 1000, this group of students, comprising 11 boys and 15 girls of varying learning abilities, had a lesson on the topic of *Mathematics and Music*. They were all aged 15 years except for one boy who was 17, and were randomly selected from five classes to participate in this video-conferencing programme. Accompanied by their teachers, as video-conferencing facilities were unavailable in their school, they gathered at the National Institute of Education[2] in the evening for the two video-conferencing sessions with the expert from the University of Cambridge.

In the original plan, the Singapore students were supposed to be joined by students from three British schools at the first session, but the British students were unable to participate due to a last minute change in the schedule. As a consequence, the first session was held entirely for the Singapore students with their UK counterparts participating only in the second session. To provide the British students with an idea what exactly took place in the first session so that they were able to participate in the second, arrangements were made for them to follow through the lesson by viewing a video-recording of that entire session.

The video-conferencing sessions

The first session on *Mathematics and Music* was presented by the expert in this specialised area in November 2004. The lesson covered the following five areas:

  (a) Types of numbers
  (b) Notes produced by vibrating strings and columns of air
  (c) Musical scales: why the difference between rational and irrational numbers is important

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[2] The National Institute of Education is the sole teacher education institute in Singapore.

(d) Composing with numbers
(e) Dancing with maths

The lesson began with a task, asking students to classify a list of numbers such as π, $-\frac{2}{5}$, $0.333\ldots$, -3, $\sqrt{2}$, 1.4142, and $\sqrt{49}$, into groups. When the student presentation was over, the expert illustrated some ways of classifying the numbers which included categorising them as natural numbers, integers, rational numbers and irrational numbers. The students were then led to consider why people had to invent the various types of numbers, in particular, irrational numbers. After discussing the relevance of irrational numbers in real life, the expert consolidated their importance by drawing on examples mentioned by the students.

The second part of the lesson dealt with musical notes produced by vibrating strings and columns of air. Not only did students learn that Pythagoras had discovered a relationship between the length of a string and the note it produced when plucked from his experiment with a vibrating string, they were also told that pleasant-sounding notes were actually produced by plucking strings whose lengths were simple fractions of the original length. Subsequently, the expert demonstrated how different notes were produced by varying the length of the vibrating string and the column of air to students on a guitar and on a recorder, a vertical woodwind with eight finger holes and a mouthpiece. The functioning of a pipe organ was also discussed. Displaying a few pictures of a pipe organ, the expert explained how the different lengths of the columns of air produced different notes. Finally, the students learned about the notions of the frequency of a note and its inverse variation with the length of a vibrating string.

The naming convention of the *Just Scale*, and its anomaly, were covered next in the lesson. Students first learned what a scale was and how each note was named. The expert then reinforced the concept of frequency of a note with a live demonstration on a keyboard. The students were also able to directly hear from the demonstration that the tone produced by playing the C and G notes in unison did not sound as pleasant to the ears as playing the C and the upper C simultaneously. The expert explained that this problem happened because of some discrepancies within the *Just Scale*. The notes were not evenly divided from each other, thus resulting in unequal frequency ratios between two consecutive notes.

As the lesson progressed, discussion of using random numbers to compose music was considered. The expert outlined the steps for composing a simple tune by using random numbers generated from either the spreadsheet available on the *MOTIVATE* website or a calculator, and illustrated such a generated tune with a live demonstration on the keyboard. Lastly, another idea of using a numerical ratio for

the lengths of notes in the composition of music was given. After describing how to do it, the expert played a piece of music composed in such a manner for the students.

In the last segment of the lesson, students explored the connection between mathematics and folk dancing which, as they discovered, basically involved the mathematical idea of symmetry. To lay the foundation for students to understand its role in folk dancing, the expert first asked them to find all the symmetries of a square and then investigate the commutative property of composite symmetries. Finally, the last student task which gave students a sense of the idea of symmetry in folk dancing was conducted. Four students, each holding a letter A, B, C or D and all standing in a line, followed the expert's instructions and acted out a set of moves. They were supposed to end up in the same order as they began with. The entire lesson eventually closed with the playing of a piece of Irish music.

The corresponding second video-conferencing session for *Mathematics and Music* was held in December 2004. Although the description of this session is short in comparison with that of the first, it does not, however, preclude its importance. The second session comprised mainly student presentations made by both the Singapore and British students with only those by Singapore students were described here. The Singapore students, grouped in fours or fives, worked on their projects under the guidance and supervision of their teachers during the one-month interval between the two sessions. Two groups then presented their projects in the second session to their British counterparts from two schools situated in different locations as well as to the same expert who conducted the lesson. One group explored the ordinary guitar and shared their finding from a simple experiment that the frets of a guitar were spaced out according to a certain ratio. This group of students had earlier conducted an internet research to find out more about the production of guitars and chanced upon the ratio. So they decided to perform an experiment to verify its existence. The other group worked on a Chinese musical instrument known as the *erhu*, a two-string bowed fiddle with a sound box, to see if the inverse relationship between the frequency of a note and the length of the string similarly held true in this case. This group concluded that the *erhu* seemed to work in a similar way as any western string instrument and that the inverse relationship also appeared to exist. Each presentation was then followed by a question-and-answer session whereby the Singapore students fielded questions from the expert and the UK students.

Instruments and Data Analysis
Two instruments were mainly used to collect data: a student questionnaire and video-recordings of the video-conferences. With the objective of capturing the

students' viewpoints of learning new knowledge in this fashion, not easily inferred from their participation in the video-conference, a questionnaire consisting of open-ended questions was distributed to every participating student immediately after the first video-conference. Following is a sample set of questions given in the questionnaire to give the reader a sense of the kinds of things that were being asked.

> 1. What were you hoping to get out of the first video-conferencing session, and did you get it?
>
> 2. What would be your reason for hesitating to speak up or answer live questions when you are asked to do so?
>
> 3. What is your general perception of the first video-conferencing session?

Because it was late at night when the video-conference ended, the students were allowed to fill in the questionnaires at home and instructed to return the completed versions to their teachers within the next few days. Twenty-two questionnaires were returned and then analysed to gauge the effectiveness of video-conferencing on student learning. Video-recording was used to document all the video-conferences. All video-recordings were reviewed to look for visual evidence that would shed light on the possible benefits and shortcomings of using video-conferencing. Data were also informally collected through personal communication with the teachers involved in this programme. The teachers provided some useful feedback on their viewpoints of using such technology in teaching and learning.

Results and Discussion

As with any new technology, there will be educators who advocate the use of video-conferencing in the classrooms because of its tremendous potential in supporting teaching and learning. On the other hand, there will also be concerns among others over its effectiveness in enhancing teaching and learning, and as long as these concerns are not addressed, any attempts of introducing it into the classrooms will likely be impeded. Therefore, this section provides a discussion of the benefits of video-conferencing as well as a consideration of some shortcomings.

The Perceived Benefits

Constructivist learning mode Students are active learners who constantly construct their own knowledge when they are engaged in purposeful and worthwhile activities (Richards, 1991; Cobb, 1994) and learning is believed to have taken place only when this happens. Unlike the common use of video-conferencing in lectures at the tertiary level, which are usually one-way presentation of content, *MOTIVATE* video-conferences, comprising not only a lecture interspersed with short student

tasks at regular intervals, but also student presentation as well as a question-and-answer session, are more interactive in nature. Thus this kind of video-conferencing seems to support a constructivist approach (see Sharpe et al., 2000; Gage, Nickson, & Beardon, 2002; Gage, 2005) where students collaborate with their peers on mathematical tasks and project work, along with the chance to engage in mathematical discovery and at the same time to enrich their mathematical content knowledge. For instance, students were asked to discuss with their peers to determine the frequency ratios for C to A and C to B in the first video-conferencing session. Although the students were unable to complete this task within the allocated time frame, they were encouraged to revisit it again as a follow-up activity after that session. Therefore, it appears reasonable to regard this form of video-conferencing as meaningful because such a learning mode seemingly finds an academic home within the Vygotsky's sociocultural theory (Vygotsky, 1986), which primarily perceives learning as having occurred through a child's social interactions with peers, mentors and experts.

Learning from an expert Using video-conferencing is a means of bringing an expert who, due to distance and time, may otherwise be inaccessible to the students (Gage, 2005), and offers a new and enriching learning experience for participating students. Indeed, the Singapore students had never met the expert before the *MOTIVATE* video-conference on *Mathematics and Music* but owing to the technology available they had a chance to learn and interact with the expert as well as to deliver short presentations of their work to her. It seems that this opportunity to interact with an expert appealed greatly to the students and was seen not only as a privilege but also fruitful and meaningful learning experience. Three students' remarks about their experience in interacting with the expert are shown in Table 1. However, some caution in interpreting these statements might be appropriate given that this is the students' first experience with video-conferencing.

Table 1
Learning from experts

	Remarks
Student 1	… it's a once in a lifetime experience when we are communicating via video-conferencing to an expert mathematics lecturer from the prestigious Cambridge university.
Student 2	We seldom get the chance to attend lessons by an expert in school. So it's good and also enjoyable.
Student 3	It is a rare opportunity that we can communicate through video-conferencing with someone from a different country.

Interaction with live audience Connecting students at geographically separate sites together for collaborative learning via video-conferencing exposes them to alternate and enriching learning experiences. Students had to share ideas, make short presentations of their project work and even face the daunting challenge of fielding questions from others regarding their project. The presence of a live audience seemed to provide a motivating force for students to treat their presentations more seriously as well as value and take pride in their own work (Gage, 2005). In this particular case, it was found from an informal chat with a teacher-in-charge that the Singapore students were concerned about making their presentations clear to the audience in the UK. Therefore, attention and care were given to details such as the use of appropriate wordings for the texts and the layout of the PowerPoint slides when they were preparing them. The survey also revealed evidence indicating that speaking to a live audience during a video-conference helped to enhance students' confidence (see Table 2).

Table 2
Improvement in Confidence

	Remarks
Student 4	It improves my confidence of speaking up in front of a mass.
Student 5	I gain confidence in talking to a group of outside people.

Receiving instant feedback Ideas are transmitted and discussed instantly between the expert and the students, without any time lag like in the case of asynchronous discussions via email. Students can receive instant verbal feedback about their work or answers to their questions from the expert. For instance in the second video-conferencing session, the expert commented that the presentation on an exploration of the mathematics involved in the design of an ordinary guitar by Singapore students was very interesting and enjoyable because it dealt with ideas which were quite different from those covered in the first session. Similarly, students can also give immediate verbal responses to the expert or other participating students at the remote end when asked. A manifestation of such a situation also occurred in the second session when a British student asked their Singapore counterparts for the music genre they liked to listen to. One student then replied "heavy metal music" which, according to the expert, was the same kind of music British students liked listening to as well.

Development of thinking skills Thinking skills such as decision making, experimental inquiry and creative problem solving are of paramount importance because they are fundamental requirements in the workplace. Therefore, students must be given opportunities to develop these skills so as to prepare them for the future. An occasion for such a skill development arose when the respective groups

of Singapore students had to decide on which projects they wanted to do for the presentation. A group of students considered working on one of the suggested projects given on the *MOTIVATE* website which asked them to examine a string instrument such as a violin. But since none of the group members could borrow or play a violin, the group explored using an alternative instrument and finally decided on a Chinese musical instrument called the *erhu*, which a group member was able to borrow and play. Additionally, with the knowledge-explosion phenomenon brought about by technology advancement and the accessibility of an immense amount of information on the internet, students must be even more discerning when they gather and examine information. The implementation of a simple experiment to verify the ratio between the frets of a guitar is yet another manifestation demonstrating that video-conferencing can provide students with a platform to hone their thinking skills.

Development of presentation skills Video-conferences with a presentation component offer students with opportunities to practise how to report their work effectively to an external audience (Chua, 2005). This is important because the audience may not necessarily have the same background knowledge as those making the presentation. Therefore, it is necessary to clearly convey ideas across to them if they are to understand what is being delivered (Gage, 2005). To achieve this outcome, Singapore students paid greater attention to clarity in idea development and coherence of ideas. For instance, rather than merely displaying a picture of the *erhu* on a PowerPoint slide, the group actually brought it to physically show the audience. To further enhance the audience's understanding of this instrument, a group member even performed a live demonstration to show how the musical notes in an octave were produced by using one string first and then two.

Development of oral skills As mentioned previously, if the audience at the remote end is to understand what is being delivered, it is then crucial for students to express ideas clearly. Therefore, it is a personal belief that opportunities should be provided for students to practise speaking clearly, fluently and confidently as well as to learn to pace their delivery and to engage the audience. These opportunities are essential especially when oral skills are seemingly regarded as invaluable and vital in the present age. In addition, such opportunities also appear to be very much needed by Singapore students who are typically perceived as being afraid of speaking up. So, based on a personal reflection of this particular video-conference, it was felt that video-conferences of similar nature as the *MOTIVATE* conferences can serve as a means of helping students become skilful and effective presenters or speakers.

Cultural exchange across the globe Video-conferencing can help to build cultural bridges among the participating students of different nationalities. When students

get to interact with people from different countries whose culture may not be the same as theirs, the cultural differences may serve as a vehicle for cultural exchange among the participants. At this juncture, there appears to be a need to emphasise that cultural exchange may not always happen in a video-conference; however, it did occur in the *Mathematics and Music* conference. In the first video-conferencing session, not only did the Singapore students learn how the different lengths of the columns of air of a pipe organ produced the various notes, they were also exposed to two typical forms of performing arts in the UK – folk dancing and Irish music, along with an explanation of the role of mathematics. A student seemed to have enjoyed such a cultural exchange (see Table 3):

Table 3
Cultural Exchange

	Remark
Student 6	The video-conferencing is interesting because you get to learn more new things outside of Singapore; example, folk dancing.

Similarly, British students also learned something new from their Singapore counterparts. They had their first encounter with the *erhu*, a Chinese musical instrument which they were unfamiliar with until a Singapore student briefly described it and played a short tune during the second session. Their fascination with this instrument and interest in it prompted some to find out more about it during the question-and-answer session.

So far, the discussion above has mainly dealt with the potential benefits of video-conferencing in supporting teaching and learning. However, like any other technology, the use of video-conferencing as a learning tool is not totally without shortcomings. Since some of the potential shortcomings can impinge on student learning, a discussion of these shortcomings at this juncture is thus deemed appropriate. Hence the rest of this section considers a few that surfaced during the *Mathematics and Music* video-conference.

The Perceived Shortcomings
Different time zones The geographical locations, from which the participating students come, may become a limitation of using video-conferencing technology. In this study, as the time zones between the UK and Singapore were eight hours apart, consequently, a suitable local time to convene a video-conference between the two countries seemed to be in the late evening. However, personal communication with the Singapore teachers-in-charge of the programme revealed that having to start the video-conference late in the evening was a concern. They were worried that their students would be too tired to concentrate during the

sessions after having spent an entire day in school. Their concerns were genuine and understandable but owing to the time difference, this schedule, although not an ideal one for Singapore students was deemed the most appropriate with all the participants' best interests in mind. Conversely, had the video-conference started in the morning, the British students and the expert would have been likewise negatively affected.

No correction of student mistakes It was noticed in the first session that not all student mistakes were pointed out and corrected by the expert during the lesson. The following transcript of an interaction between a student and the expert produces some interesting evidence of such a situation.

Student: *I have sorted the numbers and I have integers, 3, 1.9, 27, 438, 1, 1.4142. They are called integers or positive numbers.*
Expert: *Ok. Does everybody have the same thing?*
Student: *Yup! Most of them.*
Expert: *So nobody has different ways of arranging them?*
Student: *0.333... or $\frac{2}{3}$ which can be a recurring number.*
Expert: *That's true.*
Student: *0, 3, -3 and 1 are prime numbers.*
Expert: *We have zero.*
Student: [interrupted the expert] *Three! Oh, I'm sorry. Zero is not.*
Expert: *Zero is there but three isn't.* [pause] *You have -3…*
Student: [interrupted the expert again] *and one are prime numbers.*
Expert: *All right! Prime numbers, yes?*
Student: *Also irrational numbers, $\sqrt{7}$ and $\sqrt{2}$. Fractions which are $-\frac{2}{5}$ and $\frac{2}{3}$. Rational numbers, $\sqrt{49}$ which is 7. And also whole numbers 3, 27, 438, 0, 1, $\sqrt{49}$ which is 7. That's all about it.*
Expert: *Ok. Does anybody have anything different?* [Pause] *You all had the same thing, didn't you? Ok … There are lots of ways you could classify them.* [The expert then showed students the various ways of classifying the numbers.]

In this example, the student was called to answer the first student task, which asked for the classification of some numbers (see Appendix 1). In the response, the student made a few mistakes such as classifying numbers like 1.9 and 1.4142 as integers, misconstruing integers as positive numbers, and also considering -3 as a prime number. The fact that the student was able to self-correct the mistake of classifying zero as a prime number suggested that some of these mistakes could

possibly have been a slip on the part of the student. However, it would not be unreasonable to believe that the rest were attributable to the student's misconceptions of certain fundamental mathematical concepts. As such, it seems crucial for the expert to clarify all mistakes so that every student is aware of them, misconceptions are addressed, and even more importantly, no one is confused or misled as a result of not correcting these mistakes. On the other hand, it would also not be unreasonable to think that the expert was cautious about correcting the student's errors when this student could have mustered much courage to speak up in front of the class and to the expert. Furthermore, given that the entire video-conferencing session was recorded in this case, the expert might also have made a decision not to disrupt the flow of the session by correcting the student. Such a case is not unique to video-conferences and can similarly happen in traditional classroom teaching. Nevertheless, it is felt that this is still an important area for improvement worthy of any expert's immediate attention.

Technical Glitches Technical problems such as getting disconnected from the rest, having desynchronised image and voice, getting freeze frames and receiving no audio outputs can strike any time during a video-conference. So it was not surprising that the *Mathematics and Music* video-conference encountered some technical glitches. At one instance during the second video-conferencing session, Singapore students were only able to hear the presentation by a group of British students very faintly despite having to turn on the volume of the audio speakers at the local conference site to the highest level. The root of this problem was later traced to the faulty audio speakers. Besides this problem, there was the occasional time lag between image and voice. These technical problems were regarded as relatively minor and did not seem to cause much disruption and frustration because feedback from both Singapore students and teachers showed that they found the problems reasonably tolerable. Given that facilitating a video-conferencing lesson requires flexibility and skills especially when technical glitches can unexpectedly happen, an implication for teachers using this technology is, therefore, to have on-site technical assistance to deal with equipment failure or software behaviour that they are unable to handle.

Student reticence Finding students not wanting to speak up was very much in evidence especially during the first video-conferencing session. Despite all the encouraging cues from the expert and coaxing from their own teachers, most Singapore students still chose to remain rather unresponsive and hesitant in general when it came to asking questions or delivering their work. It was observed that they usually took quite a while before someone responded, unlike their British counterparts who were more spontaneous. On a couple of occasions, the teachers had to resort to calling specific students to answer, but even then some still felt

uncomfortable and procrastinated in participating in the discussion. The survey findings reveal that shyness was the most common reason given for not wanting to speak up, followed by a lack of confidence and uncertainty about their own answers (see Table 4).

Table 4
Reasons for not wanting to speak up

	Remarks
Student 7	Because of shyness and also uncertain about my own answers.
Student 8	It's embarrassing because we are shy. And we are afraid if our answers are incorrect.
Student 9	The reason is that I had no idea about what the answers are. I am too shy to speak up.

It seems that this phenomenon, which also commonly exists in traditional classroom teaching, is not characteristic of Singapore students only. Similar situations were also witnessed in the UK classrooms (Jenny Gage, personal communication) and in a study conducted by Wang and Yuen (2004) involving post-graduate students in the United States. But unlike traditional classroom teaching, the expert in the *MOTIVATE* video-conference did not know the participating students well enough to call individuals by their names to answer questions. As a result, the interaction did not turn out to be student-centred enough. Therefore, participants involved in any video-conference must understand that this technology necessitates a different way of interacting. Hence, they must take ownership of their personal learning because it is quite difficult for the expert to monitor the progress of everybody during a video-conference.

Conclusion

This article has described a video-conferencing programme in which a group of Singapore students participated along with an expert and students from the UK. The students had a lesson on a mathematics–music connection conducted by the overseas expert, and also the opportunity to make short presentations of their project work to an external audience whom they had never met before. Both the perceived benefits and shortcomings of using the video-conferencing technology are also highlighted in this article. The feedback received from the Singapore students regarding their general perception of video-conferencing was very positive and encouraging. Many felt that video-conferencing was fun and exciting and offered them an interesting and novel learning experience. Some appeared to have enjoyed it so much that they even proposed extending such an experience to other students. Although the data in this study are generally supportive of using the video-conferencing technology, it may be useful to take note of a few shortcomings.

Technical glitches may cause considerable frustration to students and impinge on their learning when they are unable to keep up with a disrupted lesson. Students may have to miss their turns of asking questions or making their presentations if nobody offers to speak up because the expert has to skip their turns in order to save time and maintain the flow of the video-conference

Despite some shortcomings, the outlook for video-conferencing still seems to be promising. The recent introduction of 3G technologies in telecommunication gadgets such as the videophones familiarises the public to this technology. Additionally, the rapid development in broadband technology and the drastic drop in equipment costs and call charges make it even more accessible. In time to come, the use of video-conferencing will likely become more widespread than ever in institutions of higher education and the workplace. Undoubtedly, the prevalence of video-conferencing at the primary and secondary levels will also become a reality. As the role of video-conferencing will continue to soar in ways as yet unimagined, it then becomes clear that it is important to take advantage of its potential to expose students to alternative learning approaches as well as to get them involved in collaborative learning at international level.

However, it should be emphasised that the impact of the use of video-conferencing technology on promoting and improving teaching and learning has yet to be fully explored. Some research on this area appears to have been done in higher education (Canning, 1999) but the existing literature has comparatively little research examining this aspect especially at the primary and secondary levels. So given the lack of evidence, more research is obviously needed in this area to substantiate the potential benefits of video-conferencing in education. Furthermore, a large amount of teaching resources on mathematics-music connections are available from textbooks and from numerous websites on the internet. So can or will Singapore mathematics teachers use these resources to develop and deliver a more economical and effective lesson via traditional classroom teaching for the students? Do students then attain equivalent experiences from such a lesson? Research studies that compare the organisation and student learning outcomes between international video-conferences and traditional classroom teaching are also needed.

Acknowledgement

References

Andrews, T., & Klease, G. (1998). Challenges of multisite video conferencing: The development of an alternative teaching/learning model. *Australian Journal of Educational Technology*, *14*(2), 88 – 97.

Arnold, T., Cayley, S., & Griffith, M. (2002). *Video-conferencing in the classroom: Communications technology across the curriculum.* Devon, UK: Devon Curriculum Services.

Canning, R. (1999). The use of video-conferencing for continuing personal development in higher education: A small-group case study. *Journal of Further and Higher Education*, *23*(1), 117 – 130.

Chua, B. L. (2005). The potential and pitfalls of using the video-conferencing technology to enhance student learning. In S. C. Chu, H. C. Lew, & W. C. Yang (Eds.), *Enriching Technology in Enhancing Mathematics for All*, Proceedings of the 10th Asian Technology Conference in Mathematics 2005, (pp. 287 – 296). Blacksburg, VA: ATCM, Inc.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*(7), 13 – 20.

Freeman, M. (1998). Video conferencing: A solution to the multi-campus large classes problem? *British Journal of Educational Technology*, *29*(3), 197 – 210.

Gage, J., Nickson, M., & Beardon, T. (2002). Can video-conferencing contribute to teaching and learning? The experience of the MOTIVATE project. Paper presented at the annual conference of British Educational Research Association, University of Exeter, England, 12 – 14 September 2002. Retrieved on 11 March 2004 from http://motivate.maths.org/reports/BERApaper02.shtml

Gage, J. (2003). Video-conferencing in the mathematics lesson. Paper presented at the British Educational Research Association conference, Edinburgh, 12 – 14 September 2003. Retrieved January 24, 2005 from http://motivate.maths.org/reports/BERA_2003_Gage.PDF

Gage, J. (2005). Video-conferencing: Case studies in mathematics classrooms. In S. Johnston-Wilder & D. Pimm (Eds.), *Teaching secondary mathematics with ICT* (pp. 191 – 202). Berkshire, England: Open University Press.

Hu, C., Wong, A. F. L., Sharpe, L., Crawford, L., Gopinathan, S., Moo, S. N., & Khine, M. S. (2001). Multipoint desktop video-conferencing for teacher training: A Singapore experience. *World Conference on Educational Multimedia, Hypermedia & Telecommunications*, *2001*(1), 792 – 797. Retrieved February 2, 2005 from http://dl.aace.org/8587.

Kollie, E. (2005). Video-conferencing expands education. *School Planning & Management, 44*(3), 43 – 46.

Martin, M. (2005). Seeing is believing: The role of video-conferencing in distance learning. *British Journal of Educational Technology*, *36*(3), 397 – 405.

Peterson, C. (2004). Making interactivity count: Best practices in video-conferencing. *Journal of Interactive Learning Research*, *15*(1), 63 – 74.

Richards, J. (1991). Mathematical discussions. In E. von Glasersfeld (Ed.), *Radical Constructivism in Mathematics* (pp. 13 - 51). Dordrecht, Netherlands: Kluwer Academic Publishing.

Schiller, J., & Mitchell, J. (1993). Interacting at a distance: Staff and student perceptions of teaching and learning via video conferencing. *Australian Journal of Educational Technology*, *9*(1), 41 – 58.

Sharpe, L., Hu, C., Crawford, L., Gopinathan, S., Moo, S. N., & Wong, A. F. L. (2000). Multipoint desktop video-conferencing as a collaborative learning tool for teacher preparation. *Educational Technology*, *40*(5), 61 – 63.

Vygotsky, L. (1986). Thought and language (Rev. ed.). Cambridge, Massachusetts: MIT Press.

Wang, S., & Yuen, S. C. (2004). An ethnographic study on a video-conferencing class. *World Conference on E-learning in Corp., Govt., Health & Higher Education*, *2004*(1), 1007 – 1012. Retrieved February 2, 2005 from http://dl.aace.org/16540.

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Appendix

Sort these numbers into groups.

27, 438, -13.1, π, $-\dfrac{2}{5}$, $0.333\ldots$, -52, 0,

$\dfrac{2}{3}$, -3, 1, $\sqrt{2}$, 1.4142, π^2, $\sqrt{49}$, $\sqrt{7}$, 1.9

Student Task