Students Representing Mathematical Knowledge through Digital Filmmaking

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During initial attempts at filmmaking by my Year 7 class my focus was on the technology. However, I observed many positive learner behaviours inherent in the filmmaking process. Could these positive learner behaviours be harnessed, through filmmaking, to improve learner outcomes in mathematics? Two trials were conducted comparing a mathematical mini-documentary making revision strategy with pen-and-paper revision. It was concluded that mini-documentary makers retained information at least as effectively as, if not better than, students who used pen-and-paper strategies. This implies that mathematics educators can be confident of positive effects on students' knowledge retention through student filmmaking in mathematics.

As a teacher of Year 7 students I was attempting to incorporate digital filmmaking technologies into my classroom. Initially my aim was to develop students' familiarity with the technology. The first production attempts were not aligned to mathematics. Production was slow and we encountered many difficulties, which were overcome, and from which, we learnt a great deal. For me, at this stage, the focus had remained on the mechanics of the filmmaking, but my attention was drawn from these processes to the discussions of the students.

Filmmaking required the students to make many decisions about their learning and how it would be portrayed. Discussions occurred about relevance of details, the priorities and sequences of information, the best ways of portraying ideas, and how to link segments. Disagreements among students required them to defend their point of view, rationalise choices, and think deeply about what they had learnt. Critical thinking and higher order thinking were occurring without any prompting from me. I had reached the stage identified by Wiberg (1995-1996) where the focus moved away from the technology to how it could be used to enhance critical thinking. I became interested in the possibility of linking filmmaking to mathematics thereby harnessing the many positive learner behaviours inherent in the filmmaking process for the benefit of the students' mathematical learning. I realised that the making of mini-documentaries about specific mathematical topics would offer my students much more than simple exposure to a new technology. My students could use filmmaking as a vehicle for enhancing their learning through collaboration, investigation, communication, expression, performance, understanding, manipulation of information, and the making of a product. This research was to investigate how these filmmaking technologies could be used as a revision strategy in mathematics and to determine if the strategy resulted in a positive impact on student learning.

Background

Current Information and Communication Technologies Research Agenda

The nature of constant technological change has many authors calling for more and more research to keep pace with how the technologies can be used to enhance student-learning outcomes. Roblyer and Knezek (2003), for example, discussed the research agenda for education and technology and emphasised the importance of showing why teachers should use particular information and communication technologies (ICT) advancements as a means of finding solutions to educational problems. There is a strong belief that pervades the literature that when used correctly ICT have a positive influence; it seems that it has been very difficult to find the evidence to prove it. Slavin (2004) believed that research, such as this mathematical filmmaking study, comparing alternative approaches with traditional has a valid function to serve. This is in line with Robler and Knezek who promoted research that showed the relative advantage of a technology-based teaching method over another because, before teachers accept a new method they must be convinced of its relative advantage. The practicalities of educational technology research are such that most researchers will continue to work in their local environments, solving problems pertinent to their situations.

Meta-Analyses Involving ICT in the Classroom

A meta-analysis by Waxman, Lin, and Michko (2003) suggested that there were few reviews of research on the effects of classroom use of technologies on student outcomes. They deemed this to be a significant gap in available research as they believed that the use of technologies often changed the teaching practices in a classroom from teacher-centred to more student-centred with subsequent improvement in student outcomes. They believed that the dramatic, present day improvement in quantity and quality of technologies available in classrooms would at least provide the opportunity for improved learning outcomes from teaching and learning with those technologies. Through this research project I investigated these opportunities in the mathematics classroom.

Kozma (2003) completed a meta-analysis of worldwide case studies showing how ICT were incorporated in innovative pedagogical practices. Some similarities became apparent. ICT were able to provide frameworks to support and improve student learning by developing the skills deemed to be of particular importance in the 21st century, such as handling information, problem-solving, communication, and collaboration. Filmmaking in mathematics is an excellent medium for eliciting these skills acknowledging Kozma's emphasis that it is how teachers effectively incorporate a technology that will lead to improved learner outcomes.

Processes Associated with Filmmaking

Primary students can now incorporate words and pictures (still and moving) in representations of their knowledge. Recognising this, Bull and Thompson (2004) called for investigations into academic strategies that utilised this combination of words and pictures into today's instructional objectives.

Strategies do not emerge from the new technology as much as from how it can be applied (Ross, Yerrick, & Molebash, 2003). This observation fits the model of Reeves (1998) who divided ICT in classroom use into learning *from* computers and learning *with* computers. In the context of this research, this analogy can be taken to the broader realm of ICT, in that it aims to discover how students can work *with* film in mathematics to improve learning outcomes.

It was while students were working *with* the video cameras and editing equipment that I noticed a great deal of communication and collaboration. McGrath (2004) believed that learners needed skills such as tracking and communicating, reflecting on ideas and understandings, and designing to make understandings visible to others. These are definitive skills required by young mathematicians and filmmaking seems purpose-built to avail their development.

Other authors have completed studies that hint at further advantages to be gained by filmmaking in mathematics. Yerrick, Ross, and Molebash (2003) noted through their observations of the use of digital video in science, that collaboration and communication were present in the learning process via multiple student voices and ideas. They went on to say that it was possible to improve content understanding using desktop digital video editing when the students were authentically engaged in the production process. This increased authenticity of learning through the use of digital cameras was also highlighted by Sharp, Garofalo, and Thompson (2004). Using a post-test only design Hopson, Simms, and Knezek (2001) found that an enriched technology environment could develop students' higher order thinking skills.

Application of Filmmaking Technologies and Practices to Classrooms

Currently, most research examples of filmmaking in specific subject areas are from tertiary institutions or from high schools. For example, Mills, Kelley, and Jones (2001) showed how digital cameras could be used to capture images in a micro-biology class. The cameras allowed students who previously suffered from the inaccuracies of hand drawing what they saw to now being able to have an accurate image of what they were studying. The advantages of using digital cameras were listed and included rapid collection of images, archiving, class discussion and comprehension, better use of class time, and student empowerment.

For students to produce a film effectively to represent their mathematical knowledge they need to produce a storyboard. This allows the articulation of content, concepts, and sequence prior to the actual filmmaking process. Storyboarding is the planning stage. It requires the makers of the film to visualise what is to be filmed. It is during this stage that a number of educational benefits pertinent to the learning of mathematics have been noted by several authors. Reeder (2005) described storyboarding in the broader sense of preparation for the design of products, not just film, and spoke of its value of communicating intention, sequence, and needs. Storyboarding requires effective communication and requires students' traditional oral and written communication skills before the use of the digital communication begins. In science class applications of digital video and editing, Ross et al. (2003) stated that in preparation for filming, communication of ideas for script, settings, camera angles, examples, and data were required through storyboarding. They added that in an educational context, an accurate storyboard was important as it allowed the teacher to check for accuracy of concepts to be portrayed by the students before the film was started. Storyboarding, they believed, added greatly to the learning process of the students as it was where connections were made between the content of the lesson and the creative aspects of communication of ideas.

A study by Pearson (2005) drew attention to the urgent need to understand the educational implications of classroom digital video and editing, to enable filmmaking to be used with maximum benefit in teaching and learning. One of the implications of Pearson's study was that ways to embed the use of video making across the curriculum needed to be encouraged.

Method

Overview

The project involved two trials, the second replicating the procedures of the first but swapping the tasks of groups, thereby allowing all students to complete a mathematical mini-documentary. The two trials used different mathematics topics.

Mathematics Topics

In trial one the topic was transformation of shapes. As a class we investigated reflection, translation, and rotation of two dimensional and irregular shapes, initially through links to an animated web page and then through practical constructions. Students investigated how to use these transformation functions to create three dimensional shapes from two dimensional, which included instructions such as degrees of turn for a rotation, and movement to new coordinates for a translation. As an extension activity, the works of M.C. Escher were examined and replicated using some of the skills learned. Assessment for this topic focussed on construction using transformation and demonstration of understanding of the mathematical terminology.

The topic for trial two was measures of central tendency. Students had an understanding of average but were introduced to the terms mean, median, and mode. Scenarios were discussed to determine which measure would give the most accurate portrayal of the specified circumstances. Practice was given for the methods of calculation for each measure of central tendency. Assessment focussed on the students' ability to choose the appropriate measure for a particular situation and also their ability to calculate and manipulate the measures.

Participants

Participants were the members of a Year 7 class at a Queensland State Primary School. Students were between 11 and 12 years of age. There were 13 girls and 14 boys in the class. Following school policy the class was assigned students with a balanced range of ability levels. The total number of participants giving their consent to be involved in the project was 27. In the both trials there were 25 students involved and 2 students absent at some point.

Instruments

The instruments used to assess learning were teacher generated class tests, based on information taught in class as per the Queensland mathematics syllabus. These tests were pencil and paper completion items. Scoring of responses was by a right-or-wrong marking scheme. The test given at the end of the week of instruction served as the pre-test. The test without notice, administered two weeks later was the post-test. The raw scores from these tests were used in the data analysis.

Apparatus

Cameras used in these trials were Sony Digital Still Cameras (3.1 mega pixels) that had limited but adequate capacity to take digital video with audio. Sony 128mb memory sticks were used to store data.

A combination of classroom computers and laptops was available with Windows XP. The movie editing software was Movie maker 2. To transfer movies to a central location for review purposes, they were burned to CDs.

Design

These trials were intended to determine the effect of making mathematical mini-documentaries as a revision strategy compared to a more traditional pen-and-paper revision approach. A variation of a pre-test/post-test control group design was used to determine the students' retention of the mathematics topics.

Procedure

For each trial the Year 7 class was instructed in the chosen mathematics topic. At the end of the week in which instruction took place, students completed a teacher-generated test on the topic that served as the pre-test. The following week the students were randomly assigned to one of two groups. These groups undertook a revision lesson on the mathematics topic. Group 1 revised their work by making mini-documentaries and group 2 completed their revision by the more traditional method of pen-and-paper work sheets. Two weeks later, without notice, students were administered the post-test.

These mini-documentary making teams of three or four students were organised just prior to the start of the revision period. Their instructions included a recommended break up of the working time, which was ten minutes for storyboarding and resource collection, twenty minutes filming, and half an hour film editing. The mini-documentaries were to outline the major concepts of relevant mathematics topic. Filming was allowed in and around the classroom. The students' brief was to make a mini-documentary, which could be viewed by other students for future revision purposes or as a teaching and learning tool in future years. Time efficiencies were achieved by encouraging students to not be overambitious with acting or camera shot selection. Groups were asked to do all speaking parts live and not to use voice over recordings during the editing phase as it was not time efficient. Finally, during the editing process students were asked to address the basics first. Only after clips were dragged onto the film timeline and correct sequence achieved were additional tasks of title slides, on screen wording, transitions, and credits to be completed.

The pen-and-paper group was instructed to complete the revision of the maths lesson on the worksheets given to them. On completion, these students could continue with related activities. They were allowed to work by themselves or with others.

The revision period was of one hour's duration. Most of the pen-and-paper revision group completed the set tasks and moved on to related activities.

All mini-documentary teams completed the film within the allocated time. These films were generally less than 90 seconds duration because the time constraints of one hour would not allow for more extensive productions. Also, the editing software had a tendency to freeze with films longer than the proposed duration (Microsoft Corporation, 2003).

Students were given the post-test without notice two weeks after the revision lesson.

Results

A univariate analysis of variance (ANOVA) was conducted to determine the significance of changes in mean (see Table 1) from the pre-test to the post-test for each revision strategy trialled. The analysis of the data was to determine the variation in learner outcomes from the mini-documentary making group to the pen-and-paper revision group. Levine's test showed that the scores had homogenous variance from pre-test to post-test.

In trial one the mini-documentary group's means showed no significant effect from pre-test to post-test $F(1, 24) = 0.300$, $p > 0.05$. As the post-test was administered without notice two weeks after the revision lesson, the results indicate that the mini-documentary makers' retention of the maths concepts, although not improved, were not significantly diminished in the interim.

Table 1
Means of the Two Revision Groups from Pre-test and Post-test in Trial One

	Pre-test		Post-test	
	M	SD	M	SD
Mini-documentary	18.7	2.3	18.1	2.7
Pen-and-paper	19.6	2	17.3	3.3

The pen-and-paper revision group means showed a significant effect from pre-test to post-test: $F(1, 22) = 4.450$, $p < 0.05$. The students in this group had a significantly lower post-test mean than pre-test mean. In the interval between completing the revision worksheets and the post-test these students showed some lack of retention of the mathematics topic of transformations.

In trial two, data were analysed as per trial one (see Table 2). Levine's test showed that the scores of both revision groups had homogenous variance from pre-test to post-test.

Table 2
Means of the Two Revision Groups in the Pre-test and Post-test in Trial Two

	Pre-test		Post-test	
	M	SD	M	SD
Mini-documentary	21.5	3.3	22.2	2.6
Pen-and-paper	20.7	2.7	20.3	2.9

The mini-documentary group means showed no significant effect from pre-test to post-test $F(1, 24) = 0.351$, $p > 0.05$. As for the previous trial the post-test was administered without notice two weeks after the revision lesson and the results indicate that the mini-documentary makers' retention of the mathematics concepts had improved slightly but not significantly. The pen-and-paper revision group means showed no significant effect from pre-test to post-test $F(1, 22) = 0.106$, $p > 0.05$. Contrary to the earlier result, the pen-and-paper revision group's retention of the mathematics concepts was not significantly diminished in the interim.

Discussion

The results of these two trials indicated that the use of mini-documentary making as a revision strategy in mathematics provides a valuable alternative to traditional approaches. Knowledge retention of mini-documentary makers was as good as, if not slightly better than, that of students who completed traditional pen-and-paper revision worksheets. This gives a positive starting point for the incorporation of filmmaking into primary schools as a legitimate form of expression in the teaching and learning process in mathematics. As this technology improves and becomes more available, as teachers and students become more adept at its uses, and as more varied applications are attempted, it seems reasonable to expect that learning outcomes will improve.

A Storyboard Example

As only ten minutes were allocated to storyboarding, the focus had to remain on the concepts to be portrayed and what techniques would best achieve them. As decisions were made, the students recorded them on their storyboards, quickly developing a plan for their films. Students used their mathematics exercise books and graph books to focus their thoughts on what concepts needed to be covered. Decisions were made as to how to portray the concepts through film. Some of these were filming of manipulatives and diagrams, students pretending to be teachers, comedic role play, and coloured chalk examples on the concrete playground.

A Mini-documentary Example

A review of a mini-documentary will give a brief insight into the production processes and the final product. From a teacher's perspective, I was keen to see that the focus of the one-hour period remained on the portrayal of the mathematical concepts. It was important that students did not lose sight of the mathematical goals while engaged in the technological process. The success of the mini-documentary revision strategy as a viable alternative to traditional pen-and-paper methods depended on students maintaining this focus. As the films were to be viewed by peers, and possibly future year seven classes, the students were keen to ensure that information portrayed was correct. They felt that they were producing an authentic product. The following review is an example of the overall process.

This was a film on transformations produced by a team of three girls. The students used a demonstration format where the viewer only sees the hands that manipulate materials. The demonstrations of transformations were effective as this team used a white L shape on a black background that gave visual clarity. Also included was an example of how a three-dimensional shape can be drawn by sliding a two dimensional shape and joining corresponding points. The film concluded with a summary of the concepts using interplay between two of the team members that was to the point and effective. The mathematical concepts were well explained and the film was visually appealing. The team's effort to convey the concepts showed an understanding of the needs of the intended audience. The film was completed within the allocated time.

Observations of the Mini-documentary Making Process

The mini-documentaries produced in these trials varied in approach and technical skill but accurate content was generally present in all. The effectiveness of these films varied owing to the different film techniques and presentation methods used by the teams. Although the filmmaking process as a revision strategy for the film-makers has proved effective in these trials, the reasons for this effectiveness have not been determined.

The process of film-making entailed a number of observable behaviours that may have contributed, in varying degrees, to the effectiveness of this revision strategy, and could be the focus of further research. These observations were of students who:

- Were motivated and engaged, staying on task throughout the activity.
- Collaborated with team members through discussions, decision making, sequencing, role sharing, and task allocation.
- Were active rather than passive in their leaning.
- Used a common mathematical language in their discussions.
- Needed to think about their thinking (metacognition) to portray concepts correctly.
- Showed pride and were creative in scripting, acting, filming, and editing.

Students' comments and interactions during the production process also give an insight into the value of the filmmaking strategy especially from a meta-cognitive perspective.

- A great deal of peer correction occurred when determining the portrayal of the mathematical concepts, sometimes requiring clarification from me if the team had reached an impasse.
- A common challenge expressed by the students was that they understood the concepts but found it difficult to explain them. The filmmaking process forced them to clarify their thoughts.
- A comment from one student was, "We had to talk maths."

Practical Implications

Mathematics Syllabus and Filmmaking

The Queensland mathematics syllabus articulated the contribution of this key learning area to lifelong learning. The following selected phrases from the Queensland Studies Authority (2004) describe these lifelong learner attributes; these attributes can be considered in terms of how filmmaking in mathematics could contribute to their development.

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- Knowledgeable person with deep understanding
    - Learners' understandings are enhanced through active engagement in mathematical investigations and in communicating their thinking and reasoning in ways that make sense to themselves and others.
- Complex thinker
    - Learners … analyse and synthesise information ….
- Responsive creator

- o [Learners] use a range of representations to communicate mathematical understandings and to transfer knowledge from one situation to another.
- Active investigator
  - o [Learners] manipulate concrete materials and make a variety of representations and displays … to assist their mathematical thinking and reasoning.
- Effective communicator
  - o [Learners] understand and use the concise language of mathematics, both verbal and symbolic.
  - o [Learners] select appropriate mathematical language to convey, logically and clearly, their mathematical understandings, thinking, and reasoning.
- Participant in an independent world
  - o Learners cooperate, collaborate, and negotiate in groups to plan, think, reason, and resolve mathematical investigations….
- Reflective and self-directed learner
  - o Learners reflect on their learning as they become metacognitively aware and self-regulating. (pp. 2-4)

From analysis of students' mathematical filmmaking processes and products it is clearly apparent that there is alignment with these descriptions of life long learning attributes.

Practical Relevance of Study

This research targeted a revision strategy using filmmaking technologies. It has shown how students can effectively work *with* rather than *from* these technologies.

For teachers to use mini-documentary making confidently in their classrooms within a reasonable time limit, students must be familiar with the filmmaking process and they must be encouraged to use simple techniques. My class had been taught the basic filmmaking process earlier in the year as a part of our Arts program. For the purposes of this research, time parity between revision strategies was very important but, for general classroom use, the strict time limit concerns for making mini-documentaries could be relaxed. This would be especially important if younger grades were involved. The process could be broken into shorter periods; storyboarding, filming, and editing could be completed in a series of short lessons.

The Queensland Studies Authority (2004) through the rationale of the mathematics syllabus has regularly confirmed the link of mathematics with technology (though not always ICT). Filmmaking seems to fit naturally into the Queensland Studies Authority's understandings of, (a) thinking, reasoning, and working mathematically, (b) the attributes of lifelong learning, (c) the cross-curricular priorities of literacy, numeracy, lifeskills, and futures perspective, and (d) understandings about learners and learning.

The findings from this study have shown the effectiveness of a filmmaking revision strategy that teachers may choose to apply across the curriculum and across grades. The next step in my research is for my students to record on film, salient points of a unit of work during, or at the end of each lesson on a given topic. By building a body of recorded information students will then produce a documentary as a culminating activity or investigation. These documentaries could fulfil the same role as a written assignment or "write up" of class work. They could also be used as an assessment piece. The research focus will be to determine not only if student learning outcomes are improved but also why.

The concept of students making films in specific subject areas such as mathematics brings with it enormous educational potential as it requires metacognitive processes, collaboration, and communication as well as technical skills to be successful. A technology that allows students to communicate their mathematical ideas incorporating, spoken word, still and moving images, in everyday mathematics classroom settings has the ability to influence positively the teaching and learning process of mathematics.

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