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Title: "The tablet PC in senior mathematics classes

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Problem Statement and Context

The authors of this paper have many years of experience both in teaching of Mathematics and in the use of technology to support that teaching and learning. Throughout that time, they have seen various new technologies emerge, to be taken up with enthusiasm and then to slowly die away again. In many instances, the issue was not with the technology itself, but with its implementation and subsequent evaluation. In many cases, the initial enthusiasm of early adopters waned as research failed to provide compelling evidence of the expected improvements in learning.

The advent of the Tablet PC and its increasing affordability, allows the chance to evaluate another new technology from a theoretical basis rather than simply from a craft perspective. The use of the word Technology will include the idea that" Technology is a process whereby practical problems are identified and solve using interventions based firmly on sound scientific theory, principles and measurement" (Clark & Estes, 1998)

The context for the research project is the senior mathematics classroom where novice mathematicians are confronted on a regular basis with high level problem solving tasks which can easily deter students from pursuing this subject with confidence, let alone consider Mathematics as a potential career pathway.

All learning remains an immensely complex task and various theoretical perspectives are both possible and desirable. A successful classroom teacher will employ an eclectic mixture of learning theory at various stages of the learning process. Some initial learning can be simply Behaviorist as in the learning of trigonometric ratios. Some learning requires that the teacher has an understanding of Cognitivist theories and as learning proceeds and matures Constructivist theories have value.

Student feedback suggests that it is in the middle stage of the learning process that the greatest difficulties occur and it is at this point that their perception of themselves as "no good at Mathematics" arises. Cognitive Load Theory provides a useful window into the mind of the young mathematician who tells you that "I don't get any of what you just taught me"!

Cognitive Load Theory has as part of its basis some early research into the structure of the human mind and its limitations. Specifically, the Working Memory of the mind acts as a bottle-neck in the whole learning process. The mind can be modeled usefully with three major sub-components; sensory memory, working memory and long term memory. Sensory memory is fleeting and lasts only of the order of 10 seconds. We are able to briefly retain images and sounds long enough to make sense of them and decide whether or not to attend to the information. Our long term memory is essentially limitless and develops and expands throughout our life as new knowledge is added and schemas are made more sophisticated and more powerful. The learning of mathematics involves the development of a large number of such powerful and encompassing but also fairly context specific understandings and patterns.

The other significant component of the human mind is the Short Term Memory, better described more recently as the Working Memory. Cognitive Load Theory has its primary focus on this aspect of learning and much of its useful theory relates to this component. The basic premise of CLT is that learning cannot occur once cognitive over-load has occurred. We would suggest that for many students who have expressed their lack of confidence in their Mathematics ability, the underlying cause will have been the experience of cognitive overload on a regular basis. (Baddeley & Hitch, 1974; Paas & van Gog, 2006; Sweller, 1988; Tuovinen & Sweller, 1999)

The source of the limitation of Working Memory lies in the limited number of channels or pieces of information that can be dealt with at any one time. Research by Miller in the 60's and 70's suggests the magic number of 7 plus or minus 2. For an average student this means that somewhere between 5 and 9 simultaneous items in working memory could lead to cognitive overload at which point no further learning will occur. (Miller, 1956)

Where a complex mathematical process is being attempted, the student is dealing with sensory data, both visual and auditory, possibly from more than one source, spatial and temporal contiguity effects, due to the layout and functioning of the classroom, the need for student note taking and for the accessing of existing schema. (Paivio, 1986)

The information itself can be useful and necessary for learning to occur - Intrinsic Cognitive Load. It is also possible for the teacher to inadvertently add unnecessary and potentially counter-productive information –Extrinsic Cognitive Load. There can be other information which widens and expands the schema being developed - Germane Cognitive Load (Chandler & Sweller, 1991; Paas, Renkl, & Sweller, 2003; Sweller, van Merrienboer, & Paas, 1998)

It is into such a complex learning milieu that we have attempted to introduce the Tablet PC in order to address a number of these issues as identified through the perspective of CLT. In needs to be pointed out immediately that the Tablet PC in this context is not seen as a replacement for all the other activities that occur in a rich classroom environment and that the students could also be in a computer laboratory working with Excel one day or outside videoing projectile motion or circular motion for subsequent analysis by mathematical software on another day. Rather the Tablet PC will be a useful tool at the very time that cognitive over-load is most likely to occur.

Unlike the few implementations reported in secondary schools (Neal & Davidson, 2008), where all students have access to their own Tablet PC, this classroom operates successfully with a single Tablet PC connected wirelessly to a Data Projector. This classroom is also different to one with an Interactive Whiteboard. The Tablet PC/Data

Projector setup eliminates the need for students to come forward to the whiteboard which is a deterrent for older students and also removes any interference with the projected images.

The Tablet PC is a pen-based technology which has numerous advantages over other interfaces especially for Mathematics notation. The slate form factor means that the equipment is highly mobile and can operate wirelessly from any part of the classroom and is able to be passed from student to student.

More than most other subjects, the written communication of Mathematics requires spatial placement of the elements of the communication. Handwriting is much more flexible and corresponds more closely with the way in which students will represent mathematics mentally and reproduce it subsequently. Mathematics notation is often two dimensional and the relative positioning of symbols is critical. Some obvious examples include the superscript notation of Indices, much of the Calculus notation and the complex layout of symbols required for Matrices and Vectors.

Another significant advantage of the Tablet PC is that it allows for the dynamic capture of a lesson in progress which can then be saved and made available subsequently on the school learning portal (Anthony, Yang, & Koedinger, 2006; White & Tutty, 2005)

It is this close connection between the task or problem, its solution and its subsequent representation which allows the teacher to minimize cognitive load and to maximize the student focus on those aspects which are intrinsic to the learning of that particular process.

The aim of this research then is to confirm, where applicable, aspects of CLT that have already been researched in other contexts and to relate the findings of this implementation to the body research under development. There is the potential to add new theory especially in those aspects of pen technology which relate to contiguity effects.

From CLT there are a number of studies which have direct relevance to the pedagogy under investigation. The value of means-end analysis in problem solving has been strongly challenged. Following the work of Sweller, a **worked example** approach was taken where the complexity of the task was judged to be high. Fully worked solutions were developed by the whole class on the Tablet PC with the students writing and retaining their own copy of the solution. Several worked examples followed including fading of the solution process whereby more and more of the solution was required to be completed by students without direct assistance (Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Moreno, 2006)

Methodology

Because this is a single technology implementation in the context of standard classroom practice throughout the rest of the secondary school, it was difficult to compare directly the effects of the project. A Design Experiment approach was taken and a particular class will be followed over a two year period. Student surveys and interviews were used to determine the perceptions of students and their learning and to suggest adaptations to the pedagogy as the research proceeds. This will be used to provide baseline evidence about teacher and student attitudes, technical expertise and proficiencies.

A parallel class, in Mathematics B was taught using more traditional approaches. A close examination of test data will be undertaken to seek out any differences in student learning which might be attributed to the Tablet PC approach. In particular, differences in problem solving ability will be investigated.

Classroom observations and video and digital images will allow for some degree of triangulation.

Preliminary Results

In keeping with a Design Approach, a number of interim results and observations have been made. Students have indicated that the Tablet PC is best employed as expected where the problem solving task is high in complexity and a class based approach was the preferred mode for learning.

For the more able students, issues of Germane Cognitive Load become increasingly important. Once a solution procedure is well known, students want to know when to employ that particular procedure and why the procedure works. Continuous practices on a well learnt procedure becomes counter-productive

The Tablet PC was not seen as necessary for low level knowledge acquisition or for review and consolidation. If anything the Tablet PC can be a distraction at those times. The practice of supplying worked answers to revision sheets and making them available through the learning portal was seen as useful. The capture of hand-written and notated solutions was seen as the most useful aspect apart from the use of the Tablet PC in the middle stage of acquiring solution procedures for particular classes of problems.

In summary, a Tablet PC appears to have the potential to be a significant component in a modern, technology rich classroom which also appeals to this generation of students.

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