

Improving existing resources for interactive learning activities using tablets and touch screens

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As creating resources for interactive technology-based learning activities can be a huge task, we investigated how existing resources can be used and modified. Data were collected from students, an observer, and a teacher for several problems in a mathematics course on a computing degree that were part of interactive learning activities using touch screen technologies. It was found that existing problems could become effective resources in these activities simply by modifying them with suitable formatting, and that locating related elements together helped students start a problem. However, it is also important that pedagogical principles are followed.

Keywords: interactive, learning, touch, tablet, BYOD

Introduction and context

When the opportunity arose to use digital ink and touch screen technologies in mathematics classes, we faced the problem of creating suitable resources. The obvious solution was to start with existing resources as these had all been carefully chosen for their potential to make a pedagogical contribution to students' learning and it is important that this basic principle is followed (Anderson et al, 2007).

For six years, we used digital ink on tablet PCs with electronic styluses and Classroom Presenter software in a first year discrete mathematics course on a computing degree at Christchurch Polytechnic Institute of Technology (based on Anderson, Anderson, Chung, Davis, Davis, Prince,... Simon, 2006). In 2014, the tablet PCs were replaced with large touch screens and Dyknow Vision software (Dyknow, 2014). As we look ahead to a "Bring Your Own Device" or BYOD environment, we intend to use tablets and smart phones with browser delivered software. Each change in technology brings advantages and disadvantages but the sequence of actions of the interactive activity we use are unchanged, and are shown in Figure 1. This activity sequence is a modified version of that introduced by Anderson, Anderson, Davis, Linnell, Prince and Razmov (2007).

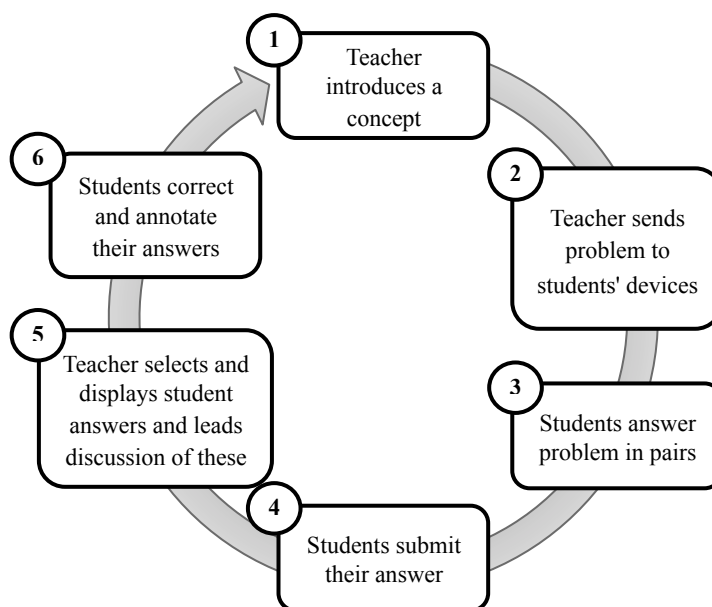


Figure 1: Activity sequence for interactive learning activities

The special feature of this activity sequence is that the teacher can display students' answers including their working. It is therefore possible to discuss with the class, not just students' solutions but more importantly, their strategies. This means that discussion is based on a very rich source of student generated strategies and allows the teacher to provide a wide variety of feedback to all students, including tips, things to avoid, and alternative

strategies. With this activity sequence, we planned to provide short activities that reinforced each concept after it was introduced, and intended that most pairs of students would be able to start solving the problems without teacher assistance thus giving them an opportunity to practice and reinforce each concept.

When creating the problems, we based many on existing problems and designed others to suit pairs of students working on tablet PCs. We divided the content of each class session into concepts and sub-concepts of a suitable size for one cycle of the activity sequence, and followed Anderson, Anderson and McDowell's (2005) guidelines for digital ink. Although these were written for a teacher using a tablet PC when presenting to a class, they appeared to be relevant to students writing their answers on tablet PCs. The guidelines include:

- provide enough room to write;
- split a problem into two if there is not enough room; and
- make diagrams large enough to write on.

We created the problems in Powerpoint slides ready for import into either Classroom Presenter or Dyknow Vision. In order to investigate how these problems impacted on students' learning, we conducted the first trial (based on Robson & Kennedy, 2013). This year we have been conducting another trial and the purpose of this paper is to use results of the first trial and initial analysis of the current trials to investigate the research question: How can existing resources be improved for use in interactive learning activities that use tablets and touch screens?

First trial

The first trial was carried out in 2008 with a class of 22 first year degree students using tablet PCs in pairs. There were 154 problems used in the course, and we categorized them by type as shown in Table 1.

Table 1: Number and types of problems created for a one semester course

Type of problem	Description	Number of problems
Text	Text and mathematical symbols only. None of the distinguishing features of the other categories.	86
Structured layout	Tables or gaps to indicate where students should write different parts of their answer.	35
Thinking problem	Matching, diagrams, correct the mistakes, best strategy, compare strategies, common misconceptions, open questions with more than one correct answer.	33
TOTAL		154

An important result of the first trial with 30 of the problems was that on average, students rated problems with a structured layout such as table or gaps to be filled, higher than those with just text and mathematical symbols (see also Robson & Kennedy, 2013). This means that existing problems can easily be modified to make them more suitable for digital ink activities, by formatting them with a structured layout. The results were summarised with the following guidelines that add to those of Anderson et al. (2005).

- Provide as much room as possible for students to write their answers. The problem itself can be displayed in a small font as students read the problem on their own device.
- Use a layout that encourages students to get started, for example, break the problem into parts.
- Use a layout that guides students to write certain parts of their answer in certain locations, for example, provide a table or gaps to be filled. This helps students see how to start solving the problem and to fit their answer on the screen. It also makes it easier for students and teacher to follow the answers that are displayed to the class.

Another outcome of the first trial was the identification of problems which students found less useful for learning, often because they found them too hard. Analysis of the data for these problems led to suggestions for improvements that would be investigated in the second trial. One of these problems is the focus of the rest of this paper with our hypothesis being that following the user interface principle of locating related elements in close proximity would improve students' ability to start the problem and hence reduce students' difficulty with it (see Watzman, 2003).

Second trial

The second trial was carried out in 2014 with 47 students in two classes and students worked individually at computers with large touch screens. After analysing the results of the first trial, six problems were chosen as having potential for being improved. Both classes (Class A and Class B) were taught by the first author. An observer, the second author, attended classes and recorded observations about modifications made to the problems and whether these appeared to be related to whether students were able to start solving the problem or to any other difficulties for students. Thus with six problems evaluated and two classes, observation data was collected in 12 different class sessions.

After the interactive activity based on each problem was complete, students answered an online survey. Data gathered included whether problems were useful for learning, how hard or easy students found problems and whether they knew how to start. In addition, observer's comments and teacher's reflections were recorded.

Results and discussion

For the six problems surveyed, an average of 81% of students reported that the problems were useful for their learning, an average of 92% reported that that problems were too easy, easy, or about right, and an average of 93% reported that they could get started. However one problem stood out from the others. 19% of students found it hard or too hard compared to an average of 8% for the other five problems. The observer also reported students having difficulties, so we examined the results for this problem in more detail.

In the first trial, the problem on the left in Figure 2 was the second hardest of the 30 problems surveyed, as measured by the percentage of students who reported that it was hard or too hard. The observer noted that students who had trouble getting started didn't realise that they needed to use the Boolean expression given in Part 2 to do Part 1 of the problem.

Problem used in first trial	Modified problem used in second trial																																																																								
<p>Functions and truth tables</p> <p>1. Complete the truth table</p> <table border="1" style="display: inline-table; margin: 10px 0;"> <thead> <tr><th>x</th><th>y</th><th>z</th><th>f(x, y, z)</th></tr> </thead> <tbody> <tr><td>1</td><td>1</td><td>1</td><td></td></tr> <tr><td>1</td><td>1</td><td>0</td><td></td></tr> <tr><td>1</td><td>0</td><td>1</td><td></td></tr> <tr><td>1</td><td>0</td><td>0</td><td></td></tr> <tr><td>0</td><td>1</td><td>1</td><td></td></tr> <tr><td>0</td><td>1</td><td>0</td><td></td></tr> <tr><td>0</td><td>0</td><td>1</td><td></td></tr> <tr><td>0</td><td>0</td><td>0</td><td></td></tr> </tbody> </table> <p>2. Simplify the expression for the function</p> <p>$f(x, y, z) = xy\bar{z} + \bar{x}\bar{y}z + xyz + \bar{x}\bar{y}\bar{z}$</p> <p>=</p> <p>=</p>	x	y	z	f(x, y, z)	1	1	1		1	1	0		1	0	1		1	0	0		0	1	1		0	1	0		0	0	1		0	0	0		<p>Functions and truth tables</p> <p>1.</p> <p>$f(x, y, z) = xy\bar{z} + \bar{x}\bar{y}z + xyz + \bar{x}\bar{y}\bar{z}$</p> <p>Use this expression and complete the truth table.</p> <table border="1" style="display: inline-table; margin: 10px 0;"> <thead> <tr><th>x</th><th>y</th><th>z</th><th>f(x, y, z)</th></tr> </thead> <tbody> <tr><td>1</td><td>1</td><td>1</td><td></td></tr> <tr><td>1</td><td>1</td><td>0</td><td></td></tr> <tr><td>1</td><td>0</td><td>1</td><td></td></tr> <tr><td>1</td><td>0</td><td>0</td><td></td></tr> <tr><td>0</td><td>1</td><td>1</td><td></td></tr> <tr><td>0</td><td>1</td><td>0</td><td></td></tr> <tr><td>0</td><td>0</td><td>1</td><td></td></tr> <tr><td>0</td><td>0</td><td>0</td><td></td></tr> </tbody> </table> <p>2. Use Boolean algebra to simplify the expression given.</p>	x	y	z	f(x, y, z)	1	1	1		1	1	0		1	0	1		1	0	0		0	1	1		0	1	0		0	0	1		0	0	0	
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Figure 2: Problems used in first and second trials

Therefore, in the second trial, we moved the Boolean expression to Part 1 where it was needed, as shown on the right in Figure 2. This time, the observer didn't see any signs of the location of the Boolean expression causing confusion, and in Class B all students were able to get started. However, in Class A only four out of 18 students appeared to know how to get started and the observer quickly realized what had happened. In introducing the relationship between truth tables and Boolean expressions, the teacher had shown how a completed truth table could be used to write a Boolean expression, but Part 1 of the problem required the use of the reverse concept. Most students in Class A appeared to have found it hard to reverse a concept which they had only just been introduced to.

Class B had a different experience as the teacher's introduction included both the forward and reverse concepts. This allowed us to test our hypothesis, that the Boolean expression needed to be moved to Part 1 of the problem where it was needed. The observer reported that all students in this class were able to get started and carry out Part 1. The observer also reported that many students in Class B had trouble with Part 2 and this is probably why they reported it as a hard problem.

In summary, Class B experienced a teacher's introduction to the problem that was pedagogically sound and a problem in which the Boolean expression was included with Part 1. These two factors probably contributed to

all students in this class being able to attempt Part 1. However, many of the students appeared to find Part 2 hard. The problem focuses two related but different concepts, so further investigation of this is needed.

Class A, on the other hand experienced a pedagogically flawed introduction to the problem. This is probably the main reason that most students had trouble starting Part 1 of the problem and highlights the importance of applying pedagogical principles to the planning of all parts of the activity sequence. The observer noted that students in this class also had difficulties with Part 2 of the problem.

Conclusion

The key result of the first trial was that existing problems can easily be modified to have a structured layout with tables or gaps to be filled. This helps students get started, thus giving them the opportunity to learn from doing the problem. Another benefit of the structured layout for the interactive learning activities in this study was that both students and teacher were familiar with the layout, making it easier for students to follow when student answers were displayed.

A useful result of the second trial was that modifying a problem so that it conformed to Watzman's (2003) user interface design principle of locating related elements together improved students' ability to start working on a problem. This would improve the potential for students to learn from the doing the problem. Another result of the second trial is that it provides evidence of the importance of applying pedagogical principles (see Anderson et al., 2007). It was seen how a teacher, when introducing a new concept, must provide an appropriate amount of information for the student activity which follows, taking into account the stage of learning of the students in the class. Furthermore, analysis and planning of concepts and sub-concepts needs to be considered.

The next stage of this investigation will be to separate the two parts of the problem focused on in this paper, so that we can further explore the reasons that students found this problem hard, investigate the effect of the number of concepts included, and further explore ways of improving resources used in interactive learning activities with tablets and touch screens.

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