Interactive teaching using tablet PCs: Designing effective questions

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Clickers have been shown to help students learn concepts when used with carefully written multi-choice questions. Tablet PCs can be used in a similar way with the advantage that students can also submit their working and strategies. But what types of questions are best suited to this interactive use of tablet PCs? In this preliminary study, students’ perceptions of a range of types of questions were analysed. Students in a course in discrete mathematics and statistics reported that most questions were useful for learning. This result is important as it is much easier for teachers to write questions for tablet PCs by formatting existing questions than to write meaningful multi-choice questions for clickers. Questions benefited from a structured layout such as a table or gaps to be filled. Students also reported that questions that encouraged in-depth thinking and discussion, such as open questions, common misconceptions, or choosing a best strategy were particularly useful for their learning.

Introduction

It is important that students actively engage with their learning as this leads to improved learning, particularly when the engagement involves hands on activities, feedback [1], and peer discussion [2]. Such pedagogical principles can be incorporated into learning activities with the innovative use of technology.[3]

To improve student engagement, Mazur [4] introduced clickers so that students could answer multi-choice questions during a lecture. He used clickers in a way that caused students to help each other understand concepts in physics. Mazur’s evidence-based interactive clicker activities are now widely used in US universities.[5] The activities have been found to help students understand concepts in many different subject areas and improve student engagement and participation, for example [6, 7].

Tablet PCs can be used in a similar way to clickers. However students and teachers can also write directly on tablet PC screens with a stylus, which means that many more types of questions and answers are possible in addition to the multi-choice questions used with clickers. In this preliminary study with a class of 22 tertiary students, student perceptions of a range of different types of questions on tablet PCs are investigated. The results will be used to inform the design and focus of a more in-depth study.

Background

Active involvement of students in Mazur’s learning activities that use clickers has been shown to improve student performance in tests.[8] Mazur’s learning system, known as Peer Instruction, begins with students’ preparation before class and involves the following activity sequence during lectures:

- Lecturer introduces a concept and then displays a multi-choice question to class.
- Students submit individual answers on clickers, discuss answers with their neighbours, and then resubmit their answers.
- Lecturer shows tally of answers, asks a few students to explain their answers to the class, and then summarises.
Anderson et al. [9] used tablet PCs to enhance established pedagogies such as engagement, feedback, and peer instruction. In their case study, using tablet PCs in this way was found to enable and support active learning. Other studies support this.[10, 11] Anderson et al. used the following activity sequence:

- Teacher introduces a concept, then distributes a question to students’ tablet PCs.
- Students submit their solutions and working.
- Teacher selects, displays to the class, and incorporates student solutions into a class discussion.

An observation in Anderson et al.’s [9] study was that peer instruction occurred spontaneously when a question was at just the right level for students to create similar but different solutions. In a similar study, Razmov and Anderson [12] often asked students to work in groups of two or three while sharing a tablet and observed that this promoted collaboration and in-depth discussion, particularly for open questions.

A key difference between Mazur’s clicker activities and Anderson’s tablet PC activities is the timing and frequency of peer instruction. With clickers, students submit an individual answer before discussing the question with peers. With tablet PCs, peer instruction can occur at any time after students receive a question but only when the nature of a question prompts students to discuss it.

Another difference between Mazur’s clicker activities and Anderson’s tablet PC activities is the nature of the questions. Mazur’s multi-choice questions, called concept tests, require students to have a thorough understanding of a concept in order to choose a correct answer. Writing this type of question is both difficult and time consuming so Mazur has set up the Peer Instruction Network [13] to facilitate the sharing of questions amongst teachers. Anderson’s questions on the other hand are the type of questions that teachers normally use in their classes. They are either closed questions that test a skill or a concept or they are open questions where more than one correct answer is possible. Thus, it is much easier for teachers to write questions for tablet PCs, than for clickers.

The special feature of using questions on tablet PCs is that the teacher can display students’ full answers including working. It is therefore possible to discuss not just solutions, but more importantly the strategies used in finding solutions. But the disadvantage of using tablet PCs is that peer instruction may not occur. In order to promote peer instruction in this study, students worked in pairs and shared a tablet PC. This study could then focus on investigating what types of questions are best suited to students working in pairs on tablet PCs.

Setting

Tablet PCs were used to teach a first year discrete mathematics and statistics course on a business computing degree. Prior to the use of the tablet PCs each class session consisted of a one-hour lecture followed by a one-hour tutorial. Since using tablet PCs, each class session is now a two hour interactive teaching session. The teacher introduces each concept and then students work in pairs on questions on their tablet PCs in a learning activity that follows Anderson et al.’s [9] activity sequence (see Background). Students usually work in pairs but in some class sessions there is a group of three and sometimes students work on their own.

The one-semester course is taught in alternate semesters by the authors of this paper and the study was conducted in the first semester that tablet PCs were used when there were 22 students in the class. The first author was the teacher and the second author attended all classes as research observer.
The questions
The questions were created on Powerpoint slides and were delivered to students using Classroom Presenter. The design of questions was constrained by the physical characteristics of the tablet PCs as writing directly on the screen of a tablet PC with an electronic pen is not quite as easy as writing with pen and paper, and the writing area is limited. However, tablet PCs allow the use of colour, writing, highlighting, drawing, and typing, so questions can be designed to take advantage of these features.

Many of the questions were designed to simply provide practice with the concept that had just been taught, but a range of different question types were created, for example, open questions with multiple answers for encouraging discussion. Questions were created with the expectation that most students would be able to attempt them. The aims were that all students would participate, that there would be peer instruction, and that the learning activities would encourage rather than discourage. All questions were designed for a pedagogical reason as recommended by Anderson et al. Another use of tablet PCs is by teachers when they are presenting a lecture. Many of the guidelines for lecturers using digital ink appear to be applicable to questions written for students, in particular:

- Plan enough room to write.
- Split a slide into two if there is not enough room.
- Make diagrams large enough to write on.
- Practice with the technology.

We tested our questions by answering them on a tablet ourselves. This testing led to changes, for example, more room provided for an answer, complex questions divided into two questions, or part of the answer filled in, so that they wouldn’t take so long to do.

We wrote eleven different types of questions. For each question, we chose a question type that we judged to be suited to the content and the pedagogy we intended using for teaching that content, as recommended by Anderson et al. Many questions were based on existing questions for the course.

Method
With ethics approval, three types of data were collected about tablet PC questions. First, one or two questions were selected for evaluation in each class session. Students completed question evaluations using tablet PCs immediately after doing selected questions. They indicated reasons for whether or not a question helped their learning and gave each question an overall rating on a five point Likert scale from 1 (low) to 5 (high). Students responded individually and provision was made on the evaluation screen for up to three students in a group to respond. There was also room for students to write further comments. See Appendix.

The second type of data collected were the answers to the questions that students submitted during the lessons and will be referred to as “student submissions”. The third type of data collected were observer’s comments and teacher’s reflections written during the course and notes taken during our many discussions of these.

Analysis of data
Several different analyses were carried out as follows.

First, to obtain an overall picture of the types of questions used in this course all questions were put into categories according to type. The number of questions of each type that was evaluated was also recorded.
Second, for those questions that were evaluated by students, their reasons for why a question was useful or not to their learning were totalled and percentages calculated.

Third, to assist making comparisons of overall student perceptions for different questions, a “question rating” was calculated for each question. This was done by averaging the ratings given by students in their question evaluations. Students’ ratings were discarded if they were ambiguous, but if the intent was clear although outside the given range, they were recorded as 1 (low) or 5 (high).

Fourth, student submissions were marked by the authors and the number of correct submissions recorded. When a question had several parts, the answer was only recorded as correct if all parts were correct.

Finally, when analysing the data for each question, observer and teacher reflections were also considered.

Students completed the question evaluations after they had submitted their answers and the class discussion of submissions had occurred. It should be noted therefore that question evaluations and question ratings apply not just to the question but to the learning activity as a whole, including answering questions, viewing student submissions, and teacher-led discussion.

Results and Discussion
In this section all questions used in the course are first categorised into type, to give an overall view of the types of questions in this study. Data for the questions that were evaluated by students are then examined for question features that students reported helped or hindered their learning. Results are discussed then summarised as a set of suggested guidelines for writing questions for tablet PCs.

Types of questions
There were 154 questions written for this course, and eleven different types of questions were identified. For each type of question, the number of questions in the course and the number of questions evaluated are shown in Table 1.

Table 1: Types of questions

<table>
<thead>
<tr>
<th>Type of question</th>
<th>Description</th>
<th>Number of questions in course</th>
<th>Number of questions evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text</td>
<td>Text and mathematical symbols only. None of the distinguishing features of the other categories.</td>
<td>86</td>
<td>6</td>
</tr>
<tr>
<td>Complete a table or fill in the gaps</td>
<td>Tables or gaps to indicate where students should write different parts of their answer.</td>
<td>35</td>
<td>14</td>
</tr>
<tr>
<td>Diagram</td>
<td>Drawing or labelling a diagram or chart.</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Colour-in</td>
<td>Shading areas on Venn diagrams.</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Compare solutions</td>
<td>A question and two strategies were given with all algebraic steps shown in full. Students were asked to compare the strategies and comment.</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Find mistakes</td>
<td>Find and correct mistakes in a full worked solution.</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Best strategy</td>
<td>Decide which strategy will lead to the solution most efficiently.</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Common misconceptions</th>
<th>Designed to alert students to common misconceptions. Questions consisted of two parts that looked similar, but required different strategies.</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matching</td>
<td>Match or categorise items.</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Open</td>
<td>More than one appropriate or correct answer. However, it was also possible for students to give incorrect answers.</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Open and diagram</td>
<td>Open questions that also required students to draw a diagram or chart.</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>154</td>
<td>30</td>
</tr>
</tbody>
</table>

Of the 154 questions, 86 (or 56%) involved only text and mathematical symbols. These were closed questions with a specific answer about a process or concept. The other 44% of questions covered a variety of different types as shown in Table 1.

Students rated table questions higher than text questions. The average question rating was 4.0 for table questions and 3.7 for text questions. The authors observed several advantages of providing a structure for students’ answers such as completing a table, adding to a diagram, or filling in gaps. A structure gave students an indication of how to get started on an answer and helped them lay out their answer in a way that would fit on the screen. Because all submissions followed a structure that students were already familiar with it was easier for students and teacher to read the submissions, and this facilitated discussion.

**Student perceptions of usefulness of questions for learning**

Question evaluations were administered regularly throughout the course. During the 22 class sessions in which tablet PCs were used, students filled in a question evaluation on 30 occasions. Students soon became familiar with the format of the questionnaire and filled them in very quickly. Students appeared to complete them willingly for most of the course but there were signs of “questionnaire fatigue” towards the end of the course, particularly for a few students. The number of question evaluations received for questions ranged from 10 to 22 with a median of 18. The wide variation was due to the number of students who attended each class session as well as the occasions when students didn’t submit question evaluations.

Students rated most questions positively. The average question rating for all questions evaluated was 4.0 and three quarters of the questions had ratings of 3.8 or more. Students recorded that most questions helped them learn with 96% of all responses for all questions reporting that the question helped learning, and this ranged from 85% to 100% for different questions.

Question ratings ranged from 2.4 to 4.7, and students also indicated when they found questions too hard or too easy. To investigate students’ different perceptions of questions, the percentage of students who found a question too hard or too easy is plotted against the question rating in Figure 1.
Figure 1: Percentage of students who found a question too hard or too easy versus question rating.

Questions that stand out from the others are labelled in Figure 1. Two questions stand out for being too hard (H1 and H2), three for being too easy (E1, E2 and E3), and three for having the highest question ratings (R1, R2 and R3). These eight questions will be examined in more detail.

**Hard questions**

Two questions that stood out as being too hard will be considered in this section.

```
Arithmetic Operations

Calculate
- - 1 - (3 - 2 * - 1 + 3 ^ 2) + 3
```

**Figure 2: Question H1**

The question labelled H1 (see Figure 2) had the highest percentage of students (36%) finding it too hard and nobody found it too easy. It also had the lowest question rating of 2.4, the only rating that was below 3, the midpoint on the Likert scale. Only one submission was correct although three pairs worked through most of the problem correctly but made a minor error in the final step. One pair stated on their submission that they couldn’t do it and five students reported in the questionnaire that they didn’t know what to do. Students’ comments on the question evaluations included “Frustrating” and “Too much thinking required”. The observer also noted that this question was too hard and that many students needed help from the teacher to get started.

For this question, students needed to understand and apply several concepts about the order of carrying out operations. It may be better to separate it into two smaller questions, for example, – 1 – (3 – 2) and – 4 * 3 ^ – 2 + 3. There would be fewer concepts in each question, and it would be easier for students to identify all their errors because this is difficult when errors affect subsequent steps.

Although 36% (8 out of 22) of students found this question too hard, 55% said this question was useful for their learning and all students reported that it made them think. It appears that students found it useful to view and discuss a variety of errors after finding a question hard.
Figure 3: Question H2

For the question labelled H2 (see Figure 3), only 11 out of 22 students submitted a question evaluation. Of these 27% reported that it was too hard. However, 18% found it too easy. There were 12 answers submitted so either one pair submitted two different answers or there were two students working on their own. Nine of the submissions were correct. In one of the incorrect submissions, the table was not filled in and the teacher noted at the time that the layout of this question needed improving. The observer commented that several students needed the layout explained before being able to get started.

Students may have had trouble starting this question because of the way it was structured. The Boolean expression that was needed to complete the truth table was given after the truth table. It may have been better to guide students by providing information in the order that it would be needed.

Although the low number of question evaluations submitted and high number of correct submissions means this question may not have been as hard as it appears on Figure 1, this question provides an example of a key observation made earlier in this study. It is important to provide a structure that guides the students as to the format of the answer required and encourages them to get started correctly.

Easy questions
Three questions that stood out as being too easy will be considered in this section.

Strategy
3x + 2y - 4z = -7  (1)
2x + 8y - 3z = -9  (2)
5x - 4y + 2z = 18  (3)

Which strategy is best?
A. Eliminate x
B. Eliminate y
C. Eliminate z

Figure 4: Question E1
Students found easy questions helpful. For Question E1 (see Figure 4), half of the students found it too easy, yet all of them said it was useful for their learning. So it appears that this question, which was designed to encourage students to think about and choose a good strategy before working out a problem, helped most students learn even though half of them thought it was too easy.

The teacher observed that the multi-choice nature of the answers provided no indication of students’ reasoning. Nine out of ten submissions identified the shortest strategy with the easiest calculations, but it was not until a class discussion of the other submission that students’ misunderstandings were revealed.

This question is really a concept test as defined by Mazur [4] as it is a multi-choice question that tests understanding of a particular concept. Mazur’s activity sequence for clickers incorporates students’ justification of answers. With multi-choice questions on tablet PCs, more in-depth peer and class discussion may occur if students are also asked to justify their answer.

**Figure 5: Questions E2 and E3**

The data for Questions E2 and E3 (see Figure 5), also illustrate that students can find easy questions useful. Although 50% of students found Question E2 too easy, all student submissions were correct, and all students found it useful for their learning. In Question E3, 28% of students found it too easy, although one student found it too hard. Like Question E1 and E2, all students found it useful for their learning.

The observer noted that students were particularly interested in other students’ submissions for Question E3. This is an example of an open question as many different correct answers are possible. Although some students felt it was too easy, it may have been at the right level for all students to learn from either creating their own answer or viewing other students’ answers. It may also be that completing easy questions contributed to students’ confidence. There is potential to further investigate the reasons for students’ high rating of easy questions.

**Highly rated questions**

The three questions that stood out because they had the highest question ratings will be considered in this section.
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For each problem, state whether it is about permutations or combinations and why.

1. 15 students apply for 6 different jobs. In how many ways can these jobs be filled?

2. There are 10 different cars but only 6 car parks.
   (a) How many different ways can the cars be parked?
   (b) How many ways can 6 people get a park?

**Figure 6: Question R1**

Question R1 (see Figure 6), which was designed to alert students to common misconceptions, stood out as it received the highest question rating of all questions at 4.7. In addition, all students said it was useful for their learning because it focussed on a specific point and challenged them at just the right level.

It appears that being asked to decide whether a question involves permutations or combinations helped students to focus on this point. Yet, fewer than half (4 out of 9) of the pairs of students submitted an answer and no submission answered the question fully by including a reason. Thus, the number and nature of student submissions for this question provided useful and immediate feedback to the teacher about the students’ stage of learning.

**Figure 7: Questions R2 and R3**

Both Questions R2 and R3 (see Figure 7) had the second highest question rating of 4.5. All students found Question R2 useful for their learning because it made them think, and 93% reported that it challenged them at just the right level. All pairs submitted correct answers and students were exposed to several different ideas when the submissions were displayed and discussed. The teacher and observer noted that the variety of answers led to more discussion and prompted students to further thinking. The open nature of this question may have contributed to its usefulness for students, by encouraging in-depth discussions.
Question R3, on the other hand, was a closed question that included a table for writing the answer and hints that may prompt peer discussion. All students recorded that it made them think and challenged them at the right level. This is an example of a high rating for a standard type of question for this topic. Like all questions in this study, it was chosen as being suited to the type of content and for a pedagogical reason, in this case to help students become familiar with a new concept by practising a standard skill. It would be easy for teachers to prepare this type of question as they can start with existing questions and only need to consider adding a structure that encourages students to get started.

In summary, the highest rated question was designed to address common misconceptions and the next two highest were an open question and a standard type of question with a table. Thus, one of the three highest rated questions was a traditional question and the other two were designed to refine or deepen students’ understanding of a concept. The latter will be termed “thinking questions” and include the last five types of question in Table 1, i.e. best strategy, common misconceptions, matching, and open questions with or without a diagram.

Thinking questions are over-represented in the highly rated questions as only eight were evaluated and two of these were in the top three. This compares with twenty standard questions, with just text or with tables added, that were evaluated but only one was in the top three. Therefore, it is worth considering all the thinking questions that were evaluated in this study. The mid-point on the Likert rating scale was 3.0 and the average question rating for thinking questions was 4.2. This compared with 4.0 for questions with a table, and 3.7 for questions with text only. It appears that students found thinking questions particularly useful to their learning. In addition, the observer and teacher reported that these questions prompted deeper discussion. In summary, the highest rated question was designed to address common misconceptions and the next two highest were an open question and a standard type of question with a table. Thus, one of the three highest rated questions was a traditional question and the other two were designed to refine or deepen students’ understanding of a concept. The latter will be termed “thinking questions” and include the last five types of question in Table 1, i.e. best strategy, common misconceptions, matching, and open questions with or without a diagram.

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Guidelines for writing questions
A few questions stood out from the others as being too hard, too easy or having a particularly high question rating. It appears that several question characteristics may improve students’ perceptions of the usefulness of a question for learning. These characteristics are summarised as a set of guidelines for writing questions. They are not a complete set of guidelines but rather those that arose in this study and should be read in conjunction with the guidelines in the Background section of this paper on which the questions in this study were based.

- Separate a question into two if it requires students to apply too many concepts.
- Provide a structure for students’ answers that encourages correct solutions.
- Include easy questions as students can find these useful.
- Ask students to justify their answers to multi-choice questions so that their strategies can be seen.
- Write questions that challenge students at the right level.
- Write questions that focus on a specific point.
- Write questions that encourage students to think, by incorporating different strategies and common misconceptions.
- Write open questions to stimulate in-depth discussion.
- Choose a type of question that suits the content.

Conclusions
The purpose of this preliminary study was to find out about types of questions that students find useful for learning. However, it was clear from the question evaluations from students that most students found most questions helped them learn. This result is important as it is
much easier for teachers to start with questions that they normally use in class and format them for tablet PCs than to write the multi-choice concept tests that suit the use of clickers. The result also provides general support for following the principles used in this study when writing questions for tablet PCs, especially the principle that questions should be written with a pedagogical goal in mind as recommended by Anderson et al. [9], and also the principle of applying relevant guidelines from those designed for teachers using digital ink when lecturing [15] to questions designed for students using digital ink on Tablet PCs.

A number of questions stood out from the others and analysis of these led to suggestions that were summarised as a set of guidelines for writing questions. This study focussed on student perceptions and was also limited by the small sample size, and lack of information from students who chose not to submit all equation evaluations. Furthermore, analysis of question type was done after the data was collected so the proportion of each question type evaluated did not reflect that of all questions used in the course, and two question types not evaluated.

The guidelines can now be explored in more depth, for example by investigating rewritten versions of the questions that were too hard or too easy, and the nature of questions that generate in-depth discussion. Limitations and results of this study can also be taken into account in the research design of further study.

When combined with the recommendations from other researchers in the Background section, the additional guidelines in this study will help teachers write questions for use with tablet PCs that students may find useful for their learning. This has important applications to the increasing use of technology, such as tablets and “bring your own device”, in interactive learning activities.

Acknowledgements
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References

12. Razmov V, Anderson R. Pedagogical techniques supported by the use of student devices in teaching software engineering. SIGCSE’06; 2006.


Appendix

<table>
<thead>
<tr>
<th>Question evaluation</th>
<th>Student A</th>
<th>B</th>
<th>C</th>
<th>Student A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>It was very useful for my learning</td>
<td>I learnt very little</td>
<td></td>
<td></td>
<td>Not much thinking required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It made me think</td>
<td></td>
<td>It was too easy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It challenged me at just the right level</td>
<td>It was too hard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I knew what to do</td>
<td>I didn't know what to do</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It focussed on a specific point</td>
<td>It tried to teach too many things</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There were several correct answers -- which was a good thing</td>
<td>There were several correct answers -- which was a bad thing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>There was too much writing required</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Any comments – why was this a “good” or “bad” question

Overall rating (1 low - 5 high) A B C

**Figure 8:** Evaluations completed by students on tablet PCs after answering selected questions