# Where are the weaknesses?

## *An electronic voting system and diagnostic tree approach to learning where students struggle with digital logic.*

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**Abstract**

An electronic voting system and diagnostic tree approach is proposed for the evaluation of student learning of course material in the digital electronics portion of EE1X, a first year undergraduate course in electronics and electrical engineering. The proposed approach overcomes a key weakness of standard summative assessment procedures, such as written tests, because it rapidly exposes the where the majority of the class are weak, allowing the students' capability in these 'weak' areas to be explored in more detail there and then. The information is primarily intended to help the lecturer shape the remaining lectures in the course to address any outstanding weaknesses, but also provides each student with almost immediate feedback on their level relative to the rest of the class via a histogram display of the answers received from the class for each question.

## 1. Introduction

Summative assessment often fails to provide students with detailed feedback about their skill level in each of the different areas covered in the course. This is compounded in digital logic courses by an increasing reliance in later lectures upon previously-taught skills. For example, in the first lectures of a digital logic course, the approximately 100 students are taught how to represent things that we are familiar with in everyday life, in ways that computers can understand. For example, the numbers we use everyday for prices, temperatures and time have to be turned into strings of ones and zeros. Naturally this is a source of confusion for the first-time learner! The course then moves onto to using these sorts of representations for the inputs and outputs for digital logic circuits, with the logic circuit performing some form of meaningful manipulation. If someone is having trouble with a particular circuit, the question the lecturer wishes to know the answer to is, is it just the latest material that is confusing the student, or has the student failed to assimilate the previous material upon which it also relies? This is straightforward to accomplish in a one-to-one laboratory situation, but difficult to ascertain in a one-to-many (lecture) situation. In this mini-investigation, an electronic voting system [1] with diagnostic tree approach [2] is proposed to efficiently assess the skills of all 100 students at once.

**2. Method**

Electronic voting systems (EVS) are familiar to viewers of popular game shows. A question and several possible alternative answers are shown on a screen. Audience members select an answer by pressing the corresponding button on a handheld unit. The data is transmitted to a central unit that aggregates the answers and displays a histogram on the screen representing the number of people that selected each answer. Such a system has been developed for use in lectures at the University of Glasgow, by a group headed by Steve Draper from the Dept of Psychology. They have kindly agreed to make their system available for a lecture later this term.

The diagnostic tree approach to EVS in lectures was developed by existing users of the system and, for example, has proven to be of great benefit in statistics. In this method, a body of questions covering all aspects of the course are prepared. More questions are prepared than could be feasibly used in the class, so that there enough questions to 'drill down' (or follow a branch) into any particular aspect in response to a high percentage of wrong answers. The approach is illustrated in Fig. 1.

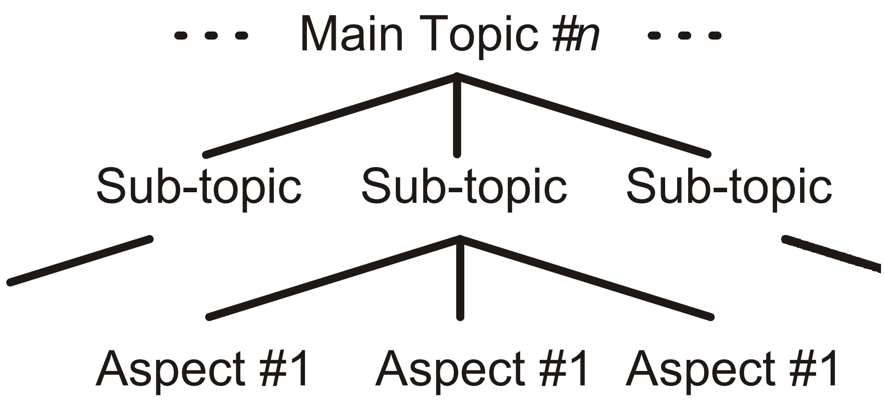


***Fig. 1 Diagram of the hierarchical organisation of questions in the diagnostic tree approach***

Since the present generation of the EVS equipment requires approximately one minute to collate the answers from 100 students, the ideal questions are of the 'thought provoking' rather than 'rapid response' variety, and so the upper limit on the number of questions that could reasonably be tested in a 40 minute period (leaving time for student briefing and de-briefing) is approximately 10-15. Thus, something like 30 - 45 questions might be reasonably expected to give enough coverage of the course material with the required depth for detailed assessment of where strengths and weaknesses lie in the students' capabilities.

A number of possible statistical distributions of responses are possible to any given multi-choice question that has only one right answer, as illustrated in Fig. 2. From these distributions it is possible to distinguish whether the class has not yet assimilated the material for practical use (e.g. yesterday's lecture) (case 1, Fig. 2), has a good understanding (case 2, Fig. 2) or if there is a specific misunderstanding (case 3, Fig. 2).

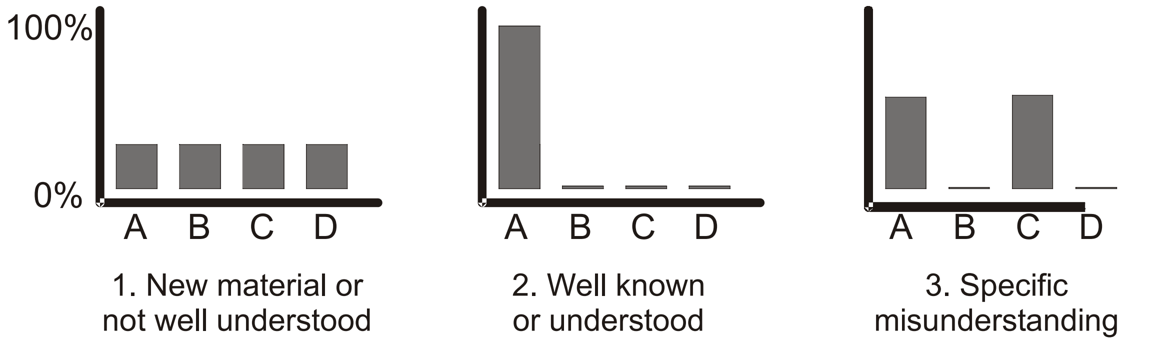


***Fig. 2 Extracting meaning from the distribution of answers received from electronic voting system. For ease of comparison, the right answer is 'A' in all cases shown.***

If the distribution of answers follows cases one and three, further questions about this area would be asked (i.e. sub-topic question would be followed by questions on specific aspects of that question - see Fig. 1), whereas if the distribution followed case two for a sub-topic question, questioning would either move onto to another sub-topic (or a second question could be asked just to confirm it wasn't a co-incidence!)

The actual diagnostic tree of questions remains to be prepared however a sample (for those who are interested) might be:-

*The decimal number $-23_{10}$ can be represented in 6-bit signed binary form - which of the following possibilities is correct?*
*A. $010111_2$*
*B. $101000_2$*
*C. $101001_2$*
*D. $110101_2$*

## 3. Discussion

The students will be advised ahead of time when this lecture will be scheduled (tentatively Dec 1) and what it will entail. At the start of the actual session, the operation of the handsets will be explained as will a basic summary of the motivation for the exercise. It will be emphasised to the students that while no marks will be recorded against their name, the aggregate results will be used to shape the content of the remaining lectures to correct for any deficiencies and that it is an opportunity for them to review progress in learning since the class test some three weeks prior (Nov 10). Since there are only aggregate results shown for each exercise, and no score is kept, the emphasis remains firmly on formative feedback. Some competitive students in the class may choose to keep a private tally, but this should make little difference to the overall outcome. The questions and answers will be displayed onto two white screens at the front of the lecture theatre. The use of the handsets is reasonably intuitive and should present no problem to this body of students. One of the students is hairing impaired, however this exercise is pretty much ideal for this situation.

In addition to recording the aggregate results to guide the content of subsequent lectures, evaluation assistants from Steve Draper's group will be present to record student feedback via questionnaire or similar. There is also a small chance of an additional senior faculty member attending to see what is expected to be the first demonstration of the EVS and diagnostic tree approach in the engineering faculty. The final report on this activity will outline what branches were taken (and the distribution of the answers at each decision point) and relate that to the balance of course material already presented. Any correlations between student capability in a particular topic area and time spent presenting it in lectures/labs/both will be assessed.

The time required for this activity is as follows:

- view EVS demonstration - 1 hour
- compose 30 - 45 questions and answers - 4 hours
- prepare electronic presentation and navigation guide - 4 hours
- give session - 1 hour
- analyse results and write report - 3 hours

**4. Conclusion**

An electronic voting system and diagnostic tree approach to question selection has been proposed as a means to establish where weaknesses exist in the understanding of digital logic in a class of approximately 100 students taking EE1X in the Dept of Electronics and Electrical Engineering. The outcome of the exercise is formative feedback to the students on where they should focus their study as well as feedback to the lecturer that will shape the content of the remaining lectures in the course (approximately four to eight lectures). The proposed evaluation exercise is expected to be the first use of the diagnostic tree approach in the Engineering faculty.

**References**

[1] http://www.psy.gla.ac.uk/~steve/ilig/

[2] http://www.psy.gla.ac.uk/~steve/ilig/qdesign.html

# Results of mini-evaluation study: "Where are the weaknesses?"

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## Abstract

An electronic voting system (EVS) and diagnostic tree approach was used for the evaluation of student learning of course material in the digital electronics portion of EE1X, a first year undergraduate course in electronics and electrical engineering. Details of the EVS system and diagnostic tree approach are contained in the original plan for this mini-evaluation. One lecture was given over to conducting the EVS system. The results were used to shape the future lectures, with one being given over to providing detailed feedback to the students and another lecture being dropped due to its complexity. Electronic and written feedback was obtained from the students. Half the students had used EVS before, but there was no correlation between having previous experience and scoring well in this session. Over two thirds of the students claimed that the EVS session 'benefited' or 'definitely benefited' them, and over a half claimed that it helped the lecturer better target problem areas.

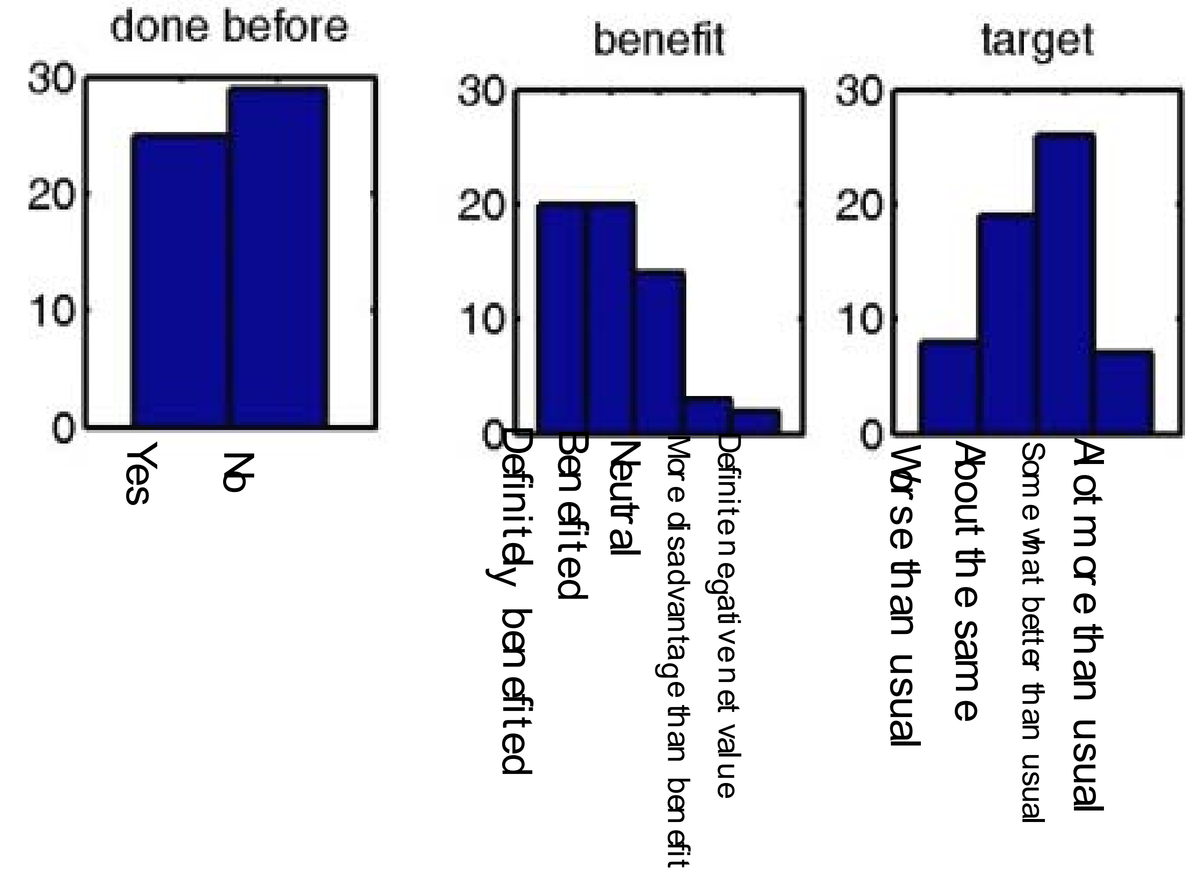
## Introduction & Method

An introduction to electronic voting systems (EVS) and the diagnostic tree method are presented in Appendix A, a copy of the original plan for this mini-evaluation exercise. This report briefly summarises the attendance, electronic feedback, and my reflections on the experience. Included in further appendices are the diagnostic tree (Appendix B), and results of the session as given to the students (Appendix C). Note that while anonymous, each handset had a unique ID number, allowing the overall score of each student to be calculated and correlated against previous experience and their feedback on the session.

## Session Attendance

The EVS session took place on Friday December 1st, 2006 in Room 408 of the Rankine Building. The EVS system was supplied by Steve Draper (also present at the session), an academic in the Psychology Dept and operated by Chris Mitchell. Written feedback was collected by evaluation assistants Mel McKendrick and Phillipa Markham. Unfortunately, the session was not advertised in advance, and only 65 students took part (from 85 who took the class test). The written feedback is presently being collated by the evaluation assistants and was unavailable at the time of writing.

**Feedback**
This section presents the students' electronic feedback on the session, with the results shown in histogram format in Fig. 1. Figure 1(a) shows that just under half the class had used EVS before. Figure 1(b) shows that 40/65 though that the session was 'benefited' or 'definitely benefited' them. Figure 1(c) shows that 33/65 thought that the session was better than usual at targeting problem areas. These results were considered to be very positive by the evaluation team.




(a) (b) (c)

***Fig. 1 Electronic Feedback from the students***

**Does previous EVS experience matter?**
A natural question might be, 'how hard is it to learn EVS and does it disadvantage a student who has no previous experience?' In order to address this, the 'EVS experience' data in Fig. 1(a) was graphically correlated against overall score as shown in Fig. 2. There is no clear trend connecting previous experience of EVS with a high score, therefore EVS could be used with confidence in a new class or in a one off session without prejudicing the results.

**Does EVS benefit all abilities?**
In order to reveal any correlation between a student's ability (as tested by EVS) and the perceived benefit to them of the EVS system, the feedback results were graphically correlated

against overall score as shown in Figs. 3(a) and (b). The sample size is small for the number of ‘bins’ that the data has been assigned, so it is not possible to draw any definite trends from the data. Therefore, it seems fair to say that all abilities are equally likely to benefit from the use of EVS.

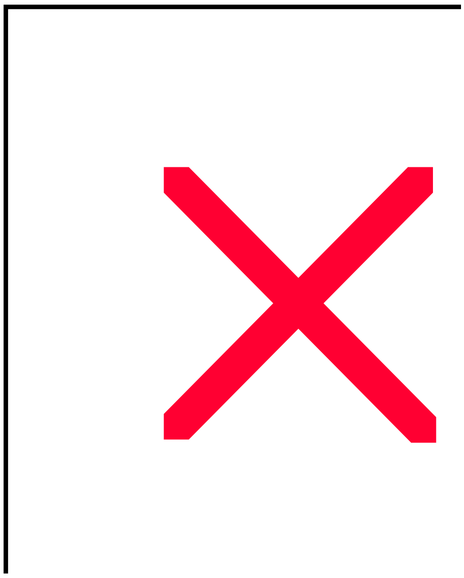
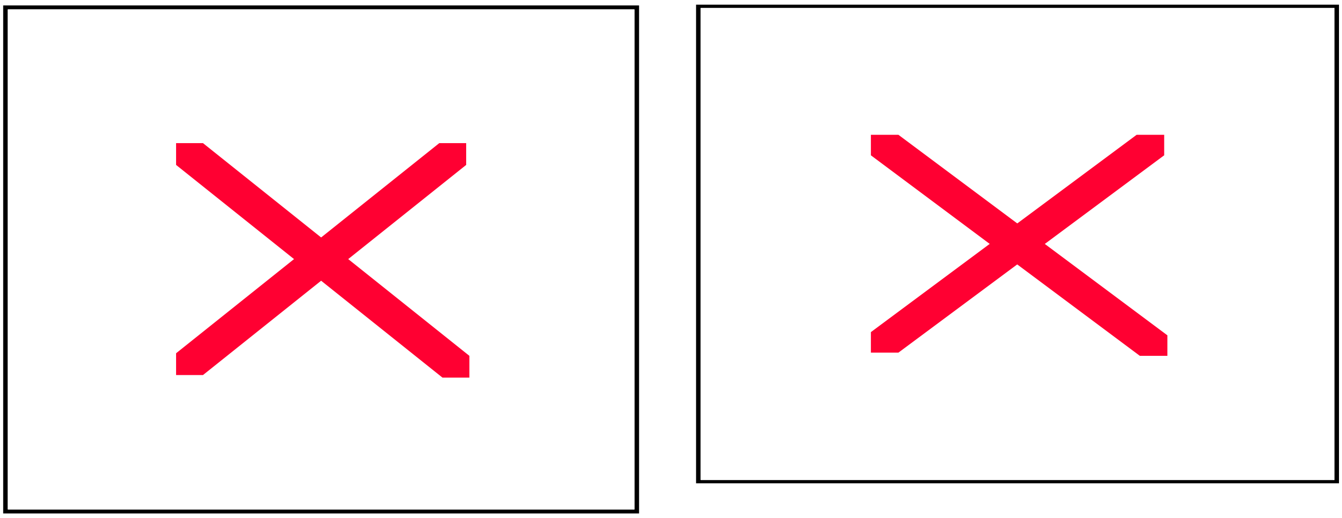


***Fig. 2. Histogram comparing performance against previous experience of EVS***



(a) (b)

***Fig. 3. Histograms comparing performance against student feedback on (a)benefit, (b) targeting***

## Discussion

I initially expected that there would be a correlation between ability and perceived benefit, however I am pleased to see that no such correlation is clear. To my mind, this means you can use EVS in confidence that you won’t unduly alienate either end of the ability spectrum.

Personal taste is perhaps the key arbiter, but the overall feedback results indicate that EVS was well received in this class and could be used in confidence in the future.

**Personal reflections on the exercise**

As usual with these sorts of things, more time is invested than you first estimate. Developing the diagnostic tree required only a couple of re-drafts, but writing the questions themselves took over four hours, with most of it being done in one sitting. Entering the questions into the Powerpoint slides took a similar amount of time. I used ‘hyperlinks’ within the Powerpoint document to help me navigate the tree. Each slide had only one question, with a reference number, and up to two hyperlinks to direct (labeled ‘Right’, ‘Wrong’ or ‘Right & Wrong’) to take me to the next question, and an index of hyperlinks at the back in case things went wrong. By this stage, I was so familiar with the tree that the hyperlinks became a luxury rather than a necessity, but I would not have wanted to be thinking through what question comes next whilst in front of the class! I also had transparencies of the questions in case there was a projector failure.

The session itself took place immediately following another lecture, compressing the time available to set up two laptops, two projectors and the infra red receivers for the EVS system. I had a spare projector that came in handy when the room’s installed projector wouldn’t function, saving having to fiddle acetates to move from question to question – something to avoid if at all possible! On the whole it was a very enjoyable exercise and I would definitely want to use EVS again where appropriate.