

# Online assessment using a graphical interface for decision problems

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## BACKGROUND

Many of the students from a combined post graduate / final year undergraduate elective course showed difficulty in answering a multistage decision problem in 2011 in the final exam. Whilst they were generally capable of applying the mathematics correctly after they had created a model, they stumbled with actually creating a model.

This was surprising as they had performed satisfactorily in the formative assessment related to this type of problem during the semester. However, the formative assessment had been administered in the form of an online computer aided assessment (CAA) system and students had only been assessed on their final mathematical answer and not on their ability to create the model required to determine this answer. Therefore new formative assessment was developed that required students to create a model inside the CAA system.

## PURPOSE

This paper investigates how to make formative assessment that will enable students to learn how to make decision trees.

## METHOD

New formative assessment questions were created with Adobe Flash that required the student to use the Flash animation to create/input their decision tree model. This formative assessment was used during the same course in 2012. At the final exam at the end of the course a similar question to that posed in 2011 was used and the student results compared. The paper discusses possible confounding factors.

## RESULTS

The number of students who answered the question in final exam in 2012 totally correctly was 65% compared with only 25% in 2011. Furthermore of the students who did not make any logic errors in the question, but then used incorrect symbols, dropped from 32% to 8%.

## CONCLUSIONS

The graphical formative assessment has made a remarkable improvement in student learning compared to the non-graphical formative assessment used previously. The style of assessment could also be adapted to other domains where a graphical model is created as the first part of solving an engineering problem.

## KEYWORDS

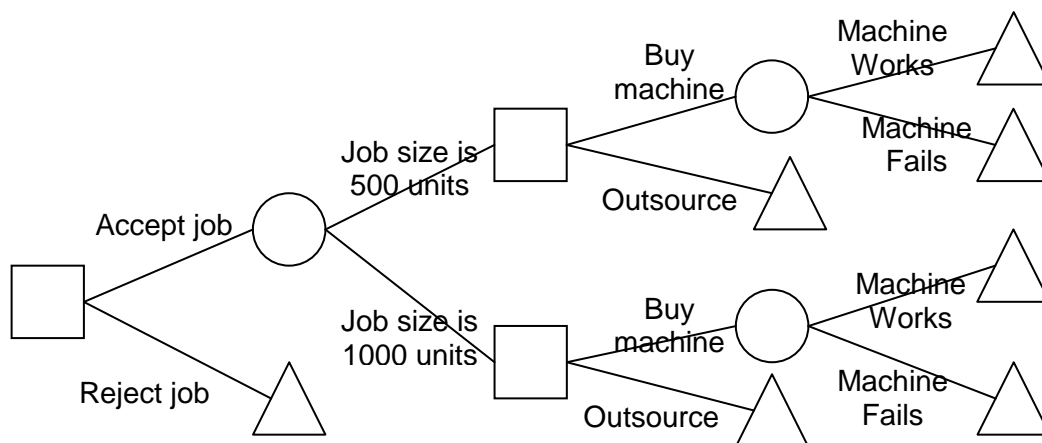
Online assessment, Computer aided assessment (CAA), Decision trees, Student learning

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## Introduction

One of the required topics for a combined final year undergraduate elective course / post graduate Risk Management course is to understand the use of decision trees. A decision tree is a graphical model of a decision problem where the range of outcomes for each decision option is known, but the actual outcome is unknown beyond a probability distribution. Once a decision tree has been drawn then the best decision can be determined from the tree using mathematical methods.

One of the questions in the 2011 exam for this subject required the students to draw a two stage decision tree and determine the appropriate course of action. A two stage decision tree models a situation where a decision is made, the outcome of the decision is found out, and, depending upon the outcome, another decision is made with more potential outcomes. After the student has modelled the problem as a decision tree then the best decisions for all of the possible second stage decisions are determined based on their outcomes. This information then indicates the expected outcomes from the first stage, which enables the best decision to be selected for the first stage. In other words the problem is modelled moving forward in time, and the model is solved working backwards through time. Coles and Rowley (1995) give more details of decision tree construction and use.



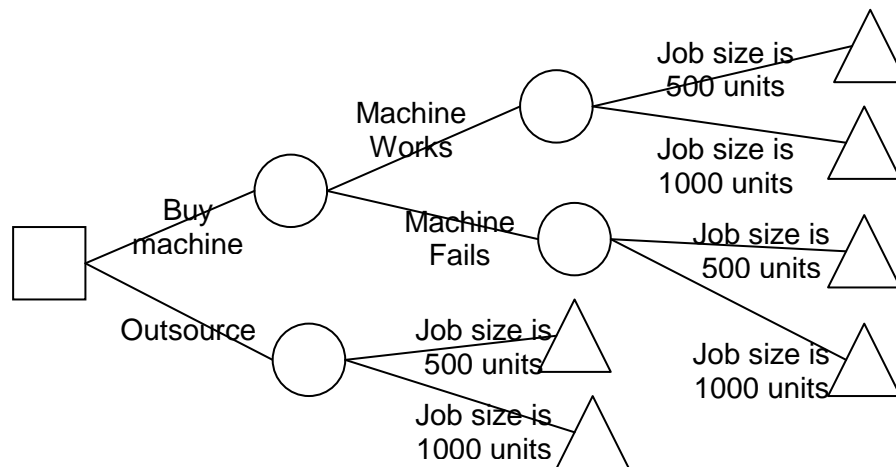
**Figure 1: Correct answer for 2011 exam**

The details of the decision in the exam question were that a company has to select whether or not to accept a job, without knowing exactly how big the job will be within a factor of 2. Later, when the company does know how big the job will be, it has to decide whether outsource part of the work or to purchase a machine that would do the job much cheaper than outsourcing, but has a risk of not being able to do the job, resulting the company outsourcing the work anyway. The decision tree that represents the correct answer to this question is shown in Figure 1.

In the decision tree shown in Figure 1 square nodes represent decisions made by the company, circle nodes represent events involving risk, and triangle nodes represent known outcomes.

In marking the exam it was found that only 25% of the students had drawn the decision tree correctly. 63% of the students had the wrong logic, while 12% had the correct logic, but did not use the standard symbols correctly.

Two particular errors stood out as quite common. One of these errors was to leave out the initial decision of whether or not to accept the job and start the tree with the random event of how big the job was. This was the most common type of error made by the undergraduate students in the class. The other common type of error observed was to buy the machine before knowing how large the job was. The details of the resulting decision tree varied from student to student, but Figure 2 gives an indicative result. This was the most common error made by the postgraduates, despite the question explicitly stating that the company “can put off the decision of whether or not to buy the [machine] until after it knows exactly how many [units] that it needs to make”.



**Figure 2: Example of a common error in 2011 exam**

Interestingly, the students were much better at using their tree to calculate the decision correctly. Many of the students were able to perform the calculations correctly based on their (perhaps wrong) decision tree. Thus whilst the students could correctly use a decision tree, they had difficulty creating the correct one.

It was hypothesised that the reason that the students performed poorly when creating a model, but performed well when using the model to do the calculations, was related to the formative assessment used during the course for this type of problem.

This course relied highly on the use of Computer Aided Assessment (CAA) for formative assessment. Davis (2011) lists advantages of using CAA instead of traditional paper based methods. However, one disadvantage is that it is difficult to create a CAA question that evaluates a diagram created by a student. The assessment related to this topic took the form of part of an online assignment where students were asked four questions requiring them to form their own decision trees and solve them. Maple TA was used for this assessment, as it enables rich mathematical questions. Two of these questions involved two stage decision trees (one of which also required Bayesian reasoning – a more advanced topic than was required in the exam paper discussed earlier). The students were given two weeks to do the assignment and, because it was online, could do and submit the assignment anywhere and anytime before the submission deadline. Using the online system allowed different numbers to be assigned to each student. However, the general outline of the problem, and the shapes of the decision trees that they needed to generate in order to solve the problems, was the same for each student.

However, the online assessment tasks only required the students to enter the numbers related to each of the main decisions and select the best decision. The type of questions used in this assignment was filling in the number questions that were able to ensure that the students had correctly calculated the value of each branch. However, the assignments had

not verified that the students had drawn the correct decision tree, or whether they had actually drawn a decision tree at all, as there was no way for the students to enter a decision tree into the CAA system.

It was therefore decided to create a formative assessment exercise that did require the students to enter their decision tree into the CAA system.

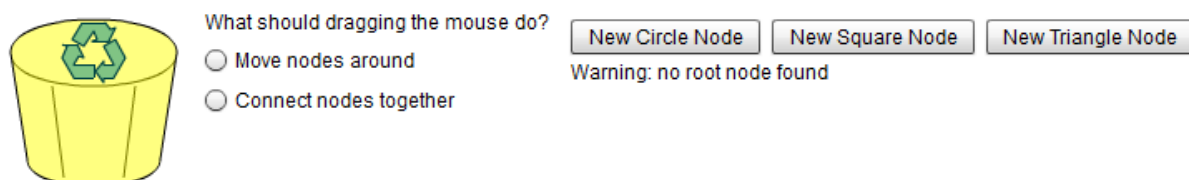
There is minimal discussion in the literature of using CAA systems to assess graphic models. Gipps (2005) claims the most common format of CAA used is multiple choice questions and other forms of selection from a list. Kendle and Nothcote (2000) equate quantitative assessment in online assessment with closed, as opposed to open ended, questions and include such things as multiple choice. Much of the previous work undertaken in the field of diagrammatic questions typically involves questions where the student must label a diagram or move a cursor to a particular location in a diagram. Scalise and Gifford (2006) introduce a taxonomy covering 28 different CAA item types. The closest example to the work in this paper would be their concept map where ideas are connected by links. However an implementation of a concept map described in Gouli et al (2004) appears to be just another “label the diagram” exercise as the ideas cannot be moved around the screen nor the links changed.

However, some work has been done using graphical assessment tools. Dietze et al (2005) created a system where surveying students are required to perform such activities as determination of a traverse on a map. Aukstakalnis et al (2008) describes an online graphical simulation system with a built in assessment module. An example examining nuclear fission is presented.

Two of the question types that can be authored in the Maple TA system are Java applets and Adobe Flash animations. Whilst the Java applet question type seemed to be more flexible, it suffers from the drawback that the CAA server needs to be restarted whenever a question is added or updated. It can be expected that the applet will need to be modified many times as it is developed and debugged, and that this would interfere with other users of the system. Thus it was decided that a flash animation would be developed that would have a user interface that allowed students to create a decision tree within the flash animation and also annotate the tree with their calculations.

## User Interface

The next problem that needed to be solved was to create a user interface for the flash animation so that the student could enter their solution. Figure 3 shows the user interface when the student first opens the assignment. Figure 4 shows the user interface as it might appear after the student has partially answered the question. The details of the decision problem are presented by the CAA system as a textual description above the Flash animation.



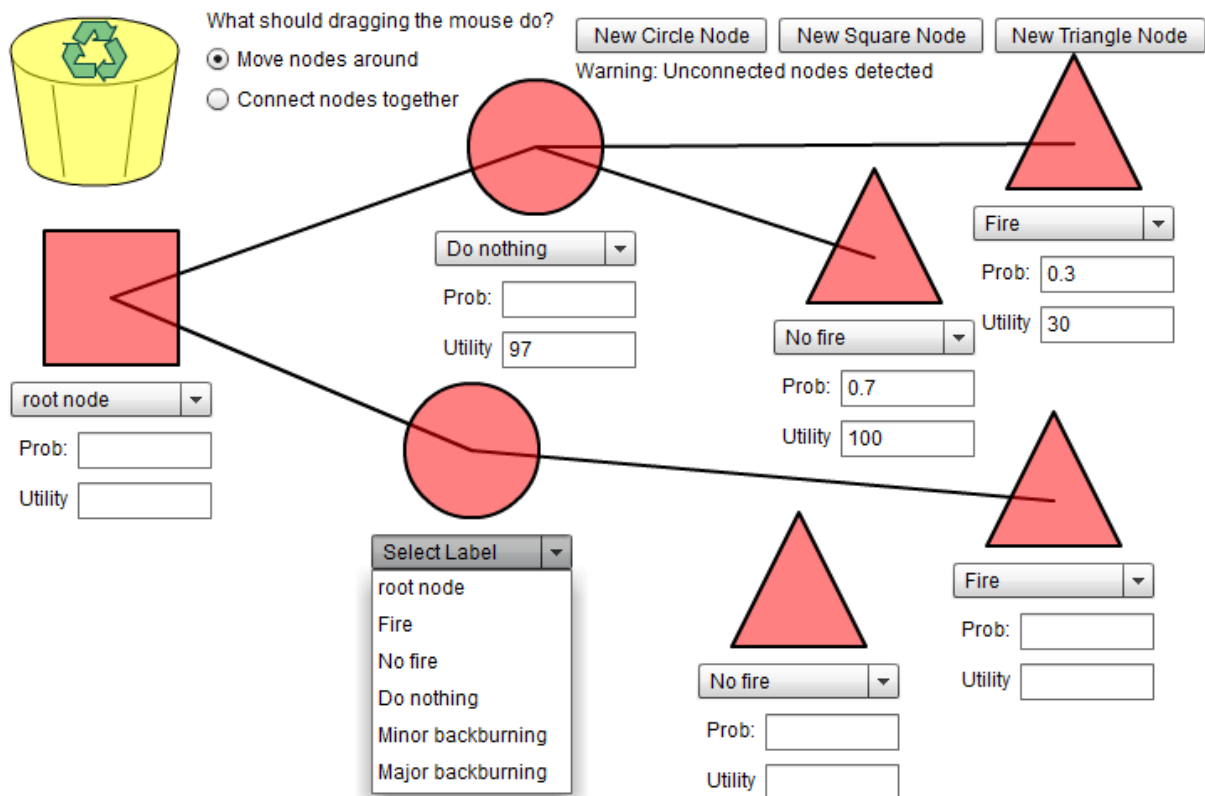
**Figure 3: User interface for the Flash animation before question is answered**

The student begins by clicking one of the “New ... Node” buttons. This places a node in the drawing area. Each node consists of a square, circle or triangle with an associated drop

down box for the description of the node and two text boxes to contain the numbers that the student will use in calculating the best decision.

Initially each node begins in the same location. When the student then clicks the “Move nodes around” radio button they are able to click and drag the shape with the mouse to move the node to the desired location. The student can then add more nodes.

In order to create the actual tree the student first clicks the “Connect nodes together” radio button. In this state when the student drags the mouse from one node to another the two nodes will be joined together instead of having the node moved. An “elastic band” effect is created while the mouse is being dragged from the start node to the current position of the mouse. When the student releases the mouse the elastic band becomes a link to the new node if the mouse is currently hovering over another node, otherwise it disappears.



**Figure 4: User interface for the Flash animation with the question partially answered**

Nodes can be deleted by dragging them to the rubbish bin icon at the top left. The icon changes colour when the node is in a position where it will be deleted when the mouse is released. Deleting a link between two nodes is effected by deleting one of its end nodes.

Warnings are placed immediately below the new node buttons for situations where the answer is in a state where the marking algorithm of the question is unable to properly grade the answer. These warnings were added because some of the relevant situations may occur even when the student has almost the entire answer correct, but the marking algorithm trips on a minor detail.

The user interface was arranged so that items with greater height were placed on the left as the left side of a decision tree typically takes up less space than the right side.

## Marking and Feedback

The first step of the marking algorithm is to find the root node of the tree. If there is more or less than exactly one root node the marking algorithm will not be able to proceed. Therefore warnings are issued to the student while they are answering the question if either of these two conditions occurs. The second step is to trace along each branch starting from the root node and note the parent nodes and child nodes for each node. If a loop is found, or if any nodes that are not connected to the root node are found then a warning is issued to the student while they are still answering the question.

For each node that should be in the correct answer marks are issued:

- If the node is present (ie if a node in the answer has the correct children, parent and grandparent to be this node)
- If the node has the correct symbol (square, circle or triangle)
- If the mathematical answers are correct. (Based on the other numbers that the student has supplied. Thus if a student makes a mathematical error for a particular node then they will lose marks for that node, but not necessarily for any nodes where the calculation depends on that answer)

The feedback provided to the students after the assignment is finished is shown in Figure 5. On the left is shown the students answer. On the right is shown the correct response. The user interface controls are replaced with a single “Show Marking” button. Clicking on this button displays a table listing each node in the correct answer and what marks the student received for each of the items above for each node. (Figure 5 shows the students answer covered by this table. Figure 6 shows a close up of part of the table.)

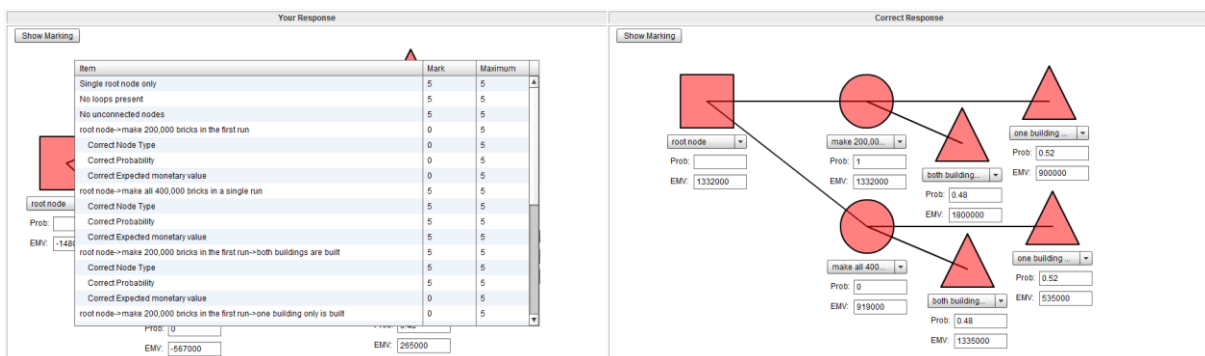


Figure 5: Feedback returned to the student after the assignment is graded

Item	Mark	Maximum
Single root node only	5	5
No loops present	5	5
No unconnected nodes	5	5
root node->make 230,000 bricks in the first run	5	5
Correct Node Type	5	5
Correct Probability	5	5
Correct Expected monetary value	5	5

Figure 6: Close up of marking details

## Issues in Authoring the Questions

Problems were found with integrating the flash animation into the CAA system. These problems related to getting information into and out of the Flash animation. According to the help manual of the CAA system information is intended to be passed in and out of the Flash animation via the use of “Flash variables”. Apparently at the time when the CAA system first added integration with Flash these variables could be accessed inside the Flash animation via global variables. The CAA system would pass information into the animation by initially setting the variables when the animation started, and would receive information by reading these variables when the animation was unloaded (when the browser moved to a new page).

The first problem was that the new compiler being used to make the animation (Flash Builder 4) did not link global variables to Flash variables. However, the variables could still be accessed via `FlexGlobals.topLevelApplication.parameters`. This was fortunate as it was the only way that the animation could determine whether it was in “student answering the question” mode, or if it was in feedback mode, and if so whether it was meant to show the student response or the correct response.

The second problem was that the CAA system was passing the names of the random variables in the Flash variables, rather than passing the values. Thus if the random value that a student received for \$x was 25 then the Flash animation would be told that the number was “\$x” and not the expected “25”.

To deal with this problem html elements with id attributes were placed around the random values in the description of the decision problem presented to the student. Javascript functions were added to the html that could read the random number from the specified html element. The animation then called the Javascript function using Flash’s `ExternalInterface.call` function to obtain the value.

The third problem was that when `FlexGlobals.topLevelApplication.parameters` was changed by the animation made with Flash Builder 4 the Flash variables were not updated and no other way of updating these variables could be found. This prevented the animation from telling the CAA system what the student’s answer was, either for recording or for grading.

To solve this problem the Flash question was placed inside a multi-part question together with another question that had a text box as the answer. This text box was hidden from the students using an inline style of `display:hidden`. The student’s answer was encoded as a string of numbers separated by letters and stored in the extra text answer box. The numbers in the string represented the type of node, the label used, the numerical answers for that node, the x and y position of the node, and a list of nodes that it was linked to. This string was then automatically saved by the CAA system as the answer to the other question, meaning that it was available next time the student logged in and opened the question.

## Validation

In order to test the effectiveness of the new graphical formative assessment questions in helping students to learn how to create decision trees it was used in the Risk Management course discussed above. A similar exam question to the one set in 2011 was set in 2012. The solution to the 2012 question used the same decision tree as the one in 2011. Cosmetic changes were made such as a different type of situation requiring a choice between purchasing a machine and outsourcing, setting the cost of the outsourcing to be a random event instead of whether the machine works, and changing all of the numbers required for the calculations.

In order to ensure that it was the graphical aspect of the formative assessment that led to any change in exam results, three of the previous four questions related to decision trees

were directly translated into the new Flash animation question. The words describing the decision problem in these three cases were kept exactly as they were the year before.

Only the simplest one of the formative assessment questions was changed. This was a simple single stage question. In the original assignment the potential outcomes of the decisions were simply given. In the new version the students had to calculate the profits and losses that comprised the various outcomes. Since this was only a single stage decision problem, and the exam question was a two stage problem, it is unlikely that this change affected the results when the other more complex questions much more closely related to the exam question did not change.

Another potentially confounding factor is that because the two exams were sat by different cohorts that any difference in results would be because of differences in the innate abilities of the students. However, the average result for the students for the whole course was several marks lower in 2012 than in 2011. Therefore this factor would weigh against the hypothesis, rather than for it.

A further possibility is that some members in the 2012 cohort had access to the 2011 paper. However, both cohorts of students had access to 10 previous year's exam papers (2000-2009) in the eLearning site of the course. Eight of these exam papers also had detailed worked solutions available in the eLearning system. It is therefore expected that it is unlikely that the students would have sought out an 11th exam paper to study, particularly as no solutions were available for that particular exam. However, the abovementioned changes were made to the question in the second year to reduce any effect in the case that a student had seen the previous exam paper.

A final confounding factor to consider is that one cohort might have been exposed to teaching of this topic in a previous year, while the other had not. Whilst this is a possibility for the undergraduates, it is extremely unlikely for the postgraduates because they are mostly international students studying at this university for their first semester and they do not share a previous common history.

## Results

The decision trees drawn in the exam paper were categorised as either completely correct, correct except for symbols (squares, circles and triangles), or containing incorrect logic. Results are presented in Table 1.

**Table 1: Before and after comparison of exam results. Numbers refer to numbers of students**

		Completely correct	Correct except for symbols	Incorrect logic	Total
2011	Undergraduates	12 (23%)	8 (15%)	32 (61%)	52
	Postgraduates	24 (26%)	9 (9%)	59 (64%)	92
2012	Undergraduates	65 (68%)	6 (6%)	25 (26%)	96
	Postgraduates	48 (61%)	4 (5%)	27 (34%)	79

Clearly there has been a major improvement in student performance. In 2011 without the formative assessment of the ability to create a decision tree only 25% of the students answered the question completely correctly. In 2012 when formative assessment of the ability to create a decision tree was implemented 65% of the students answered the question completely correctly. Furthermore, in 2011, 32% of the students who did not make logic errors did not use the standard symbols. In 2012 this dropped to only 8%.



## Conclusions and Further Work

This paper has shown the remarkable improvement in learning outcomes from the introduction of graphical formative assessment on student ability to model decision problems. Many of the ideas behind the setting up of this formative assessment would transfer to other domains where a graphical model is created as the first part of solving an engineering problem.

Future work is planned to investigate how the students think and learn to model decision tree problems by getting some students to perform a “think aloud” exercise of using the Flash animation to model the decision tree problem with an investigator present. Comparisons will be made between students who did and did not perform well on the question in the final exam. This will provide greater insight into how students model problems and will be used to further refine the formative assessment.

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