

## *Case Study*

# Numerical Calculations

Undergraduates in engineering, as in all scientific subjects, must be able to solve numerical problems. In the days of smaller classes, it was possible to devote time to seeing that individual students gained enough practice in this skill. Now, however, sufficient time is frequently not available. The skill is important not only in itself, but also in reinforcing material taught in lectures: to be able to use principles taught as theory greatly helps in understanding the practical consequences of that theory.

For many students, however, solving problems is often beset by not knowing what to do next – even not knowing where to start. This is where demonstrators in examples classes come into their own. The aim of this project was provide a template that allows lecturers to pose numerical problems to students in such a way that they appear one step at a time. Wrong answers result in a hint being given and students being offered a further attempt. Successive failures lead to progressively more helpful hints.

Of course, this type of interaction (with one or more fixed questions) has been widely available in e-learning programs for some time. However, students gain increased benefit from practice with more and more questions (rather than by repeating a limited set). In turn, this requires more time from lecturing staff which may often not be available. This has led to questions being written in which the initial parameters are chosen randomly. Though this is an excellent solution, it is normally only available to those with access to expert programming help. (Not only must random parameters be chosen, but all results coming from them calculated. Further, the parameters probably cannot be chosen completely randomly but must instead be restricted to a range compatible with the text of the question.) The template described here is a way for lecturers to write randomised questions within these restrictions.

Toolkits – the on-line version of Xerte – has already achieved much success by offering straightforward templates for adding text, graphics, animations and other media, and more complex facilities (such as Google maps). This template uses an aspect of Toolkits that had previously not been investigated *viz* that Actionscript (Flash's scripting language) is available in Toolkits. The template uses it by letting variables be set up with values within ranges defined by the user and then allowing them to be used to calculate further variables. Text can be written incorporating these variables. Here is an example:

- Declare radius to be a number between 10 and 100 in units of 5;
- Declare A to be a variable that is the product of  $\pi$  and radius<sup>2</sup>;
- Write this text on the screen: 'What is the area of a circle of radius' + radius + ' m (to three significant figures)?'.

The quotation marks and addition signs in the text mean that the value of radius is substituted into the text. When the template is run, it might randomly choose radius to be 35. In this case A will be 3850.

The student must now enter the correct answer (which the template already knows to be the value of  $A$  – 3850 in our example).

Figure 1 The student has entered the correct answer.

According to whether the student enters 3850 or some other number, the template can be instructed to respond either “Correct” or “Wrong”. However, the response can be much more sophisticated. First, we can quote the correct answer in the response to a wrong answer:

- ‘Wrong – the answer is ’ +  $A$  + ‘ m<sup>2</sup>.’.

Next, we can define how many attempts the students can have. Only after the last attempt does the above message appear. After earlier attempts, we can have a simpler message:

- ‘Wrong – have another try’.

We can make the responses more intelligent again by having a hint. We can therefore have this set of responses:

- After the first wrong answer: 'Wrong – try again and remember that the formula for area is  $\pi r^2$  where r is the radius.';
- After the second wrong answer: 'Wrong – substitute r = ' + radius + ' m into  $\pi r^2$  and try again.';
- After the third wrong answer: 'Wrong – the answer is ' + A + ' m<sup>2</sup>'.

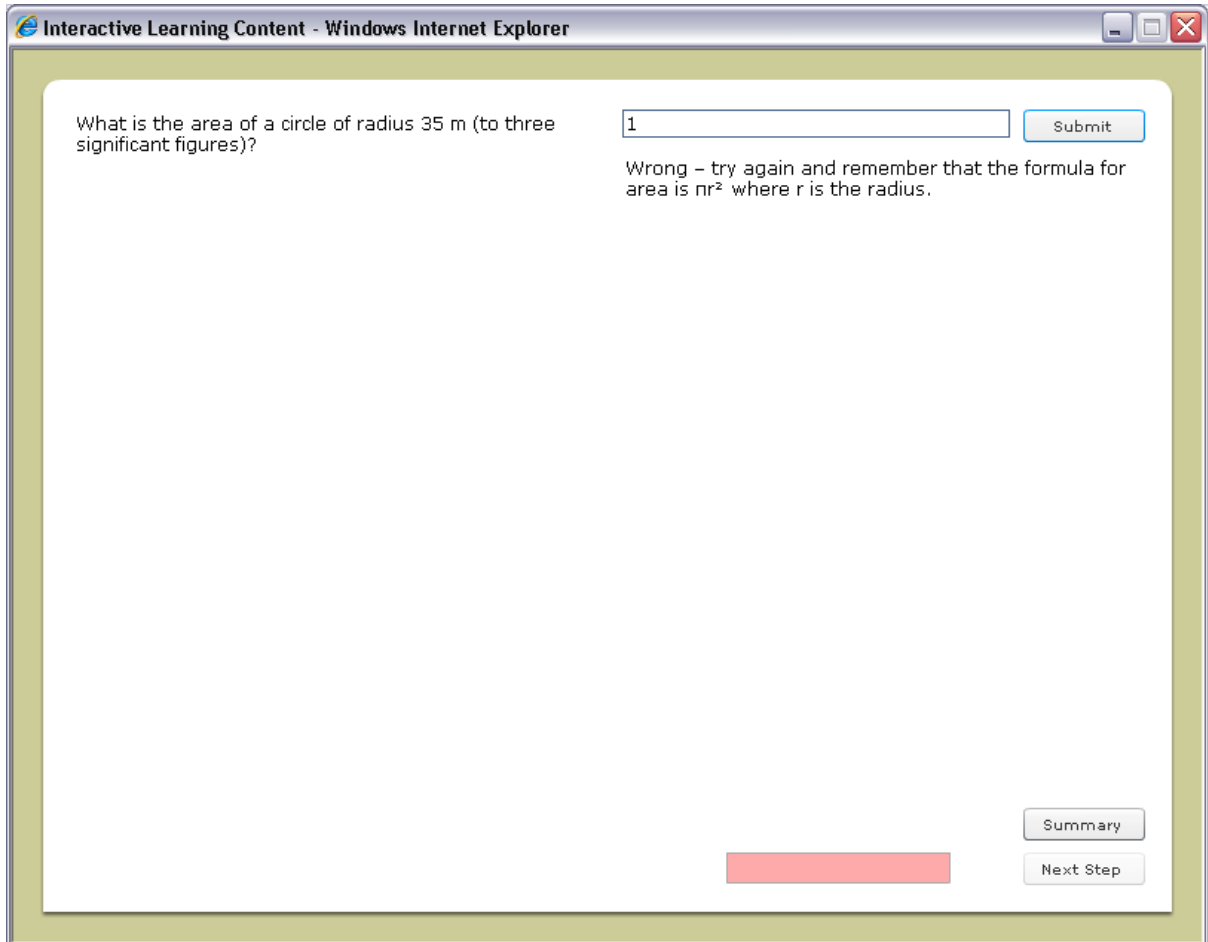


Figure 2 The correct formula is being shown to the student.

Interactive Learning Content - Windows Internet Explorer

What is the area of a circle of radius 35 m (to three significant figures)?

Submit

Wrong - substitute r = 35 m into nr<sup>2</sup>.

Summary

Next Step

Figure 3 The student is explicitly instructed to substitute 35 m into the formula.

Besides responding to answers that are not right in a general sense, we can also respond to answers that are not right in a *specific* way. Continuing with our example, we might look for someone omitting the prefactor of  $\pi$  *i.e.* who thinks the area is  $r^2$  (1225 m<sup>2</sup> in the case of r being 35 m).

- 'Wrong – you've omitted the prefactor of  $\pi$ '.

Interactive Learning Content - Windows Internet Explorer

What is the area of a circle of radius 35 m (to three significant figures)?

You've forgotten the factor of  $\pi$ . Try again.

Figure 4 The template has detected that the student has omitted  $\pi$ .

The example we have chosen has been a simple one – it consists of one step only. However, most numerical calculations have several steps and typically the answer from one stage is fed into a later one. The template has been designed for the multi-step problem. Furthermore, a diagram can be shown with the text to explain both the question and the hints.

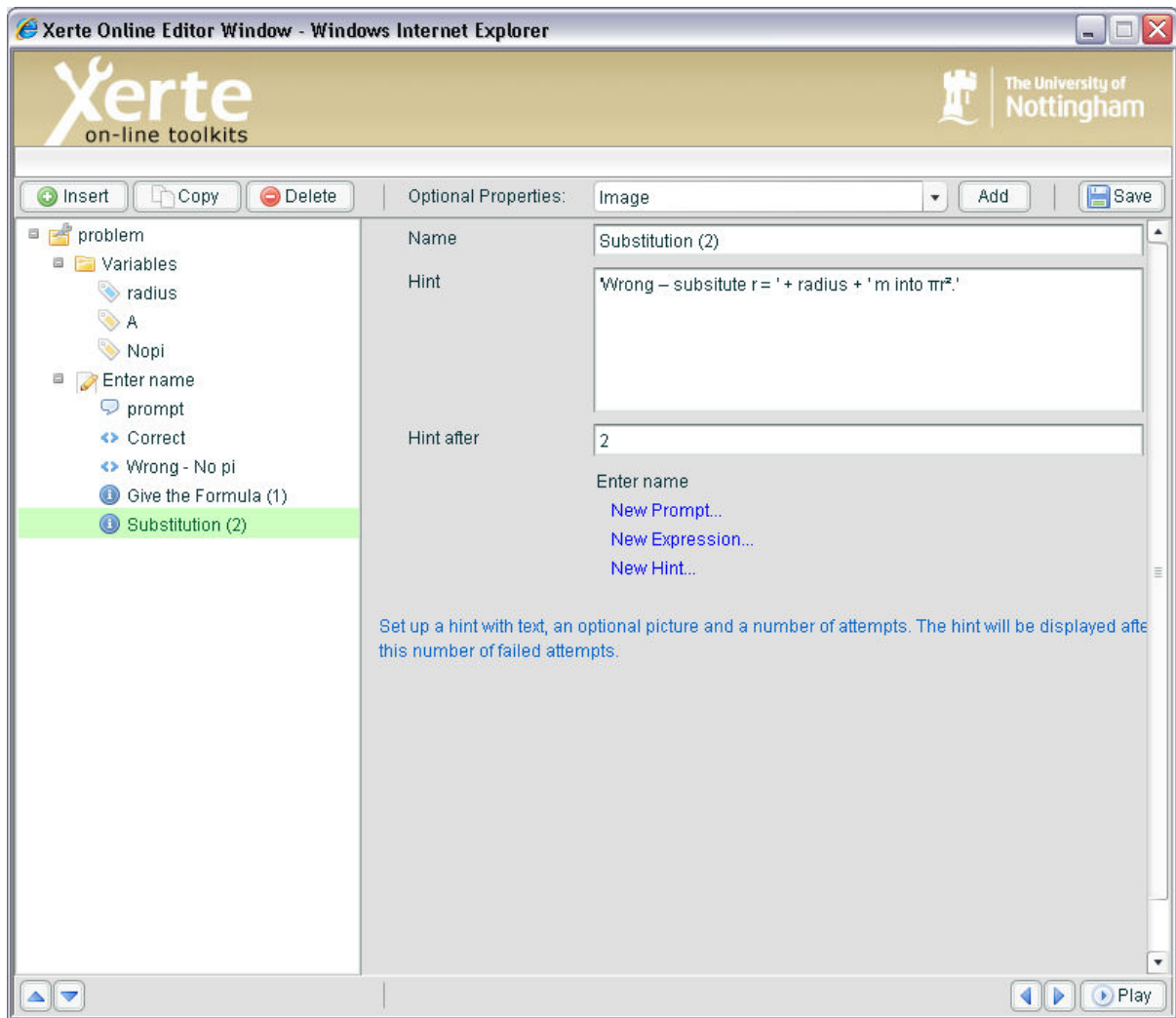


Figure 5 The complete template for the example described here for the area of a circle.

This template has already been used for engineering undergraduates and the questionnaires returned by them indicate it is already proving very successful. The lecturers using it have found there is a skill in breaking down questions into stages and composing hints which, they report, has had a beneficial effect on their teaching too.

This template offers the benefits of formative assessment with students receiving context-specific comments on their work but without requiring intervention (and hence time) from teaching staff. An example from Engineering can be seen here:

[http://www.nottingham.ac.uk/toolkits/play\\_503](http://www.nottingham.ac.uk/toolkits/play_503)