Using quizzes to deliver a course online

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• New 20-credit course
• SQA Advanced Higher / Further Maths A-Level
• Ready for September
• Online
• Jointly with Richard Gratwick
# Fundamentals of Algebra and Calculus

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A typical week

Week 3: Polynomials and rational functions

- Getting started
- 1. Polynomials
- 2. Graphs of polynomials
- 3. The Binomial Theorem
- 4. Rational functions

Week 3 Practice Quiz
Week 3 Final Test

Restricted Not available unless: The activity Week 3 Practice Quiz is complete and passed
Coherently Organised Digital Exercises and Expositions

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ARTICLE HISTORY
Compiled May 20, 2020

ABSTRACT
We describe an organising principle for online learning materials that term coherently organised digital exercises and expositions. Larger in scale than instructor lessons, but smaller than a programme of study, this innovation in instructional practice is increasingly guiding our thinking in the development of university mathematics courses. Essentially we have taken the book and put it into automatically-graded online quizzes. In doing this we have grasped the potential provided by new technology to implement evidence-based practice such as spaced interval practice. The paper discusses details of this innovation, and how we have implemented it. On the basis of these experiences, we believe this innovation has the potential to change the model of education for university mathematics courses in substantial and novel ways.

KEYWORDS
Learning design; online assessment; university mathematics education; Online teaching and learning.

A typical section

“Textbook in the quiz”

Exposition

Video worked examples

Problems
A typical question: STACK

Fully factorise the polynomial \( p(x) = 3 x^4 + 16 x^3 + 3 x^2 - 46 x + 24 \), given that \( x = -3 \) is a root.

\[ p(x) = (x^2 + 2x - 3)(x + 4)(3x - 2) \]

Your last answer was interpreted as follows:

\[ (x^2 + 2x - 3)(x + 4)(3x - 2) \]

The variables found in your answer were: \([x]\)

Your answer is partially correct.
Your answer is not factored. You could still do some more work on the term \( x^2 + 2x - 3 \).
The factor \( 3x - 2 \) is correct.
The factor \( x + 4 \) is correct.

Marks for this submission: 0.50/1.00.
Three strategies
Faded worked examples

Worked Example

Worked Example with last step as a task

Worked example with more steps to complete

Problem solving

“The fading procedure fosters learning”

From Example Study to Problem Solving: Smooth Transitions Help Learning

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ABSTRACT. Research has shown that it is effective to combine example study and problem solving in the initial acquisition of cognitive skills. Present methods for combining these learning modes are static, however, and do not support a transition from example study in early stages of skill acquisition to later problem solving. Against this background, the authors proposed a successive integration of problem-solving elements into example study until the learners solved problems on their own (i.e., complete example — increasingly more incomplete examples — problem to-be-solved). The authors tested the effectiveness of such a fading procedure against the traditional method of solving examples-problems pairs. In a field experiment and in 3
"Give an example"

For each case below, type in a quadratic, e.g. $2x^2+3x+1$, whose graph has exactly the given number of intersections with $y = x^2$. If it is not possible, then enter none.

No intersection: $y =$

1 intersection: $y =$

2 intersections: $y =$

3 intersections: $y =$

Check
The critical role of retrieval practice in long-term retention

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Learning is usually thought to occur during episodes of studying, whereas retrieval of information on testing simply serves to assess what was learned. We review research that contradicts this traditional view by demonstrating that retrieval practice is actually a powerful mnemonic enhancer, often producing large gains in long-term retention relative to repeated studying. Retrieval practice is often effective even without feedback (i.e., giving the correct answer), but feedback enhances the benefits of testing. In addition, retrieval practice promises to consolidate knowledge that can be flexibly retrieved and transferred to different contexts. The promise of retrieval practice to consolidating memories has important implications for both the study of memory and its application to educational practice.

Introduction

A curious peculiarity of our memory is that things are impressed better by active than by passive repetition. I mean that in learning (by heart, for example), when we almost know the piece, it pays better to wait and recall it by an effort within, than to look at the book again. If we recover the words the former way, we shall probably know them the next time; if in the latter way, we shall likely need the book once more.

William James [1]

Psychologists have often studied learning by alternating series of study and test trials. In other words, material is presented in the study (S) and a test (T) is subsequently given to determine what was learned. After this procedure is repeated over numerous ST trials, performance (e.g., the number of items recalled) is plotted against trials to depict the rate of learning; the outcome is referenced to a learning curve and it is negatively accelerated and is fit by a power function. Thus, most learning occurs on early ST trials, and the amount of learning decreases with additional trials. The critical assumption is that learning occurs during the study phase of the STSTST... sequences, and the test phase is simply there to measure what has been learned during previous occasions of study. The test is usually considered a neutral event. For example, researchers in the 1900s debated whether learning ignored the possibility that learning occurred during the retrieval tests [2-5]. Exactly the same assumption is built into our educational systems. Students are thought to learn via lectures, reading, highlighting, study groups, and so on; tests are given in the classroom to measure what has been learned from studying. Again, tests are considered assessments, gauging the knowledge that has been acquired without affecting it in any way.

In this article, we review evidence that turns this conventional wisdom on its head: retrieval practice (as versus during testing) often produces greater learning and long-term retention than studying. We discuss research that elucidates the conditions under which retrieval practice is most effective, as well as evidence demonstrating that the mnemonic benefits of retrieval practice are transferable to different contexts. We also describe current theories on the mechanisms underlying the beneficial effects of testing. Finally, we discuss educational implications of this research, arguing that more frequent retrieval practice in the classroom would increase long-term retention and transfer.

The testing effect and repeated retrieval

The finding that retrieval of information from memory produces better retention than re-reading the same information for an equivalent amount of time has been termed the testing effect [6]. Although the phenomenon was first reported over 300 years ago [7], research on the testing effect has been sporadic at best until recently (but see Box 1 for some classic studies). In the last 10 years, much research has shown powerful mnemonic benefits of retrieval practice [8-10]. The data in Figure 1 come from a study in which two groups of students retrieved information several times.
At the start of integration (Week 4) – recall practice of differentiation (Week 2)
Complete the following table of standard derivatives. Try to do this without checking your notes -- which of the most important standard derivatives can you remember?

<table>
<thead>
<tr>
<th>Function</th>
<th>Derivative</th>
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<tbody>
<tr>
<td>$x^n$</td>
<td>$n^\times x^{n-1}$</td>
</tr>
<tr>
<td>$\sin(x)$</td>
<td>$\cos(x)$</td>
</tr>
<tr>
<td>$\cos(x)$</td>
<td>$-\sin(x)$</td>
</tr>
<tr>
<td>$k$</td>
<td>$0$</td>
</tr>
<tr>
<td>$e^{\times x}$</td>
<td>$e^{\times x}$</td>
</tr>
</tbody>
</table>

What about the derivatives of these functions?

$\{\ln(x), \sec(x), \tan(x)\}$
Further ideas

Multiple choice

Which of the following are antiderivatives of $x^5$?

- (a) $5x^4 + x$
- (b) $\frac{x^6}{6} + 5$
- (c) $\frac{x^6}{6} + C$
- (d) $\frac{x^6}{6}$
- (e) $5x^4$
- (f) $\frac{x^5}{6}$

Proof comprehension

Bickerton, R. and Sangwin, C. J. (2020)
Next steps
Read more about FAC

www.maths.ed.ac.uk/gkinnear/research

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<tr>
<th></th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Gain</th>
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<tbody>
<tr>
<td>FAC</td>
<td>62.1</td>
<td>77.4</td>
<td>15.3</td>
</tr>
<tr>
<td>Non-FAC</td>
<td>76.1</td>
<td>78.1</td>
<td>2.0</td>
</tr>
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“Developing effective resources for online teaching and assessment of mathematics”
with Igor’ Kontorovich and Chris Sangwin

1. STACK server
2. Training
3. Content
1. Indefinite integration
The technique known as integration by parts is used to integrate a product of two functions, such as in these two examples:

\[ \int e^{3x} \sin 4x \, dx \quad \text{and} \quad \int e^{3x} \cos 4x \, dx \]

Note that in the first example, the integrand is the product of the functions \(e^{3x}\) and \(\sin 4x\), and in the second example the integrand is the product of the functions \(e^{3x}\) and \(\cos 4x\). Note also that we can change the order of the terms in the product if we wish and write:

\[ \int (4x^2) e^{3x} \, dx \quad \text{and} \quad \int (3x) e^{3x} \, dx \]

When you must never do is integrate each term in the product separately and then multiply - the integral of a product is not the product of the separate integrals. However, it is often possible to find integrals involving products using the method of integration by parts - you can think of this as a product rule for integrals.

The integration by parts formula states:

\[
\int u \, dv = uv - \int v \, du
\]

where \(u\) and \(v\) are functions of \(x\).

**Example 15**
Find the integral of the product of \(x\) with \(\sin x\); that is, find \(\int x \sin x \, dx\).

**Solution**
Compare the required integral with the formula for integration by parts: we choose:

\[ f = x \quad \text{and} \quad g = \sin x \]

It follows that:

\[ \frac{df}{dx} = 1 \quad \text{and} \quad \int g \, dx = \int \sin x \, dx = -\cos x \]

(When integrating \(g\) there is no need to worry about a constant of integration. When you become confident with the method, you may like to think about why this is the case.)

Applying the formula we obtain:

\[ \int x \sin x \, dx = x(-\cos x) - \int (-\cos x) \, dx \]

\[ = -x \cos x + \int \cos x \, dx = -x \cos x + \sin x + c \]

Key Point 5
Integration by Parts for Indefinite Integrals

For indefinite integrals, given functions \(g(x)\) and \(h(x)\):

\[ \int f(x) \, g(x) \, dx = \int f(x) \, h(x) \, dx - \int f'(x) \, h(x) \, dx \]

Alternatively, given functions \(u\) and \(v\):

\[ \int u \, dv = uv - \int v \, du \]

Study the formula carefully and note the following observations. Firstly, to apply the formula we must be able to differentiate the function \(f\) to find \(f'\), and we must be able to integrate the function \(g\).

Secondly, the formula replace one integral, that on the left, with a different integral, that on the right. The intention is that the latter, while it may look more complicated in the formula above, is simpler to evaluate. Consider the following example:
STACK demo

tinyurl.com/stack-demo-site
Thank you!
References

Articles about FAC


Other references


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