

A comprehensive web-based learning environment for upper-secondary level mathematics students: promoting good-practice for teachers and encouraging students to become independent learners

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Abstract

“MEI online resources for mathematics” is a web-based learning environment designed to support the teaching and learning of mathematics at A level (pre-University). The environment contains thousands of resources including text-based pages, interactive resources and multiple-choice assessments. The environment is designed to support students learning in a conventional school/college setting, students learning with limited contact time through the Further Mathematics Network and students learning independently. It also features extensive resources for teachers. It has over 20,000 registered users.

This is a practice-oriented paper that will deal with two main themes.

The first is the use of the environment by teachers. The comprehensive nature of the resources allows teachers to use them for their own preparation and the teachers’ resources encourage good-practice. Interactive resources are integrated into the environment to encourage teachers to use them at appropriate points in their teaching. Consequently, the environment forms a key element of many teachers’ professional development.

The second is the effect of the environment on students’ learning of mathematics. The design encourages students to use the environment as part of a “blended-learning” solution, resulting in them becoming better independent learners.

This paper will also consider the transferability of the resources in the environment.

1 Introduction

“MEI online resources for mathematics” is a web-based learning environment with the following key features:

- The resources in the environment cover the content of A level Mathematics courses comprehensively and are structured to reflect the way the courses are delivered, even referencing the most widely-used textbooks.
- Interactive and active-learning resources are fully integrated into the structure of the environment at the level of specific teaching topics.
- There are additional resources specifically to support teachers.

The effects of these features are that:

1. The environment encourages good practice in teaching and learning and supports teachers in reinforcing their own knowledge of mathematics.
2. Many teachers who use the environment make greater use of ICT-based resources and active learning resources in their teaching.
3. The environment encourages students to develop their study-skills, resulting in them becoming better independent learners.

Access to the environment is given free to schools and colleges that register with the Further Mathematics Network and to students studying through the Further Mathematics Network. In addition, schools and colleges can choose to pay a subscription to gain individual access for their own students. In total, the environment has over 20,000 registered users.

2 Background

The environment has been designed to support students studying for A levels in Mathematics. A levels are optional, specialised qualifications taken by pre-university students in England. All students aged 14-16 are required to study for GCSE qualifications, one of which is a mandatory GCSE in Mathematics. They can then continue education post-16 with a variety of qualifications, with by far the most popular being A levels, which are studied for two years. The majority of students taking A levels use them as entry-level qualifications for university. A level Mathematics is studied by students wanting to study mathematics and mathematics-related courses at university. There is a second A level in Mathematics: A level Further Mathematics. This both broadens and strengthens students' knowledge of mathematics and is aimed at the more able A level Mathematics students. Currently approximately 15% of A level Mathematics students study this second A level. Further information about the content of the A levels in Mathematics can be found in '*The changes to AS/ A-level Further Mathematics for September 2004*' (Stripp, 2004).

"MEI online resources for mathematics" is a web-based learning environment designed to support the teaching and learning of A level Mathematics. The environment contains thousands of text-based pages, hundreds of interactive resources and hundreds of multiple-choice tests. The tests give immediate feedback and so act as formative assessments, allowing students to check their own progress. The text-based resources include study plans, to help students manage their studies independently; notes and examples; "Crucial points", to reinforce important concepts and help students avoid common errors; exercises of questions and comprehensive hand-written solutions to exemplify to students how they should present their own solutions. The interactive resources feature JavaScript interactive random question generators that allow students to practise techniques and receive feedback, thus also acting as formative assessment. Also included are many Flash-based and other resources.

A sample of the resources can be viewed at <http://www.resources.mei.org.uk/sample/>

3 Research methodology

A questionnaire to survey both teachers and students, to assess their opinions on the environment and attempt to discover its effects upon teaching and learning was created. It was a structured questionnaire that primarily contained multiple choice items on rating

scales, but in several questions there was an opportunity for open-ended responses to be added. This allowed for both qualitative and quantitative analysis to be undertaken.

The survey was carried out online between 11th February and 4th March 2008, with a link to the survey having been placed on the environment's log-in page, so all users who accessed the resources during that time period had an opportunity to respond. Users' names and login usernames were collected to verify that the responses were genuine. We believe that those who responded would on the whole likely be representative of the users of the environment, from both students and teachers, but this would be extremely difficult to verify categorically. In total there were 253 responses: 101 teachers and 152 students.

The results of the survey can be seen in appendix A (or alternatively found at <http://www.mei.org.uk/files/pdf/orsurvey.pdf>). Specific results from the analysis of the survey will be discussed in the subsequent sections.

4 The effects of using the environment on teachers and students

1. The environment encourages good practice in teaching and learning and supports teachers in reinforcing their own knowledge of mathematics.
2. Many teachers who use the environment make greater use of ICT-based resources and active learning resources in their teaching.
3. The environment encourages students to develop their study-skills resulting in them becoming better independent learners.

The following sub-sections will deal with these points separately.

4.1 Encouraging good practice in teaching and learning and supporting teachers in their knowledge of mathematics

It has been widely reported that many Mathematics teachers need support with pedagogical methods for teaching mathematics effectively and the mathematical content of the courses they are teaching, especially at A level. This was identified in the Smith report: "Overwhelmingly, concerns expressed ... about the current overall state of mathematics teaching in schools and colleges in England have focussed on subject matter knowledge and subject specific pedagogy" (Smith, 2004).

It is essential that teachers are confident in their own knowledge of the mathematics they are teaching. One of the major factors which made the most significant contributions to high achievement in 14–19 mathematics is: "Secure subject knowledge on the part of the teacher, underpinning an approach to mathematics in which all topics are seen as part of a coherent set of related ideas, with clear progression and links to previous and future learning." (HMI, 2004). The resources in the environment are comprehensive, covering all aspects of the A level Mathematics specifications, so teachers can refer to them to ensure they have a full understanding of the mathematics before attempting to teach it. Many teachers use the environment for their own preparation, in addition to directing their students to use it for support. Of the teachers who responded to the survey, 78% reported that they "always" or "often" used the resources in the environment before teaching a unit. In order to encourage the teachers to use the environment its resources are tailored to the units of A level Mathematics they are teaching; 96% of teachers

responded that this was a “very important” or “important” factor in affecting how often they used them.

Teachers’ deficiencies in subject knowledge can become a very significant issue in A level Further Mathematics. Although students are only required to study 6 units to achieve A level Mathematics, there are over 20 different units available. Many of these are studied by students working towards A level Further Mathematics and this overlaps to some extent with undergraduate study. Consequently, teachers are often required to teach material they may not have met before, or not met at this level. The Royal Society report into the UK science and mathematics teaching workforce identified that in, order to retain mathematics teachers in the profession, support should be available to ensure that subject knowledge is maintained, developed and applied (RS, 2007).

Teachers who have not taught a unit before, or who want to extend their knowledge beyond the material they are currently teaching, can use the environment to learn more mathematics themselves. This will clearly not apply to all teachers. In the survey the teachers were asked how often they used the environment to reinforce their own knowledge of mathematics; 24% responded that they used the environment for this “Always” or “Often” and 50% of teachers responded that they used the environment for this “Sometimes”. This confirms that the environment performs a valuable role in helping teachers to be adequately prepared for all units they are teaching. One individual teacher commented: “I’m delighted to be able to use the resources, as my own understanding of Further Mathematics is not as good as it might be. The resources have therefore helped me enormously in teaching this.”

4.2 Encouraging teachers to make greater use of ICT based and active-learning resources

As many teachers use the site for preparation, this presents an opportunity to encourage good practice in the teaching and learning of mathematics, especially in the use of ICT-based and active-learning resources. The HMI report identified that whilst a lot of GCSE (pre-16) teaching of mathematics is innovative, there is “...a lack of imagination and the confidence to try new approaches amongst A level teachers.”(HMI, 2004).

Appropriate use of ICT is encouraged by integrating relevant, high-quality ICT-based materials into each sub-topic “section”, so that teachers can be confident the resources listed are appropriate to what they are teaching. There are many Flash-based interactive materials, designed for teachers to use with Interactive Whiteboards. There are also many JavaScript interactive questions, spreadsheets, PowerPoint presentations and links to external websites. For example, there is a graph of a quadratic equation where the vertex can be “dragged” and the resulting equation and roots are displayed, even in the cases where the roots are imaginary! This multiple representation of concepts is one of the main ways in which ICT can be used to aid students’ understanding (Crisan, 2004). The teachers were asked whether using the environment had had an impact on how often they used certain methods in their teaching. 41% of teachers reported that they used a projector and/or Interactive Whiteboard more often, 40% reported that they used mathematics websites more often and 35% said they set ICT-based work for students outside class more often.

The teachers’ resources sections also contain many active learning resources such as ideas for open-ended questions, card-based activities and extension materials. For

example, there are jigsaws of 24 equilateral triangles with expressions on each edge such that when (30) pairs of equivalent expressions are placed next to each other it forms a large hexagon. These types of activities are increasingly being used in A level Mathematics classrooms and the use of more varied, interactive teaching methods is appreciated by students. A recent QCA report provided evidence that “Non-completers from most centres were positive about the support available to them while they had been on the ... course but more than half of non-completing students said that different teaching methods could have helped them to continue.” (QCA, 2007). Teachers’ are more likely to use active learning resources as a consequence of using the environment: 64% of teachers responded that using the environment had resulted in them using active learning materials (e.g. jigsaws/ matching activities) more often in their teaching.

The utility of these interactive and active-learning materials is enhanced by placing them in the environment directly alongside the mathematics they are designed to support. 77% of teachers reported that the integration of the interactive/active learning resources into the relevant sections of the environment was “very important” or “important” in encouraging them to use them.

4.3 Encouraging students to become more independent learners

The environment is designed to support three main groups of students. As well as supporting their study of mathematics, it is also expected that their general study-skills will improve so they can become more independent as learners.

The first group are those students who are being taught A level Mathematics in their school or college. The environment has been written to complement the traditional textbooks available: each module is split into topic-based “chapters” and these chapters are split into sub-topic “sections” that correspond to approximately one week’s work. Students seeking support have the option of referring to the web-based materials, a text-book or seeing a tutor. In making this choice they are managing their own learning support. The feedback from the formative assessment within the environment complements this by highlighting when they need to seek support. Of the students who responded to the survey, 81% reported that they “always” or “often” used the environment to look something up when they were stuck.

The second group are students studying through the Further Mathematics Network. The Further Mathematics Network is a government funded-programme enabling students to study A level Further Mathematics (a second A level in mathematics) with an external tutor, in parallel to studying A level Mathematics at the school or college they regularly attend. For more information see:

www.fmnetwork.org.uk/files/FMNetworkBrochure.pdf. As students studying through the Network will typically have far less student-teacher contact time than those being taught at a school or college, the environment is a key part of their tuition. The formative assessments, handwritten solutions and interactive resources are equally useful for these students as they are for the first group of students. In addition to this, the environment features study-plans for each sub-topic which help students structure their work and suggest which resources to use. As has already been mentioned the environment should form part of a “blended-learning” solution of web-based resources, text-book and tutor support. The references to the textbooks in the study-plans and the hand-written solutions encourage effective use of textbooks, an independent learning skill that it is very beneficial for students to develop to support their future studies at

university. 94% of students reported that the fact that the resources in the environment were tailored to the textbooks they were using was a “very important” or “important” factor in encouraging them to use them.

The third group are students who are studying completely independently. These correspond to a small proportion of the users of the environment and are mainly adult learners who are returning to education. Mature students often perform well and many of these are likely to be successful independent learners already.

Feedback from the users strongly supports the idea that the resources help students become better independent learners. 71% of teachers thought the environment encouraged their students to become better independent learners and 74% of students thought that their study skills had improved as a result of using the environment. One student in particular responded that “It has helped me take learning into my own hands when I need to reiterate a method or learn something completely new for a more advanced question that I am tackling and has not been dealt with in class.”

5 Transferability of the resources in the environment

The resources in the environment can also support the teaching and learning of mathematics more generally. The design allows the resources to be used to support undergraduate students, students on initial teacher education programmes and employees who need high-level mathematical skills.

There are currently three universities using the resources for undergraduates. The University of West of England has used the resources to support the first year of its engineering courses, helping students from a diverse range of mathematical backgrounds to succeed on their ‘Engineering Maths 1’ course. The use of the resources to support such students is the subject of further research (Golden et al., 2007). The University of Wolverhampton has also used the resources in a similar fashion for their first year mathematics undergraduates. At the University of Warwick the resources have been restructured by topic and made available on the university’s own online learning environment, to support students on any undergraduate course who require extra support with mathematics.

The environment is also used by a number of initial teacher training courses. Students on these courses typically have a mathematics, or mathematics-related, degree. The environment allows them to familiarise themselves with the content and structure of A level Mathematics. Many students on initial teacher education courses will only have the opportunity to teach 11-16 year old pupils during their training and so the resources give them the opportunity to study how mathematics is developed post-16. The arguments above about how the resources encourage good-practice for teachers also apply to students on initial teacher education courses.

The design of the resources could also support their use by employees who need high-level mathematical skills; however, this potential has not yet been developed.

6 Concluding Remarks

6.1 The environment encourages good practice in teaching and learning and also helps teachers to reinforce their own knowledge of mathematics.

Teachers are very likely to use the environment for preparation because its resources are comprehensive and are structured to match the units they are teaching. This is reinforced by suggested teaching ideas and active learning resources. Teachers also use the environment to reinforce and extend their own mathematical knowledge.

6.2 Many teachers who use the resources make greater use of ICT-based and active learning resources in their teaching.

High-quality interactive resources, fully integrated into the structure of the environment at the level of specific teaching topics, encourage teachers to use ICT appropriately in their teaching.

6.3 The environment encourages students to develop their study-skills, helping them to become better independent learners.

Students are encouraged to use the resources as part of a “blended-learning” approach, seeking support from their tutors, the environment and textbooks. The feedback from the formative assessments within the environment complements this by highlighting when they need to seek support.

6.4 The resources in the environment are transferable and can be used to support students’ learning of mathematics in other situations:

- Undergraduates needing support with mathematics
- Students on initial teacher education programmes in mathematics
- Employees who need high-level mathematical skills

Bibliography

CRISAN, C. (2004). Mathematics teachers’ learning about and incorporation of ICT into classroom practices. *Proceedings of the British Society for Research into Learning Mathematics* 24(2), pp15-20

<http://www.bsrlm.org.uk/IPs/ip24-2/BSRLM-IP-24-2-3.pdf>

GOLDEN, K., et al (2007) Encouraging student use of feedback, reflection and engagement through web-based learning support *MSOR Connections*, 7(2), pp7-10.

http://mathstore.ac.uk/newsletter/may2007/pdf/07_golden_k_et_al_websupport.pdf

HMI (2006). Evaluating mathematics provision for 14–19-year-olds

<http://www.ofsted.gov.uk/assets/4207.pdf>

QCA (2007). Evaluation of participation in GCE mathematics

http://www.qca.org.uk/libraryAssets/media/QCA_3388_Maths_GCE_eval_report.pdf

THE ROYAL SOCIETY (2007). The UK’s science and mathematics teaching workforce.

<http://royalsociety.org/downloaddoc.asp?id=5088>

SMITH (2004). Making mathematics count. *DfES*

http://www.dfes.gov.uk/mathsinquiry/Maths_Final.pdf

STRIPP, C. (2004). The changes to AS/ A-level Further Mathematics for September 2004. *MSOR Connections*, 4(3), pp15-16.

http://mathstore.ac.uk/newsletter/aug2004/pdf/further_maths.pdf

Appendix A – Survey Results

Students

1 Type of student

AS/A level student	108
FSMQ Additional Mathematics	5
Further Mathematics Network	37
Other	2
Total	152

2 How often do you use the resources for the following:

		Always	Often	Sometimes	Never	N/A
a	To learn a unit without any help from a tutor/teacher	10%	14%	36%	36%	5%
b	To reinforce what you have been taught in class	15%	45%	31%	5%	4%
c	To look something up if you are stuck	36%	46%	14%	3%	2%
d	To find interactive/active learning resources to help you understand a topic	9%	34%	39%	15%	3%
e	As a source of extra questions to practise on	14%	26%	38%	18%	3%
f	To reinforce your own knowledge of mathematics	12%	34%	36%	15%	3%

3 How important are the following factors in encouraging you to use the resources

		Very important	Important	Has some affect	Has no affect	N/A
a	The resources are tailored to the units I'm learning	68%	26%	3%	1%	2%
b	The resources cover a large number of units	34%	52%	9%	2%	3%
c	The interactive/active-learning resources are integrated in to each section	28%	39%	21%	9%	4%
d	The resources are set an appropriate level for me	36%	46%	11%	3%	4%

4 Please rate the quality of the following resources

		Excellent	Good	Adequate	Poor	N/A
a	Notes/study plans/glossaries	25%	57%	11%	3%	5%
b	Additional exercises	16%	59%	15%	1%	9%
c	Worked solutions to textbook questions/additional exercises	37%	38%	16%	5%	5%
d	Interactive resources	19%	47%	25%	2%	7%
e	Active learning resources	14%	51%	24%	1%	9%
f	Multiple choice tests/chapter assessments	36%	46%	12%	2%	5%

5 Do you think the resources have helped you to develop your study skills?

Yes	No	No response
74%	26%	1%

Teachers

7 Type of user

Subscriber to the full A level resources	66
Subscriber to the FSMQ Additional Mathematics resources	1
School/College registered with the Further Mathematics Network	20
Other/no response	14
Total	101

8 How often do you use the resources for the following:

		Always	Often	Sometimes	Never	N/A
a	Preparing for a unit before you teach it	39%	39%	19%	4%	0%
b	To get extra teaching ideas	26%	46%	27%	2%	0%
c	As a source of interactive/active learning resources	14%	47%	35%	5%	0%
d	As a source of extra questions	23%	46%	29%	2%	1%
e	To reinforce your own knowledge of mathematics	13%	11%	50%	22%	5%
f	To set work for students to do outside class	22%	33%	38%	6%	2%

9 How important are the following factors in affecting how often you use the resources

		Very important	Important	Has some affect	Has no affect	N/A
a	The resources are tailored to the units I'm teaching	75%	20%	3%	1%	1%
b	The resources cover a large number of units	47%	42%	7%	3%	2%
c	The interactive/active-learning resources are integrated in to each section	38%	39%	18%	6%	0%
d	The resources are set at an appropriate level for students	53%	42%	5%	0%	0%

10 Please rate the quality of the following resources

		Excellent	Good	Adequate	Poor	N/A
a	Notes/study plans/glossaries	40%	49%	9%	2%	1%
b	Additional exercises	38%	55%	5%	0%	2%
c	Worked solutions to textbook questions/additional exercises	43%	43%	12%	0%	3%
d	Interactive resources	24%	48%	23%	0%	6%
e	Active learning resources	27%	45%	18%	0%	11%
f	Multiple choice tests/chapter assessments	45%	45%	8%	0%	3%

11 Has using the resources had an impact on how often you do the following in your teaching?

		More often	No difference	Less often	N/A
a	Use a projector and/or Interactive Whiteboard	41%	56%	0%	3%
b	Use mathematical software (e.g. graph-plotters or spreadsheets) for teaching and learning	20%	75%	2%	3%
c	Set ICT-based work for students in class	19%	71%	2%	8%
d	Set ICT-based work for students to do outside lessons	35%	55%	3%	7%
e	Use mathematics websites	40%	54%	2%	4%
f	Use active-learning materials (e.g. jigsaws/matching activities)	63%	32%	0%	5%

12 Do you think the resources encourage students to become more independent learners?

Yes	No	No response
71%	23%	6%