*International Journal of Mathematical Education in Science and Technology*, Vol. 39, No. 8, 15 December 2008, 1003–1021

# *Biomathtutor*: evaluation of a new multimedia e-learning resource to support mathematics in the biosciences

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(*Received 20 November 2007*)

The objective of this study was to evaluate *biomathtutor* by (i) investigating the impact of *biomathtutor* on the mathematics skills competencies of bioscience undergraduates, and (ii) assessing students' and tutors' reactions to *biomathtutor*, identifying whether and how tutors might integrate it into their curricula and blend it with more traditional teaching practices to enhance their students' learning experiences. A multi-method approach was adopted in which a quasi-experiment and non-experimental evaluation of *biomathtutor* were used to collect both quantitative and qualitative data, using mathematics tests, questionnaires, tutor interviews and student focus groups. Eighty-nine bioscience undergraduates and eight tutors participated in the study. A comparison of student performance in the quasi-experiment, which adopted a pre-test-intervention-post-test methodology, revealed no significant difference between pre-test and post-test scores for either the 'control' group (no intervention) or for any of the mathematics learning support interventions used, including *biomathtutor*. Despite the limitations of the quasi-experiment which are discussed, tutors' and their students' reactions towards *biomathtutor* were very positive, with both groups agreeing that *biomathtutor* represents a very well designed and useful learning resource that has a valuable role to play in supporting mathematics learning within bioscience curricula. Students felt that using *biomathtutor* had helped them acquire new biological and mathematical knowledge and had increased their competence and confidence in mathematics, with many students confirming that they would use *biomathtutor* again. Tutors felt it would be useful to embed *biomathtutor*, where possible, into their curricula, perhaps linking it to assessment strategies or integrating it with their current more traditional teaching practices. Students indicated that they too would like to see *biomathtutor* embedded within their curricula, primarily because it would motivate them to use the resource. Modifications to *biomathtutor*, which may need to be considered in light of any potential further development of this resource, are discussed.

**Keywords:** *biomathtutor*; evaluation; bioscience; mathematics support; undergraduates; *mathtutor*

## 1. Introduction

### 1.1. *Background to the development of* biomathtutor

During the past decade, growing concern surrounding the perceived decline in the basic mathematical skills of bioscience university entrants [1–4] has led academic tutors to adopt

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ISSN 0020–739X print/ISSN 1464–5211 online

DOI: 10.1080/00207390802136537
http://www.informaworld.com

a variety of strategies in an attempt to address this skills deficit and support their students' mathematics learning [5,6]. These strategies have included the adoption of computer-assisted learning (CAL) materials with a view to either integrating them into the curriculum and providing opportunities for students to use them within timetabled classroom settings, and/or encouraging their more independent use by students prepared to engage in self-directed learning [7].

*Biomathtutor* [8] is a prototype multimedia e-learning resource, the first designed specifically to support mathematics learning in the biosciences. It represents the culmination of a collaborative project involving a small group of UK academics and the Educational Broadcasting Services Trust (EBST) [9]. *Biomathtutor* has adopted the technologies used and expertize developed in the production of *mathtutor* [10], but has exchanged the latter's more traditional mathematics teaching model for a learning model that it is hoped will prove more attractive to bioscience undergraduates, many of whom are maths-anxious and lack confidence in their mathematical abilities. The aim of *biomathtutor* has been to capture students' interest and curiosity by presenting them with a filmed bioscience-based scenario and to use the latter to gently guide students through the mathematics they need to understand and grow confident and competent in using routinely. Coles' contextual learning model [11] has been adopted to provide problem-solving in an e-learning environment, with a view to motivating bioscience students to *want*, rather than merely *need*, to engage with the mathematics content of their curricula [12–14].

### 1.2. *Design and structure of* biomathtutor

*Biomathtutor* was originally designed for delivery via DVD-ROM but is now available online [8]. It comprises four main components, with free navigation throughout.

#### 1.2.1. *Case-study film*

A case-study scenario, covering practical aspects of haematology and microbiology, is presented via a professionally produced and narrated film, 24 min in length. The film introduces a student, Rebecca, who visits her doctor with the symptoms of anaemia and a mouth infection. Her doctor obtains a mouth swab for analysis and sends Rebecca to the hospital for a blood test. The film illustrates a hospital laboratory where a full analysis of Rebecca's blood sample is carried out, and a microbiology laboratory where the cause of Rebecca's mouth infection is isolated and identified. The film concludes back in the doctor's surgery, where Rebecca receives her test results and is prescribed appropriate medication. A haematological–microbiological scenario was selected because most entrants onto bioscience degree programmes will have studied some haematology during their post-16 secondary education and, therefore, the biological terminology should be familiar to them. In contrast, few will have studied microbiology before entering university and, therefore, this represents a new and exciting topic for students. In addition, the scenario scripted around a student was one with which it was felt undergraduates might more readily identify.

#### 1.2.2. *Case-study questions*

Linked to the content of the case-study film are 33 interactive questions for students to attempt on screen. Nine questions are related specifically to haematological aspects of the case-study, while the remaining twenty-four relate to the microbiological sections. Most of the questions require learners to complete a calculation. Students receive immediate on-screen feedback on their submitted answers and the questions are hyperlinked to associated mathematics tutorials where students can obtain additional guidance.

#### 1.2.3. *Extension questions*

Twenty-four additional extension questions, which cover the same range of basic mathematical concepts presented in similar biological contexts, are also available for students to attempt, with a view to reinforcing their learning.

#### 1.2.4. *Mathematics tutorials*

Students can access five relatively brief (5–10 min) face-to-face filmed tutorials in which a mathematics tutor explains some of the mathematical concepts students encounter in the interactive questions; topics include powers, SI units, nomenclature, cell volume and percentage.

### 1.3. *Research questions*

The aims of this study were to investigate the impact of *biomathtutor* on the mathematics skills competencies of bioscience undergraduates, and to assess students' and their tutors' reactions to *biomathtutor*, identifying whether and how tutors might integrate it into their curricula and blend it with more traditional teaching practices to enhance their students' learning experiences.

## 2. Methodology

A multi-method approach was adopted in which a quasi-experiment [15] and non-experimental evaluations of *biomathtutor* were used to collect both quantitative and qualitative data. This approach was based on Kirkpatrick's four-level framework for evaluation [16], which is widely recognized as offering a conceptual framework applicable to integrated e-learning environments [17].

### 2.1. *Research population and samples*

Academic tutors from eight UK universities, representing both pre- (two) and post-1992 (six) institutions, volunteered to participate along with the groups of students they taught. The focus of this study was first-year students enrolled on a variety of bioscience degree programmes and samples comprised Stage 1 (direct-entry) or Stage 0 (foundation year) undergraduates. Eight pre-university students enrolled in a science summer school also participated in the non-experimental evaluation of *biomathtutor*. Ethics approval for the project required that students participate on a voluntary basis and necessitated students providing informed consent for both the quasi-experiment and the non-experimental evaluations. Samples of students were, therefore, self-selecting, and students were free to withdraw from the project at any time. Students and their tutors were provided with information sheets explaining the aims of the study and outlining their respective roles.

### 2.2. *Effects of learning resources on students' mathematical skills*

To determine the effects, if any, of *biomathtutor*, on students' mathematical skills competencies a quasi-experimental pre-test-intervention-post-test methodology was adopted [15]. At the start of the quasi-experiment, all volunteer students were presented with a paper-based, 20-item pre-test to assess the level of their mathematical skills competencies. The test, used previously and described by Tariq [18], began with 10 traditional basic pure abstract mathematics questions. These tested students' abilities to work with fractions, proportions and powers, to calculate volume and surface area and to transpose equations; some items also tested students' knowledge of prefixes for SI units. These mathematical concepts represented those integrated in *biomathtutor*. Questions 11–20 presented students with brief word problems in which the mathematical concepts introduced in questions 1–10 were set within biological contexts. Tutors were asked to deliver the pre-test in class, under examination conditions. Students were allowed up to 1 h in which to complete the test and were permitted the use of calculators. Following the pre-test, tutors randomly assigned their volunteer students to one of the following groups:

*Group A*: Students had access to *biomathtutor*, either via a DVD-ROM or their university's intranet or virtual learning environment (VLE). This intervention represented a multimedia mathematics e-learning resource with the content presented within biological contexts.

*Group B*: Each student was provided with a *biomathtutor* workbook. Printed in full colour, the workbook represented a paper-based version of *biomathtutor*. The content summarized all stages of the case-study scenario, presented all the case-study and extension questions (with boxes for inserting answers), and provided answers to all questions (with full explanations) towards the end of the workbook. However, students did not have access to either the case-study film or the mathematics tutorials. This intervention represented a paper-based mathematics learning resource (i.e. non-multimedia) with the content presented within biological contexts.

*Group C*: Students had access to *mathtutor*, via their institution's intranet or VLE, or via the Internet [10]. Students were directed to those specific sections of *mathtutor* that addressed the mathematical concepts covered in *biomathtutor*. This intervention represented a multimedia mathematics e-learning resource, but one in which the content had no biological context.

*Group D*: Students, representing a 'control' group, were asked not to access any additional mathematics learning resources.

The number of 'experimental' groups it proved feasible to establish within any participating university was dependent upon the number of students volunteering to participate in the study. Where fewer than 20 students volunteered, all were assigned to Group A (i.e. *biomathtutor*). Students were asked to access only the learning resource they were assigned, if any, but were assured that all the learning resources would be made available to them upon completion of the post-test. In addition to the information sheet distributed at the start of the project, a brief handout was prepared for each group of students, explaining their specific task during the intervention period.

Following the period of intervention, which, for logistical reasons, varied with each university, students were presented with a second paper-based mathematics test (post-test), in which test items were similar to those in the pre-test, with only numbers and the names of biological subjects changed. Students' performances in the pre- and post-tests were compared to assess the effects, if any, of the various interventions.

### 2.3. *Students' and tutors' reactions to* biomathtutor

Following completion of the post-test, all students were provided with an opportunity to use *biomathtutor*, before being asked whether they wished to participate in its evaluation. Two paper-based questionnaires were designed, one for students, the other for their tutors. Each of the questionnaires comprised 10 sections, with a total of 57 items for tutors and 66 items for students. The majority of items asked participants to rate statements on a four-point Likert scale, i.e. strongly agree, agree, disagree or strongly disagree. Two open-ended questions sought respondents' specific 'likes' and 'dislikes' and space was provided for additional comments. Some demographic information was also collected from both groups of participants. Quantitative data from the questionnaires were entered into and analysed using SPSS (Statistical Package for the Social Sciences). Responses to open-ended questions were transcribed and the content of the transcripts coded, categorized and key themes identified through an iterative process.

Although questionnaires are efficient tools for collecting a broad range of data, they often have limited value in addressing the 'why' behind participants' views [15,19]. Therefore, in order to examine the latter in more detail follow-up interviews were held with individual tutors and focus group sessions were conducted with students to provide an in-depth understanding of the issues surrounding the value, use and potential further development of *biomathtutor*. Focus group and interview schedules followed the themes contained in the questionnaires, but were semi-structured allowing participants to discuss any issues not raised previously. All interviews and focus group sessions were recorded, transcribed and their content analysed by coding and categorizing the content of the transcripts and identifying key themes. Both questionnaires and the focus group and interview schedules were piloted with students, academic tutors and colleagues.

The use of various methodologies and data collection instruments enabled data to be cross-checked, reduced bias and helped establish the data's validity [15]. Such triangulation minimized the artefacts of method, whilst using quantitative and qualitative data from both students and their tutors permitted the evaluation of *biomathtutor* to be studied from more than one perspective, to provide a greater insight into the various issues and therefore build a richer picture.

## 3. Results

### 3.1. *Effects of learning resources on students' mathematical skills*

A total of 89 first-year undergraduates from 5 of the partner universities (two pre- and three post-1992) participated in the quasi-experiment, completing both the pre- and post-test. The original intention had been to treat each participating institution's contribution as a separate quasi-experiment, with a view to reducing the influence of uncontrolled variables. However, due to the low level of student participation, particularly when it came to the post-test, the decision was taken to analyse the results collectively.

A comparison of student performance in the two mathematics tests revealed no significant difference overall between pre-test ($M=7.8$; $\mathrm{SD}=3.3$) and post-test scores ($M=8.0$; $\mathrm{SD}=3.9$; $t=0.5, \mathrm{df}=88, p=0.618$, effect size $r=0.05$). Further comparisons revealed no significant difference between pre-test and post-test scores for either the 'control' group or for any of the three interventions and, with the exception of the *mathtutor* intervention, only very small effects (Table 1). A large negative effect was observed with the *mathtutor* intervention, with students assigned to *mathtutor* scoring marginally less well in the post-test than in the pre-test. In addition, there was no significant difference between any of the intervention groups, including the 'control' group, and only very small effects, with regard to both the pre-test ($F(3, 85) = 1.127$, $p = 0.343$, effect size $\omega = 0.07$) and the post-test scores ($F(3, 85) = 1.413$, $p = 0.245$, effect size $\omega = 0.12$).

A comparison of student performances in the pure abstract test items (questions 1–10) and the contextualized word problems (questions 11–20) revealed significant positive correlations between total scores for the 10 abstract items and the 10 contextual items in both the pre-test ($r = 0.44, p < 0.001$) and the post-test ($r = 0.62, p < 0.001$), indicating that the abstract and the contextualized questions were measuring similar mathematical knowledge and skills. In both tests, students' mean scores were significantly higher for the 10 abstract questions than for the 10 contextualized word problems and the effect sizes were large (Table 2). In addition, whilst there was no significant difference between mean 'abstract' scores for the two tests ($t(88) = 1.128$, $p = 0.262$, effect size $r = 0.12$), the students' performance on the 10 contextualized items did improve slightly but significantly in the post-test ($t(83) = -3.383$, $p = 0.001$, effect size $r = 0.35$); familiarity with the style of word problems may account for this, since it may have resulted in some improvements in students' confidence and competence (Table 2). The results of multivariate ANOVAs (MANOVAs) of pre- and post-test data revealed that none of the interventions, including the 'control', had any significant effect on students' performances in the abstract or in the contextualized questions in either the pre-test ($F(6, 166) = 0.765$, $p = 0.598$, effect size partial $\eta^2 = 0.03$), i.e. prior to assignment of the intervention, if any, or in the post-test ($F(6, 156) = 1.297$, $p = 0.261$, effect size partial $\eta^2 = 0.05$), i.e. following the period of intervention, if any.

Table 1. Comparison of student performance in the pre-test and post-test.

| Intervention | Test | Mean (SD) | $t$ | df | $p$ | Effect size $r^a$ |
|---|---|---|---|---|---|---|
| *Biomathtutor* DVD | Pre-test<br>Post-test | 8.4 (3.4)<br>8.7 (4.1) | −0.602 | 44 | 0.550 | 0.09 |
| *Biomathtutor* workbook | Pre-test<br>Post-test | 7.2 (3.7)<br>7.4 (4.0) | −0.267 | 29 | 0.792 | 0.05 |
| *Mathtutor* | Pre-test<br>Post-test | 6.8 (2.5)<br>5.8 (2.3) | 1.369 | 5 | 0.229 | 0.52 |
| 'Control' group | Pre-test<br>Post-test | 7.1 (2.1)<br>7.5 (3.3) | −0.469 | 7 | 0.654 | 0.18 |

Note: [a]Pearson's correlation coefficient $r$ [20].

Table 2. Comparison of student performance in the 10 abstract and 10 contextualized questions.

| Test | Type of test item | Mean (SD) | $t$ | df | $p$ | Effect size $r^a$ |
|---|---|---|---|---|---|---|
| Pre-test | Abstract<br>Contextualized | 5.4 (2.2)<br>2.4 (1.8) | 12.889 | 88 | <0.001* | 0.81 |
| Post-test | Abstract<br>Contextualized | 5.4 (2.3)<br>2.9 (2.0) | 11.101 | 83 | <0.001* | 0.77 |

Notes: *Means for ten abstract and ten contextualized questions are significantly different.
[a]Pearson's correlation coefficient $r$ [20].

### 3.2. *Students' and tutors' reactions to* biomathtutor

The aim of this non-experimental evaluation was to gauge students' and their tutors' reactions to *biomathtutor* and to seek their views on the potential for *biomathtutor* to enhance students' mathematics learning in the context of the biosciences. It also sought participants' opinions regarding whether and how *biomathtutor* might be best integrated into curricula and how it might be further developed.

#### 3.2.1. *Characteristics of student and tutor samples*

Twenty-seven students (12 from a pre-1992 university and 15 from two post-1992 institutions) volunteered to participate in the evaluation of *biomathtutor*. Nineteen were first-year undergraduates who had participated in the quasi-experiment; seventeen had been assigned to the *biomathtutor* DVD intervention and two to the *biomathtutor* workbook intervention. The remaining eight students, who were enrolled on a 'fast-track' pre-university science summer course, did not participate in the quasi-experiment. The duration of access to *biomathtutor* prior to its evaluation varied to accommodate students' and their tutors' curricular commitments and timetable constraints. However, all participants had the opportunity to use *biomathtutor* for at least 2 weeks prior to its evaluation. The students (10 males, 15 females, 2 unspecified), whose ages ranged between 18 and 48 years ($M = 24$; $SD = 9$; $N = 24$), were enrolled on a range of bioscience courses, including Biochemistry, Biomedical Science, Forensic Biology, Human Biology and Pharmacology; 8 were attending a pre-university science summer school, 6 were in Stage 0 and 13 were in Stage 1.

Six of the eight participating tutors were based in post-1992 universities, while the remaining two tutors were from research-intensive pre-1992 institutions. Five of the tutors had facilitated their students' participation in the quasi-experiment. The four male and four female tutors' teaching experience ranged from 10 to 30 years ($M = 18.5$; $SD = 8$; $N = 8$), teaching a diversity of bioscience subjects (e.g. cell biology, molecular biology, human biology, immunology and haematology) and/or mathematics and statistics. All tutors were involved to a greater or lesser extent in mathematics learning support.

#### 3.2.2. *Using* biomathtutor *prior to its evaluation*

Forty-five percent of students had accessed *biomathtutor* only once, 48% had accessed it two to four times and 7% had accessed it more than four times. The median amount of time students spent using *biomathtutor* during each visit was 30 min and almost the entire sample (96%) worked alone; the remaining 4% provided no indication of how they worked. In contrast to the students, 25% of tutors had accessed *biomathtutor* only once, 50% had accessed it two to four times and 25% had accessed it more than four times. However, the median amount of time tutors spent using *biomathtutor* during each visit was only 15 min. While 75% of tutors worked alone, the remaining 25% had worked alongside colleagues.

#### 3.2.3. *Design of* biomathtutor

Students' and their tutors' views regarding the design of *biomathtutor* were positive, with 'agree' or 'strongly agree' being the most common (mode) response for each of the eight statements (Table 3). Participants felt that they could navigate easily through *biomathtutor*, since sectionalizing the materials made them readily accessible and that the use of colour, sound and language were appropriate.

> *It was easy to use and understand* (student)
> [Liked] *The easy to navigate layout and user friendly interface. The user is able to do what they want when they want and access and use the program at leisure* (student)

Students and tutors did, however, suggest some modifications to *biomathtutor*. These included the insertion of an introductory screen or overview of the programme at the start, as well as the provision of a glossary of biological terms with which learners may be unfamiliar. Tutors also highlighted the need to ensure that the specific requirements of disabled users were accommodated so that *biomathtutor* was fully accessible to all, e.g. through incorporating sub-titles or providing a downloadable printable script for hearing-impaired learners. Both groups also suggested that all the sections should be more extensively inter-linked with one another, rather in the style of a website, so that students could move around the programme with greater freedom. For example, students temporarily exiting from the case-study film at a particular point, in order to answer some of the interactive questions and/or view a tutorial, wanted to be able to return to the precise section of case-study film they had been viewing previously.

Tutors, acutely aware and concerned about the reduction in practical class sessions that today's bioscience undergraduate students experience, particularly liked the fact that *biomathtutor* illustrates a highly practical and laboratory-based 'real-life' scenario, providing students with an insight into how to solve practical problems in a laboratory setting, and demonstrates how to use specialized laboratory equipment and methodologies.

Table 3. Frequencies of students' and tutors' responses to statements concerning the design of *biomathtutor*.

| | Percentage of participants | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Strongly disagree | | Disagree | | Agree | | Strongly agree | | Missing | |
| Summary of statements | S[a] | T[a] | S | T | S | T | S | T | S | T |
| User interface is very well designed. | 0 | 0 | 7 | 13 | 78 | 38 | 15 | 50 | 0 | 0 |
| Division into sections and subsections helped in navigation. | 4 | 0 | 4 | 0 | 67 | 38 | 22 | 63 | 4 | 0 |
| Clear order in which to work through sections. | 0 | 0 | 11 | 13 | 78 | 63 | 7 | 25 | 4 | 0 |
| Liked the colour schemes. | 4 | 0 | 11 | 0 | 67 | 88 | 19 | 13 | 0 | 0 |
| Easy to access a tutorial for help. | 0 | 0 | 15 | 13 | 63 | 63 | 19 | 13 | 4 | 13 |
| Sound was used as and when appropriate. | 0 | 0 | 11 | 0 | 70 | 50 | 11 | 50 | 7 | 0 |
| Language and vocabulary used was easy to understand. | 0 | 0 | 7 | 0 | 56 | 38 | 37 | 63 | 0 | 0 |
| Able to exit easily at will. | 0 | 0 | 4 | 0 | 59 | 63 | 30 | 38 | 7 | 0 |

Note: [a]S = students; T = tutors.

### 3.2.4. Biomathtutor *as a learning tool*

Most students felt that *biomathtutor* provided an excellent learning experience, helping them acquire new knowledge, and increasing their competence, and for some, their confidence in mathematics; the mode response for all 12 statements was 'agree' (Table 4), with many students confirming that they would use *biomathtutor* again.

> *Biomathtutor helps students to understand the importance of maths to bioscience, and makes things simple* (student)
> *I really hated maths but after watching this I discovered that I have an interest in maths* (student)
> *I thought that* biomathtutor *was great, excellent for lone study and review* (student)

Tutors were even more positive than the students regarding the potential of *biomathtutor* to support learning, with a mode response of 'strongly agree' recorded for four of the nine statements (Table 5). Tutors agreed that *biomathtutor* had the potential to enhance their students' knowledge of the mathematics and bioscience topics it covered and that, therefore, it would be useful to integrate it into their curricula and possibly link it to assessment strategies. Tutors felt that *biomathtutor* had most to offer to Stage 1 students, but that it was not particularly relevant for use with students below that level, e.g. pre-university or foundation year (Stage 0) students. However, they also considered it a useful revision tool for Stages 2 and 3 undergraduates.

> *It sets the boring topics into context so I am hoping it will engage the better students early in the module as well as instruct the weaker ones.* (tutor)

Both groups felt that students may require some additional tutor and/or peer support, particularly if students had specific queries regarding *biomathtutor*'s content; suggestions

Table 4. Frequencies of students' responses to statements about *biomathtutor* as a learning tool.

| | Percentage of students | | | | |
|---|---|---|---|---|---|
| Summary of statements | Strongly disagree | Disagree | Agree | Strongly agree | Missing |
| Biological contexts helped me understand the maths. | 0 | 7 | 70 | 19 | 4 |
| Biological contexts helped motivate me to understand the maths. | 0 | 15 | 52 | 33 | 0 |
| Problem-solving approach was relevant to my learning needs regarding the application of maths. | 0 | 7 | 56 | 33 | 4 |
| Questions helped me self-assess my maths competence. | 4 | 4 | 70 | 22 | 0 |
| Increased my confidence in maths. | 7 | 26 | 48 | 19 | 0 |
| Improved my competence in maths. | 0 | 15 | 63 | 22 | 0 |
| Helped me gain new maths knowledge. | 0 | 11 | 70 | 19 | 0 |
| Helped me gain new biological knowledge. | 4 | 0 | 67 | 22 | 7 |
| Provided an excellent learning experience. | 0 | 22 | 52 | 26 | 0 |
| Enjoyed working through *biomathtutor*. | 0 | 15 | 59 | 26 | 0 |
| Would use *biomathtutor* again to help develop and practise maths skills. | 4 | 15 | 59 | 22 | 0 |
| Would use *biomathtutor* again to refresh knowledge of the biology topics. | 0 | 7 | 59 | 33 | 0 |

Table 5. Frequencies of tutors' responses to statements about *biomathtutor* as a learning tool.

| | Percentage of tutors | | | | |
|---|---|---|---|---|---|
| Summary of statements | Strongly disagree | Disagree | Agree | Strongly agree | Missing |
| *Biomathtutor* is a useful maths teaching tool for bioscience undergraduates. | 0 | 0 | 50 | 50 | 0 |
| Presenting maths in biological contexts should help students' understanding of maths. | 0 | 13 | 13 | 75 | 0 |
| Problem-solving approach is relevant to students' learning needs regarding the application of maths. | 0 | 13 | 25 | 63 | 0 |
| Questions should help students self-assess their competence in maths. | 0 | 0 | 50 | 50 | 0 |
| Students should be able to integrate knowledge acquired with existing knowledge. | 0 | 0 | 75 | 25 | 0 |
| Potential to enhance competence in maths. | 0 | 13 | 25 | 63 | 0 |
| Potential to enhance haematology knowledge. | 0 | 0 | 50 | 38 | 13 |
| Potential to enhance microbiology knowledge. | 0 | 0 | 63 | 25 | 13 |
| Would like to see content extended to other bioscience fields. | 0 | 0 | 25 | 75 | 0 |

included the establishment of electronic discussion boards or blogs via institutions' VLEs to which students and tutors could contribute.

#### 3.2.5. *Case-study film, case-study questions and extension (practice) questions*

In general, students agreed with the statements concerning the case-study film and the associated interactive questions, indicating that the film was enjoyable to watch, informative and that it enhanced their knowledge of biology and mathematics; the mode response for each of the 12 statements was 'agree' (Table 6). Students liked the interactive questions and believed that they provided a valuable learning experience; they also found the on-screen feedback on answers helpful.

> *The film footage made biological ideas seem more realistic and made the theory more accessible to me* (student)
> *Questions were related to my science course – like calculation on haemocytometers'* (student)
> *There are many questions which I could go through and the language was easy to understand as I am a foreigner* (student)

The case-study film and interactive questions were also very well received by tutors, the majority of whom agreed that the film and interactive questions provided valuable learning experiences that would help reinforce students' understanding of mathematics; the mode response for six of the nine statements was 'strongly agree' (Table 7).

> *The film is excellent – good for demonstrating method as well as maths* (tutor)
> *It's compact, well prepared video. Attention to detail, clear what they're doing and how they're doing it. Stand alone – which is useful* (tutor)

Table 6. Frequencies of students' responses to statements about the case-study film and case-study questions.

| Summary of statements | Percentage of students | | | | |
|---|---|---|---|---|---|
| | Strongly disagree | Disagree | Agree | Strongly agree | Missing |
| Film is enjoyable to watch. | 11 | 19 | 52 | 11 | 7 |
| Liked the option to view individual sections of film. | 11 | 0 | 56 | 22 | 11 |
| Film is very informative. | 4 | 7 | 63 | 11 | 15 |
| Film helps visualize and understand the scenario. | 7 | 7 | 56 | 22 | 7 |
| Film provides a valuable learning experience. | 7 | 11 | 48 | 26 | 7 |
| Film enhanced my knowledge of haematology. | 4 | 4 | 67 | 19 | 7 |
| Film enhanced my knowledge of microbiology. | 0 | 11 | 59 | 15 | 15 |
| Film enhanced my knowledge of the application of maths. | 4 | 22 | 48 | 15 | 11 |
| Questions provide a valuable learning experience. | 0 | 7 | 74 | 11 | 7 |
| Questions are relevant to the case-study. | 0 | 4 | 82 | 7 | 7 |
| Information on how to answer questions is clear. | 0 | 15 | 70 | 7 | 7 |
| Feedback on answers to questions was helpful. | 4 | 0 | 67 | 15 | 15 |

Table 7. Frequencies of tutors' responses to statements about the case-study film and case-study questions.

| Summary of statements | Percentage of tutors | | | | |
|---|---|---|---|---|---|
| | Strongly disagree | Disagree | Agree | Strongly agree | Missing |
| Film is enjoyable to watch. | 0 | 0 | 63 | 38 | 0 |
| Liked the option to view individual sections of film. | 0 | 0 | 63 | 38 | 0 |
| Film is very informative. | 0 | 0 | 75 | 25 | 0 |
| Film should help students visualize and understand the scenario. | 0 | 0 | 25 | 75 | 0 |
| Film provides a valuable learning experience. | 0 | 0 | 38 | 63 | 0 |
| Questions provide valuable learning experience. | 0 | 0 | 38 | 63 | 0 |
| Questions are relevant to case-study. | 0 | 0 | 38 | 63 | 0 |
| Information on how to answer questions is clear. | 0 | 13 | 25 | 63 | 0 |
| Feedback on answers to questions is helpful. | 0 | 0 | 38 | 63 | 0 |

Overall, both the students (63%) and their tutors (88%) believed that the number of case study questions was 'about right' and that intellectually the questions were neither too easy nor too difficult.

Students and tutors felt that the extension questions also helped reinforce understanding of the mathematics and that the feedback on answers was helpful (Table 8).

> *I thought they were quite a comprehensive set of questions; ok some were work it out this way then change the variables round and work it out the other, but I think that's again quite useful so they do see those inter-relationships as well and get a bit more fluent with manipulating the equations round*' (tutor)

### 3.2.6. *Maths tutorials*

Although *biomathtutor* includes five tutorials, the 'powers' and 'SI units' tutorials were those most viewed by students and tutors, perhaps because they were the first in the list of tutorials, rather than because these were topics with which students needed particular help (Table 9). The viewing figures declined steadily through the remaining three tutorials, with only 52% of students and 50% of tutors viewing the 'percent' tutorial, the last in the list (Tables 9 and 10), perhaps because both groups of participants were viewing the tutorials primarily for the purpose of evaluating them rather than for use in their teaching and learning.

Overall, students and their tutors liked the tutorials, believing their purpose was clear and that they were helpful in supporting learning.

> *I quite like the fact that it's written as he speaks because I think students do need to see the maths develop rather than having it all on a screen and be talked through it* (tutor)

Although both groups felt that the tutorials were neither too long nor their content too difficult, two students commented that:

> *The only negative thing about it is that if you're doing it on your own it's easy for you to get bored as someone's just talking, and if you're not getting it, it's easy to just turn it off* (student)
> *It wasn't that easy to fast forward through bits of the tutorials I understood already* (student)

Table 8. Frequencies of students' and tutors' responses to statements about the extension (practice) questions.

| | Percentage of participants | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Strongly disagree | | Disagree | | Agree | | Strongly agree | | Missing | |
| Summary of statements | S[a] | T[a] | S | T | S | T | S | T | S | T |
| Opportunity for practice offered a valuable learning experience. | 0 | 0 | 4 | 0 | 70 | 38 | 19 | 63 | 7 | 0 |
| Helps reinforce understanding of maths. | 0 | 0 | 7 | 0 | 67 | 38 | 15 | 63 | 11 | 0 |
| Information on how to answer questions is clear. | 0 | 0 | 15 | 0 | 59 | 38 | 19 | 63 | 7 | 0 |
| Feedback on answers to questions is helpful. | 0 | 0 | 11 | 0 | 48 | 38 | 26 | 63 | 15 | 0 |

Note: [a]S = students; T = tutors.

Suggestions for improving the tutorials included incorporating graphical representations and animations to give the tutorials a more contemporary feel.

### 3.2.7. *Likes and dislikes*

Two open-ended questions asked students and tutors to comment on those aspects of *biomathtutor* they liked best and those aspects they liked least. Examples of comments include:

Liked best . . .

*That it was interactive and gave practical examples* (student)
*The explanations were easy to understand* (student)
*Very good biological and mathematical support for the topics covered and clear helpful feedback with the questions* (tutor)
*Liked the entire package and it had a coherent structure* (tutor)

Table 9. Summary of students' responses to statements concerning the five mathematics tutorials.

| | Median response[a] | | | | |
|---|---|---|---|---|---|
| Summary of statements | Powers | SI units | Nomenclature | Cell volume | Percent |
| Tutorial's purpose was clear. | 4 | 4 | 3 | 3 | 2 |
| Provided clear explanation of topic. | 3.5 | 4 | 3 | 3 | 1 |
| Helped me understand relevance to bioscience. | 3 | 3 | 3 | 3 | 1 |
| Better understanding of topic by end. | 3 | 3 | 3 | 3 | 0.5 |
| More confident by end. | 3 | 3 | 3 | 3 | 0.5 |
| Content too difficult. | 1 | 1 | 1 | 1 | 0.5 |
| Tutorial too long. | 2 | 2 | 1 | 2 | 0 |
| Tutorial helpful in supporting learning. | 3 | 3 | 3 | 3 | 0.5 |
| Percentage of students who viewed the tutorial (%) | 67 | 67 | 63 | 63 | 52 |

Note: [a]Not viewed = 0; strongly disagree = 1; disagree = 2; neutral = 3; agree = 4; strongly agree = 5.

Table 10. Summary of tutors' responses to statements concerning the five mathematics tutorials.

| | Median response[a] | | | | |
|---|---|---|---|---|---|
| Summary of statements | Powers | SI units | Nomenclature | Cell volume | Percent |
| Tutorial's purpose was clear. | 4 | 3.5 | 3.5 | 2 | 2 |
| Provided clear explanation of topic. | 4 | 4 | 4 | 2 | 2 |
| Should help students understand relevance. | 4 | 4 | 4 | 0 | 0 |
| Should provide better understanding by end. | 3 | 3 | 3 | 0 | 0 |
| Content too difficult for students. | 1 | 1 | 1 | 0.5 | 0.5 |
| Tutorial too long. | 2 | 2 | 1 | 0 | 0 |
| Helpful in supporting learning. | 3.5 | 3.5 | 3.5 | 1.5 | 1.5 |
| Percentage of tutors who viewed the tutorial (%) | 63 | 63 | 63 | 50 | 50 |

Note: [a]Not viewed = 0; strongly disagree = 1; disagree = 2; neutral = 3; agree = 4; strongly agree = 5.

Liked least . . .

*The use of only one case study was disappointing. I'd have preferred more case studies encompassing different clinical conditions with other clinical and pathology tests performed and additional data to analyze* (student)
*Sometimes feedback on extension questions is too rudimentary* (tutor)
*Tutorials often take quite a long time to get to the point* (tutor)

### 3.2.8. *Students' experiences of and attitudes toward mathematics*

Students who participated in this study were self-selecting, and therefore probably less maths-anxious than many bioscience undergraduates. Overall, $\geq$74% of the sample had enjoyed their secondary-level maths experience, reported that their maths teaching had been very good and believed that they were 'good at maths'. Despite this statistic, 33% of students claimed to lack confidence in mathematics and over 80% believed that with more help and practice they would be better at mathematics; only two students claimed to dislike mathematics. Although almost 50% of students had underestimated the mathematical content of their course before starting their undergraduate programme, 85% of students now recognized that their bioscience course would require them to be mathematically competent. Tutors expressed concern that a significant proportion of their students are maths-anxious, lack confidence and possess a negative attitude towards the subject, resulting in many struggling with aspects of the curriculum.

Students were also asked to reveal the mathematics qualifications they held. Almost two-thirds of students (63%) had achieved a pass grade (A*–C) in mathematics at GCSE level (or equivalent), but only a third (33.5%) had acquired a higher mathematics qualification, i.e. at AS or A2 level (Appendix). Although some students had not acquired conventional UK mathematics qualifications, i.e. a GCSE, AS or A2, they had obtained alternative qualifications in mathematics or numeracy, including key skill levels 1 and 2, and overseas qualifications equivalent to a GCSE.

### 3.2.9. *Views on integrating* biomathtutor *into the curriculum*

Seven of the eight tutors believed there was potential for integrating *biomathtutor* into their curricula and wished to use it in their classroom sessions, either in part or in its entirety. However, many of them acknowledged that they might encounter some difficulties integrating the resource. For example, the biological content of *biomathtutor* may not match that of the curriculum, there may be insufficient time available or they may have to rely on colleagues' willingness to adopt *biomathtutor*.

*If it's support material I don't think there would be a problem . . . Things like the module specifications are so tightly drawn these days that if you want to put an assessment in that wasn't already described, then you would have to change the paperwork* (tutor)
*Integrating into foundation year would conflict with other topics to be taught and biology content would not be covered in foundation year* (tutor)
*Would depend on other members of staff integrating the resource* (tutor)

Students indicated that they too would like to see *biomathtutor* integrated in their curricula, primarily because it would motivate them to use the learning resource. They also felt it would be better if they could use *biomathtutor* in classroom sessions rather than on their own at home, as they would be less likely to get bored using it and a tutor would be available to answer any queries they might have.

## 4. Discussion

The results of the quasi-experiment suggest that none of the mathematics learning resources used in this study, including *biomathtutor*, had any significant effect on the students' mathematics competencies. In addition, the students' poor overall performance in both the pre-and post-tests, confirm the findings of previous studies [3,4,18]. However, perhaps few learning resources could be expected to significantly affect learners' competencies when the former are accessed intermittently over only a relatively short period of time (3–4 weeks in the case of this study).

The negative effect obtained with those students assigned *Mathtutor* [10] is interesting. *Mathtutor* was designed primarily for students studying post-16 mathematics at secondary level and first-year undergraduates embarking upon courses in mathematics, engineering or the physical sciences. Although it has been adopted to some extent to support undergraduate teaching in the biosciences, its traditional model for mathematics teaching is believed by many tutors to be inappropriate for the majority of bioscience undergraduates because it fails to take account of the students' lack of confidence and often profound anxieties when confronted with anything mathematical [2].

Educational 'field' studies, such as the quasi-experiment described, are notoriously difficult to carry out successfully, particularly in higher education, where it is virtually impossible to control the behaviour of students or the many intrinsic and extrinsic variables that exist. For example, where more than one experimental group was included 'cross-contamination' between groups may have occurred, with students accessing resources assigned to their peers. In addition, some students may not have taken their participation seriously enough or perhaps decided they had insufficient time to use the resource assigned to them. It was also impossible to control for the students' backgrounds in mathematics, affective factors such as maths-anxiety, dyslexia and dyscalculia, and the learning environment (including other sources of mathematics support available to different students).

Increasingly, ethics committees' requirements for informed consent and participation on a voluntary basis exacerbate the problems educational researchers face, leading to low levels of student participation and/or high levels of student withdrawal from investigations once they are underway. For example, fewer than 350 students volunteered to participate and attempt the pre-test (out of a pool of $\approx$2000), and only 89 students returned to attempt the post-test. These figures may reflect bioscience students' apprehension and unwillingness to contribute to studies involving mathematics, particularly when their contributions are not formally recognized or rewarded. The reluctance on the part of many students to support such studies is reflected in the following student comments: 'don't want to do it', 'have no time', 'not interested', 'can't be bothered'.

Despite the outcome of the quasi-experiment, students felt that using *biomathtutor* had increased their competence and confidence in mathematics. Overall, tutors' and their students' reactions towards the *biomathtutor* prototype were very positive, with both groups agreeing that *biomathtutor* represents a very well designed and valuable learning resource, which has an important role to play in supporting mathematics learning within bioscience curricula. *Biomathtutor* facilitates students' learning and understanding through allowing them to more readily visualize the case-study scenario, practise their mathematics skills via the interactive questions, and access video tutorials for assistance. Students requested that these various components be inter-linked more extensively so that they could access the resources as they wished, rather than being forced down a prescribed route. This may accommodate those students who prefer to dip in and out of a resource, while still catering for those students who want to spend a significant amount of time working through the materials. Such requests reflect how learners interact differently with e-learning materials and how they like to access resources in different sequences and to different extents [21]. Students also wanted to be able to download or print sections of *biomathtutor* so that, for example, they could record their calculations along with any additional notes to read through at a later date. Gilbert et al. [21] found that students do tend to download or print documents from e-learning environments, and suggested that this style of working needs to be accommodated when designing component materials and learning objects. In addition, Pearson and Trinidad [22] suggest that ensuring the learning environment closely matches the students' preferred method of learning results in improved achievement of learning outcomes. Designers of CAL materials, therefore, need to accommodate users' individual learning styles and approaches to such resources as much as possible, as well as ensuring accessibility to all users, including those with specific disabilities such as motor, visual or hearing impairments.

The reactions of students and their tutors towards mathematics e-learning resources such as *biomathtutor* are often very positive when non-experimental evaluation studies such as these are carried out. However, even if *biomathtutor* were to be modified to more closely match students' approaches to e-learning, unless those students who really need to use such resources can be persuaded to do so, they will have only limited success in supporting and enhancing mathematics learning. Students argued that they would be more motivated to engage with *biomathutor* if it was embedded in their curricula, its use was compulsory rather than merely optional and it was linked to other strategies, e.g. summative assessments, group activities, electronic discussion boards, tutorials or practical exercises. This concurs with Hudson and co-authors' suggestion that facilitating the meaningful engagement of learners in e-learning environments often involves the use of a variety of strategies, including discussion fora, group activities and peer formative assessment [23].

Tutors cited a number of potential problems with regard to embedding *biomathtutor* within curricula, e.g. formally timetabling its use in an already full programme, the irrelevance of some or all of the biological content to specific modules and the bureaucracy associated with changes to module specifications and validation. Nevertheless, many tutors confirmed that they planned to integrate it into their current teaching practices in the following academic year and recognized the need to implement specific strategies to encourage their students to use *biomathtutor*; suggestions included awarding exemption from other compulsory elements of a module or linking *biomathtutor* directly to summative assessments.

Successful integration of *biomathtutor* may depend not only upon tutors' and students' individual motivations, but also upon the support mechanisms available to both groups. Students reported that if they had any questions or queries regarding the content of *biomathtutor*, their impulse would be to ask their tutor. Although the tutors in this sample claimed to be happy to provide additional support, it cannot be assumed that all tutors would have the same desire or necessary time to devote to such an activity. One suggestion was the establishment of electronic discussion boards or blogs, where tutors could answer most frequently asked questions or where students could provide peer support or peer-assisted learning. The establishment of a social networking structure may enable CAL materials such as *biomathtutor* to be more effective and learners to capitalize on their potential by engaging in more collaborative learning. However, Condie and Livingston [24] caution that blending traditional and online learning approaches does require greater understanding in terms of striking a balance between the two and considering implications for the roles of students and their tutors [24].

Within this study *biomathtutor* was used in a variety of learning contexts. Some tutors used it within specific modules (skills-, maths- or bioscience-focused) or as part of a pre-university course, while others linked it to personal tutor schemes or independent learning strategies. Tutors and students alike valued the flexibility that *biomathtutor* offers, enabling students to access mathematics learning support whenever and wherever they like; they particularly liked the fact that the integrated mathematics tutorials can be paused at any point and replayed as often as required. CAL materials have the potential to eliminate temporal and physical barriers to learning by removing the time and space constraints imposed by formal timetabled classroom sessions. Childs and co-authors concluded that such flexibility, combined with integration into the curriculum, is one of the key benefits provided by e-learning [25].

When asked about the potential future adaptation of *biomathtutor* for 'mobile' technologies such as Internet-phones or Personal Digital Assistants (PDAs), the majority of participants eschewed this idea, citing factors such as the costs involved in downloading to mobile phones, and the limited numbers of students who actually own or have access to PDAs. Further, students clearly perceived their mobile phones as being for personal and private social use rather than for activities associated with their academic studies. Students' attitudes towards the adaptation of e-learning materials for new 'mobile' technologies certainly require further investigation.

Although the small sample of students and their tutors that participated in this evaluation of *biomathtutor* makes it difficult to generalize the results to all bioscience undergraduates or to all tutors, the results contribute to the conceptual understanding of how bioscience students and their tutors engage with e-learning, specifically within a mathematical, combined with biological, context, and how blended learning strategies might be used to greater effect in helping undergraduates overcome their apprehension of mathematics.

## 5. Conclusions

The main conclusions of this study were that:

- although *biomathtutor* had no apparent significant effect on the students' mathematics competencies, and *mathtutor* appeared to have a negative effect, further studies over a longer timeframe are recommended;
- tutors' and their students' reactions towards the *biomathtutor* prototype were very positive, with both groups agreeing that *biomathtutor* represents a very well designed and valuable learning resource which has an important role to play in supporting mathematics learning within bioscience curricula;
- any future modifications to *biomathtutor* should include: the more extensive inter-linking of components; the provision of downloading and printing facilities; ensuring accessibility to learners with motor, visual or hearing impairments; and the incorporation of graphical representations and animations;
- *biomathutor* may be embedded within curricula or used to support independent learning. However, in both instances its use should be linked to other strategies (e.g. assessments or student exemption from course components), and/or support mechanisms (e.g. tutor support or social networking facilities) in order to motivate students to use the resource.

- students' attitudes towards the use of new 'mobile' technologies in support of e-learning require further investigation;
- although the overall verdict on the *biomathtutor* prototype was highly positive, some modifications in design will need to be considered before the content can be extended to incorporate more case-study scenarios and learning objects with a view to maximizing its potential to support mathematics learning in the biosciences.

## Acknowledgements

Vicki Tariq is grateful to the Higher Education Funding Council for England (HEFCE) for the National Teaching Fellowship Award 2003, which funded the development of *biomathtutor*, and to the Higher Education Academy for funding this 12-month evaluation and research project via its e-learning research grant scheme. This article is dedicated to the memory of Dr Jim Stevenson, Chief Executive Officer of the EBS Trust, whose contribution to the production of *biomathtutor* was invaluable.

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## Appendix: GCSEs, AS- and A2-levels

The General Certificate of Secondary Education (GCSE) represents the main qualification achieved after 2 years' study by 16-year olds at the end of their compulsory secondary level education; the subjects are graded from A* to G, but only grades A*–C allow access to Advanced Level (A-level) study. Traditionally, A-level qualifications were normally awarded to pupils aged 18 years after 2 years' further study of an 'advanced' syllabus (pass grades range from A to E). In 2000 a series of reforms were introduced which aimed to broaden the post-16 curriculum. These reforms included the introduction of Advanced Subsidiary (AS) level and A2-level qualifications. Pupils may 'cash-in' an AS qualification (after one further year of post-16 study) or continue studying the subject for a further year to achieve the higher A2 qualification (equivalent to the traditional A-level) [26].