

The design of a computer-based maths toolbox for engineering students.

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1. Introduction (*see full report for further details on the motivation for study / literature background*)

The objective of this work was the preliminary design of a multifaceted computer-based mathematics resource for undergraduate and pre-entry engineering students. Specifically, guidelines are developed for effectively collating and integrating learning, support, application, communication and diagnostic tools to produce an Engineer's *Mathematics Gateway*. Similarly, consideration is given to effective ways of integrating the gateway into engineering curricula, and indeed creating a local (e.g. departmental) identity for gateway use. Unlike other mathematics learning resources, design features are considered which effectively accommodate collaborative learning, student feedback, and formative and formal diagnostic testing, and enable teachers to readily adapt and structure content to meet specific learning needs. It should be noted that Imperial College London has in recent years developed an online mathematics database known as METRIC for student and lecturer use (Sangwin 2005). An allied objective of this research was to further evaluate the student and lecturer experience of METRIC, and where possible, extract generic and desirable features to guide the mathematics gateway design.

2. Methodology

In order to develop design guidelines for the mathematics gateway, consultations were held with key personnel from across Imperial College London. This included discussions with academic staff, educationalists, learning technologists and ICT staff. Discussions with academic staff involved mathematics representatives from all 9 Engineering departments within the College¹, as well as the departments of Mathematics, Physics and Chemistry; typical interview / discussion points are summarised in Table 1. Discussions were also held with representatives of some key UK centres and organisations who have taken a lead in mathematics education and support of new and incoming University students (see below).

Student evaluations were also carried out through the administration of a Mathematics and Online Learning Experiences survey to all engineering, physics and chemistry students; an outline of the questions is presented in Appendix 1. This enabled the exploration of general student internet habits and learning-resource experiences, as well as experiences with the Institution's current mathematics online resource (METRIC). Specifically, the questionnaire was organised under 4 sections:

¹ i.e. departments of: Aeronautics, Bioengineering, Chemical Engineering, Civil and Environmental Engineering, Computing, Electrical and Electronic Engineering, Earth Science and Engineering, Materials, Mechanical Engineering.

background information, mathematics learning experiences, online learning experience (use of mathematics resources), internet habits and e-learning. Such a design enabled some analysis of departmental and demographic trends, as well as any association between learning-resource use and mathematics related achievement and confidence; when such associations showed differences in mean scores (greater than ~ 0.2) these were tested for significance using a two-tailed independent t-test with $p < 0.01$. The questionnaire was administered online using the SurveyMonkey software (SurveyMonkey.com, Portland, OR, USA; access date January 2009). The total sample size consisted of 812 undergraduate students; data on the background of the participants is given in Table 2. Specific to the elite status of the Institution, the great majority of students hold a grade A in A-level² mathematics or equivalent and approximately 50% of them hold an A-level in Further Mathematics.

As part of collating existing good practice, attention was also given to the content and design features of some existing national and international mathematics resources. Specifically, these included: HELM (www.lboro.ac.uk/research/helm), Math.se (www.math.se), Mathcentre (www.mathcentre.ac.uk), Mathtutor (www.mathtutor.ac.uk), MathWorld (<http://mathworld.wolfram.com>), and nrich (<http://nrich.maths.org/public>). Where possible, relevant discussions were held with the associated representatives of each site regarding the perceived benefits and limitations of the resource.

3. Results and Discussion

Student survey

Maths learning experience (*see full report for further details*)

- Table 1: Perceived difficulty of mathematics at the beginning of the course compared with other subjects. Students who hold an A-level in Further Mathematics score significantly better ($p < 0.01$) than those who do not.
- Table 2: Mastery examination grades. Students who hold an A-level in Further Mathematics score significantly better ($p < 0.01$) than those who do not.
- Figure 1: Features the survey participants liked most in METRIC (N = 346)

Study Habits and Online Learning Experiences.

Student responses to the use and benefit of some key methods and resources for mathematics learning are summarised in Figure 2. As expected, lectures and tutorials are the primary learning resources, followed by informal discussions with peers. However, in terms of perceived benefits, peer discussions ranked comparably with the traditional learning options. Currently, approximately 40% of the students indicate the use of online resources for mathematics learning.

In Figure 3, the use and benefit of the mathematics learning resource data is shown for both high and low achieving students on the mastery exam. No association was demonstrated between use of resources and level of achievement. However, when comparing low and high achieving students, the benefits of lectures and tutorials were perceived less by the former group, but that of online resources as higher ($p < 0.01$). Interestingly, all students valued the benefits of peer discussions in their learning, but especially those achieving low marks in the mastery exam.

² Advanced level General Certificate of Education qualification common in England, Northern Ireland and Wales; undertaken over a 2-year period.

The perceived level of mathematics contextualisation within the engineering discipline is illustrated in Table 5. Responses to this question were compared to responses to perceived mathematics difficulty in the first year, as well as perceived current ability to tackle applied problems. Students who felt that mathematics were *easier* or *much easier* when compared with other courses scored significantly better (i.e. recognise significantly greater contextualisation of mathematics) when compared with students who found mathematics *more difficult* or *much more difficult*. Similarly, students who felt *strong* or *very strong* in applying mathematics to other courses scored significantly better when compared with those who feel *weak* or *very weak*. One interpretation of this data is that students who are able to see the relevance of mathematics to engineering also perform better. It could also be the case of course that students of higher mathematics ability are simply making the better connections to other subjects. In other words, contextualisation may be an indicator of, or antecedent for, achievement, and indeed both.

Fifty-eight per cent of the respondents indicated 1-3 hours internet browsing on a daily basis during term time, including email. A further 34% indicated more than 3 hours browsing on a daily basis. Given the tight teaching schedules during most days, such figures indicate a surprisingly high internet usage. In terms of social (personal) vs. study-related usage, scores distributions are summarised in Figure 4. High work-based use is indicated irrespective of the fact that few courses in engineering make explicit use of or reference to internet material. A trend of decreased browsing time spent on social networking with increasing year of study was noted. The differences are not statistically significant except for the 4th year students who spend significantly less time on social networking (mean score = 3.85) than 1st (4.46), 2nd (4.34) and 3rd (4.31) year students ($p < 0.01$). It should be noted that this may not be associated to student maturity but to the increased popularity of social networking online in the last 2-3 years.

For sources of primary information, approximately 64% of respondents use Wikipedia (www.wikipedia.org) at least twice a week (27% every day); approximately 90% use Wikipedia at least once a week. A selection of the comments on what features make this resource so attractive were: “simple and hassle free; one click, one search, one page”, “because it just works and has everything”, “linked information”, “summary of information”, “very easy to use”, “quick and accurate”, “straight to the point”, “good introduction to concepts”, “compact and easy to understand”, “quick reference or confirmation”.

Figure 5 gives a summary of main student responses when asked to comment on other online resources found especially helpful in learning new material (mathematics or otherwise). Highest responses were for Wolfram’s Mathworld (mathworld.wolfram.com). Typical comments on why this site was viewed as helpful included: “simple search and easy content layout”, “much like Wikipedia, but accompanied with useful applets”, “very comprehensive”, “everything about mathematics is there”, “basically, a free online textbook”. This again supports the notion that students respond well to information content which is well-organised, direct and simple in access.

In Figure 6 student views on features attractive to an online learning resource are summarised. Consistent with responses on the Institution’s METRIC site, examples and exercises feature strongly. Popular responses are also given for structured tests, access to equation solvers (known to students through other coursework), video tutorials and online tutor help. For those students who specified other features for this question ($N = 73$), these principally again related to worked

examples (i.e. “step-by-step” examples) and video tutorials (and lectures). Links to external reading and information sources was also specified by some students. Interestingly, whereas the students use the internet for social networking and chat almost daily, a discussion forum was not popular (25%) among the proposed features for an online learning resource. It is evident that a plethora of worked examples is a key attractive feature of an online learning tool for mathematics.

- Finally, the attractive features of some external online mathematics resources are summarised in Table 6

Table 4. In the UK, sites also exist for problem solving and investigational activities which closely relate to core modules in mathematics and statistics, i.e. www.risps.co.uk and the related site www.making-statistics-vital.co.uk. In a similar way, www.mathsrevision.net provides summary notes and examples of A-level and GCSE mathematics material which is mapped onto the requirements of specific examination boards. Whilst the different online resources have specific features complementing student learning, and some organise the content under general disciplines (e.g. Mathcentre and MathWorld), much scope exists for detailed engineering-discipline specific content mapping and examples.

Interviews with academic and teaching support staff (see full report for further details)

- Particular weak areas in mathematics were identified as spatial visualisation (i.e. “anything over 1D”, matrices, 3D analytic geometry), algebraic manipulations, abstract notions, complex numbers and mechanics.
- Staff referred to the seemingly modular and methodological understanding and application of mathematics that many students adopt as a key barrier to transferring skills and knowledge to engineering contexts.
- However, feelings were mixed with regard to the use of engineering examples in mathematics: some lecturers feel that core mathematics should be taught in an abstract way, without contextualisation, whereas others believe that discipline-related case studies / examples should be used where possible.
- Staff proposed interactive graphics and tools which would help demonstrate or visualise the learning material in interesting and engaging ways.

4. Design guidelines for a maths gateway (see full report for further details)

Site design

- The gateway should be designed to offer guidance to pre-entry students on how to use the site, its immediate relevance to first-year University teaching, and what mathematics modules in specific need to be covered prior the start of the undergraduate course. Therefore, the gateway should enable teachers to set up *linear* (sequential) course plans.
- The gateway should be easily adaptable to departmental needs; this would allow for variation in the choice of specific theory and examples (i.e. contextualisation), as well as create a departmental identity for the site.
- A modular database, from which teachers can readily construct a course-plan, would provide a mechanism for greater coherency with existing course / lecture material. Similarly, a working database of discipline-specific examples would enable generic mathematics methodologies to be easily contextualised within a range of engineering disciplines.

- Examples should have a grading system to indicate their level of difficulty. Such a grading system would allow students to self-assess their progress, i.e. from basic method repetition to engineering application.
- The professional design and ease of use of the gateway are important features. Students make wide use of professionally built websites and software (including the local VLE), and thus have high standards for, and expectations of, any online resource.
- Content should be organised in concise, step-by-step formats, with the use of links / hyperlinks to support student needs for further elaboration on concepts and methods (c.f. Wikipedia). Supportive videos, animations, simulations and demonstrations should also be employed, with a direct and transparent rating system from the students to indicate the benefit of such media.
- Motivation for gateway use can be further increased through the inclusion of diagnostic tests and online tutorial and exercise questions. For example, the administration of any core exercise sheets could be carried out within the mathematics gateway.
- The site should have the facility for students to enter mathematical symbols and equations. Rapid equation and data entry in an intuitive quick-to-learn format is essential to enable the use of a range of engineering mathematics problems. Such a feature would also widen options for online assessment and diagnostic testing.
- Automated feedback methods should be designed to inform the student of process errors, rather than errors of final numerical solution. Such methods would act as the first line of student help (e.g. through prompts and *hints*), prior to any additional support from, e.g., an online tutor (see below).
- Potential interfaces with equation solvers such as Mathematica, MAPLE or gPROMS, would provide students with a *gateway* site for both mathematics learning and practical application. Furthermore, examples and exercises which utilise such commercial software would broaden the site's relevance and interest to the students.
- It is important for the gateway to be easily accessible. Hence, it may be necessary for the site to be housed in a frequently student-accessed environment; this could be the local VLE or a University portal. However, the choice (and even version) of VLE requires careful consideration to ensure the support of the desired gateway features.

Maths content

A core curriculum for European-wide engineering mathematics content has been reported by the SEFI Mathematics Working Group (Mustoe and Lawson 2002). Useful in this documentation is the identification of content levels which “reflect the hierarchical structure of mathematics and the way in which mathematics can be linked to real applications of ever-greater sophistication as the student progresses through the engineering degree”. Such a structure infers a need to guide students through content, which of course is implicit within lecture and curriculum designs. However, such guidance and material organisation is often missing in online resources, where often students pick and choose subjects for further help rather than follow a programme whereby the level of background knowledge can be increased or decreased as deemed necessary by the student. A simple year / course / lecture topic map indicating mathematics needs may help to focus student efforts on content, and indeed foster motivation.

Discussions with staff led to the identification of some specific mathematics content viewed as exceptionally difficult for learning. As mentioned above, these included spatial visualisation, algebraic manipulations, abstract notions, complex numbers and mechanics. It is noted that elements of such content depict more mathematics *skills* and applications than knowledge. Special attention is needed to better relate such material to existing student understanding, and to provide a wider range of examples and exercises to demonstrate both concept and application. Furthermore, perhaps greater attempts are needed to explicitly identify generic and transferable mathematics skills, such as rules of logic, function and equation visualisation, algebraic substitution and manipulation. Similarly, skills enabling tools, such as graphical interfaces, plotting tools and interactive mathematics experiments were proposed almost unanimously by all engineering staff involved in mathematics teaching. Such features are also expected to be attractive to teachers as lesson aids.

Special effort should be given to troublesome topics in mathematics which inevitably lead to a transformation in understanding once overcome, i.e. *threshold concepts* (Meyer and Land 2003, Cousin 2006). Although ongoing research is needed to identify such thresholds in mathematics and engineering education, the approach may lead to a sub-core of critical mathematics concepts which are enabling of other understanding. One interesting approach being explored by researchers at Imperial College is the use of student-generated concept maps to identify the development of understanding and its wider connection to engineering content (Holloway 2009). The use of mathematics concept mathematics for content management may also help students in connecting understanding, and relating these to their engineering topics.

As mentioned previously, the content of the gateway should focus on examples and worked solutions, exercises for practice and graded tests for self-evaluation. Examples and exercises should include both general and engineering-oriented formats. The benefit of abstract mathematics tuition is training in the use of consistent mathematical language and notation (c.f. HELM project (Davis *et al.* 2005, Sangwin 2005)). However, where possible, explicit demonstrations as how to apply and transfer general concepts should be made.

Social learning (see full report for further details)

- Data from this research shows that students do not on the whole consider online social networks as relevant or helpful for academic learning.
- Such beliefs may denote the student inexperience with such a learning format, and examples of effective online learning groups have been reported in the literature (Clouder *et al.* 2006, Hall *et al.* 2009). An online social dimension could complement actual work (i.e. tutorial, study or design) groups, and indeed act as a means of welcoming and inducting new students to the University community.

5. Towards a maths gateway website.

As a means of consolidating the guidelines described above, an outline design for the mathematics gateway is presented in Figure 7. Figure 7(a) provides an overview of the entire site, which includes components such as equation solvers, department-specific resources, online tutor calling / booking, basic mathematics tools, and year and department specific entry to the online resource area. Figure 7(b) provides an overview of the online resource area for pre-entry students, and includes topic and concept maps, diagnostic tests (and subsequent study plans), information to help foster motivation for mathematics study, and extra attention on typical troublesome topics. Key mathematics content can be driven by institution specific

software (such as METRIC in the case of Imperial College), or be linked to other external resources. Where possible, an indexing system to connect to specific topics of the external resource (rather than its home page for example) is needed; such connections are referred to indexed links in Figure 7. An overview of the online resource area for year specific students is given in Figure 7(c). Here, specific content organisation is under a lecture page so as to emphasise needs of and connections to specific lecture topics. Options also exist for teacher uploads of problem sheets and tests, as well as for formal online testing.

As a further national consultation and engagement exercise, the above data and recommendations were presented at a meeting organised by the Higher Education Academy (HEA) in April 2009. The meeting was attended by 20 participants with representation from the Universities of Aston, Bradford, Derby, Kingston, Leeds, Portsmouth, Sheffield, Wolverhampton, Imperial College and the HEA. Expressions of interest were also sent by representatives from the Universities of Coventry, Glasgow and Loughborough. Key discussion points in the meeting included: practices and experiences in light of the survey data of this work; the effectiveness and viability of online tutor groups; the extent of and approach to mathematics contextualisation; and views on the gateway design outlines presented in Figures 7(a)-7(c). Main issues, recommendations and suggestions from the meeting are summarised below:

- The possible separate and relatively short-term development of two attractive components of the mathematics gateway: (i) a shared national database of engineering-subject specific problems and examples; (ii) the identification of, and resource development for, *troublesome* mathematics topics.
- Encouragement for the development of attributes such as: (i) the use of motivational and promotional material to raise student interest in mathematics learning and indeed the engineering profession; (ii) student guidance on the nature of mathematics learning at University, and other general school-University transitional guidance; (iii) the personalisation of mathematics, i.e. “people and engineers who do mathematics for...” rather than “this is the mathematics you need”.
- The quality of online mathematics communication will depend on how effectively the language of mathematics (e.g. equations, symbols and sketches) can be transcribed in real-time. This was considered by the group as a fundamental technological barrier to the online learning and teaching of mathematics. Similarly, correct student motivation is needed to encourage students to contribute and interact online. Nevertheless the social dimension of learning was deemed by the group as important.
- At one extreme *contextualisation* can be viewed as abstract mathematics teaching but motivated by examples of potential use and applications. At another extreme, it can be viewed as problem-based learning. The group felt that a gradation of such contextualisation is required, such that students who haven’t grasped basic mathematical principles are not confused or distracted by an overly complex problem scenario. In other words, weak students may benefit more from traditional, first-principles teaching. Problems and examples should therefore represent the range of abstract to applied situations, and where possible identify approaches to dealing with applied problems.
- Assessment components within the site, such as online submission of problems, can act as an important motivational driver for student use.
- The availability of such a site may also prompt teachers to consider the mathematics content and needs of their lectures. Where the *service teaching* of

mathematics takes place (e.g. teachers from the mathematics department), the site would act as a helpful resource for the teachers themselves.

6. Conclusions

The aim of this work was to propose features of an online mathematics gateway which would be attractive to both pre-entry and current University students, but also to staff involved in mathematics teaching. Discussions with key people in education, mathematics education and e-learning were conducted at Imperial College London and nationally and a student survey was utilised in order to meet the objective. It is proposed that a mathematics gateway should be flexible in order to address the different needs of pre-entry and University students but also to accommodate departmental needs in content, including worked solutions of discipline-oriented examples. Social aspects of the gateway should be explored, especially for pre-entry students. Continuous enhancement through user feedback and publicity should be enforced to ensure sustainability and beneficial use of the tool.

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Appendix: Outline of questions for the student survey.

- (1) Please specify your department.
- (2) Please indicate your current year of study.
- (3) What is your gender?
- (4) What mathematics qualification(s) do you hold?
- (5) How difficult was it for you to cope with the mathematics at the start of your course as compared to the other courses?
- (6) During your 1st year of studies, were you tested in Maths under a Mastery rubric (i.e. you needed to obtain a mark over a threshold in order to pass the exam)?
- (7) What mark did you obtain at the mathematics Mastery exam?
- (8) Please note how much you used and how beneficial were each one of the following methods and resources for learning mathematics:
 - a. Lectures and lecture notes.
 - b. Tutorials (study groups) and tutorial sheets.
 - c. Online resources (e.g. METRIC).
 - d. Library (i.e. use of books).
 - e. Discussion with peers (i.e. U/grads in your or other departments or colleges).
- (9) How much discipline-oriented (e.g. engineering-oriented) were your mathematics lectures and tutorial sheets?
- (10) How would you characterise your current ability to tackle problems that involve mathematics in courses other than mathematics?
- (11) Have you ever heard of METRIC? (It is an Imperial College online mathematics database meant to be used for reference and practice during the course of your studies)
- (12) How did you hear about METRIC?
- (13) How many times did you log on to (or used the CD of) METRIC
 - a. prior to entry?
 - b. during the 1st term?
 - c. since the end of 1st term?
- (14) Did you experience any problems when using METRIC?
- (15) What feature(s) did you like most in METRIC?
- (16) Overall how useful did you find METRIC in your mathematics learning experience in the college?
- (17) In average, how much time a day during term time do you spend browsing the internet (including emails)?
- (18) How often do you use the internet for
 - a. social networking (logging on to websites like Facebook, Myspace, Bebo, Windows Live and chat rooms)?
 - b. purposes related to your studies?
- (19) How often do you use
 - a. Wikipedia (either related to your studies or not)?
 - b. the portal MyImperial?
 - c. a Virtual Learning Environment (VLE) (e.g. Blackboard, Moodle or departmental)?
 - d. Olivia (library's online course on how to search for and use info)?If you use any of the above at least twice a week, please tell us why
- (20) Have you used software or online resources which you found especially helpful in learning new material (maths or otherwise)?
- (21) Which features do you think would make an online learning resource more attractive to you and enhance your learning experience?

Table 1: Typical discussion points with academic staff involved in mathematics teaching at Imperial College.

Mathematics teaching	Online resources
Weak mathematics subjects	Use of Virtual Learning Environments (VLEs)
Remedial mathematics course	Use of other online tools to enhance teaching
Tutor-to-student ratio in mathematics courses	Opinion on and use of METRIC
Use of engineering examples in mathematics	Features in an online mathematics tool
Use of diagnostic and/or mastery tests	

Table 2: Background info of survey participants.

Department	Response count	Response frequency
Physics	153	18.8%
Bioengineering	107	13.2%
Chemistry	101	12.4%
Mechanical Engineering	78	9.6%
Chemical Engineering	75	9.2%
Aeronautics	65	8.0%
Computing	62	7.6%
Civil & Environmental Engineering	61	7.5%
Electrical & Electronic Engineering	59	7.3%
Materials	32	3.9%
Earth Science & Engineering	19	2.3%
Year of Study		
1 st	304	37.4%
2 nd	250	30.8%
3 rd	174	21.4%
4 th	84	10.3%
Gender		
Male	574	70.7%
Female	238	29.3%
Qualification		
A-Level	669	82.4%
A-Level equivalent	143	17.6%

Tables 3-5: See full report.

- Table 3: Perceived difficulty of mathematics at the beginning of the course compared with other subjects. Students who hold an A-level in Further Maths score significantly better ($p < 0.01$) than those who do not.
- Table 4: Mastery examination grades. A 4-point scale (shown in brackets) was used to score the achievement in mastery. Students who hold an A-level in Further Maths score significantly better ($p < 0.01$) than those who do not.
- Table 3: Perceived level of mathematics contextualisation within the engineering discipline. A 5-point scale (shown in brackets) was used to score student perception.

Table 4: Overview of some current online mathematics resources.

Resource	Attractive features
<p>Mathcentre</p> <p>www.mathcentre.ac.uk access: free level: bridging; university</p>	<ul style="list-style-type: none"> ▪ content organisation into subjects (i.e. disciplines) such as bioscience, economics, engineering ▪ topic lists within each subject leading to materials ▪ materials include: quick-reference and facts and formulae leaflets; teach yourself and revision booklets; iPOD and 3GP downloads ▪ video tutorials through Mathtutor (www.mathtutor.ac.uk) as well as diagnostics tests; specifically aimed as a bridging resources with more than 80 topics and online or DVD-ROM formats ▪ 16 general mathematics topics under the engineering subject ▪ student and staff areas ▪ staff information on: “best practice guides and case studies”; research papers on mathematics education ▪ links to external resources
<p>Math.se</p> <p>www.math.se access: subscription level: bridging</p>	<ul style="list-style-type: none"> ▪ online tutor support ▪ online test submission and marking ▪ student discussion forum, group projects and networking opportunities ▪ interactive components ▪ study plans ▪ scaled tests – “basic tests” and “final tests”
<p>MathWorld</p> <p>mathworld.wolfram.com access: free level: university (but wide usage)</p>	<ul style="list-style-type: none"> ▪ comprehensive mathematics database ▪ content organisation under key topics and alphabetical lists; advanced search engine facility also provided ▪ some (very limited) topics under applied mathematics for engineering ▪ selection of engineering relevant interactive material under the “Wolfram Demonstrations Project” (i.e. for the dynamic (visual) computations to “illuminate concepts in science, technology, mathematics, art, finance,...”) ▪ interactive demonstration materials indexed to core content pages ▪ links and citations to books and journal articles ▪ quick reference sheets provided through “capsule summaries” ▪ interactive entries with the use of Mathematica for simulation / application / derivation / visualisation; also use of animated GIFs and LiveGraphics 3D Applets ▪ user uploads possible
<p>nrich</p> <p>nrich.maths.org access: free level: school (ages 5-19)</p>	<ul style="list-style-type: none"> ▪ mathematical games, problems and articles organised under different school learning stages ▪ forum for sharing solutions and discussion ▪ online tutor support: discussions organised under categories such as “please explain” ▪ material organised under monthly themes, such as “analysing”, “mathematical modelling” and “statistics” ▪ student and staff areas ▪ staff information on: supporting material for the month’s theme; curriculum mapping documents which identify how nrich components relate to specific content and process (skills) needs of school curricula; research / education papers; mathematics shop for purchasing textbook and activity materials ▪ use of colourful icons in the organisation of the site ▪ problem level indicators using a star grading system ▪ link to thesaurus.maths.org ▪ “used for extension problems and wider reading for our most able sixth form students” (Mathematics teacher and Deputy Head; private communication)

Figure 2: Features the survey participants liked most in METRIC (N = 346) (see full report)

Figure 3: Use and benefit of different resources to learn mathematics. Absolute number of responses per category is shown in each column.

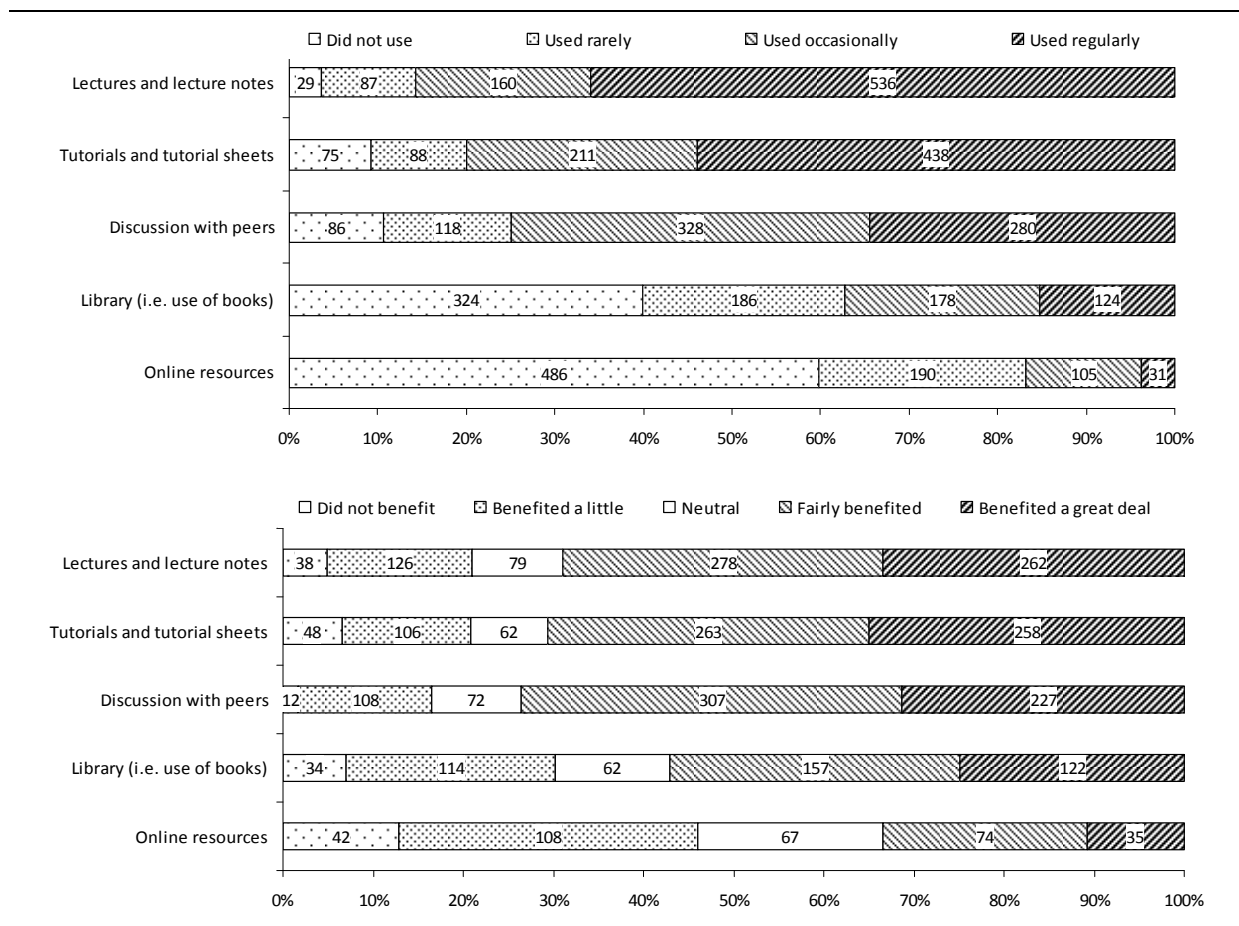


Figure 4: Mean scores for (a) use and (b) benefit of learning resources for high and low achieving students (i.e. mastery grade). A 4-point scale was used to score the level of use and a 5-point scale the level of benefit of learning resources.

(a) Score 1 represents *did not use* and score 4 represents *used regularly*.

(b) Score 1 represents *did not benefit* and score 5 represents *benefited a great deal*.

‡ denotes significant difference ($p < 0.01$).

Low achieving students feel significantly less benefited from using lectures and tutorials and more benefited from using online resources than high achieving students.

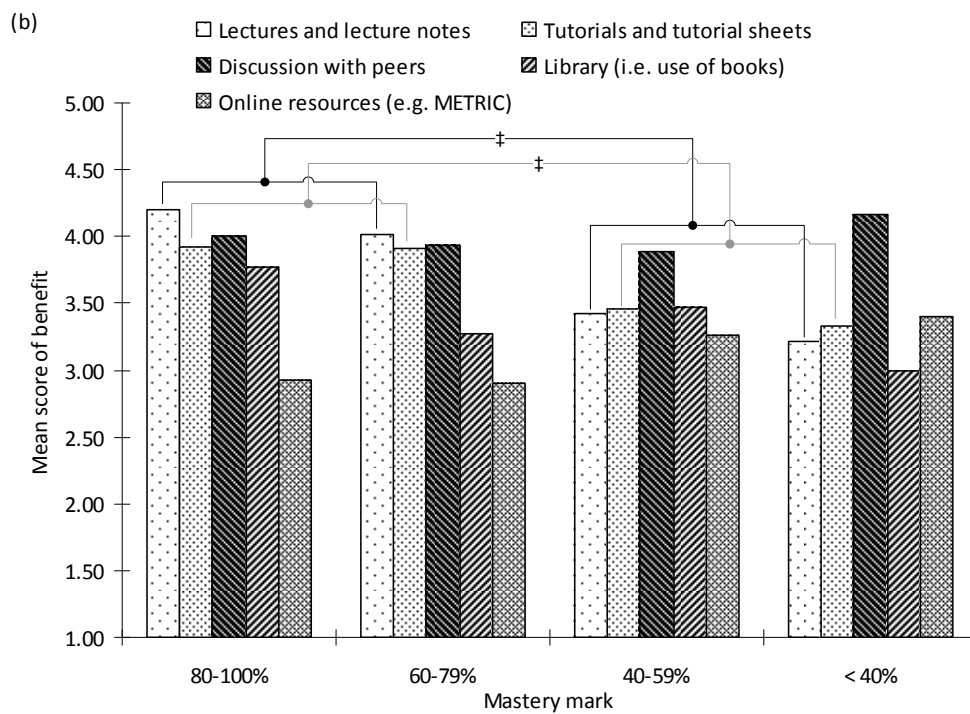
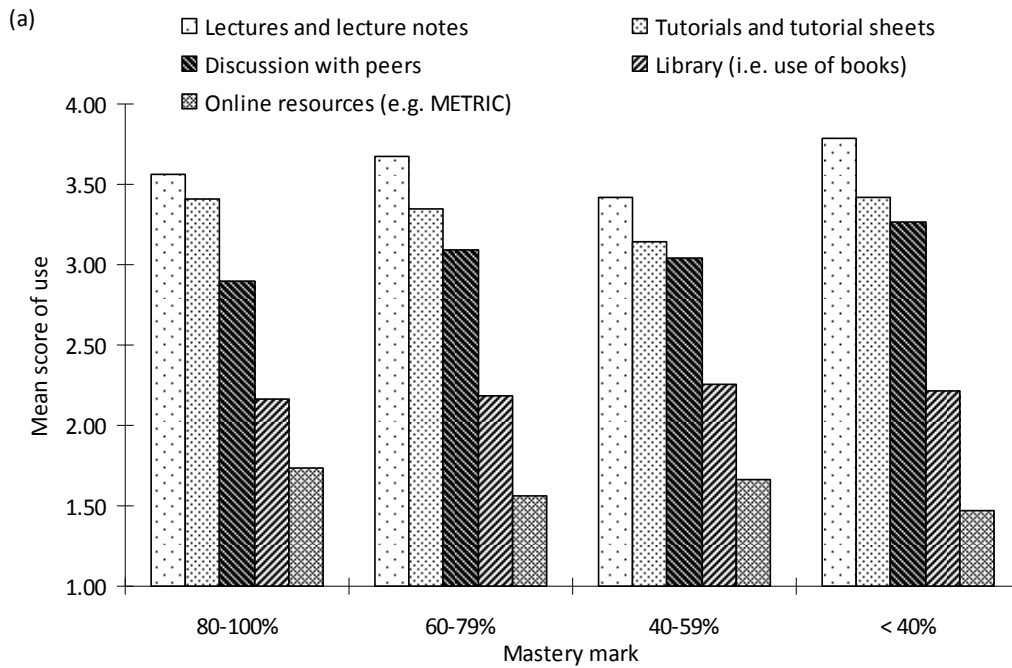


Figure 5: Use of internet. Absolute number of responses per category is shown in each column.

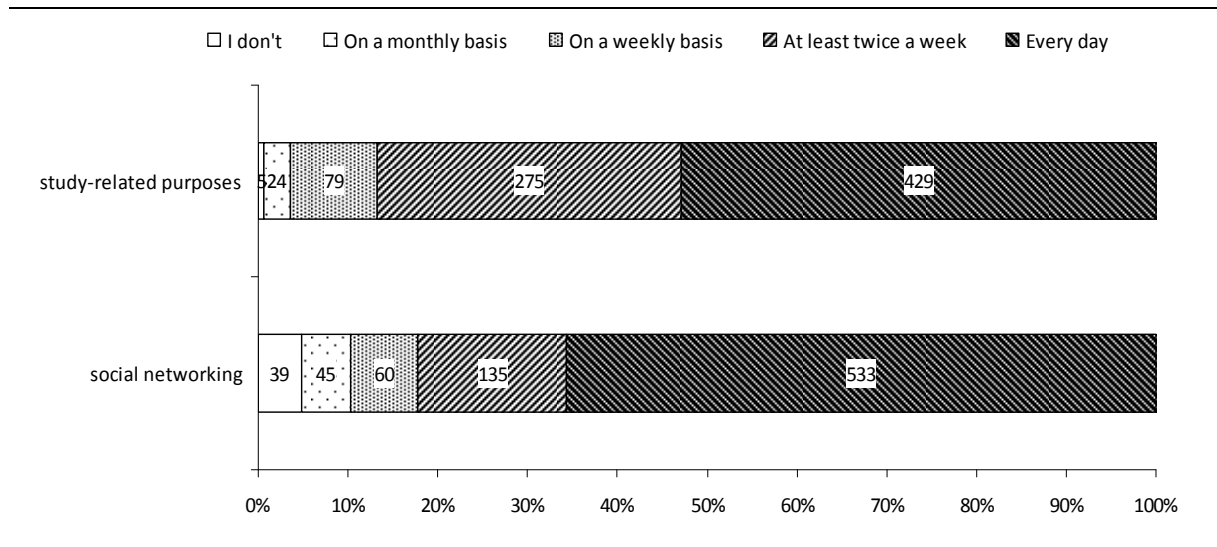


Figure 6: Online resources found especially helpful in learning new material (sample size $N = 113$).

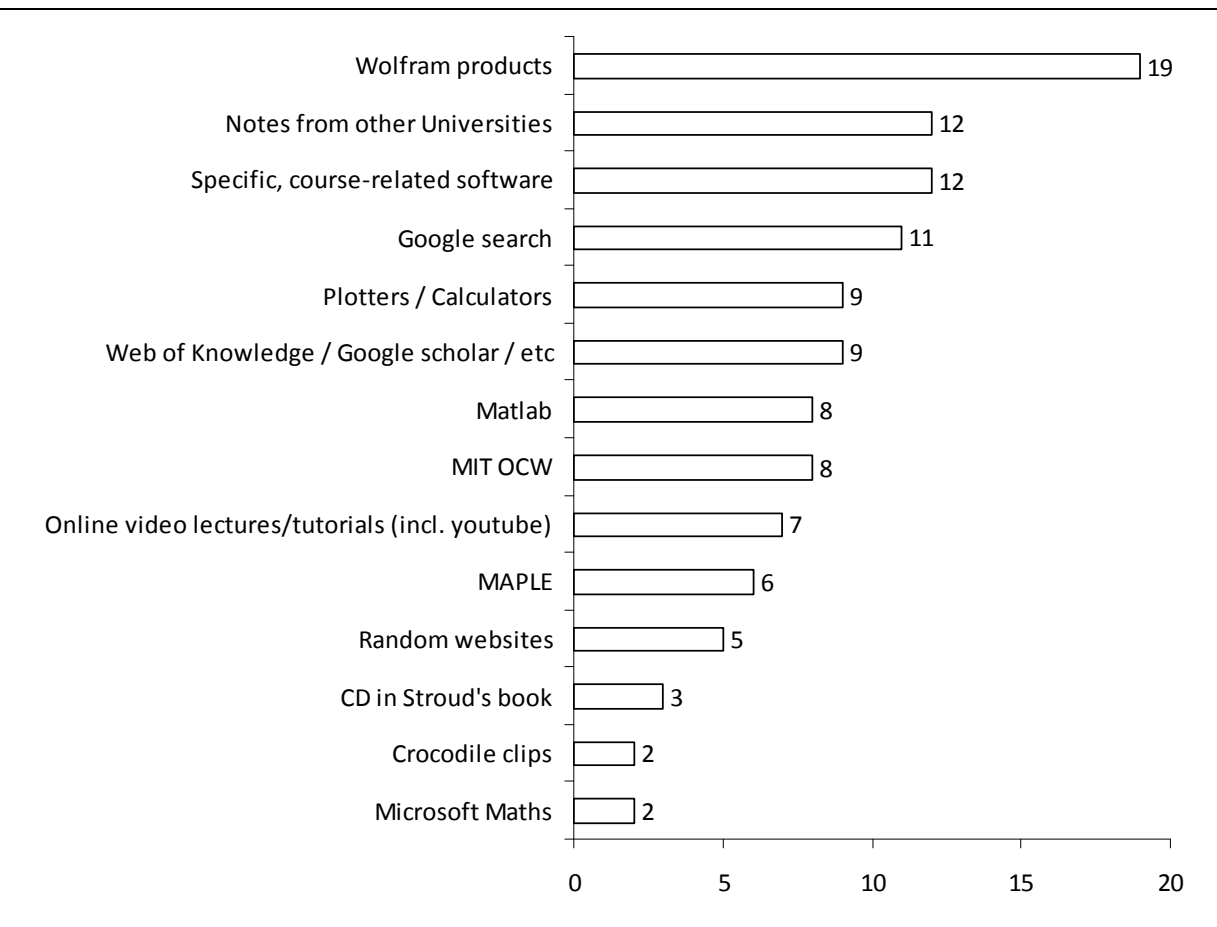


Figure 7: Features attractive to an online learning resource.

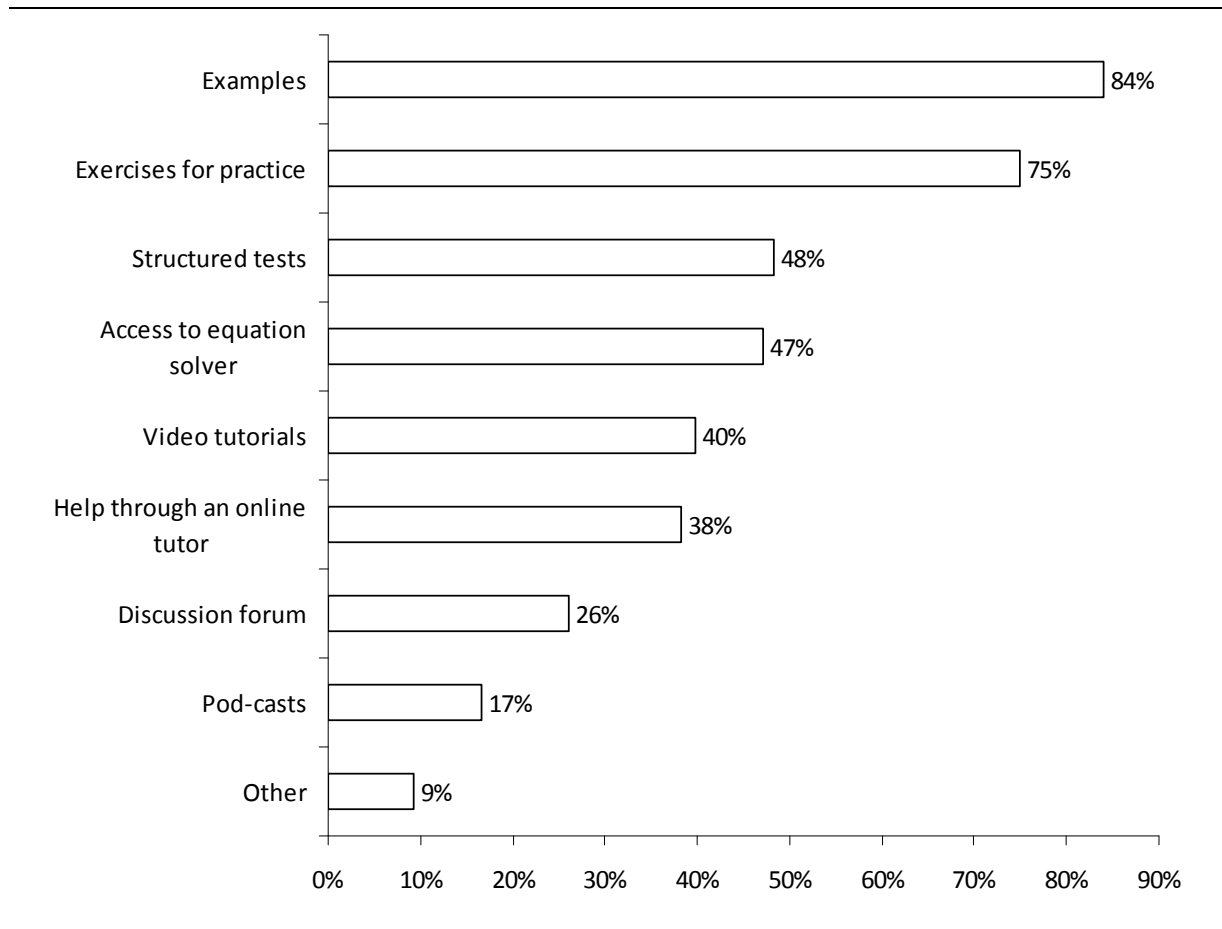
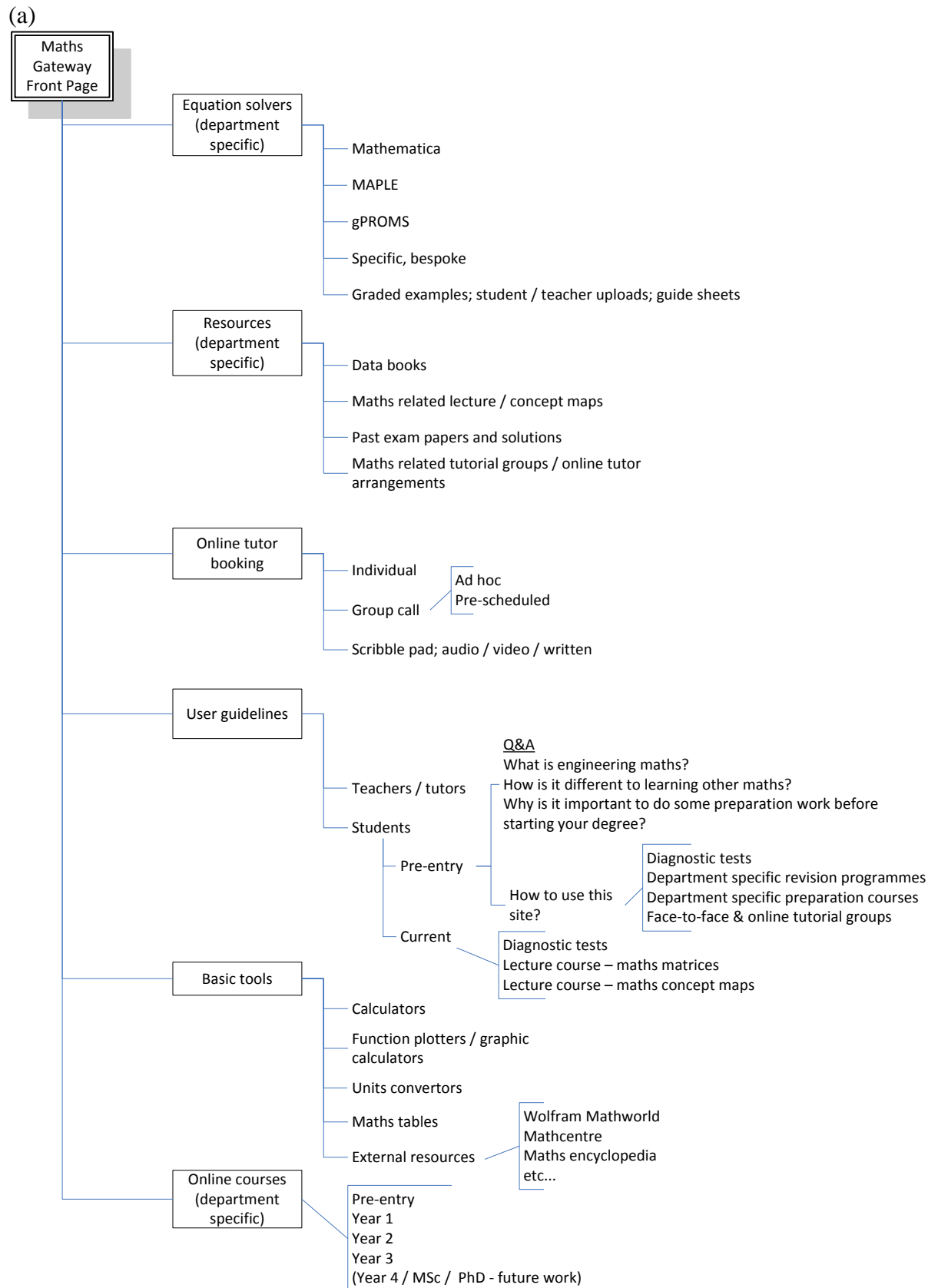
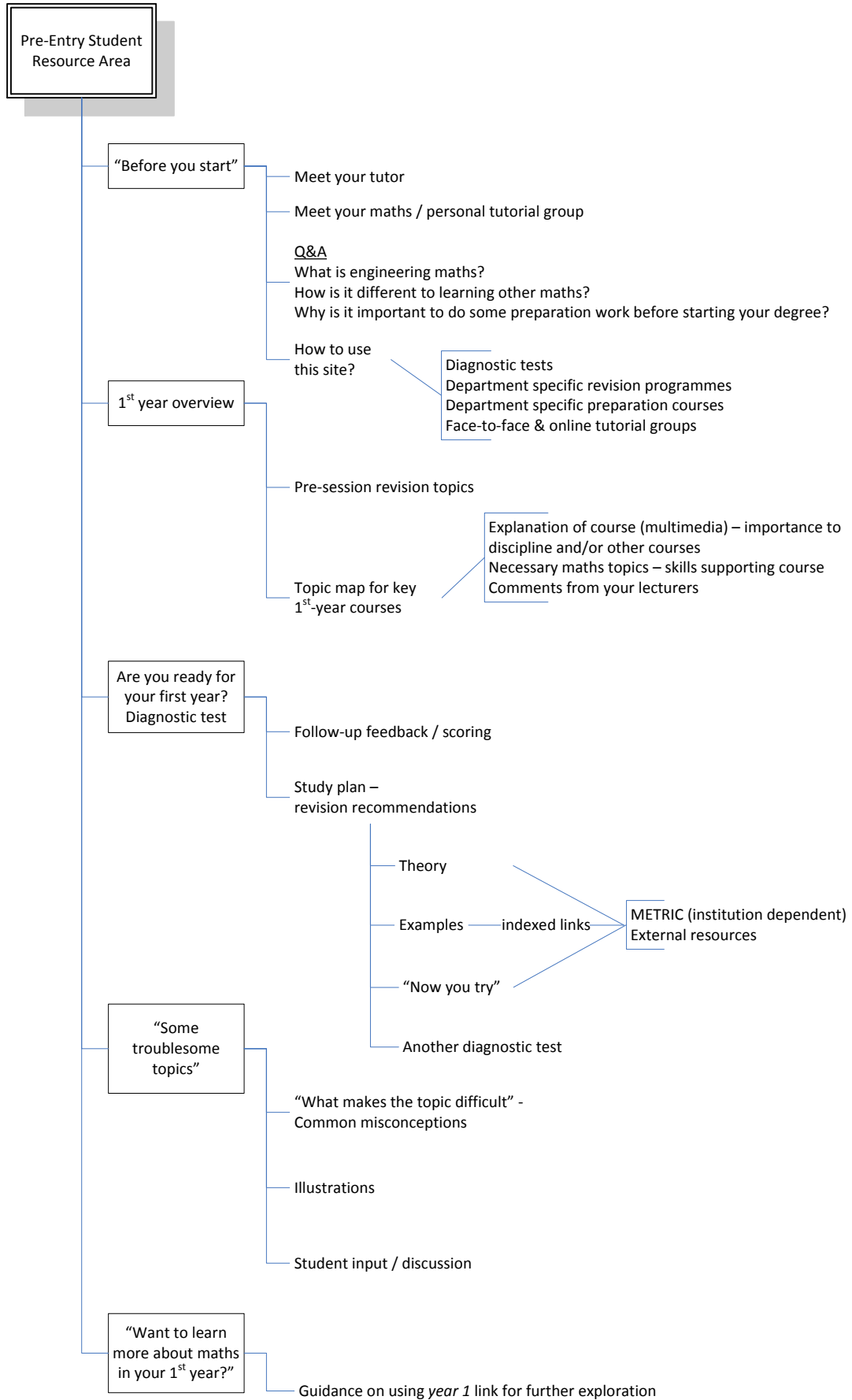


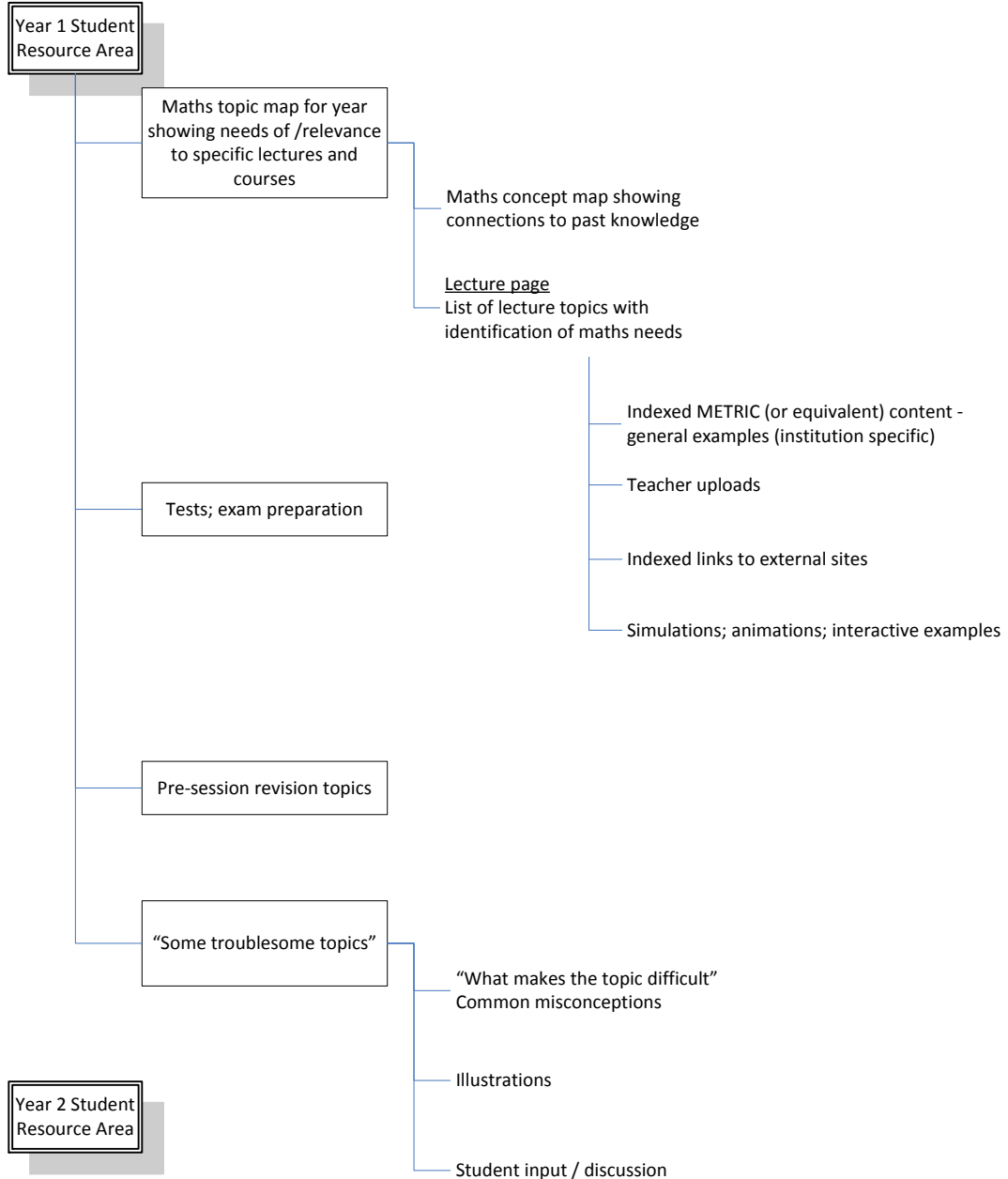
Figure 8: Site outline plans for the mathematics gateway: (a) overall site; (b) pre-entry student resource area; (c) year specific resource area.



(b)



(c)



(Similar to Year 1)

Year 3 Student Resource Area