



## Project Plan: ExPOUND (Loughborough University)

### Overview of Project

#### 1. Background

Many undergraduates arrive enthusiastic about mathematics, but become alienated as the emphasis shifts from performing calculations to understanding/reconstructing/adapting/applying theorems and proofs, and eventually leave feeling that they no longer like mathematics (Solomon, 2007). This impacts the whole mathematics education system because it includes some students who would have become strong mathematics teachers. Given the government's commitment to increasing the number choosing to study mathematics and related subjects at university (eg, Further Mathematics Network, More Maths Grads), it is important that the community finds ways to help students succeed in making the transition to proof-based mathematics.

Interacting with theorems and proofs requires new skills that are usually not developed at earlier stages. Research in mathematics education indicates that new undergraduate students do not typically understand the status of definitions in mathematics (Vinner, 1991), that their beliefs about what constitutes proof differ from those of mathematicians (Harel & Sowder, 2007), and that weak understanding of logical language prevents them from determining whether a proof is valid (Selden & Selden, 2003).

In order to fully understand a proof, students need to develop (at least) two key skills:

1. *Inferring warrants*: Identifying the earlier statements, definitions or theorems that imply each line of the proof (Alcock & Weber, 2005).
2. *Identifying structure*: Recognising the overall type of proof and breaking it into subproofs leading to intermediate results (eg, Yang & Lin, 2008).

Both skills are important for being able to see similarities and differences across proofs and being able to reconstruct or adapt them appropriately, as is required for examinations.

It is vital that students learn these skills because later pure mathematics courses are 'all proofs': students will typically be expected to understand and reconstruct around 20 15-line proofs and many shorter arguments, all of which are based on formal definitions and are expressed in similar notation. At present many resort to rote memorisation, and even those who do well in examinations may achieve this without deep understanding of why their proofs are valid (Bergqvist, 2007).

When presenting a proof lecturers give additional verbal explanation about warrants for lines and overall structure, but this is not recorded and it is not clear that students can follow it in real time. One might ask, why not just record the lecture? While this would allow a student to see explanations again, it does not address the problems of directing attention precisely and of seeing relationships in real time. One might also ask, why not provide additional written information to accompany the proof? This would also preserve the explanation, but proofs can already be intimidating, and annotations or a "two column" approach could easily more than double the length.

#### References

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- Harel, G., & Sowder, L. (2007). Toward a comprehensive perspective on proof, In F. Lester (Ed.), *Second Handbook of Research on Mathematics Teaching and Learning*, National Council of Teachers of Mathematics.
- Selden, J. & Selden, A., (2003). Validation of proofs considered as texts: can undergraduates tell whether an argument proves a theorem? *Journal for Research in Mathematics Education*, 34, 4-36.
- Solomon, Y. (2007) Not belonging? What makes a functional learner identity in the under-graduate mathematics community of practice? *Studies in Higher Education*, 32, 79-96
- Vinner, S. (1991). The role of definitions in teaching and learning mathematics. In D. O. Tall (Ed.), *Advanced Mathematical Thinking* (pp. 65-81). Dordrecht: Kluwer.
- Yang, K.-L. & Lin, F.-L. (2008). A model of reading comprehension of geometry proof. *Educational Studies in Mathematics*, 67, 59-76.

## 2. Aims and Objectives

This project proposes to construct a web application that will allow lecturers to create and share *e-Proofs*: interactive versions of proofs (or other longer arguments/derivations) annotated to highlight their structure and to indicate the warrants that must be inferred in order to understand their line-by-line validity. The student interacts with an e-Proof by scrolling through the screens or selecting a particular screen to watch. They can then click to hear the audio explanation; annotations appear and disappear as this proceeds. This means that:

- Attention is directed precisely.
- Relationships are explicitly highlighted by coordinating the appearance of annotations with audio commentary.
- Audio can be replayed as many times as the student wishes.
- Visuals are clear and without extraneous distractors.
- Annotations appear one at a time and do not have to involve adding words to the proof, so the integrity of the proof itself is preserved.
- Navigation to a specific point of difficulty is straightforward.

In this format, the reasoning one needs to do to understand a proof is made explicit in a way that could not be achieved in a lecture or a book.

The ExPOUND authoring tool will offer the lecturer the following functionality to enable the construction of an e-Proof:

- Mathematical notation editor (LaTeX-based) for writing each line;
- Facility to choose, for each “screen”, which parts are to be visible, invisible or “greyed out”;
- Audio file import and facility to associate an individual file with an individual screen;
- Facility to add arrows, boxes and other annotation to the screen, synchronising the appearance of these with the audio commentary;
- ‘Playback’ control options;
- Export to content package: \*.zip file; the work required to export to appropriate standards (IMS CP / SCORM 1.2) will be scoped and inform the development roadmap.

## 3. Overall Approach

The development of ExPOUND will be guided by the following principles in line with those of the JISC e-Learning Programme:

- **Open Source:** the source code and documentation for the web application will be made freely available under the terms of the GNU GPL (except where third-party components are used, which will themselves be OS if possible).
- **Open Standards:** it is likely that the application will be based on PHP / MySQL, Flash, and XML. The project will scope the work required to export e-Proofs as IMS / SCORM content packages. ExPOUND will be developed as a web application rather than as a desktop application as was originally envisaged so that for the end-user it is platform-independent.

The development team will develop for and test against multiple browsers and operating systems. In the first workpackage, the team will investigate the feasibility of basing ExPOUND on the Xerte Online Toolkit developed at Nottingham, promoted by JISC Techdis, and itself adhering to the open source / open standards approach.

- **Sharing:** e-Proofs created during the piloting of ExPOUND and thereafter will be made available through JORUM and [mathcentre.ac.uk](http://mathcentre.ac.uk). In its early stages, the project will look at the feasibility of exporting project files as well as completed e-Proofs so that lecturers in other institutions can edit them and create their own versions (eg. adding a supplementary audio comment or annotation).
- **Universal benefit:** the tool itself and e-Proofs created with the tool will be useful to mathematics lecturers and students across the sector. In addition, as mathematical techniques are important to other subjects such as engineering, the benefits are potentially much wider.
- **Evidence-based and supporting good practice:** as outlined in Section 9, the project builds on previous research and academic practice within the project team and addresses serious issues in the subject area. Lara Alcock is a researcher in undergraduate mathematics education and a member of the MEC research group, which is the largest single group of academics in the UK researching mathematics education in HE (over 50% of its work was designated as internationally-recognised or better in the recent RAE).
- **Continuous engagement:** in addition to maintaining regular communication between the project team and JISC, the project team will seek the engagement of other stakeholders including the MSOR Network.

The development approach (see Technical Approach below) will allow for relatively easy integration of ExPOUND in due course with Moodle via the latter's plug-in architecture, an enhancement which would be of benefit to Loughborough and other Moodle institutions. However, at this stage the priority is to produce a tool that can be used by any mathematics lecturer without tie-in to a particular VLE, again in line with JISC principles.

With respect to sustainability and sharing of project outputs, several members of the project team have relevant experience via other JISC projects, including projects focused on tool development (eg, WebPA - <http://webpaproject.lboro.ac.uk/>). Similarly the MEC led a successful FDTL4 Project "Helping Engineers Learn Mathematics" which developed extensive e-assessment materials (<http://helm.lboro.ac.uk>). 34 FE and HE establishments are registered to use HELM resources. Sustainability will be addressed partly by embedding the use of ExPOUND at Loughborough, and partly by promoting an external user community in a way already successful with WebPA.

The project will investigate the feasibility / desirability of packaging e-Proofs as IMS CP or SCORM 1.2 packages but will NOT undertake the work of implementing the recommendations. Similarly, while it may be useful in due course to have audio editing functionality built in to the tool, it is not envisaged that there will be sufficient time / budget to undertake the work required at this stage. (ExPOUND V1 will allow the user to browse for and embed in the e-Proof individual audio files which have been edited externally using a tool such as Audacity.)

We have identified the following critical success factors for the project:

- Engagement of mathematics lecturers at Loughborough
- Positive response from students at Loughborough
- Engagement of mathematics lecturers across the sector ,eg. through the MSOR Network
- Positive response from students across the sector
- Integration of tool / tool output into VLE
- Technical future-proofing

## 4. Project Outputs

Tangible deliverables:

- 2 interim reports and a final project report;
- 1 interim 3<sup>rd</sup> party project evaluation and a final project evaluation;
- ExPOUND V1.x e-Proof authoring tool released to the sector;
- Full technical documentation and user guides (including Captivate video tutorials);
- Project website;
- Website for ExPOUND user community;
- At least 8 completed e-Proofs published via JORUM / mathcentre.ac.uk / ExPOUND user website;
- Recommendations / roadmap for further development.

Less tangible knowledge and experience:

- Students at Loughborough (and beyond, depending upon the speed with which lecture usage follows take-up of the tool) will have access to new learning resources designed to teach skills in proof comprehension that are usually not an explicit focus of lectures.
- Lecturers involved in testing early versions of ExPOUND will have the opportunity to articulate their views on what they are hoping their students will understand. This information will be included in the project reports where appropriate, and will be used to expand the team's knowledge of the technical and pedagogical requirements of current mathematics lecturers.
- Students involved in testing early versions of ExPOUND (in the context of wider projects) will have the opportunity to articulate their views about what is necessary for them to understand proofs. This information will likely inform those team members involved in mathematics education research regarding possible research projects involving use of the tool.
- Formal and informal discussions between team members and mathematics department colleagues will contribute to an increase in our shared knowledge about the teaching and learning of undergraduate mathematics, and the ways in which both general and specialist technologies might contribute to this.

## 5. Project Outcomes

As in 4., plus:

- Some lecturers will incorporate the e-Proofs produced into their courses, with a significant likely impact on what students attend to and what lecturers discuss.
- Updates about the tool will be shared with the undergraduate mathematics teaching community via the MSOR Network (conference and website). These will include theoretical discussion about the problems the tool is designed to address, thereby raising awareness within this community of mathematics education research that focuses specifically on the learning of proof.
- Impact upon the mathematics education research community is likely to be greatest after the end of the project, and dependent upon further funding being secured to conduct related research.

## 6. Stakeholder Analysis

Internal

Stakeholder	Interest / stake	Importance
All mathematics students in the courses for which e-Proofs are produced	To be given fair and equal access to the online application	High
Academic staff in mathematics at Loughborough	To have a comparable experience and continuation	Medium

	of service between each version.	
IT Services team responsible for institutional Moodle installation	To have involvement in the scoping of integration of the ExPOUND tool into the system used at Loughborough	Medium
Pro Vice Chancellor for Teaching (PVCT) at Loughborough	To make sure the application and recommendations are of the highest standard so that Loughborough's reputation is assured.	Low

### External

Stakeholder	Interest / stake	Importance
MSOR Network	To receive and disseminate information about the tool to community members who may be interested in using it to improve their teaching, thus assisting with community building	High
Potential adopting institutions	Adopting pilot institutions during the project will need to have full support both technically and pedagogically to ensure a successful adoption.	Medium / low

## 7. Risk Analysis

Risk	Probability (1-5) (5 = high)	Severity (1-5) (5 = severe)	Score (P x S)	Action to Prevent/Manage Risk
Failure of staff to deliver targets and / or to required level	2	4	8/25	Staff Induction, training and continuous development. Realistic timetable and achievable targets. Previous experience in learning technology development. Support and commitment from all.
Failure to engage academics to use the application	2	4	8/25	Sufficiently many mathematics staff members are fully committed to the application and understand the project's aims and objectives. Realistic timetable and achievable targets.
Low take up by other institutions	3	2	6/25	Development of a application that can be used primarily in math, but could provide a crossover into other subject disciplines
Failure to engage a suitable external evaluator	1	1	1/25	Low risk, low severity
Departure of project team	2	4	8/25	Where possible, ensure others can

staff				pick up responsibilities
Unexpected technical obstacles	3	3	9/25	The team have already conducted extensive research during the proposal preparation stage and are confident of finding workarounds for any difficulties

## 8. Standards

Name of standard or specification	Version	Notes
Web Standards (CSS, XHTML)	eg. CSS V2	The project will adopt the standards associated with web development practices
Open source	GNU	The project will incorporate open source best practice where possible
Open Standards	PHP v5, MySQL	The project will use accepted frameworks on which to build the tool to enhance the probability of cross platform implementation
	IMS / SCORM	During the scoping (WP5) for future work and export format the project will consider the standards accepted and used in education
Sharing	JORUM	The project will through the contributor licence make the e-proofs created by the project available to all other academic tutors wishing to re-use the examples
Creative commons	TBC	Where appropriate the project will seek to release all the documentation and reports under the creative commons licence.
Proprietary: Flash / ActionScript	TBC	Flash is a proprietary format owned by Adobe (NB - <a href="http://standards.jisc.ac.uk/catalogue/Flash.phtml">http://standards.jisc.ac.uk/catalogue/Flash.phtml</a> needs updating). However, it is virtually ubiquitous and likely to be the best bet for the ExPOUND tool / e-Proof interfaces. The Xerte Online Toolkit promoted by Techdis is Flash-based.

## 9. Technical Development

The project will adopt an *agile* style development methodology. This will assist in the rapid development practices that the project wishes to use. These practices will ensure that the project is delivered with a high level of user input to ascertain the specified requirements are met in a timely and appropriate manor.

In addition the project will try to develop the application using a RESTful style architecture allowing for any future web service or API to be developed. This will be assist in making it possible to offer interoperability easily in the future.

A version control system (potentially SVN) will be used by the project. This will allow the safe and secure storage of the tools code, allowing updated to be easily developed and help manage the development process. Through this the project hopes to produce a robust system promoting the open source ethos of open, available code. In addition the SVN will allow the project to deliver updates and fixes to the code easily to any adopting institutions.

## 10. Intellectual Property Rights

The outputs of the project will be released under appropriate licences. The tool's source code will be the copyright ownership of Loughborough University and as such will be made available via the GNU GPL which supports the Copyleft movement.

In addition the documentation, associated reports and other tangible outputs from the project will be made available to the wider community, predominantly through the project's website and the institution's open access repository under the most relevant creative commons licence. As the project intends to utilise the exhaustive knowledge and tools available to the educational sector, where possible the project will prevent duplication and use tools and applications such as the Xerte Online Toolkit whose open source licences are compatible. Where other licences are used by third party services the project will seek the advice and guidance of OSS-Watch and the JISC Legal advisory services. All the work in this area will be fed back into the JISC community in the most appropriate way.

Furthermore, the expected output of the example e-Proofs will be released to the community via the JORUM service under a derivative of the Creative Commons licence that is yet to be decided.

Lastly the project team reserves the right to publish articles in scholarly or other journals, conference proceedings, etc, based on the results of the project. Where it is possible the project team will try to maintain the copyright for the materials and make them available to the wider community via the institutional open access repository.

## *Project Resources*

### 11. Project Partners

N/A

### 12. Project Management

#### Project Staff

Staff	Title	Role	Contact
Dr Lara Alcock	Lecturer in Mathematics Education, Mathematics Education Centre (MEC)	Pedagogic Lead	<a href="mailto:l.j.alcock@lboro.ac.uk">l.j.alcock@lboro.ac.uk</a> / 01509 22 8255
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Charles Shields	Head of E-learning	Project Manager [REDACTED]	<a href="mailto:c.f.g.shields@lboro.ac.uk">c.f.g.shields@lboro.ac.uk</a> / 01509 222405
Nicola Wilkinson	Senior Developer, EngCETL	Developer	<a href="mailto:n.wilkinson@lboro.ac.uk">n.wilkinson@lboro.ac.uk</a> / 01509 227186

Project Acronym: ExPOUND  
Version: 1.01  
Contact: Lara Alcock – l.j.alcock@lboro.ac.uk  
Date: 9 April 2009

All mail relating to the project should be sent to:

Charles Shields  
Project ExPOUND  
University Library  
Loughborough University  
Leics LE11 3TU

### **Training**

No specific training needs have been identified at this stage.

### **Project Management / Decision Making**

Charles Shields, Head of E-learning based in the University Library, has been designated the Project Manager for ExPOUND. However, the project is officially a Mathematics Education Centre project, with the Pedagogic Lead, Dr Lara Alcock, reporting to the Centre Director, Dr Carol Robinson. From a contractual point of view, the institutional signatory is the Head of the School of Mathematics, Professor Chris Linton.

It is not considered necessary to set up a local management committee. The direct involvement of the Head of E-learning in the project will help to ensure that development and dissemination dovetail with the University's e-learning strategy.

Charles Shields reports in terms of organisational structure to the University Librarian but, in his capacity as 'owner' of the E-learning strategy, he reports to the high-level E-learning Advisory Group, consisting of *inter alia* the PVC(T), the three ADTs, the Director of IT, the Director of the Teaching Centre, and the Managers of the two CETLs. The E-learning Advisory Group will receive regular progress reports on Project ExPOUND and will be asked for guidance if and when appropriate.

## **13. Programme Support**

The project intends to maintain regular contact with the programme manager. In addition, specific support is sought on identifying any relevant crossover work that JISC are funding, including toolkits that may be relevant to the work being carried out. The project would also like to make use of any community building work that JISC are able to provide.

## **14. Budget**

See Appendix A.

## Detailed Project Planning

### 15. Workpackages

See Appendix B.

### 16. Evaluation Plan

Timing	Factor to Evaluate	Questions to Address	Method(s)	Measure of Success
Throughout	Project management	Is the project proceeding smoothly? Do team members understand their individual roles? Is everyone working towards same goals?	External consultant	Stated project outputs are delivered.
Alpha, Beta and 2 <sup>nd</sup> phase	Usability of tool	Are the tool and its supporting documentation straightforward to use for mathematicians?	Morae analysis	Mathematicians are able to focus on the content of their e-Proofs during creation and not on the tool
Alpha, Beta and 2 <sup>nd</sup> phase	Usability of e-proofs	Are the produced e-Proofs straightforward to use for students	Morae analysis + usage data	Students able to focus on content of e-Proofs rather than their use + usage comparable with other materials available via the VLE
Throughout but esp. 2 <sup>nd</sup> phase	Community building	Is the tool taken up by others beyond Loughborough?	Usage data	Interest in ExPOUND beyond Loughborough
2 <sup>nd</sup> phase	Barriers to acceptance	Are there technical barriers? Institutional barriers? Cultural barriers?		Extent of use both internally and externally
2 <sup>nd</sup> phase and beyond	Pedagogic effectiveness of e-proofs	Does study of an e-Proof lead to improved understanding of the theorem and proof?	Student feedback + preliminary interviews	Positive feedback on e-Proofs from courses in which they are used + evidence that students engage with content of proofs as lecturers intend

## 17. Quality Plan

<b>Alpha Version with Documentation</b>					
<b>Output Timing</b>	<b>Quality criteria</b>	<b>QA method(s)</b>	<b>Evidence of compliance</b>	<b>Quality responsibilities</b>	<b>Quality tools (if applicable)</b>
06/09 – 08/09	Effective project management	Various	External project evaluation report	Charles Shields; external consultant	Derivative of PRINCE2; MS Project
06/09 – 08/09	Code review within project team		Review documentation	Nicola Wilkinson	Use of bug tracking software / SVN

<b>Beta Version with Documentation</b>					
<b>Output Timing</b>	<b>Quality criteria</b>	<b>QA method(s)</b>	<b>Evidence of compliance</b>	<b>Quality responsibilities</b>	<b>Quality tools (if applicable)</b>
08/09 – 12/09	Effective project management	Various	External project evaluation report	Charles Shields; external consultant	Derivative of PRINCE2; MS Project
08/09 – 12/09	Code review incl. external		Review documentation	Nicola Wilkinson	Use of bug tracking software / SVN
08/09 – 12/09	Quality of documentation	3 <sup>rd</sup> party proof-reading		Charles Shields; Lara Alcock; Nicola Wilkinson	

<b>ExPOUND Version 1 with Documentation</b>					
<b>Output Timing</b>	<b>Quality criteria</b>	<b>QA method(s)</b>	<b>Evidence of compliance</b>	<b>Quality responsibilities</b>	<b>Quality tools (if applicable)</b>
11/09 – 04/10	Effective project management	Various	External project evaluation report	Charles Shields; external consultant	Derivative of PRINCE2; MS Project
11/09 – 04/10	Code review incl. external		Review documentation	Nicola Wilkinson	Use of bug tracking software / SVN

<b>First Set of ExPOUND e-Proofs</b>					
<b>Output Timing</b>	<b>Quality criteria</b>	<b>QA method(s)</b>	<b>Evidence of compliance</b>	<b>Quality responsibilities</b>	<b>Quality tools (if applicable)</b>
11/09 – 04/10	Peer review of sample e-proofs	Non-authoring lecturer to review each e-Proof produced during the project	Short report produced for each e-Proof	Lara Alcock	n/a

Output	Project Website					
	Timing	Quality criteria	QA method(s)	Evidence of compliance	Quality responsibilities	Quality tools (if applicable)
05/09-06/09	Effective project management	Various			Charles Shields	Derivative of PRINCE2; MS Project
05/09-06/09	Usability and accessibility		Code validation		Lee Barnett	

## 18. Dissemination Plan

Timing	Dissemination Activity	Audience	Purpose	Key Message
From the start	JISC website	All	Top-level information about the project	To tell people the project was accepted and has started; link project in with other L&TI projects
Regular intervals	JISC L&TI programme meetings	Other project teams	Share experiences / expertise	What has worked and what hasn't
Throughout	Project website	All users and potential adopters of ExPOUND tool, including; practioners, educational researchers and learning technologists	Provide information about the project and tool	This will be one of the key dissemination routes and will house all of the project out puts
Throughout	Developer's blog	Other developers, JISC projects, Open source community	Provide a narrative about the development process and practices	Help to inform those interested in the development process
Autumn 09 onwards	Conferences	Practitioners, educational research community, learning technologists	Raise awareness of the project and increase the likelihood of the adoption of the tool	Value of the project and to share the success.
11/09 – 04/10	Sample e-Proofs available through JORUM (Open)	Mathematicians and others teaching undergraduate mathematics	Show what can be done with the tool; provide materials that are useful in their own right	Students benefit from e-Proofs; lecturers can create them easily with ExPOUND
Throughout	MSOR website / mailing list	Mathematicians and others teaching undergraduate mathematics	Provide information to those who may be interested in using the tool;	This tool can address some of the problems inherent in providing

			community building	students with guidance on how to understand proofs
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## 19. Exit and Sustainability Plans

Project Outputs	Action for Take-up & Embedding	Action for Exit
ExPOUND tool V1	Will be available through the project website / Sourceforge	N/A
8 x sample e-proofs	Available through Open JORUM etc, these will serve to show maths lecturers across the sector what can be done with the tool.	N/A
Project website	Loughborough will host this site until at least May 2012.	N/A

Project Outputs	Why Sustainable	Scenarios for Taking Forward	Issues to Address
ExPOUND tool V1		Further development, potentially at Loughborough or elsewhere in the user community, to add math-specific functionality (eg support for diagrams) or to add functionality that broadens the scope of the tool to other subject areas.	Tendency for feature creep. ExPOUND should not become yet another generic e-learning authoring tool. Needs to remain easy to learn / use for the average maths lecturer.
Project website	Will be essentially User Generated Content, ie maintained by the whole user community not just the project team.	Link project website into the redeveloped mathcentre.ac.uk website.	Keeping the user community engaged without further funded development.

**NB: a Sustainability Plan is one of the deliverables of the project, in Workpackage 3.**

## Appendixes

### Appendix A. Project Budget

### Appendix B. Workpackages