Collaborative Research: Resource of Open Problems for Education (ROPE)

1 Introduction

At the heart of teaching and learning mathematics—and many other disciplines—is a learner's engagement with questions, or problems, which challenge her or him to understand and apply the material s/he is learning. We propose to develop a resource that will provide an on-line electronic library of innovative, well-tested and documented problems that instructors and students may use in a wide range of courses and for a wide range of assignment types. This "Resource of Open Problems for Education" (ROPE) will allow searching and browsing to find appropriate problems; will include descriptive information about problem usage and the numbers of users endorsing the problems; and will allow users to share problem collections and lists drawn from the library. Because it will be an open resource, institutions and individuals with limited resources will still have full access to it, and the community of ROPE users will be able to provide added value to the library. The goals of ROPE are:

- To be a *free, open-source resource* that will give instructors and students access to good mathematics problems. The cost of textbooks and supporting materials for courses is increasingly untenable. We believe that as academic practitioners we should work to have an accessible resource that does not discriminate on the basis of wealth and which does not demand advertising or private data for its use.
- To be an *extensive, broad, and well-vetted resource* of problems that can complement existing text problems, be used with open-source textbooks, or be used to create practice worksheets, quizzes or exams. Instructors and students benefit from the availability of good problems that they may use directly or adapt.
- To provide the mechanism for a *community of users* of these problems, who may contribute problems, content and feedback on problems, and who may share the groups of problems they use for specific homework sets or courses.

2 Description

Internet users go to Amazon to search for material products to buy, and Google to find pages on the internet. While we do not pretend to be creating a resource with the ubiquity or power of either

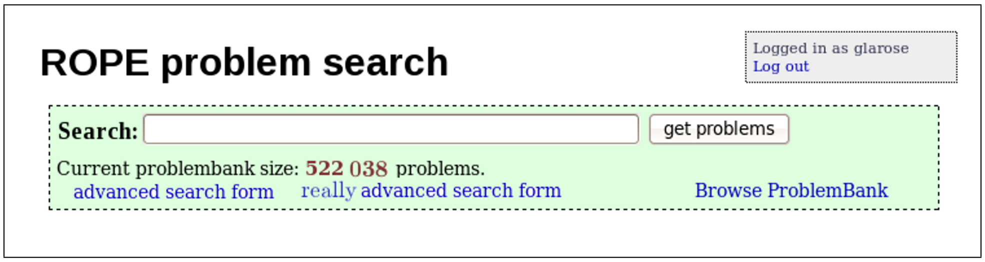

Fig. 1: Mock-up of ROPE search page

Fig. 2: Mock-up of ROPE results page

of those, we do hope to develop ROPE into the place where mathematics teachers and learners go to find problems and inspiration for problems for the courses they are teaching and learning. We imagine going to the ROPE search page, such as is shown in figure 1, and searching for a topic or problem, with the result suggested in figure 2. These mock-ups illustrate a number of the core features that ROPE will have:

- Users will be able to search on arbitrary keywords, or with GMail or Google-like tags (e.g., “course:calculus”).
- There will be alternate search forms that will allow users to explicitly select specific courses, chapter or section headings, etc.
- Search results will be easily managed, with a view of the problems and easy ways to view the source (e.g., LaTeX) for the problems, add them to *Problem Collections* owned by the user, or download the source as a small file.
- All problems will have useful metadata that describe them, including the background mathe-

matics required for the problem (e.g., calculus and optimization), level of difficulty (e.g., easy, medium, hard), type of problem (e.g., symbolic, numerical, graphical), etc.

- Users will be able to rate problems, endorse them, and leave comments, and these data will be available to allows other users to evaluate the problem and how they might want to use them.
- Users will have the ability to build their own problem collections and share them with other users (if they like), and thereby download a full source file (e.g., in LaTeX) for a problem set, other assignment, or even full list of all problem sets for a course that.

In the following we discuss the three key functionalities we envision for ROPE: the searchable problem library, from which users may view and download problems; the collections feature, and ability to create collections of collections; and its community of users and how that will integrate with the other two features.

2.1 Searchable Problem Library

2.2 Collections of Problems and Collections

2.3 Community of Users

All of the following needs to be repackaged into the preceding subsections, or deleted.

Users will be able to search this library for problems by course, topic, type of problem (e.g., computational, conceptual, etc.), level of difficulty, and other characteristics. Problems will be contributed by the community of users and will have associated descriptive information that will include user feedback and comments, as well as statistics on the frequency of the problem's use. Users will be able to rate problems using a commonly understood "like" feature (similar to those used on social networking sites), they will be able to create and share collections of problems they may refer to later for use in homework, quizzes or exams, and they will be able to comment on problems for the benefit of other users. The problems will be available in multiple formats, and will be applicable to different uses. In time we expect that the library will be extended to include other disciplines besides mathematics.

This electronic library will be an open library: problems will be openly available for use and modification by all users. Open-source software has a (relatively) long and well-established history and tradition in the development of modern computing platforms, and provides the basis for a large portion of the computing infrastructure on which current technology from the Internet to smartphones run. The idea underlying this software, of an open development of resources that may be taken, redeveloped and repurposed for the common good, is one which these same technologies are increasingly making available to other venues. We are seeing the development of open-content textbooks, websites that allow open sharing of expertise in programming, car repair and evaluation of professorial instruction, and more. In this environment a Resource of Open Problems for Education (ROPE) will not only fit in, but thrive.

It is an opportune time for the development of this resource of open problems. Mathematics educators are exploring innovative pedagogies including writing projects, inquiry-based learning, and on-line teaching and assessment. There is a substantial community that is developing open-content textbooks and open-source software as a reaction to high textbook prices and expensive proprietary educational and research software. There are natural connections between the proposed ROPE and educators who are looking for new resources in their teaching, as well as with the open-content texts and open-source software that are being developed. ROPE will provide pedagogical innovators with new and different problems to use as they work on different ways to improve their instruction; will provide authors and users of open-content textbooks a problem resource to populate and augment the problem lists in their texts; and will be able to connect with open-source software projects that deliver and display mathematical content and problems.

As a result of these connections and flexibility, we expect ROPE to be used by instructors in a wide range of manners. Instructors will be able to use it to construct homework sets in courses for which they have lecture notes but an inadequate set of available homework problems. They will be able to use it to augment the problems that they have available from their textbook, for use on homework sets, quizzes, exams, or other assignments—a use which may be particularly relevant for users of open-content texts. Authors will be able to use it as a resource for problems and problem sets for their textbooks, and will be able to contribute problems for their texts to the library. On-line courses and homework systems will be able to use it to populate their assignments. To provide for its long-term sustainability and flexibility, ROPE will have an underlying data structure that will allow the addition of new problem formats and filters to transform existing formats into others (e.g., by transforming a problem written in LaTeX to HTML or PDF, or from LaTeX to a problem for an on-line homework system) and include a well-documented and extensible Application Programming Interface (API). Through the latter, other applications will be able to "talk" to ROPE; this will allow the library to serve problems to other resources (e.g., the problem library for an on-line homework system).

3 Context

While there is no resource currently available that provides the functionality and material that will be included in the Resource of Open Problems for Education, there is existing software that will provide a basis for ROPE, and which will inform its development. Three applications that are closely related to the work we seek to do with ROPE are: an existing problem library developed in the mathematics department at the University of Michigan by Gavin LaRose; the National Problem Library (NPL) used by the WeBWorK [3] on-line testing and assessment system, for which Gavin LaRose has been a software developer; and Edfinity, a proprietary startup providing content and self-publishing options for educators.

The problem library in use at the University of Michigan currently provides a subset of the features we envision for ROPE: it has an on-line, searchable interface that allows users at the University to search through over 500 problems drawn from precalculus and calculus homework assignments, quizzes and exams. Problems are described by course, chapter, section, keywords, difficulty, type, original use, year used, author, and general math topic. The experience developing the underlying data structures and interface for this will be of great use in the development of ROPE, and we expect to be able to reuse some portions of its programming code as ROPE is created.

The WeBWorK NPL provides a similar search functionality for over 25,000 problems written for WeBWorK, and is integrated into WeBWorK to allow creation of problem sets from those problems through a library browser interface. The data structures used in the NPL will provide added insight on the development of ROPE, and its interface with the WeBWorK system will be of particular use as we consider the API for ROPE and how that may allow connections with other systems.

Edfinity is similar in some ways to ROPE (and the WeBWorK NPL), in providing a searchable database of problems with the capability of collecting problems into a problem set. They also allow authors to self-publish problems, with the promise of royalties if the problem is used frequently by other educators.

In addition to the Michigan problem bank, WeBWorK's NPL and Edfinity, there are other problem collections that have been developed to serve specific purposes, and we hope to work with the developers and maintainers of those to enhance ROPE and to build connections with them. These include the MathQuest/MathVote question library at Carroll College [1], which includes many questions for use with in-class voting systems; the GoodQuestions project [5], which provides similar types of questions; and Quadbase [4], which is closest in spirit to ROPE but provides more limited options for searching and problem format, and which does not support external use or problem

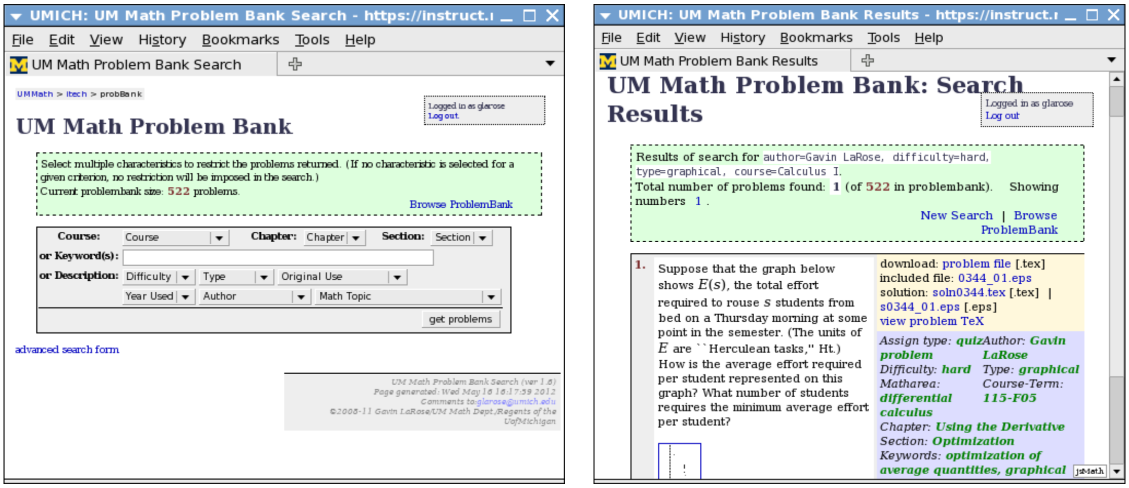

Figure 1: UM Problem Library: left, search form; right, sample search result

sharing, nor the community feedback aspects that we envision for ROPE. In addition, the Mathematical Association of America (MAA), which is the largest professional organization supporting the teaching and learning of undergraduate mathematics, has been exploring the possibility of creating a problem bank for problems found in its journals. The MAA is also the hosting institution for the WeBWorK project. We have been in discussion with the leadership of the MAA about ROPE and will pursue the possibility that it can be connected to the idea of a journal problem library as well.

In addition to these specific applications which support some subset of the features of ROPE, there are a growing number of social networking and shopping sites that provide us with interface design principles that will be commonly understood and useful to the users of ROPE. Sites including Facebook, LinkedIn, and Amazon allow users to “like” ideas or objects, providing a powerful and simple feedback mechanism that informs others of the popularity and usefulness of the “liked” item. These sites also allow users to set up collections of objects (like wish lists and shopping carts) that may be used personally or shared with others. Our development of the interface for ROPE will be informed by these sites, and ROPE will adopt these ideas to give users feedback on problems in the library, and to develop problem collections which they may use semester to semester and which they may share with colleagues or with all users of the system.

4 Project Details

The problem library in use in the mathematics department at the University of Michigan is shown in Figure 1, which shows the search interface and a sample problem as displayed in a search result. This illustrates in a general way the basic search characteristics that will be supported by ROPE: the ability to locate problems that are associated with specific topics in a course, which are of varying levels of difficulty, that have specific characteristics (such as use of graphically presented or tabular data), or which were used in specific contexts (as homework problems, on quizzes, etc.). This project will dramatically rework this application, allowing it to address the goals that are laid out in the introduction of this proposal, by including

- scalability to support many more users, problems and problem formats,
- community site membership and interactions,
- problem moderation and editing,
- problem filtering to generate alternate formats from existing formats,
- a modern, flexible interface that supports these features, and
- a well-documented API that will allow other applications to communicate with ROPE in manners other than through the browser interface.

These goals are described in greater detail in the following subsections.

4.1 Scalability

The problem library at the University of Michigan runs behind the University web-login system and has access restricted to instructors in the mathematics department. It accordingly supports a user base of several hundred users, all of whom are defined by external data sources and need no further identification or system characteristics. ROPE will support thousands of users with internally defined characteristics (names, e-mail addresses, password information, etc.). Accordingly, we will in the course of the project expand the database used for the University of Michigan system to support this. In addition, we will establish the workflow to allow for users to author, submit and rate problems, determine the appropriate manner in which moderation, editing of and commenting on problems should take place, and add these functions to the problem code.

Problem types supported by the University of Michigan problem bank are LaTeX and external formats (*Word* or *OpenOffice* document snippets). All problems for the problem bank are currently maintained as separate files. For ROPE we will completely revise the problem data structures so that all problem data are maintained in the system's database, and completely rework the data maintained for problems to extend the types of descriptive data for the problems and to support additional file formats and the ability to add additional formats as they become useful.

4.2 Community and Site Moderation

An aspect that is missing from the current problem bank is a mechanism for users to provide feedback on the quality and usefulness of problems. ROPE will address this by including the ability for users to vote and comment on problems in the library. The data management and manner in which this is to be done will be added to the current problembank model. In addition, problem view/download statistics will be provided as part of the metadata about problems.

We will determine the nature of the voting/commenting system used, in consultation with the Advisory Group, with the goal of maximizing its usefulness and minimizing the possibility of any abuse. ROPE will also support comment and problem flagging so that problems or comments with errors can be updated by ROPE moderators. We anticipate that the moderators will initially be drawn from the grant personnel, and will work with the Advisory Group to determine the best manner to expand the group of people who are engaged in this activity. (We discuss the project's Advisory Group in the following sections.) ROPE will also support problem authoring or submission from users in its community. The degree of moderation for this activity (if any) will also be determined by the project personnel, including our Advisory Group.

In addition, ROPE will support a sharable problem collection feature. This will allow users to create problem lists for their own uses—homework sets for given courses, etc.—and to share these lists. Thus an instructor teaching a course will be able to share her/his problem lists with other faculty at her/his institution, or with colleagues at other institutions. In addition, book authors (and publishers) could build problem lists for their texts that would then be openly available for anyone using those texts.

4.3 Problem Filtering

As we add additional problem formats to ROPE, we will build in the ability to convert between some of the formats and output types, and to add additional filters as they are needed and developed. We anticipate three initial filters:

- a filter converting TEX formatted problems to PDF output;
- a filter converting TEX formatted problems to a rudimentary WeBWorK problem file; and

- a filter converting WeBWorK formatted problems to $\TeX$ output.

These will serve to provide significant additional functionality to ROPE and will be templates that illustrate the manner in which additional filters may be constructed.

4.4 Interface

Considering these features and goals, it is clear that the simple search and results interface used by the University of Michigan problem bank system (Figure 1) will need to be completely re-imagined. We, with our Advisory Group, will work to develop an entirely new interface that supports the precision of searching that we need and the multitude of new data and features that ROPE will support.

4.5 API and Documentation

A natural extension to the filtering system that will be developed for ROPE is a mechanism by which other applications can use the generated problem formats. To allow this, we will develop an easily used API by which external applications may query ROPE to get file or problem data for specified problems. A first application for this will be to allow the open-source web homework system WeBWorK to include problems drawn from ROPE. We will work with WeBWorK developers and the WeBWorK leadership group on this aspect of the project.

5 Project Implementation and Timeline

To implement ROPE, as described in the preceding section, we have the timeline laid out in Figure 2. This illustrates the four phases in which we expect work on ROPE to be carried out. The first, to be completed by the end of the spring semester of 2015, is a *Data and Interface Design* phase. In this time we, in consultation with the Advisory Group, will determine the requirements for the database supporting ROPE and lay out its on-line user interface.

The second phase of work, *Alpha Product Development* will be carried out in the summer of 2015 and, as necessary, fall of 2015. In this phase Gavin LaRose will work with the hired programming consultant to develop the database and software required for the initial version of ROPE. Dana Ernst and Spencer Hamblen will develop problems for, and recruit alpha-testers to use, this initial version, which we will launch in the fall of 2015. A key part of our alpha testing will be recruitment of 15 alpha testing consultants. These will be users who will be paid a small honorarium to encourage their use of ROPE, and their contributions to the library. These users

date	personnel	activity	outcome
January 15	PMs	team meeting (JMM)	initial design and data proposal
Spring 15	AG, PMs PMs	on-site meeting on-line meetings	feedback on design and data proposal finalize design and data models
Summer 15	PM, Pr PMs PMs, EE	programming work library development on-site meeting	database, alpha software developed initial library population initial evaluation
Fall 15, Spring 16	PM PMs PMs, At	programming work library development initial testing	user interface finished (if necessary) expansion of library population alpha testing of ROPE
January 16	PMs	team meeting (JMM)	evaluation of alpha software, initial library
Spring 16	PMs	on-site team meeting	filter & API data proposal
Summer 16	AG, PMs PMs PM, Pr	on-site meeting on-line meetings programming work	feedback on filters & API, alpha test finalize model for moderation finalize filter & API ruleset debug alpha software implement filtering and API
Fall 16	PMs, Bt PMs, EE	beta testing on-site meeting	beta use of ROPE second evaluation
January 17	PMs	team meeting (JMM)	evaluation and planning
Spring 17	PMs	dissemination	continued beta use of ROPE
Summer 17	PM PMs	programming work editorial work	debugging, updates beta to production documentation completed
Fall 17, Spring 18	PMs	programming work editorial work	production service debugging documentation updated

Figure 2: Project Timeline: personnel notation—PMs = grant project managers (Ernst, Hamblen, LaRose); AG = Advisory Group; Pr = contract programmer; EE = External Evaluator; At = Alpha testers; Bt = Beta testers

will be contacted regularly in the course of the fall and spring semesters to get their feedback on aspects of the system which need revision as well as on those components which are working well.

In the third phase of the project, *Extensions and Beta Development*, taking place in spring and summer 2016, we will develop the technical requirements for the problem filtering supported by ROPE and the API by which other applications may interact with it. In the spring and summer we will finalize these requirements with the Advisory Group, and in the summer Gavin LaRose will work with the programmer consultant to implement these features. Also in the summer Dana Ernst and Spencer Hamblen will continue to expand ROPE and recruit additional beta testing consultants. These users will serve in a similar role to the alpha testing consultants.

The final phase of the project will see it move from beta to a *Production Service*. This phase will take place in summer and fall of 2017. There are three components of this: finishing debugging and updates that were suggested by the beta testing, moving the service to production hardware, and completing documentation and dissemination. The first two phases of these will be completed by Gavin LaRose, in conjunction with the systems support staff at the University of Michigan's mathematics department. The remaining tasks will be accomplished by all project managers, with Dana Ernst and Spencer Hamblen taking the lead.

Finally, the Math Department at the University of Michigan will be able to provide the required technical support to initially implement and subsequently maintain the computer hardware required for this project. While it is in development and alpha and beta testing ROPE will be hosted on webservers that are currently maintained in the Department and which have the required server capacity to support the project. As the project is transformed to a production service we will move it onto its own server, purchased using grant money, which will be housed and supported in the Department.

6 Project Personnel

The grant will be managed by Gavin LaRose, University of Michigan, Dana Ernst, Northern Arizona University and Spencer Hamblen, McDaniel College. Stephen DeBacker, University of Michigan, will oversee the project as it is implemented at the University of Michigan. Their expertise position them well to successfully carry out this project.

Gavin LaRose is a lecturer IV and manager of instructional technology in the Department of Mathematics at the University of Michigan. His research interests are in applied mathematics, specifically biological modeling, but he has for the majority of his time post-Ph.D. been primarily focused on undergraduate education. He has been a developer for the WeBWorK open-source homework system and wrote the majority of the testing module for that system. In his role in instructional technology at the University of Michigan he has created a wide range of on-line applications in use at the University of Michigan, including data management and tutorial systems. He is the author of the problem library that is currently in use at the University of Michigan, which will serve as the early prototype for ROPE. He has won several teaching awards, most recently the University of Michigan College of Literature, Sciences and the Arts *Matthews Underclass Teaching Award* and the Michigan MAA Section's teaching award.

Stephen DeBacker is an *Arthur F. Thurnau* professor of mathematics in the Department of Mathematics at the University of Michigan, a named chair designation given to tenured faculty whose commitment to and investment in undergraduate teaching has had a demonstrable impact on the intellectual development and lives of their students. His research interests are in questions in harmonic analysis for reductive p-adic groups, and specifically in stability questions. As the Director of Undergraduate Programs in the mathematics department, he oversees the department's major and non-majors courses and content, advising of majors, and significant educational initiatives in the department. He will work with Gavin LaRose to oversee the project as it is implemented at the University of Michigan.

Dana Ernst recently completed his fourth year as an assistant professor at Plymouth State University in Plymouth, NH. However, in the fall of 2012, he will begin working at Northern Arizona University, where one of his main service duties will be to revamp the calculus sequence to include more inquiry-based pedagogy. Ernst's primary research interests are in the interplay between combinatorics and algebraic structures. Ernst is also passionate about undergraduate mathematics education and recently his research interests have included topics in this area. In particular, he is studying the effectiveness of a collaborative approach to inquiry-based learning. Furthermore, he is interested in the use of technology to aid in the learning of mathematics and would like to study its impact on student success. In addition to using free and open-source software (such as *Sage*), Ernst is inspired by the recent open-content textbook movement and strongly believes that educators should choose free, open-source, or low cost textbooks when viable alternatives exist. Ernst has been the recipient of several teaching awards, most recently being named the 2009 and the 2011 *Plymouth State University Distinguished Mathematics Professor*, an honor determined by the math majors at Plymouth State University. Moreover, he was recently a finalist, and PSU's sole nominee, for the statewide *New Hampshire Excellence in Education Award*.

Spencer Hamblen is an Associate Professor at McDaniel College in Westminster, MD. His main research interest is Galois representations and deformation theory, but has recently been working in arithmetic dynamics and leading student research on classical arithmetic functions and problems in elementary number theory. His interest in the ways problems shape students' view of mathematics began while a graduate student at Cornell working with the GoodQuestions project. This interest has continued in his current teaching of courses that rely heavily on student problem-solving and other inquiry-based learning courses.

The Advisory Group for the grant represents constituencies that will have particular interest in ROPE, and includes individuals with a wide range of backgrounds and experience that will allow them to provide insight and advice on the project. **Robert Beezer** is professor of mathematics at the University of Puget Sound. He is an open-content textbook author, having authored a linear algebra textbook, and is an advocate for open-content authoring who has worked with other text-book authors. He is also involved in the Sage open-source mathematics software system. **Matt Boelkins** is associate professor of mathematics at Grand Valley State University and is currently developing an open-content calculus textbook. **Michael Dorff** is associate professor of mathematics at Brigham Young University. He is the director of the NSF-funded BYU summer mathematics REU and the director of the NSF-funded Center for Undergraduate Research in Mathematics (CURM). **Steve Dunbar** is professor of mathematics at the University of Nebraska, Lincoln, and is the MAA's Director of Competitions. He has made some initial steps toward coding problems from the American Mathematics Competitions, which he directs, to make them useful for other applications. **Kathi Fletcher** is a Shuttleworth Foundation Fellow working on the development of open educational resources and has a background in computer science. She is working to accelerate both the production of high-quality, reusable Open Educational Resources (OER) and the development of innovative learning environments that build upon OER. **Jeff Holt** is professor of mathematics at the University of Virginia, and is one of the authors and continued developers of the WeBWorK national problem library. **Aaron Wangberg** is associate professor at Winona State University. His group has written whiteboard and adaptive homework tools which utilize WeBWorK and the National Problem Library to conduct mathematics education research. His group leads the discussion with the Research in Undergraduate Mathematics Education community on how to conduct and disseminate research programs using an open framework.

All of the members of the advisory group have expressed enthusiasm for the ROPE project and willingness to serve in this capacity.

The project will have an external evaluator, **Doug Ensley**, who will meet on-site twice in the course of the project to provide formative feedback. Doug Ensley is professor of mathematics at Shippensburg University, has been editor of the Mathematical Sciences Digital Library, has written a discrete mathematics textbook, and is currently second vice president of the MAA. He has written a library of computer based material for the teaching and learning of mathematics and has written award winning Adobe Flash educational materials.

In addition to these individuals, we will hire a programmer to assist with the coding and database revision that will be done to the University of Michigan codebase in the course of developing ROPE. These revisions will be significant, and the programmer will work in close collaboration with Gavin LaRose to develop a codebase for ROPE which will then be open and easily maintained and extended as appropriate.

7 Intellectual Merit

ROPE project will address a current need in undergraduate mathematics education: the need for a widely available source of good problems that instructors can use in a variety of educational venues. Much of the learning that takes place in mathematics, and other STEM fields, is driven by students' work, and the success of that learning is fundamentally dependent on the types of problems on which they work. We therefore expect ROPE to have the potential to be a significant and widely used tool to enhance student learning.

There are several specific aspects of ROPE which will have direct bearing on this.

- Its on-line search page that allows precise searches for specific types of problems.
- The open nature of the system that allows a wide range of uses of the problems in the library.
- The user feedback and statistics available for the problems in the library.
- Users' ability to create their own problem sets, and to share these with other users.
- The explicitly extensible design of the system, allowing multiple problem formats and conversions between them.

Taking these together, we expect that ROPE will develop into an easy-to-use, widely adopted resource with a correspondingly significant impact on student learning of undergraduate mathematics.

8 Broader Impacts

The broad impact of ROPE will stem from its accessibility, ease-of-use and extensibility. We believe that the features that we are including in ROPE will result in its use by many faculty at many institutions. We expect that the largest group of users of ROPE will be faculty who are browsing for additional homework, test or quiz problems for their courses. Even with a well-written textbook there are routine and inevitable cases in an instructor will be at a loss to find a problem that s/he likes, and ROPE will be the perfect resource to fill that gap. In addition, as open-content textbooks expand in popularity and availability, the usefulness of ROPE will similarly increase. We anticipate that textbook authors may choose to define problem sets in ROPE for use by instructors using their texts whether they are publishing open-content textbooks or working with a publisher (though it is clear that the attractiveness of ROPE to the former may be significantly greater). And because ROPE will be designed from the outset to be flexible and extensible, it will be able to meet the changing needs of faculty in the future and make connections with other software projects for which a library of open problems will be useful.

All told, we expect that ROPE should have very broad impact, reaching instructors at all types of colleges and universities who are teaching any standard mathematics course in any of a number of different ways. We further expect that as ROPE develops we will be able to extend it to include other disciplines, also increasing its impact.

9 Dissemination

Key to the success of ROPE will be its dissemination: for it to be able to reach and help many instructors, they must know of its existence. To successfully ensure that mathematics faculty are aware of ROPE, we will pursue a four-fold dissemination plan: generating a primary user base by soliciting and engaging likely users, publicizing the availability of ROPE to the networks of colleagues available to the Ernst, Hamblen and LaRose, publicizing ROPE to the larger community, and communicating with professional organizations and open-source projects to make connections with their members.

To generate a primary user base for ROPE, we will actively solicit alpha and beta testing consultants of ROPE. These users (about 15 individuals for each of the alpha and beta development phases of the project) will be selected by Ernst, Hamblen and LaRose (in consultation with the Advisory Group) as people we expect will have interest in ROPE, and whose role with the project is likely to be more than simply searching for problems. We will encourage their participation in rating problems, making comments and providing problem groups, by offering them a small honorarium for their work. Having these individuals will provide a critical mass of actively engaged users of ROPE in the critical phases of its development, which will help develop its user-base in the long term.

The personnel managing this project are well-positioned to communicate with a large number of faculty who are likely to be users of ROPE because of their connections with other projects and organizations. All three of the Ernst, Hamblen and LaRose are Project NExT [2] Fellows, and Gavin LaRose is a member of the Project NExT leadership team. Project NExT is a professional development program of the MAA which supports new math faculty in all aspects of their professional career, with an emphasis on teaching. There are over 1300 Fellows from all parts of the United States and some surrounding countries and territories, and they are distinguished by their energetic embrace of new ideas and effective teaching strategies. We will publicize ROPE to the Project NExT Fellows, and have good reason to expect that many of them will become significant users of ROPE. In addition, the mathematics department at the University of Michigan provides a large potential base of users not only at the University but at other institutions as well. Each academic year, approximately 150 graduate students, post-doctoral and regular faculty teach in its Introductory Program courses, and we will publicize the availability of ROPE to them. The majority of these graduate students and post-docs go on to take other academic positions, and will take their use of ROPE with them to those positions.

To promote awareness of ROPE among individuals and groups with whom we and the Advisory Group do not have personal contact, we will disseminate information about ROPE at national mathematics meetings. This dissemination will include presentations in poster and contributed sessions at the MAA's MathFest in the summer and the Joint Mathematics Meetings (JMM) in the winter, which attract essentially all potential users of ROPE (though we suspect they may not all choose to come to our presentations). At the JMM we will also rent a booth in the exhibit hall for the meeting to have a demonstration of ROPE. Because the exhibits are a popular attraction of the JMM, we expect this will increase the number of people who are aware of ROPE by several hundred. In addition, we will disseminate fliers about ROPE at the booth and in person at the meetings.

Finally, we will work with professional organizations and the larger open-source communities to promote ROPE. The project personnel are involved with many communities with whom we will make contact, including the MAA, WeBWorK and Sage, and we will work to develop additional contacts and communication channels with these groups.

10 Evaluation

The success of ROPE will be measured by a number of quantitative, measurable outcomes that will assess the degree to which it has been adopted by the mathematics community, and by a

Outcome	**Goal for summer ’16**	**Goal for Summer ’17**
# of supported courses	6	15
# of problems	2000	5000
# of registered users	200	1000
# of users who submitted rating data	50	150
# of problem collections	50	200
# of problem authors	30	75
# of institutions using	15	40

Figure 3: Primary Measurable Outcomes and Goals

number of more qualitative measures that seek to discern its impact on student learning. Both of these will be adjusted and expanded in consultation with our external evaluator. As indicated in the project timeline, our first consultation with the evaluator will be early in the project development, in the summer of 2015. This early meeting will allow us to work with the evaluator to determine if the outcomes that we have set forth are appropriate, revise the goals that we have for our measurable outcomes, and determine areas in which our evaluation plan may be improved. The second visit will be just past the midpoint of the project, in fall 2016, to provide us with an objective assessment of the manner in which the evaluation plan has been put into place and what it can tell us. At that time the evaluator will also work with us to arrive at an updated plan that can be carried forward to provide a long-term and sustainable evaluation cycle for the project.

Our primary measurable outcomes have to do with the scope of the library and its number of users. Because the usefulness of ROPE will be driven by the number of problems it provides, this will be our first measure of success; in tandem with this, we will consider the number of courses for which there are a reasonable number of problems. For the purposes of our evaluation, we consider a reasonable number to be that which we feel would likely allow a user to populate homework assignments for the course—about 200 problems. Given the resource, however, the next measurable objective is to have a significant base of users who are using the problems in ROPE, authoring and submitting additional problems, and providing feedback on the problems. To judge users’ engagement with ROPE, we will use as measures the number of users who register with the site, the number who are providing feedback on problems, the number of problem collections users have defined in the system, and the number of users who have contributed at least five problems to the library. In Figure 3 we summarize these measures and our goals for them over the course of the project.

Measuring the impact of ROPE on student learning is an exceedingly formidable problem. We are therefore forced to consider indirect measures that may suggest the quality of the resource which we are providing and its impact. The two primary measures that we will use for this are the ratings and comments on the problems in ROPE and the number of students and courses using problems from ROPE. We have some faith in the ability of instructors to reasonably evaluate the usefulness and quality of problems that they assign in their courses. Because of this, we will use the ratings they give to problems and comments that they have about the problems in ROPE as an indirect measure of the quality of the problem library. Our measurable outcome for this goal is that 20% of the problems in ROPE will have been marked as “liked” by at least 2% of the registered number of users. A second indirect measure of impact is to determine how many students are in classes using ROPE. We will assess this through the end of our alpha testing (that is, when the number of users is small enough for us to be able to do this). We will contact our alpha testing consultants to determine the number of problems they are using, the number of courses they are using the problems for, and the number of students in those courses. From these users our goal is to have 300 students using at least 20 problems from ROPE by the summer of 2016.