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 means 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 an extensive collection of 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 have a mechanism for users to create *problem collections, and collections of collections* to group problems from the resource and which they may use themselves or share with other users. This will allow instructors to create problem sets, quizzes, and collections of these for a course, authors to define groups of problems that complement their text, and students to create practice worksheets or other study aides. This flexibility in use and sharing of collections will allow more and better use cases for the resource.
- 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.

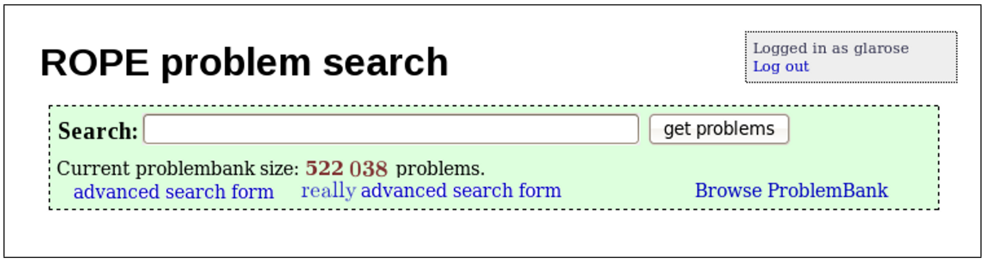

Figure 1: Mock-up of ROPE search page

Figure 2: Mock-up of ROPE results page

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 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 mathematics 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. In a final section we discuss some of the extensions and technical details that we expect to make it as flexible, useful and usable as we expect.

2.1 Searchable Problem Library

We envision that instructors will come to ROPE to find problems for homework or quizzes; or students will come to look for problems for review or practice; or authors will come to create collections of problems to augment those they have in their text; etc. To serve these varied communities and needs, we need to have a large collection of problems that may be searched on multiple criteria. Therefore, all problems in the resource will be tagged to make it easy to find problems associated with a course or course-topic, type of problem (e.g., one that requires graphical understanding), and other characteristics.

Once problems are found that a user wants to use, s/he will be able to view or download the substance (e.g., LaTeX code) for the problem, or add it to a collection of problems in ROPE that s/he has created. When viewing the problems, s/he will have access to the complete description of the problem as it has been entered into the ROPE database. This description will include information such as that indicated in Table 1. It will be possible to search on these fields, or in the text of the problems themselves.

We expect that most of the problems in ROPE will be coded as LaTeX code snippets, because

Characteristic	Description
Author	Some identifier of the author, e.g., username
Date	An indicator of the date the problem was authored
Difficulty	e.g., easy, medium or hard
Type	e.g., symbolic, numerical, graphical, or multiple
Course	An indicator of the course in which the problem might be used
MajorTopic	"Chapter" level topic categorization
MinorTopic	"Section" level topic categorization
RelatedProblems	Other problems in ROPE with which this is associated
RequiredTech	Technology required to solve the problem
Keywords	Specific keywords describing the problem

Table 1: Metadata describing ROPE problems

that is the most commonly used mark-up for mathematics documents. However, because this is not uniform, we intend ROPE to support other formats, e.g., small *Word* or *OpenOffice* document files. Where possible, our goal will be for it to be possible to convert between formats when viewing or downloading problems; this is addressed in greater detail in below, in section 2.4.

2.2 Collections of Problems and Collections

Any user of a problem resource is unlikely to use a single problem and then stop. We anticipate that most users will be looking for groups of problems to use on quizzes, homeworks, study sheets, or to complement different sections of their textbook. ROPE will therefore support the definition of such collections by its users. The simplest such collection would be a list of problems, such as might appear in a problem set, study guide or quiz.

In addition, a collection in ROPE may contain other collections and textual metadata. Thus, a user may construct a collection of problem sets for a course that s/he is teaching, or may construct a collection of problem sets with embedded information that provides context (e.g., the textbook being used, or the expectations for the ordering of material, etc.) for her/him when s/he returns to use the sets again, or for others with whom s/he shares the collection.

The ability to define such flexible and extensible sets also allows textbook authors (for texts published by a standard publisher, or for authors of open-content texts) to establish collections of problems to complement the text. These collections could then be shared with any user who is using the text. We hope that this will be an invaluable resource for authors of open-content textbooks, and other authors creating problem sets to complement their texts, and instructors interested in sharing resources. One immediate application of the collections in ROPE is the ability to share complete problem-centered course notes. An increasing number of instructors are using Inquiry Based Learning (IBL) in their classrooms, for which course notes most commonly consist of problem sets with some context and other information. This type of collection of materials will be very easy to create and distribute through ROPE.

2.3 Community of Users

Users of ROPE will be able to use the problems in the resource, build their own collections of problems, and add to it. Integral to our vision for ROPE is that users will be active in contributing problems, rating problems that exist, and providing valuable feedback to other users about problems and how they may have been effectively used.

As suggested in the mock-up results page (Figure 2), users will be able to rate problems, and endorse them to others. They will also be able to use comments about the problems that may be useful to other users. As users create problem collections that they share with other users, they will be making connections within the community that will provide further added value to the resource.

We also expect that users will be able to contribute additional problems to ROPE. The grant PIs will work with an advisory group to determine the best model for moderation and vetting of contributed problems, and to cultivate a userbase that will end up forming the community that we imagine for ROPE.

2.4 Extensions and Technical Details

There are a number of things that a problem database such as ROPE should support. These include: flexibility to support different problem formats and types; format conversion utilities that allow problems to be converted between formats; and a well-documented API that will allow other applications to communicate with ROPE in manners other than through the browser interface.

As we indicated above, we expect that most mathematics problems will be coded in LaTeX snippets, but that there will be users for whom this will not be appropriate. ROPE will therefore support other formats such as small *Word* or *OpenOffice* files, plain text, and we expect others. In particular, problems in PGML (a mark-up language used for some WeBWorK problems), PG (the standard WeBWorK mark-up language), and similar formats would be easy to include. We will work with our advisory group to determine other formats that ROPE should support, and determine how this may fit into the technical framework that underlies the application.

Given a variety of formats, of course, for the resource to be as useful as we envision it must be possible to convert between formats. A user of *Word* may not find LaTeX snippets tremendously useful, for example. We will therefore support conversion between formats, insofar as that is possible, and generation of generic intermediate formats (e.g., plain text) where that becomes prohibitively difficult. This will allow users with all different backgrounds to find and use problems regardless of the format in which they were originally created. There are a number of conversions that will be most easily implemented, and with which we will start: conversion of LaTeX to plain text is straightforward, and conversion of LaTeX into WeBWorK problem templates will be similarly easy to manage. Conversion into fully-functional WeBWorK problems will be possible for ROPE problems with appropriate metadata, and we will specify how these data may be coded in the problems to allow that conversion. Conversion between LaTeX and *Word* or *OpenOffice* is more difficult, but there are several existing applications that do this to some degree or another, including some that are open source and which we would therefore be able to adapt (e.g., latex2rtf [7]. In a similar vein we expect to add conversion between *Word* or *OpenOffice* and LaTeX as we continue to develop ROPE.

Finally, ROPE is to be an open resource. We will therefore develop, document and publicize an API that will allow other developers to interact with it in meaninful and useful manners. This will allow external applications to query ROPE to get file or problem data for specified problems or problem collections. Among the possible external applications that we anticipate might be able to take advantage of this ability are the open-source web homework system WeBWorK, open content text authors who can have automatically generated sets of problems for their text, and technically capable users who are able to write programs to automate the task of gathering and compiling problem collections.

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 Open Problem Library (OPL) used by the WeBWorK [3] system, for which Gavin LaRose has been a software developer; and Edfinity [6], 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 OPL (Open Problem Library) 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. But it is, necessarily, strictly a resource of problems for WeBWorK, and therefore does not provide the flexibility and extensibility that we envision for ROPE. None the less, we do expect that the data structures used in the OPL 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 OPL), 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. However, it is not an open-source application and does not support the same flexibility in problem collection creation that we envision for ROPE.

In addition to the Michigan problem bank, WeBWorK's OPL 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 sharing, nor the community feedback aspects that we envision for ROPE.

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.

Finally, we believe that the educational world in which we are working has reached a tipping point that argues strongly for the development of a resource such as ROPE. There is increasing outcry about the constraints and disadvantages of commercial products and the cost of higher education—which is only compounded by the cost of textbooks and other class resources. The open source movement continues to demonstrate that it is possible for uniformly recognized content and programs to be developed collaboratively and openly. And mathematics instructors are increasingly connected by social networks and intentional communities, one of which is the Inquiry Based Learning (IBL) community. As more open-content textbooks become available, ROPE will be able to provide a problem resource that complements their problems and work. Programs such as WeBWorK and project such as Wikipedia demonstrate that free, open development can create products and content which is broadly useful and which complements and competes well with commercial products. And communities such as Project NExT [2] have developed in to networks of college faculty who are actively engaged with the use of available resources and technology to improve their teaching.

4 Project Implementation and Timeline

Our timeline to implement ROPE, is shown in Figure 3. In summary, we will have an alpha version of the system running after summer and fall of 2015, to be tested in spring 2016. In the summer of 2016 we will resolve issues that are determined in the alpha test, and add features to the system. In the 2016–17 academic year the system will be in beta-testing. Following summer 2017 we expect to have the system in production.

All programming and software development will be managed by a hired programming consultant and Gavin LaRose. Problem creation and expansion of the problem database will be managed by Dana Ernst and Spencer Hamblen. They will also recruit alpha and beta testers, who will be paid a small honorarium to contribute problems and provide regular feedback on their use of the system and how it may be improved or how it is working well.

date	personnel	activity	outcome
January 15	PIs	team meeting (JMM)	initial design and data proposal
Spring 15	AG, PIs PIs	on-site meeting on-line meetings	feedback on design and data proposal finalize design and data models
Summer 15	PIs, Pr PIs PIs, EE	programming work library development on-site meeting	database, alpha software developed initial library population initial evaluation
Fall 15, Spring 16	PI PIs PIs, At	programming work library development initial testing	user interface finished expansion of library population alpha testing of ROPE
January 16	PIs	team meeting (JMM) at JMM	evaluation of alpha software, initial library dissemination
Spring 16	PIs	on-site team meeting	alpha test evaluation and feature analysis
Summer 16	AG, PIs PIs, Pr	on-site meeting programming work	alpha test feedback, features, path to beta finalize model for moderation develop beta software
Fall 16	PIs, Bt PIs, EE	beta testing on-site meeting	beta use of ROPE second evaluation
January 17	PIs	team meeting (JMM) JMM	evaluation and planning dissemination
Spring 17	PIs	dissemination	continued beta use of ROPE
Summer 17	PI PIs	programming work editorial work	debugging, updates beta to production documentation completed
Fall 17, Spring 18	PIs	programming work editorial work	production service debugging documentation updated

Figure 3: Project Timeline: personnel notation—PIs = grant PIs (Ernst, Hamblen, LaRose); AG = Advisory Group; Pr = contract programmer; EE = External Evaluator; At = Alpha testers; Bt = Beta testers

In its alpha and beta stages of development, we expect that ROPE will have a usable number of problems and a subset of the full functionality that the final system will have. Essential functions (problem search, collections and the community of users) will be in place for alpha testing. Extensions such as the conversion of problems from one format to another is a component of the system that and full implementation of an open API are likely to wait for the beta development phase.

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.

5 Project Personnel

The PIs for the grant are Gavin LaRose, University of Michigan, Dana Ernst, Northern Arizona University and Spencer Hamblen, McDaniel College.

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, including the University of Michigan College of Literature, Sciences and the Arts *Matthews Underclass Teaching Award*, the Michigan MAA Section's teaching award, and the MAA's *Haimo Award for Distinguished College or University Teaching of Mathematics*.

Dana Ernst is currently an Assistant Professor at Northern Arizona University in Flagstaff, AZ. He previously spent four years as an Assistant Professor at Plymouth State University in Plymouth, NH. Ernst's primary research interests are in the combinatorics of Coxeter groups and their associated algebraic structures. His interests also include the scholarship of teaching and learning (SoTL) with a specialization in inquiry-based learning (IBL). He is a Special Projects Coordinator for the Academy of Inquiry-Based Learning and a mentor for several new IBL practitioners. Ernst is also a coauthor for *Math Ed Matters*, which is a monthly column sponsored by the Mathematical Association of America. The column explores topics and current events related to undergraduate mathematics education. Moreover, he serves on the editorial panel for *Math Horizons*. In addition to using free and open-source software (e.g., *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 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 textbook authors. He is also involved in the Sage open-source mathematics software system. **Matt Boelkins** is professor of mathematics at Grand Valley State University and is has developed an open-content calculus textbook. He is an associate editor of the journal PRIMUS (Problems, Resources, and Issues in Mathematics Undergraduate Studies), which is one of the main journals devoted to the teaching of collegiate mathematics. 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). **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 Open Problem Library.

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.

6 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 was a member of the Project NExT leadership team from 1997–2012. 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 almost 1500 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.

7 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 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 4 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

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 4: Primary Measurable Outcomes and Goals

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.

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