Purdue's Engineer of 2020
2010-2011 Seed Grant Program
Purdue University

Project Title:
POET (Purdue Optimization modeling Education Tool): Using Visualization to Effectively Teach Mathematical Optimization Modeling Skills

Total Budget Requested: $40,000.00

Target Attribute(s) to be studied/implemented:
Abilities (communication, decision-making), Knowledge Areas (science & math, analytical skills, open-ended design & problem solving skills, integration of analytical, problem solving & design skills)

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A Project description

A.1 Objective of study and motivation

Operations research—and in particular, optimization—is one of the key components of the engineering curriculum at Purdue and at other institutions. Optimization has been successfully applied to a myriad of problems in engineering and management: examples include air transportation, compiler design, facility planning, humanitarian logistics, and radiation therapy. As the world's technological, economic, and societal challenges increase in size and complexity, preparing "renaissance engineers" to be well-versed in applying operations research techniques to a variety of important decision-making problems becomes even more crucial.

An optimization course aimed at undergraduate engineering students, such as "Operations Research – Optimization" (IE 335) at Purdue, typically focuses on two main areas:

- learning how to formulate valid, tractable *optimization models* (e.g., linear programs and integer programs) from both structured and ill-structured problem descriptions, and
- learning the inner workings of the *algorithms* that solve these models.

Although learning about the algorithmic aspects of optimization can help develop good quantitative intuition, it is the less important area between the two: students can use off-the-shelf software to solve optimization models without remembering the details of the algorithms. Excellent modeling skills, on the other hand, are vital to putting optimization techniques into practice. Without accurate and tractable models, algorithms, no matter how sophisticated, are useless. In addition, since modeling requires creativity, contextual knowledge, and natural language processing, expert human modelers will not be replaced by automation techniques any time soon. In short, **modeling is the most important skill students can learn in an undergraduate optimization course.**

Unfortunately, despite the fact that undergraduate engineering students have been engaging in modeling activities (i.e., mathematical "word" or "story" problems) since elementary school, many students find it difficult to learn how to build good optimization models. This phenomenon is supported anecdotally by many educators in operations research (e.g., Sokol 2005). For example, in IE 335, modeling questions consistently have the lowest average score on homework assignments and exams. Despite this, there has been relatively little work done on systematically understanding why optimization modeling is such a difficult skill to learn, and how such insights can lead to effective modeling pedagogies. The work in this proposal aims to fill this gap.

The objective of this study is to help undergraduate engineering students overcome their difficulties in optimization modeling by

- determining and understanding commonly made mistakes in optimization modeling;
- developing a **visual, web-based environment** that teaches students to formulate valid and tractable optimization models;
- evaluating the effectiveness of the developed visual, web-based environment in optimization model education.

Insights from this research have potential for impact beyond the industrial engineering curriculum. Mathematical optimization techniques are instrumental to many engineering fields. In fact, students in other engineering disciplines, such as civil engineering, electrical engineering, and mechanical engineering, often take IE 335 as a technical elective. By effectively teaching optimization modeling skills to our engineering students, we can provide our students with a powerful set of tools that can help solve important, complex problems in engineering and management.

Consider a building with 5 rooms. There are 3 wireless network routers that provide wireless Internet access in the building. The strength of the wireless signal provided by these routers depends on the power provided to the router. For each room $i = 1, \ldots, 5$ and router $j = 1, \ldots, 3$, let a_{ij} be the amount of signal strength provided to the ith room for every watt of power provided to router j. For each room $i = 1, \ldots, 5$, let d_i be the desired signal strength for room i. For each router $j = 1, \ldots, 3$, let c_j be the cost of providing one watt of power to router j. Assume that interference between routers is always negligible.

Formulate a linear program that minimizes the cost of powering the routers so that each room receives its desired signal strength, using the decision variables

x_j = number of watts provided to router j for all $j = 1, \ldots, 3$.

$$\begin{aligned} \text{minimize} \quad & \textstyle\sum_{j=1}^{3} c_j x_j \\ \text{subject to} \quad & \textstyle\sum_{j=1}^{3} a_{ij} x_j \geq d_i \quad \text{for } i = 1, \ldots, 5; \\ & x_j \geq 0 \quad \text{for } j = 1, \ldots, 3. \end{aligned}$$

Figure 1: An optimization modeling problem (left) used for the pilot study and a correct response (right).

A.2 Background literature

An *optimization model* (sometimes called a *mathematical program*) is a mathematical representation of a decision-making problem, consisting of variables that reflect the decisions to be made, and an objective function in these variables that is to be minimized or maximized, subject to a set of mathematical constraints on the variables that express the limits on the possible decisions that can be made. To illustrate, consider the optimization model shown in the right panel of Figure 1: it has decision variables x_1, x_2, x_3, an objective function $\sum_{j=1}^{3} c_j x_j$ that is to be minimized, and constraints on the decision variables ($\sum_{j=1}^{3} a_{ij} x_j \geq d_i, i = 1, \ldots, 5; x_j \geq 0, j = 1, \ldots, 3$).

Optimization modeling is the process of transforming a decision-making problem given by a story (left in Figure 1) into an optimization model (right in Figure 1). One of the PIs has observed in classroom practices that students find the optimization modeling process harder than applying complex algorithmic ideas to solve these optimization models. This arguably counterintuitive observation is the motivation behind the proposed project.

Education in optimization modeling, and more generally, education in operations research modeling, is an emerging field, with some existing exploratory research. However, the literature on understanding the mathematical problem solving process in mathematics education is rather extensive and relevant to this proposal, since operations research modeling shares many similarities with mathematical problem solving. Existing research in both fields, as well as a pilot study by the PIs, have identified two major deficiencies in a novice student's optimization modeling process:

- **a lack of conceptual understanding** of the underlying problem, and
- **a lack of self-assessment** in the modeling/solving process.

In the following section, we describe these two problems and discuss the notion of **visualization** as a potential solution to the problems.

A.2.1 A lack of conceptual understanding

Contemporary approaches to solving mathematical story problems have emphasized the need for a proper conceptual understanding of the problem. That is, in order to be successful, problem solvers must have an accurate mental representation of the pattern of information that is indicated by the story problem (Hayes and Simon 1976; Riley and Greeno 1988). Several researchers in mathematics education have focused on students' conceptual understanding of the structural aspects of story problems. Mayer et al. (1984) asserted that the ability to classify the underlying mathematical structure of story problems is essential to understanding and transfer of story problem solving skills; they found that when students miscategorize problems, they more frequently commit errors. In this vein, researchers have developed different structure-based story problem typologies for elementary mathematics and algebra (e.g. Mayer 1982; Riley et al. 1983; Marshall 1995).

Researchers have developed interactive environments that encourage students to gain a deeper conceptual understanding of story problems. For example, Marshall (1995) developed the Story Problem Solver (SPS), which guides students to map problem objects and values onto a structural representation of a story problem. Another example is Tutorials in Problem Solving (TiPS), a more recent conceptually-oriented interactive environment for teaching arithmetic and problem-solving skills to remedial adult populations (Derry and The TiPS Research Group 2001). Similar to SPS, TiPS provides a structural problem representation schema for students to use as a launching pad for solving story problems. Students using the TiPS problem representation schema were more successful in problem solving than those using a heuristic problem-solving approach.

A.2.2 A lack of self-assessment

Preliminary studies have shown that self-assessment is a key difference between the behavior of novices and experts in operations research modeling. Willemain (1994, 1995), for example, conducted a study on the thought processes of 12 expert modelers in operations research. Willemain audiotaped these experts while they spent one hour formulating a model for four problems of varying open-endedness, and studied the issues on which the expert modelers focused. Willemain observed that the expert modelers alternated between focusing on the mathematical structure of the model and assessing the validity of the model. Powell and Willemain took a similar approach in studying the thought processes of 28 MBA students who were novice modelers (Powell and Willemain 2007; Willemain and Powell 2007). Powell and Willemain found that in contrast to the expert modelers, these novice modelers did not effectively assess their progress regularly; instead, they often settled prematurely on a single approach and followed it uncritically.

A.2.3 Visualization as a potential aid

Researchers have studied the role of visualization in the thought process of novice and expert operations research modelers and mathematical problem solvers. For example, Waisel et al. (2008) studied the role of visualization in the thought processes of expert modelers by studying their sketches, and found that, among other things, sketches were used more when the focus was on the mathematical structure of the model or on determining the results of the model. Cummins (1991) found that students' story problem performance improved when they first drew or selected pictures that represented the problem's structure. Stylianou (2002) studied the role of visualization in the problem solving strategies of professional mathematicians. The findings of Stylianou's study suggest ways in which experienced mathematical problem solvers use diagrams to perform specific tasks of mathematical analysis.

A pilot study by the PIs of this proposal also offers some preliminary evidence that visualization may be a useful aid for students in the optimization modeling process. On December 9, 2009, the PIs conducted a pilot study with 73 student volunteers from IE 335 to investigate the influence of visualization techniques on students' ability to correctly formulate an optimization model. Figure 1 shows the story problem given to the student volunteers along with one of many potential correct responses. Half of the student volunteers (the drawing group) was asked to first draw a diagram describing the constraints in the story problem; the other half (the control group) was not. 41.7% of the drawing group provided a correct response, compared to 35.1% of the control group. Although the difference in the number of correct responses between two groups is not statistically significant, there were certain types of mistakes that appeared significantly more often with one group than the other. For example, all five participants who made mistakes in using aggregated constraints instead of individual constraints were in the control group; five out of six participants who made mistakes in the direction of inequalities were in the drawing group.

A.3 Evaluation

A.3.1 General approach

Based on prior studies, including our pilot study, we propose to develop a web-based, interactive tool, called the **Purdue Optimization modeling Education Tool (POET)**, that students can use to learn how to formulate valid optimization models. As discussed in Section A.2, existing research has identified two major deficiencies in novice students' optimization modeling processes: a lack of conceptual understanding and a lack of self-assessment. We propose to alleviate these problems using POET. For example, POET will provide a typology of constraint patterns, with corresponding visual artifacts representing the structure of the different constraint patterns (e.g., a circle connecting to a box via an arrow represents $x \leq b$). A user will be able to play with the artifacts (e.g., adding/removing constraints and changing parameters associated with constraints) to understand the structural properties of the different constraint patterns. In addition, the feasible solutions described by the collection of user-constructed constraints will be visualized instantly, so that users will be able to easily self-assess the correctness and quality of their optimization model. Figure 2 shows a rudimentary prototype of POET.

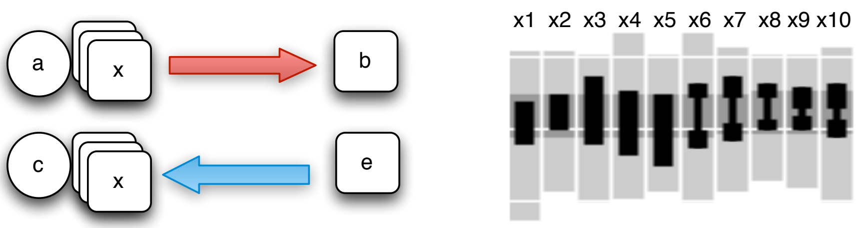

Figure 2: A prototype of POET (left: constraint patterns, right: visualization of feasible solutions)

Developing an effective educational tool, however, cannot be achieved in a single step. Though we have identified two major issues in novice students' optimization modeling processes, our understanding of students' difficulties in this area is still evolving. As such, we will conduct more exploratory studies to better understand the pedagogical issues and how to effectively remedy problem areas and address student needs.

In this light, we will conduct this study iteratively, following the *iterative development approach* used in software engineering (Larman and Basili 2003). This project consists of three cycles (detailed in Table 1 in Section B); each cycle consists of three phases:

1. *Problem* - understanding the problems,
2. *Solution* - proposing a solution, and
3. *Evaluation* - evaluating the solution.

By iterating through these cycles, we will deepen our understanding of the cognitive aspects of optimization modeling, and make continual progress in developing POET. Due to the scope of this project and the time requirements of this seed grant program, the activities in this proposal cover the first two of the three cycles shown in Table 1.

A.3.2 Implementation methods

In order to make POET visually elegant and interactive, it will be implemented using state-of-the-art interactive web technologies and optimization algorithms. Based on the initial assessment of required features, we decided to develop the sophisticated visualization and web-service capabilities using Ruby on

Rails and Adobe Flex/Flash, supported by the MySQL database. To provide instant interactivity, we will develop optimization algorithms that will quickly calculate feasible solutions for dynamically changing constraints. Implementing rapid optimization algorithms for dynamically changing constraints is a very interesting research problem in itself, and may be of independent interest.

A.3.3 Evaluation measures

Observing students' performances on quizzes and exams in IE 335 is one way we will evaluate the effectiveness of POET. However, the classroom setting may make it difficult to conduct rigorously controlled studies, such as those discussed by Powell and Willemain (2007). Thus, we will conduct several heuristic evaluations, survey studies, interview/focus group studies, and a separate controlled lab study in order to better understand how students use the proposed solutions. These additional studies will also provide more detailed measures that will help us understand which aspects of POET contribute to improvements in the students' performances. For example, one of the PIs has a modern eye-tracker (Tobii X60) and a video camera, so it will be possible to observe the cognitive procedures of study participants in detail.

A.3.4 Expected results

We expect that this research will increase our understanding of students' cognitive procedures and difficulties in the optimization modeling process. In addition, we expect to show that novice students' abilities to formulate valid optimization models will improve when provided with visualization tools for guiding self-assessment and enhancing conceptual understanding. Eventually, we also expect that POET will serve not only as a widely-used tool for optimization modeling education but also as a research platform for researchers to collaboratively conduct optimization-modeling-related research.

A.4 Plan for dissemination

The logistics in disseminating POET itself is relatively straightforward, since it will be a web-based system. A more important issue is how to raise awareness of this tool and the accompanying research. In addition to the usual academic venues (e.g., publishing scholarly articles in journals and presenting results at appropriate conferences, such as INFORMS), we plan to invite instructors of optimization-relevant courses at Purdue to use POET. For example, we plan to reach out to the instructors of the following optimization-related courses in the College of Engineering: IE 535, IE 537, IE 538, IE 630, IE 634, IE 639, ECE 580, and AAE 550. In the future, we will contact instructors at other institutions worldwide to promote POET.

In addition to these dissemination activities, we will target the following funding opportunities to continue the research in this proposal after the study is completed:

- NSF - Course, Curriculum, and Laboratory Improvement (CCLI),
- NSF - Research and Evaluation on Education in Science and Engineering (REESE).

B Timeline and implementation strategy

Table 1: The work plan of the proposed study

Cycle	Phase	Description	Deadline
Announcement		The winners of the Engineer of 2020 Seed Grant Program will be announced.	2/29/2010
Cycle 0	Preparation	(1) Submit an IRB application for this project.	1/30/2010
		(2) Acquire permission from IE 335 students to use their homework, quizzes, and examinations for this research.	2/16/2010
		(3) Recruit IE 335 students for an interview study during Summer 2010.	2/16/2010
		(4) Post a project description to the SURF website.	3/1/2010
		(5) Finalize literature review.	5/30/2010
Cycle 1	Problem	(1) Construct taxonomy of student mistakes by analyzing homework, quizzes, and examinations in IE 335.	6/20/2010
		(2) Conduct an interview study with undergraduate students who previously took IE 335.	8/1/2010
		(3) Construct taxonomy of constraint patterns by analyzing textbooks.	8/1/2010
	Solution	(1) Construct lecture materials based on constraint patterns.	8/20/2010
		(2) Develop prototypes for POET to test visualization components.	8/20/2010
	Evaluation	Evaluate the effectiveness of the constraint pattern taxonomy in teaching IE 335 students.	9/1/2010
Mid-year report		Present the results of Cycle 1 at the Engineering of 2020 Workshop.	9/30/2010 (TBA)
Cycle 2	Problem	Develop sample visual representations of different constraint patterns and test their intuitiveness through a survey study.	10/1/2010
	Solution	Develop POET v0.1, a web-based, interactive conceptual-understanding-oriented optimization model builder (without tools for self-assessment).	12/1/2010
	Evaluation	(1) Conduct a heuristic evaluation study using expert reviewers to find any potential issues.	1/30/2011
		(2) Conduct a survey study and a controlled lab study to investigate the effectiveness of POET v0.1.	3/30/2011
		(3) Invite instructors in other optimization-related courses to test POET.	5/4/2011
Final report		Submit the final report for this project.	9/10/2011
Dissemination		Present the results of this project at the INFORMS Annual Meeting 2011.	11/12/2011
Cycle 3	Problem	Conduct a survey study to identify the most useful types of feedback and self-assessment.	Future research
	Solution	Develop POET v0.2, which will include feedback for self-assessment.	Future research
	Evaluation	Conduct a survey study and a controlled lab study to test the effectiveness of visual feedback tools on students' self-assessment skills.	Future research

C. Personnel Requirements

Please indicate the portion of FTE that each faculty member will dedicate to the project

Faculty member	Summer 2010	Fall 2010	Spring 2011
Rachael H. Kenney	10%	20%	10%
Nelson A. Uhan	20%	20%	10%
Ji Soo Yi	10%	10%	20%

D. Budget

Faculty/Staff Member Funding *Please indicate the funding (dollars and time) you are requesting for the grant for this project)*			
	Grant funds requested		
Faculty/Staff Name:	% Time	Fringe Benefits	$$
Rachael H. Kenney	100% (4 days)	392.00	1052.00
Nelson A. Uhan	100% (4 days)	459.00	1230.00
Ji Soo Yi	100% (4 days)	453.00	1215.00
Subtotal Faculty/Staff Funding		$ 1304.00	$ 3497.00

Graduate Students				
	Grant funds requested			
Type of position	% Time	Insurance + Fee Remit	Fringe Benefits	$$
Research Assistant	50% (1yr)	9620.00	92.00	18495.00
Subtotal Grad Student Personnel		$9620.00	$92.00	$18495.00

Undergraduate Student Funding *Please indicate the student resources (funding and time) you are requesting from the grant for this project.*			
	Grant funds requested		
Type of position	Hrs/week	Fringe Benefits	$$
Research Assistant (Summer)	(Salary, 3 mo.)	357.00	4200.00
Subtotal Undergrad Student Personnel		357.00	4200.00

Equipment & Software Funding *Please list all specialized equipment and software required for the project. (Do not include standard computer equipment and commonly-available software, e.g. Microsoft Office, Microsoft Windows). Mark whether any of the equipment or software is provided by the department. (Note that only 10% of the funds can be used to purchase equipment and it needs to be dedicated to the goals of the project.*	
Name of Equipment	Funds Requested
Subtotal Equipment	$0.00

Name of Software	
Subtotal Software	$0.00
Other miscellaneous items (Computer media, cables, etc)	
Subtotal miscellaneous	$0.00
Other expenses	
Conference travel	2435.00
Subtotal other expenses	2435.00

E Budget justification

A large portion of the budget is allotted for hiring one graduate research assistant for one year ($18,495), and one undergraduate summer research assistant for three months ($4,200). These research assistants will serve as the main workforce of the project under the guidance of the three PIs. The graduate research assistant will develop POET and conduct evaluation studies. The undergraduate summer research assistant will focus on constructing the taxonomy of common modeling mistakes and constraint patterns. The PIs will try to hire the undergraduate research assistant through the Summer Undergraduate Research Fellowships (SURF) program. If hiring through the SURF program is successful, the saved funds ($2,800) will be used to pay non-IE-335 student volunteers (about $10 / hour) for participating in additional survey studies or web-based experiments. Otherwise, the allotted funds will be fully used to support the undergraduate research assistant. A small portion of the budget ($2,435) will be used to support the travel of a PI to an academic conference (e.g., the INFORMS Annual Meeting) in order to report the results of the project to the operations research community and raise awareness of the developed tool, POET. The remainder of the budget ($3,496) will be used to pay a fraction of the PIs' summer salaries.

F References

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S. J. Derry, The TiPS Research Group. 2001. Development and Assessment of Tutorials in Problem Solving (TiPS): A Remedial Mathematics Tutor. Final Report to the Office of Naval Research (N00014-93-1-0310), Wisconsin Center for Education Research, Unversity of Wisconsin-Madison, Madison, WI.

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S. G. Powell, T. R. Willemain. 2007. How novices formulate models. Part I: qualitative insights and implications for teaching. *Journal of the Operational Research Society* 58:983–995.

M. S. Riley, J. G. Greeno. 1988. Developmental analysis of understanding language about quantities and solving problems. *Cognition and Instruction* 5:49–101.

M. S. Riley, J. G. Greeno, J. I. Heller. 1983. Development of children's problem solving ability in arithmetic. In H. P. Ginsburg, ed., *The Development of Mathematical Thinking*. Academic Press, New York.

J. Sokol. 2005. Teaching O. R. modeling. *OR/MS Today* December 2005.

D. A. Stylianou. 2002. On the interaction of visualization and analysis: the negotiation of a visual representation in expert problem solving. *Journal of Mathematical Behavior* 21:303–317.

L. B. Waisel, W. A. Wallace, T. R. Willemain. 2008. Visualization and model formulation: an analysis of the sketches of the expert modellers. *Journal of the Operational Research Society* 59:353–361.

T. R. Willemain. 1994. Insights on modeling from a dozen experts. *Operations Research* 42:213–222.

T. R. Willemain. 1995. Model formulation: what experts think about and when. *Operations Research* 43:916–932.

T. R. Willemain, S. G. Powell. 2007. How novices formulate models. Part II: a quantitative description of behaviour. *Journal of the Operational Research Society* 58:1271–1283.

Biographical Sketch
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Professional Preparation

Harvard University	Applied Mathematics	A.B., 2002
Harvard University	Applied Mathematics	S.M., 2002
Massachusetts Institute of Technology	Operations Research	Ph.D., 2008

Academic Appointments

2008 - Present Assistant Professor, School of Industrial Engineering, Purdue University

Publications

1. D. Altner, Ö. Ergun, N. A. Uhan. The maximum flow network interdiction problem: valid inequalities, integrality gaps, and approximability. *Operations Research Letters*, 38:33-38, 2010.
2. A. S. Schulz, N. A. Uhan. Sharing supermodular costs. Submitted, August 2007, under 4th revision, November 2009. (Extended abstract in M. Charikar et al., editors, *Approximation, Randomization, and Combinatorial Optimization: Algorithms and Techniques (APPROX 2007 and RANDOM 2007)*, volume 4627 of *Lecture Notes in Computer Science*, pp. 271-285, 2007, Springer, Berlin.)
3. A. S. Schulz, N. A. Uhan. Near-optimal solutions and large integrality gaps for almost all instances of single-machine precedence-constrained scheduling. Submitted, May 2009.
4. M. Mastrolilli, M. Queyranne, A. S. Schulz, O. Svensson, N. A. Uhan. Minimizing the sum of weighted completion times in concurrent open shops. Submitted, November 2009.
5. A. S. Schulz, N. A. Uhan. Approximating the least core value and the least core of supermodular cost cooperative games. Working paper, October 2009.
6. Q. J. Hu, L. B. Schwarz, N. A. Uhan. The impact of GPOs on healthcare-product supply chains. Working paper, November 2009.

Synergistic Activities

Faculty Advisor, INFORMS Student Chapter, Purdue University, 2009 – Present.

First Place, INFORMS George E. Nicholson Student Paper Competition, 2007.

Reviewer for *Discrete Optimization*, *European Journal of Operational Research*, *Journal of Scheduling*, *Manufacturing & Service Operations Management*, *Mathematical Programming Series A*, *Naval Research Logistics*, *Networks*, *Operations Research*.

Member of INFORMS, SIAM.

Collaborators and Other Affiliations

(a) Collaborators

Douglas Altner (United States Naval Academy)
Özlem Ergun (Georgia Institute of Technology)
Qiaohai Hu (Purdue University)
Monaldo Mastrolilli (IDSIA)
Maurice Queyranne (University of British Columbia)
Andreas S. Schulz (Massachusetts Institute of Technology)
Leroy B. Schwarz (Purdue University)
Ola Svensson (IDSIA)

(b) Graduate and Postdoctoral Advisors

Andreas S. Schulz (Massachusetts Institute of Technology)

(c) Graduate Advisees and Postgraduate Scholars Sponsored

Rama Sri Sindhura Balireddi (Purdue University, current M.S. student)
Kan Fang (Purdue University, current Ph.D. student)
Mohan Gopaladesikan (Purdue University, current M.S. student)

Current and Pending Support
Nelson A. Uhan

- Project/Proposal Title: TFM algorithms and modeling: a response to subtopic C.5.6 of amendment 6

Support:	Pending
Agency:	NASA
Total Award Amount:	$1,061,386.00
Total Award Period:	March 2010 – February 2013
PI:	Steven Landry (Purdue)
Co-PIs:	Leyla Ozsen (California State University, San Fransisco), Dengfeng Sun (Purdue), Nelson Uhan (Purdue)

Biographical Sketch: KENNEY, Rachael H.

PROFESSIONAL PREPARATION

University of Dayton	Mathematics B.S. 1999
University of Dayton	Applied Mathematics M.S 2000
North Carolina State University	Mathematics Education Ph.D. 2008

APPOINTMENTS

2008-present	Purdue University, Assistant Professor, Joint appointment in Departments of Mathematics and Curriculum and Instruction
2000-2008	North Carolina State University, Lecturer, Department of Mathematics

PUBLICATIONS

Kenney, R. (2009). Linking college pre-calculus students' uses of graphing calcultors to their understanding of mathematical symbols. *Proceedings of the Twenty-Ninth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.*

Woodward, J., Kenney, R., Zhang, D., Guebert, A., Cetintas, S., Tzur, R., & Xin, Y. (2009). Conceptual based task design: Megan's progress to the anticipatory stage of multiplicative double countind (mDC). *Proceedings of the Twenty-Ninth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.*

Kenney, R. (2009). Pre-Calculus students interactions with mathematical symbols. *Proceedings of the 12th SIGMAA conference on Research in Undergraduate Mathematics Education*, Raleigh, NC.

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Kenney, R. (2005). Students understanding of logarithmic functions. *Proceedings of the Twenty-Ninth Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.*

Diestelkamp, W.S., Hartke, S.G., Kenney, R.H., (2004). On the degree of local permutation polynomials, *Journal of Combinatorial Mathematics and Combinatorial Computing*. 50, 129-140.

COLLABORATORS AND OTHER AFFILIATIONS

Collaborators:
Margaret Gayle, North Carolina Department of Public Instruction
Yukiko Maeda, Purdue University
Allison McCullach, North Carolina State University
Jill Newton, Purdue University
Ron Tzur, University of Colorado Denver
Yan Ping Xin, Purdue University

Graduate Advisors:
Hollylynne Stohl Lee, North Carolina State University
Karen Hollebrands, North Carolina State University

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Rachael Kenney

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Developing Assessment-Competence in Secondary Mathematics Teachers (DASMaT)

Source of Support: NSF

Total Award Amount: $ 430,104 Total Award Period Covered: 09/01/10 - 08/31/12

Location of Project: Purdue University

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 1.13 Sumr: 1.10

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: S.H.A.R.E. (Supporting Heightened Algebra Readiness Experiences) 2

Source of Support: Indiana Department of Education

Total Award Amount: $ 221,361 Total Award Period Covered: 05/01/10 - 06/30/13

Location of Project: Purdue University

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.50 Sumr: 1.00

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Special Meeting for the Development of Advanced Mathematics Courses for Mathematics Education Graduate Students

Source of Support: NSF

Total Award Amount: $ 212,639 Total Award Period Covered: 07/01/10 - 12/31/13

Location of Project: Purdue University

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

BIOGRAPHICAL SKETCH

Ji Soo Yi

School of Industrial Engineering
Purdue University
315 N. Grant Street, West Lafayette, IN 47907
Phone: 765-496-7213 / Fax: 765-494-1299
E-mail: yij@purdue.edu

(i) Professional Preparation

Seoul National University	Industrial Engineering	B.S., 1998
Georgia Institute of Technology	Industrial and Systems Engineering	Ph.D., 2008

(ii) Appointments

2008 - Present Assistant Professor, School of Industrial Engineering, Purdue University

(iii) Publications

(a) Eight significant publications

1. Yi, J. S., Kang, Y. A., Stasko, J., & Jacko, J. A. (2008). Understanding and Characterizing Insights: How do People Gain Insights Using Information Visualization. *Proceedings of the 2008 Conference on BEyond time and errors: novel evaLuation methods for Information Visualization (BELIV '08)*, Florence, Italy, April 5, 2009, 39 - 44. (http://portal.acm.org/citation.cfm?id=1377966.1377971)

2. Yi, J. S., Kang, Y. A., Stasko, J., & Jacko, J. A. (2007). Toward a Deeper Understanding of the Role of Interaction in Information Visualization. *IEEE Transactions on Visualization and Computer Graphics (TVCG)*, **13**(6), 1224 - 1231. (http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4376144)

3. Law, C. M., Yi, J. S., Choi, Y. S., & Jacko, J. A. (2007). Unresolved Problems in Accessibility and Universal Design Guidelines. *Ergonomics in Design: The Quarterly of Human Factors Applications*, **15**(3), 7-11.

4. Barnard, L., Yi, J. S., Jacko, J. A., & Sears, A. (2007). Capturing the Effects of Context on Human Performance in Mobile Computing Systems. *Personal and Ubiquitous Computing*, **11**(2), 81-96. (http://portal.acm.org/citation.cfm?id=1229063.1229065)

5. Choi, Y. S., Yi, J. S., Jacko, J. A., & Law, C. M. (2006). Are "Universal Design Resources" Designed for Designers? *Proceedings of the 8th International Conference on Assistive Technologies (ASSETS '06)*, Portland, OR, October 23-25, 2006, 87-94. (http://portal.acm.org/citation.cfm?id=1168987.1169003)

6. Yi, J. S., Melton, R., Stasko, J., & Jacko, J. A. (2005). Dust & Magnet: Multivariate Information Visualization using a Magnet Metaphor. *Information Visualization*, **4**(4), 239-256. (http://www.palgrave-journals.com/ivs/journal/v4/n4/abs/9500099a.html)

7. Barnard, L., Yi, J. S., Jacko, J. A., & Sears, A. (2005). An Empirical Comparison of Use-in-Motion Evaluation Scenarios for Mobile Computing Devices. *International Journal of Human-Computer Studies*, **62**, 487-520. (http://portal.acm.org/citation.cfm?id=1080546)

8. Yi, J. S., Choi, Y. S., Jacko, J. A., & Sears, A. (2005). Context Awareness via a Single Device-Attached Accelerometer during Mobile Computing. *Proceedings of the 7th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI '05)*, Salzburg, Austria, September 19-22, 2004, 303-306. (http://portal.acm.org/citation.cfm?id=1085777.1085839)

(iv) Synergistic Activities

- A member of Editorial Board of International Journal of Human Computer Interaction (IJHCI)
- A member of Program Committee for IEEE InfoVis Conference 2009 (InfoVis '09)
- A reviewer for Information Visualization, International Journal of Human-Computer Interaction (IJHCI), International Journal of Human-Computer Science (IJHCS), Universal Access in the Information Society (UAIS), Transactions on Computer-Human Interaction (TOCHI), and Computers & Industrial Engineering.
- A developer of several information visualization tools, such as Dust & Magnet, Visual Nursing Home Choice, TimeMatrix, SimulSort, and TagDive
- A member of Scientific Advisory Board for the first International Conference on Human Factors and Ergonomics in Healthcare (ICHFEH 2010).
- A member of Institute of Electrical and Electronics Engineers (IEEE), Association for Computing Machinery (ACM), and Human Factors and Ergonomics Society (HFES).

(v) Collaborators & Other Affiliations

(a) Collaborators and Co-Editors

Leon Barnard, Ataccama Software; Young Sang Choi, Georgia Institute of Technology; Paula J. Edwards, Georgia Institute of Technology; Julie A. Jacko, University of Minnesota; Yoon Young Jung, NHN Corporation; Youn-ah Kang, Georgia Institute of Technology; Thitima Kongnakorn; Chris M. Law, RMIT University; V. Kathlene Leonard, Mobients; Anna McDaniel, Indiana University-Purdue University Indianapolis; Amy Mobley, Purdue University; Kevin P. Moloney, Georgia Institute of Technology; Carolos Morales, Purdue University; Mathew J. Palakal, Indiana University-Purdue University Indianapolis; Kimberly Plake, Purdue University; Rachel M. Ponder, Georgia Institute of Technology; Francois Sainfort, University of Minnesota; Andrew Sears, UMBC; Brani Vidakovic, Georgia Institute of Technology; Karen Yehle, Purdue University

(b) Graduate and Postdoctoral Advisors

John T. Stasko, Georgia Institute of Technology

(c) Thesis Advisor and Postgraduate-Scholar Sponsor

Inkyoung Hur (Purdue University, current MS student)
Bum chul Kwon (Purdue University, current Ph.D. student)
Sung-Hee Kim (Purdue University, current Ph.D. student)

Current and Pending Grants – Ji Soo Yi

ACTIVE/PENDING (Indicate) Active
Source and Project Number: the School of Industrial Engineering and the e-Enterprise Center
Principal Investigator: Shimon Nof, Ph.D.
Title of Project (or Subproject): Collaboratorium
Dates of Approved/Proposed Project: 2/10/2009 – 2/9/2010
Annual Direct Costs of Overall project: $120,000
The major goals of this project are: Enable and optimize human, system, and research collaboration while learning how to further improve it by the science of interactive collaboration.
OVERLAP: ??

ACTIVE/PENDING (Indicate) Active
Source and Project Number: Regenstrief Center for Healthcare Engineering
Principal Investigator: Ji Soo Yi
Title of Project (or Subproject): Testing an Interactive Web-Based Nutrition Tool in Patients Enrolled in Cardiac Rehabilitation
Dates of Approved/Proposed Project: 7/1/2009 – 6/30/2010
Annual Direct Costs of Overall project: $40,000
The major goals of this project are: The objective of this pilot project is to test a web-based interactive nutrition tool, called "Food Magnet" with patients diagnosed with coronary heart disease.
OVERLAP: ??

From: "Joseph F. Pekny" <pekny@purdue.edu>
Subject: **RE: REMINDER: Engineer of 2020 Seed Grant Program**
Date: January 22, 2010 11:42:48 AM EST
To: "'Ji Soo Yi'" <yij@purdue.edu>
Cc: "Nelson Uhan" <nuhan@purdue.edu>, "Rachael Kenney" <rhkenney@math.purdue.edu>
Reply-To: <pekny@purdue.edu>

Ji Soo,

I endorse your proposal. Indeed I find this particular topic particularly compelling because of the importance of optimization for helping students think holistically and quantitatively and the potential of your proposed approach to make learning optimization methods more intuitive.

Good Luck,
Joe Pekny
Interim Head of Industrial Engineering

From: Ji Soo Yi [mailto:yij@purdue.edu]
Sent: Thursday, January 21, 2010 10:04 AM
To: Joseph Pekny
Cc: Nelson Uhan; Rachael Kenney
Subject: Fwd: REMINDER: Engineer of 2020 Seed Grant Program

Dear Dr. Pekny:

Upon the request for proposal for the Engineer of 2020 Seed Grant Program, Dr. Uhan, Dr. Kenney (an assistant professor in Mathematics, Curriculum & Instruction), and I put together a proposal, titled "Purdue Optimization Modeler: Using Visualization to Effectively Teach Mathematical Optimization Modeling Skills". The main idea is developing a visualization tool to teach undergraduate students (e.g., IE335) how to construct optimization models from story problems. We believe that learning how to construct a model is more pressing educational issue than learning how to solve the model (which can be easily done using computer software). I also believe that you personally find this proposal interesting given your research background.

In the last minute, however, we found out that it is "suggested" to have an endorsement from the head of our department. It is unfortunate that you are on an international trip now, so I am not sure if you are able to access email. If you can, please let us have your endorsement via email. If not, I will try to catch you when you come to campus tomorrow afternoon.

The current draft of our proposal and a sample letter of endorsement are attached for your information.

Best regards,
Ji Soo Yi

Assistant Professor
School of Industrial Engineering
Purdue University
http://web.ics.purdue.edu/~yij/