Coaching Researchers
to
Write Successful Grants

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Research Development: A Leadership Challenge

• Research Administration has traditionally been a “downstream” function
• Competition is increasing; smaller percentage of proposals are funded
• Universities increasingly reliant on external funding
• More focus is needed “upstream”

GOAL:
More faculty writing better proposals!
Contrasting perspectives

**Academic writing:**
- **Researcher-centered:** Scholarly passion
- **Past oriented:** Work you have done
- **Expository:** Explaining to reader
- **Impersonal:** Objective, dispassionate
- **Individualistic:** Usually solo activity
- **Verbosity rewarded:** Few length constraints:
- **Specialized terminology:** “Insider jargon”

World of ideas
*Thesis, theme, theory:*

**Grant writing:**
- **Sponsor-centered:** Service attitude
- **Future oriented:** Work you wish to do
- **Persuasive:** “Sell” the reader
- **Personal:** Convey excitement
- **Team-oriented:** Feedback needed
- **Brevity rewarded:** Strict length constraints
- **Accessible language:** Broad audience

World of action
*Project, activities, outcomes*
Taken together with the findings from the present study that (a) workplace aggression in the primary job was more closely associated with negative work experiences and (b) both situational and individual characteristics played a role in aggression in the secondary job, future research might benefit from a greater focus on the subjective salience of the job as a moderator of the relationship between workplace experiences and supervisor-targeted aggression. Indeed, despite the differential effects of situational and individual difference factors on aggression, it is notable that the individual difference factors exerted a consistent but relatively low-level effect on aggression across contexts, whereas the more salient situational experiences exerted context-specific effects.

Grant Writing: A Low Probability Game?

• Proposal success rates average 20 to 30 per cent (NSF, NIH, USDA, most private foundations)

• More than half (60%) are rejected on first reading because:
  - Proposal did not match program
  - Applicant did not follow directions

New & Quick, Grantseeker’s Toolkit, 1998
The Critics Weigh In...

(Actual comments made by actual reviewers)

• “The problem statement, such as it is, is too global, showing no relationship to reality with no potential solution being indicated or even possible.”

• “This problem has been studied to death. I’m surprised the writer doesn’t know this.”

• “It is almost impossible to understand what the author wants to study or what the main theme is. The problem is full of jargon and totally unclear as stated.”

• “I cannot ascertain what approach the researcher will take in examining the problem as outlined.”

• The writer has a flair for the dramatic. The world will not collapse if we do not fund a study of students’ daydreams.”
So what’s the problem?…

“The problem makes the proposal.”

☑ An important need or issue that should be addressed
☑ A gap between where we are now and where we could be
☑ A limitation of current knowledge or way of doing things

It’s also an opportunity…

☑ A fresh idea that can advance our understanding or address a societal need
☑ A refinement that improves efficiency or lowers the cost of goods and/or services
☑ A new paradigm that reshapes our thinking or way of doing things
What makes a proposal competitive?

- Significance (important area of research)
- Original approach
- Strong likelihood of success, i.e., will make a significant contribution to the field
- Knowledge and experience in the discipline
- Experience in essential methodology
- Succinct, logical and focused project plan
- Realistic amount of work
- Sufficient detail
- Cost effective
Top Ten Reasons for Failure*

1. Lack of original ideas
2. Diffuse, unfocused or superficial Research Plan
3. Lack of knowledge of relevant published work
4. Lack of experience in essential methodology
5. Uncertainty concerning future directions
6. Questionable reasoning in experimental approach
7. Absence of acceptable scientific rationale
8. Unrealistically large amount of work
9. Lack of sufficient experimental detail
10. Uncritical approach

*presented at an NIH grants conference
Consider the Reviewer...

- Many competitive programs utilize review panels (especially federal and state)
- Most private foundations use staff to “screen” proposals for Program Director
- The more competitive, the more reviewer(s) will look for reasons to reject proposals
Success = Good Ideas - Pitfalls

• There is plenty of evidence to show that good ideas are often undermined by missteps in proposal preparation

• The following are some common proposal pitfalls and strategies to avoid them
A Starting Point...

• What are you passionate about?

• What is the problem (and why is it important)?

• How is existing knowledge or practice inadequate?

• Why is your idea better?

• How is it new, unique, different?

• What will it contribute and who will benefit from it?
1. Verify the match

- Develop your funding search skills
- Study program goals and eligibility
- Make contact with program officer before starting proposal!

- Read program announcement carefully; note questions
- Research previous awards!
- Send brief (2-3 short paragraphs) overview of proposed project
- Inquire about alternative funding sources
2. Structure the Proposal

Always follow the format provided by the sponsor! Where none is provided, build your case in distinct sections:

I. Problem Statement; or Significance of the Research
II. Project Purpose (Overall goal + Specific objectives)
   *NB: Cite “fit” with program objectives!* 
III. Research Design; or Workplan (Activities + Timelines)
IV. Applicant Qualifications and Capabilities
V. Evaluation Plan; or Expected Outcomes
VI. Budget (Summary + Justifications)

Appendix (supplementary materials)
3. Prove the importance of your project

- State your purpose and case for need up front; build a compelling argument
- Think “Op Ed,” not academic journal
- Cite an authoritative source(s)

EX:
“This proposal addresses a priority of the World AIDS Foundation: AIDS prevention in developing countries. Specifically, we propose to conduct a series of five-day AIDS prevention workshops in four cities in Indonesia. The participants will be…”
Start with the Pitch: Sell Your Idea!

I. Set the Stage – Lay Out the Problem ("Who Cares?")
   A. Get the reviewer interested at the outset
   B. Identify the importance—stress the need
   C. Summarize the state of the art
   D. Describe technical challenges to solving the problem and potential benefits

II. State the Theme – Your Solution
   E. Describe the concept and establish credibility
   F. Describe your project’s fundamental purpose

III. Create a Vision ("So What?")
   G. Show how your work will advance the field
   H. Envision the world with the problem solved

The “pitch” should be the opening 2 - 3 paragraphs of the proposal’s very first section (after the abstract), regardless of what that section is called (INTRODUCTION, BACKGROUND, PROBLEM STATEMENT, SIGNIFICANCE OF THE RESEARCH, SPECIFIC AIMS, etc.)
Intravenous Magnesium as a Treatment Modality for Recurrent Airway Obstruction

I. SETTING THE STAGE

(A) Recurrent Airway Obstruction (RAO) is a progressive, debilitating respiratory disease, occurring in 50% of mature horses, (B) with 5% affected severely enough to result in an end to their working careers or to euthanasia. It is a chronic, recurrent condition with clinical characteristics that are well recognized, although its pathogenesis is complex, multifactorial, and currently not well understood. As an indication of industry concern, in June of 2000, 30 of the world’s leading investigators were joined by pharmaceutical companies at a Michigan State University conference devoted entirely to improving RAO prevention and management. (C) Further, current management and therapeutic regimens for horses with chronic or severe disease are either not efficacious or are not able to be implemented. (D) For example, drugs commonly used to manage RAO, such as corticosteroids with anti-inflammatory properties and bronchodilators that open the passageways, also stress the heart, adding additional risk to an already debilitated animal. Strategies to remove environmental precipitators such as dust and mold often fail as many horse owners are unable or unwilling to comply with such husbandry recommendations.

II. PROJECT THEMES

(E) With this study, we propose to administer intravenous magnesium to horses with acute and chronic RAO to determine if this treatment improves respiratory function and/or reduces arterial hypertension, without the deleterious side effects of other commonly administered drugs. Recent case reports show magnesium to be efficacious for acute human asthmatics who fail to respond to more conventional therapy. (F) As RAO is increasingly seen as an equine analog to asthma in humans (replacing the previous use of the COPD model), and severely affected RAO horses demonstrate many of the same clinical signs as human asthmatics, RAO horses could be equally responsive to this treatment.
III. VISION

(G) Should the research hypothesis be proved, clinicians will have another viable treatment modality at their disposal, one that is inexpensive, and effective in treating a resistant disease without the damaging side effects of other modalities. (H) Additionally, horse owners and breeders could reduce the significant financial losses caused by the malady, currently estimated at more than $800 million annually in the US alone.¹¹
4. Assume an uninformed but intelligent reader

- Use clear, accessible language
- Stick with direct statements and active voice
- Avoid insider jargon and acronyms

“An expanding awareness of the limitations of our training settings, the political fallout of our training mission, the consequence of having therapists work in a particular work setting, and the need to change established institutional structures (e.g., child protective services, Aid to Families with Dependent Children, juvenile court) are examples of the contextualization of training and supervision.”
Passive vs. Active Voice

• *It has been demonstrated by research that...*

• *The SAP program is being implemented by our department...*

• *Following administration of the third dosage, measurements will be taken...*

• *Research shows clearly that...*

• *Our department launched SAP this year...*

• *After dosage 3, we will measure...*
5. Formulate specific, measurable objectives

**Goal:** General statement of the project’s overall purpose(s)

“Our aim with this innovative curriculum is to improve the supply of graduates with National Registry certification.”

**Objective:** A specific, measurable outcome or milepost

Which is the better objective? Why?

“It is anticipated that completion of the new curriculum will result in enhanced student scores.”

“At least 90 per cent of course graduates will pass the National Registry Examination.”
6. Illustrate: Project concept and the work plan

1) Overall concept:

2) Work plan:

1) Visualize the overall project with a drawing

2) Specify major tasks and timelines; use Gantt charts, calendars or flow charts
7. Follow application instructions exactly!

• Common sins:
  - Late submission
  - Narrative too long
  - Fonts, margins, spacing too small
  - Signatures, certifications missing
  - Budget narrative missing
  - Insufficient number of copies
  - Inappropriate binding
8. Pay attention to all review criteria

- Read evaluation standards carefully; then reference them in the project narrative
- Touch all the bases—not just the ones you’re comfortable with

Reviewers will use the criteria to “score” your proposal
What is the intellectual merit of the proposed activity?

What are the broader impacts of the proposed activity?

Program specific criteria may be listed in the program announcement.
1) How important is the proposed activity to **advancing knowledge and understanding** within its own field or across different fields?

2) How **well qualified** is the proposer to conduct the project?

3) To what extent does the proposed activity explore **creative and original concepts**?

4) How **well conceived and organized** is the proposed activity?

5) Is there sufficient **access to necessary resources**?
Broader Impacts – 5 strands

1) How well does the activity advance discovery and understanding while promoting teaching, training and learning?

2) How well does the proposed activity broaden the participation of women and underrepresented groups? (“Diversity”)

3) To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks and partnerships?

4) Will the results be disseminated broadly to enhance scientific and technological understanding?

5) What may be the benefits of the proposed activity to society?

Examples:
Possible rankings by reviewers

Individual rankings:
- “Excellent”
- “Very Good”
- “Good” (not good!)
- “Fair”
- “Poor”

Panel recommendation:
- “HIGH PRIORITY”
- “MEDIUM PRIORITY”
- “LOW PRIORITY”

Remember:
Panels rarely reach a consensus ranking; only those proposals with a majority of “Excellents” are likely to be funded
NSF:

Distribution of Average Reviewer Ratings for Awards and Declines, FY 2010

Awards: 13,000
Declines: 43,000
Five criteria apply to all NIH proposals:

- **Significance**: ability of project to improve health
- **Approach**: feasibility of research methods & budget
- **Innovation**: originality of project approach*
- **Investigator**: qualifications and experience of investigator(s)
- **Environment**: suitability of facilities, equipment & institutional support

**NEW CRITERION (2010): IMPACT**

*Final score and most important!*
Peer Review: New Scoring System

- Old 1 to 5 scale replaced by a **9-point** scale
  (1 = “Exceptional” and 9 = “Poor”)
- Most important new score is the final **IMPACT** rating:
  (10 to 90)
- Ratings will be in whole #’s only; no decimals
- Reviewers will also provide ratings for each of five traditional NIH criteria
  - Significance
  - Investigator(s)
  - Innovation
  - Approach
  - Environment
New Scoring System, cont’d

- Preliminary score: Reviewers send in their scores for the 5 present traditional criteria, plus the final IMPACT score
- **Note:** Impact score is an **independent** rating, not an average of the 5!
- Applications in the lower half are “less competitive,” and will **Not be Discussed**
- PI’s of “ND” proposals WILL receive all scores from individual reviewers, but no overall IMPACT score
- After discussing competitive proposals, reviewers may change their scores
- Reviewer scores are averaged, x 10, for a range of **10 – 90**
- Average IMPACT scores are then **percentiled** for final ranking to determine **funding order**
### New Scoring System, cont’d

**Definition of 9-point scale:**

<table>
<thead>
<tr>
<th>Impact</th>
<th>Score</th>
<th>Descriptor</th>
<th>Additional Guidance on Strengths/Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>1</td>
<td>Exceptional</td>
<td>Exceptionally strong with essentially no weaknesses</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Outstanding</td>
<td>Extremely strong with negligible weaknesses</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Excellent</td>
<td>Very strong with only some minor weaknesses</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Very Good</td>
<td>Strong but with numerous minor weaknesses</td>
</tr>
<tr>
<td>Medium</td>
<td>5</td>
<td>Good</td>
<td>Strong but with at least one moderate weakness</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Satisfactory</td>
<td>Some strengths but also some moderate weaknesses</td>
</tr>
<tr>
<td>Low</td>
<td>7</td>
<td>Fair</td>
<td>Some strengths but with at least one major weakness</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Marginal</td>
<td>A few strengths and a few major weaknesses</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Poor</td>
<td>Very few strengths and numerous major weaknesses</td>
</tr>
</tbody>
</table>

**Non-numeric score options:** NR = Not Recommended for Further Consideration, DF = Deferred, AB = Abstention, CF = Conflict, NP = Not Present, ND = Not Discussed

**Minor Weakness:** An easily addressable weakness that does not substantially lessen impact

**Moderate Weakness:** A weakness that lessens impact

**Major Weakness:** A weakness that severely limits impact
Proposal Success Rates 1995 - 2011
9. Polish the abstract

- Written last, but read first by reviewers
- Must be an intriguing “first advertisement”
- Should reflect entire scope of project
- Summarizes project purpose and methods
- Must convey:
  - What researcher intends to do
  - Why it’s important
  - Expected outcome(s)
  - How work will be accomplished
- Has to be both CONCISE and COMPLETE!

This may be the only narrative that some reviewers will read
10. Presubmission review

- Ask seasoned colleagues for comments and suggestions
- Should be qualified to critiques proposal content
- Check your ego at the door
- Allow time for rewrites!
11. Use proofreaders

- Find an eagle eyed perfectionist
- Proofreaders read for **form**, not **content**
- Must be someone who has no stake in the project!
- Learn to love what s/he will do for you
- Zero tolerance--no error is too small to correct
- Root out inconsistencies in **format** as well as typos, misspellings, grammar, etc.
12. Write, rewrite & rewrite

- Most winning proposals have been polished repeatedly
- Let it rest in between; sleep on every rewrite
- Fight the evil Pride of Authorship
- Must allow time!

(Famous rewriters: Hemingway, Michener)
And Tips for Success...

• Fit research and grant writing into your job
• Find a mentor(s)
• Read successful grants; attend workshops
• Find collaborators; network
• Get on a review panel!
• Get funding alerts; conduct your own searches regularly
• Think big, think small, think different
• Submit, revise & resubmit!
• Treat it like a game (which it is)
A. **A Starting Point.** The following questions are a necessary starting point for any grant proposal: You need a brief, convincing answer to each of them as a way of testing your readiness to start writing. Answer each of the following in 25 words or less:

1. What are you passionate about? (In terms of research, that is)______________________________

2. What is the problem (or need) and why is it important?____________________________________

2a. What sources or kinds of data can you use to validate the importance of your proposed project?____________________________________________

3. How is existing knowledge or practice inadequate?__________________________________________

4. Why is your idea better?_______________________________________________________________

5. How is it new, unique, different?_________________________________________________________

6. What will it contribute and who will benefit from it?________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________

_____________________________________________________________________________
B. Writing Style: Simplicity. Substitute a single word for each of the following phrases:

<table>
<thead>
<tr>
<th>Original Phrase</th>
<th>Substitute Word</th>
</tr>
</thead>
<tbody>
<tr>
<td>at this point in time</td>
<td>___________</td>
</tr>
<tr>
<td>at that point in time</td>
<td>___________</td>
</tr>
<tr>
<td>has the ability to</td>
<td>___________</td>
</tr>
<tr>
<td>has the potential to</td>
<td>___________</td>
</tr>
<tr>
<td>in light of the fact that</td>
<td>___________</td>
</tr>
<tr>
<td>in the event that</td>
<td>___________</td>
</tr>
<tr>
<td>in the vicinity of</td>
<td>___________</td>
</tr>
<tr>
<td>owing to the fact that</td>
<td>___________</td>
</tr>
<tr>
<td>in the course of</td>
<td>___________</td>
</tr>
<tr>
<td>in the near future</td>
<td>___________</td>
</tr>
</tbody>
</table>

C. Writing Style: Jargon, Passive vs. Active Voice. Reduce the following sentences to a simpler form with fewer words and active voice that conveys the same meaning:

*It is the objective of the research team to obtain data that can be used in conjunction with a comprehensive chemical kinetics modeling study to generate a detailed understanding of the fundamental chemical processes that lead to engine knock.*

______________________________________________________________________________

______________________________________________________________________________

*It has been determined that this study will develop an effective commercialization strategy for solar energy systems by analyzing the factors that are impeding commercial projects and by prioritizing the potential government and industry actions that can facilitate the viability of the projects.*

______________________________________________________________________________

______________________________________________________________________________

D. Writing Style: Tentative phrasing. Rewrite the following sentences in a more positive tone:

*A general review of the literature indicates that this topic has likely not been previously investigated.*

______________________________________________________________________________

______________________________________________________________________________

*By investigating the characteristics of chalogenic glass, we hope to determine new future roles for it in the field of micro photonics.*

______________________________________________________________________________

______________________________________________________________________________

*While it is true that Dr. Schmidt has never worked on a kinesiology project, his extensive research in biology will contribute to our work.*

______________________________________________________________________________
E. Funding sources. Using the NSF Awards database, identify at least two grant programs that might fund your research. Read the mission statements for those programs, note the terminology used to describe program purpose, goals and objectives, and identify the program officers.

1. ____________________________________________________________________________

2. ____________________________________________________________________________

F. Goals and Objectives. Write a goal statement for your proposal: ____________________________

______________________________________________________________________________

______________________________________________________________________________

Write three specific, measurable objectives for your proposal:

1. ____________________________________________________________________________

2. ____________________________________________________________________________

3. ____________________________________________________________________________

G. Project Summary: The Pitch. Read carefully the attached Project Summary from a successful NSF proposal: “WITS: A Wireless Interactive Teaching System.” What features of this writing made it successful? (It was funded twice). Identify the specific writing strategies that “sold” this concept to two separate NSF review panels. Points to consider:

Title: What makes this title “strategic”?
Tone: What is the overall feeling you get from this document? What words are used to communicate feeling?
Bullets: Why use them? What do they do? How are they structured?
Significance: How does the writer convey the importance of the issue to be addressed?
Success: Why is this project likely to succeed?
Final argument: What is the purpose of the last paragraph?

H. Preabstract. Write a preabstract for your proposal that you will use to initiate contact with an NSF program officer. Summarize the nature of your research, specify your goal and objectives, and indicate why you think it could be suitable for funding by that program. Close by asking if the concept is an appropriate fit.
Grant Writing Exercises

Answer key

Vigorous writing is concise. A sentence should have no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make every sentence short, or that he detail and treat his subject only in outline, but that every word tell.

- William Strunk

Perfection is achieved, not when there is nothing more to add, but when there is nothing left to take out.

- Antoine de Saint-Exupery

I have made this letter longer than usual because I lack the time to make it shorter.

- Blaise Pascal

The greatest possible merit of style is, of course, to make the words disappear into the thought.

- Nathaniel Hawthorne

The time to begin writing an article is when you have finished it to your satisfaction. By that time you begin to clearly and logically perceive what it is that you really want to say.

- Mark Twain
1. Writing issue: Sludge phrases. For each of the following phrases, substitute a single word that says the same thing.

at that point in time \hspace{1cm} \textit{then}

at this point in time \hspace{1cm} \textit{now}

in the event that \hspace{1cm} \textit{if}

until such time as \hspace{1cm} \textit{until}

on account of \hspace{1cm} \textit{because}

in the majority of cases \hspace{1cm} \textit{usually}

each and every one \hspace{1cm} \textit{all}

the question as to whether \hspace{1cm} \textit{if}

has the capability of \hspace{1cm} \textit{can}

in spite of the fact that \hspace{1cm} \textit{though or although}

in the final analysis \hspace{1cm} \textit{finally}

in a hasty manner \hspace{1cm} \textit{hasty}

in close proximity \hspace{1cm} \textit{close}

a large percentage of \hspace{1cm} \textit{most}

owing to the fact that \hspace{1cm} \textit{because}

need to be established \hspace{1cm} \textit{needed}

give consideration to \hspace{1cm} \textit{consider}

with the exception of \hspace{1cm} \textit{except}

there is no doubt that \hspace{1cm} \textit{doubtless}

it would thus appear that \hspace{1cm} \textit{apparently}
2. **Writing issues: Passive voice, verbosity.** Rewrite the following sentences using active voice, strong verbs, and eliminating unnecessary words.

a. *Initiatives are being introduced in nearly every industrialized nation designed to improve the quality of their schools.*

**Most industrialized nations are working to improve their schools.**

b. *In general, it is recognized that people who have a great deal of expertise in a given area are capable of exercising considerable influence over others.*

**Experts can greatly influence their peers.**

c. *It is the objective of this study to develop an effective commercialization strategy for solar energy systems by analyzing the factors that are impeding commercial projects and by prioritizing the potential government and industry actions that can facilitate the viability of the projects.*

**We will consider why current solar energy systems have not been adopted commercially and will evaluate steps industry and government can take to achieve this goal.**

3. **Writing issue: Tentative phrasing.** Rewrite the following sentences in a more positive tone.

a. *A general review of the literature indicates that this topic has likely not been previously investigated.*

**Our study will be the first of its kind in this neglected field.**

b. *By investigating the characteristics of chalogenic glass, we hope to determine new future roles for it in the field of microphotonics.*

**This study will contribute to scientific knowledge about the role of chalogenic glass in the developing field of microphotonics.**

c. *While it is true that Dr. Schmidt has never worked on a kinesiology project, his extensive research in biology will contribute to our work.*

**Dr. Schmidt’s biological perspectives on muscle spindles will contribute significantly to our study and its subsequent dissemination.**
4. Writing issue: Repetitive sentence structures. Rewrite the following passage, using a different structure and rhythm for each new fact or idea.

Mount St. Helens erupted on May 18, 1980. A cloud of hot rock and gas surged northward from its collapsing slope. The cloud devastated more than 500 square kilometers of forests and lakes. The effects of Mount St. Helens were well documented with geophysical instruments. The origin of the eruption is not well understood. Volcanic explosions are driven by a rapid expansion of steam. Some scientists believe the steam comes from groundwater heated by magma. Other scientists believe the steam comes from water originally dissolved in the magma. We have to understand the source of steam in volcanic eruptions. We have to determine how much water the magma contains.

Rewrite suggestion: Michael Alley. Create an interesting rhythm by using a variety of grammatical structure to start each sentence.

Subject - Verb
Mount St. Helens erupted on May 18, 1980.

Participial phrase
Its slope collapsing, the mountain emitted a cloud of hot rock and gases.

Prepositional phrase
Within minutes, the cloud devastated more than 500 square kilometers of forests and lakes.

Introductory clause
Although the effects of the eruption were well documented, the origin is not well understood.

Transition word
Recently, debate has arisen over the source for the steam.

Verb (Question)
Is it groundwater heated by magma or water originally dissolved in the magma itself?

Infinitive phrase
To understand the source of steam in volcanic eruptions, we have to determine how much water the magma contains.

Author’s original:

Mount St. Helens erupted on May 18, 1980. Its slope collapsing, the mountain emitted a cloud of hot rock and gases. Within minutes, the cloud devastated more than 500 square kilometers of forests and lakes. Although the effects of the eruption were well documented, the origin is not well understood. Volcanic eruptions are driven by a rapid expansion of steam. Recently, debate has arisen over the source for the steam. Is it groundwater heated by magma or water originally dissolved in the magma itself? To understand the source of steam in volcanic eruptions, we have to determine how much water the magma contains.

The Wireless Interactive Teaching System (WITS) represents an exciting new approach to improving the quality of STEM (science, technology, engineering, and math) education for undergraduate students. WITS is an inexpensive, portable wireless system of handheld computers designed to enable and enhance active learning in economics classes using interactive exercises – classroom “experiments”. These experiments can be used to illustrate vividly many different concepts in economics. Decision and outcome data from the exercises are projected on a screen as needed during class and can be posted on a website for use in answering a related homework assignment. Based on our assessment data collected to date in economics principles we can provide potential adopters with evidence of its positive and meaningful impact on learning (Ball, Eckel, and Rojas, 2006).

We request funding to extend and apply the WITS system in three ways:

- **New exercises and materials:** we plan to create and test ten new modules for use in microeconomic theory and economics elective courses, as well as courses in related disciplines such as political science and public policy. We also plan to create student and instructor manuals for our previously developed principles exercises as well as for new exercises.
- **New users:** we plan to conduct training sessions for senior graduate students and targeted faculty at the PI's two very different universities, and assist them in developing and implementing interactive exercises in their classes. This training will also help us to prepare for future broad dissemination.
- **New audiences:** we plan two new sets of tests to see whether the learning gains we have seen with WITS generalize across other educational settings. The first is with students in microeconomic theory. The second is with minority and community college students.

**Intellectual Merit:** Many students have difficulty learning economics. Earlier research with the WITS system successfully demonstrated that allowing students to experience economic theory through economics experiments improved student performance, especially for groups that currently struggle most with the material – women and freshmen. The current proposal would allow us to extend WITS to microeconomic theory and courses that apply theory to real world problems. Success in intermediate micro course is an essential element of an undergraduate economics degree; applied courses teach students how to think about difficult problems using economics. The flexibility of the WITS system enhances the instructor's ability to help students develop and test their own hypotheses, so that students learn economics by “doing science”.

**Broader Impacts:** We plan to conduct evaluations of the system in two new student populations: community college students and minority students (both at UTD and at an HBC.) These new pilot venues allow us to evaluate the potential uses of the system and its flexibility in meeting alternative educational needs and goals. Given the results of our initial pilot program, it is particularly important to test the system in environments where students have varying ethnicities, ability levels and learning styles.

Broader impacts of the research also include its impact on the recruitment of women students into economics, and building interdisciplinary and cross-institution bridges. A concern expressed at NSF and elsewhere is the low rate of participation of women and minorities in STEM disciplines, including economics. Our previous evaluations indicate that women and younger students benefit most from learning with the WITS system. If this mode of teaching helps women to succeed in undergraduate economics, then more of them may choose to attend graduate school, eventually increasing participation in the field. Furthermore, the WITS system can be adapted for teaching in other STEM disciplines, thus extending the learning gains beyond economics. Additional broader impacts involve building intellectual bridges between economics and other social sciences, as we implement the use of the system in other fields, and between two major research universities, an HBCU and community colleges. Finally, since both undergraduate and graduate students have been and will continue to be involved in the WITS project we are helping to achieve the NSF's goal of integrating research and education.