RESEARCH CORPORATION FOR SCIENCE ADVANCEMENT
Cottrell Scholar Award Application

EDUCATIONAL PROPOSAL: *Each applicant is expected to propose a plan that has promise to improve undergraduate science education. This is an opportunity to share the philosophy and principles that guide you as a scholar-educator. Competitive applications must include concrete examples of efforts to date, your educational plan, and how that plan supports and complements your department's undergraduate educational priorities. Your educational plan must be substantive and demonstrate a long-term commitment to your role as a scholar-educator. RCSA program officers screen educational plans/proposals initially, and only those that pass this screening are submitted to peer review of both the education and research proposals, giving equal weight to both.*

STATEMENT OF THE PROBLEM, SIGNIFICANCE OF THE PROBLEM, AND YOUR PLAN OF PROCEDURE (Describe your department's recognized areas of educational priorities and explicitly detail how your plan fits. State clearly the problems or issues you wish to address and how they relate to any ongoing work. Cite precedent. Carefully outline the importance of your plan and the impact it may have on your undergraduate students. A viable approach should be given, including examples from your own experience and/or from the literature. Indicate ways in which the completion of this work has a broader impact. Use Arial 11 point font. Limit to four pages.)

PROBLEM AND SIGNIFICANCE

Specific Aim: *My ultimate goal with regards to science education is to contribute to the development of an engaged and scientifically literate public, while equipping student scientists with the necessary skills and enthusiasm to be effective ambassadors of science.*

The need – scientific literacy

Scientific literacy is the matrix of knowledge needed to understand enough about the physical universe to deal with issues that come across our horizon, in the news or elsewhere.

- *Why Science?*
- *James Trefil, 2008*

Introduction. I believe that an essential characteristic of any effective science education program is the capacity to equip students with the necessary skills for engaging fellow citizens in scientific exploration and inquiry. I agree with the AAAS resource *Science for All Americans* that students' knowledge and ability to use science depends largely on the "character, distribution, and effectiveness of the education people receive."[32] Yet a report of US STEM education from the National Science Board indicates that US students are at or near the bottom when compared to other OECD countries with regards to science comprehension.[33] To address the challenges with STEM education, the board compiled recommendations that includes, "provide education that increases the public's knowledge of, and appreciation for, the importance of science and technology in the context of quality of life, economic prosperity, and national security."[33] In doing so, public literacy of science topics will be enhanced and facilitate greater "public discourse on issues pertaining to science and technology."[33] As outlined below and with NSF support, I am currently addressing this recommendation by developing resources that improve the public's literacy of solar energy science. These resources are disseminated through existing infrastructure and a new program for undergraduate researchers (Energy Ambassadors). With support from the Cottrell Program, I will expand these initiatives to incorporate nanoscience and catalysis concepts. Over the award period:

(1) well-known demonstrations[34-37] will be updated to introduce nanoscaling and structure/function relationships in a colorful and inviting manner to high school and undergraduate students,
(2) a *Nano Ambassadors' Program* will be developed to introduce nanoscience concepts and connect Indiana University (IU) undergraduate researchers with their home communities,
(3) inquiry-based learning resources will be developed collaboratively with Indiana's Columbus Signature Academy and distributed via the Internet and IU's Nanoscience Center (IUNano), and
(4) outreach to underrepresented STEM groups will continue to be integrated with these efforts.

Why Nanoscience? Advances in nanoscience are intimately linked to addressing the social and economic issues challenging the US today,[38] making it a premier topic for addressing the National Science Board's recommendation. For example, enhancements in catalyst performance are required for affordable fuel cells and can be achieved with nanocatalysts.[39] Yet, poor understanding of the underlying science by non-specialists, poor communication of nanoscale principles by scientists, and the sensationalist nature with which nanoscience can be represented in popular culture (e.g., Crichton's *Prey*[40] which outlined a nano-robotic threat) increase the already challenging task of adopting appropriate public polices with regards to nanoscience.[41-43] These reasons also leave non-scientists poorly equipped to enter emerging nanotechnology fields (e.g., as sales personnel, patent officers, lobbyists). Thus, new means of introducing, teaching, and distributing information about nanoscience are critically needed. *Outlined here are activities that highlight my dedication to promoting scientific literacy and new initiatives that will enhance public literacy about nanoscience by engaging undergraduate and graduate students as educators themselves.*

ACHIEVEMENTS TO DATE

- Redesigned IU's *Chemistry 100: The World of Chemistry* to include activities that improve students' literacy of chemistry topics. *Chem 100* is a large (~80 students/semester) introductory course for undergraduates studying humanities/social sciences. The redesign involved:
  (1) selecting *Chemistry in Context*[44] as a suitable textbook and incorporating science/science policy movies such as *An Inconvenient Truth*[45] into class then discussing how accurately the science was presented in the film and counter-point articles.[46]
  (2) developing a *Science Media Project* in which students follow a chemistry topic in print media then provide critiques of 3 articles and create their own news article intended for their family/friends.
  (3) developing a *Children's Book Project* where students explain a chemistry topic (e.g., ozone depletion; see Figure 3) for kids age 7-8.

  By analyzing sources of science news and putting complex ideas into their own words, students become better equipped to evaluate the science media they encounter outside of class as well as more effective communicators of science themselves. I have given a presentation on these classroom innovations at the spring 2010 American Chemical Society (ACS) Conference in a symposium on *Sustainability in the Classroom*[47] and published an invited manuscript in the corresponding ACS Symposium Book.[48] *Chem 100* was also selected as a course for IU's 2010 Themester on *Sustainability,* and the students' books were displayed in the closing ceremony attended by Bloomington 2nd graders. Subsequently, I gave an invited talk on this project in IU's annual workshop, *Tales from the Trenches: Strategies for Teaching Effectively*.

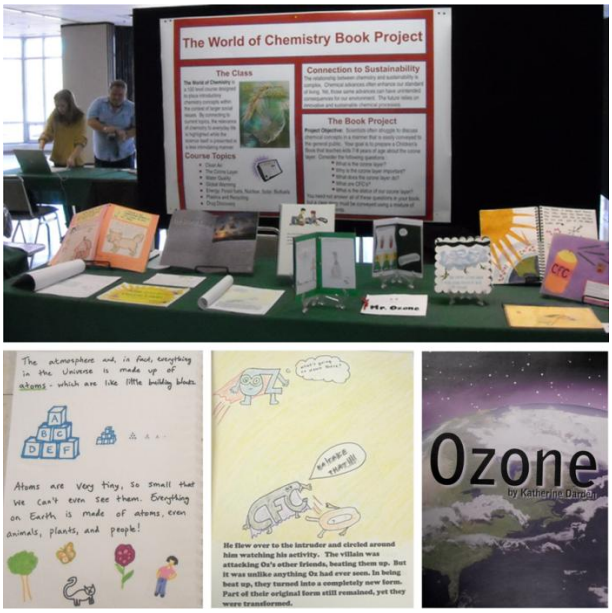

Figure 3. Top: photograph from Themester's closing ceremony display for Chem 100. Bottom: select pages from students' Book Projects on ozone depletion.

- Co-founded a *Chemistry of Everyday Life Seminar Series* with an *ACS Innovative Project Grant.* This series has brought chemistry to the Bloomington public biannually since 2010. For example, in spring 2011 Professor Charles Bamforth spoke on the chemistry of beer, with his seminar being co-sponsored by a local brewery and attended by 200+ individuals including Bloomington's home brewing community.
- Involved in outreach activities that target underrepresented STEM groups. Examples include:
  (1) being elected to IU's *Women in Science (WIS) Program* board which implements programs that promote participation of women in STEM fields. I have highlighted my group's research by giving a *WIS Laboratory Tour* with nano-themed demonstrations (see **PLANNED ACTIVITIES**) and the keynote address at the annual *IU WIS Research Conference* in 2009.
  (2) co-founding a Women in Chemistry group at IU, which is now recognized by the department as a regular committee appointment.
- Outreached to K-12 educators. Examples include:
  (1) giving yearly talks at IU's *Project-Based Learning Workshop* called *Molecules Matter* for high school science teachers;
  (2) founding *Energy Ambassadors* - the proposed *Nano Ambassadors' Program* is based on this effective educational tool (see **PLANNED ACTIVITIES**); and
  (3) collaborating with Columbus Signature Academy, an Indiana New "Tech"nology High School (see **PLANNED ACTIVITIES**).

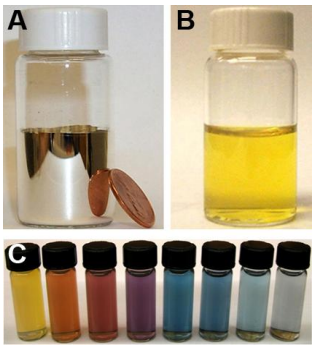

Figure 4. Photographs of (A) the typical result from the "silver mirror" test, (B) when it has been modified with the addition of a polymer, (C) and when silver nanoparticles have been galvanically replaced with increasing amounts of gold (left to right).[36,37]

EDUCATIONAL PROPOSAL: *(continued)*

PLANNED ACTIVITIES

Introducing Nanoscience. As I observed when teaching *Chem 100*, nothing sparks students' attention more than a good demonstration. When coupled with thought provoking questions, retention of core concepts is enhanced.[49] Thus, I start each unit of *Chem 100* with a demonstration that serves as a reference throughout the course. To introduce the concepts of nanoscaling and structure-function relationships, I modify two well-known demonstrations so they are colorful and easily accessible to the general public. The first compares the result from *Tollens' Test for Aldehydes* which yields a "Silver Mirror" with that obtained when a polymeric capping agent is added, yielding a stable nanoparticle solution (Figures 4A,B).[34,36] In the second demonstration, silver nanoparticles are galvanically replaced with gold to change their light scattering properties and thus color of the colloidal solution (Figure 4C).[37] These demonstrations will be/are used with the proposed *Nano Ambassadors' Program* and collaboration with Columbus New Tech. Also, *Chem 100* students will continue to be encouraged to select nano-topics for the science literacy projects outlined in **ACHIEVEMENTS TO DATE.**

Nano Ambassadors. How do I reach the people in small towns in rural Indiana and enhance public literacy about nanoscience? As it turns out, I interact with very effective messengers everyday: the IU undergraduates. At IU, many students are in-state and exactly from places I hope to reach with information about nanoscience. I will pilot a *Nano Ambassadors' Program* (based on my successful *Energy Ambassadors' Program*; see **ASSESSMENT PLAN**) involving IU undergraduates. (1) During each academic year, 1-2 undergraduates will be recruited with the help of the Chemistry Department's Academic Advisor (see Letter of Collaboration 1) to assist with the proposed research and become *Nano Ambassadors*. (2) During the month of May when high schools are still in session but summer break has started at IU, these students will return to their hometowns and team-teach an exciting chemistry class with their former teacher in which they discuss their research and its underlying science by performing the described demonstrations. Students serving as *Nano Ambassadors* will receive a stipend for their work. I will supervise the interactions these students have with their former high schools, which will include assistance with drafting letters of contact, packaging demonstration materials into "teaching kits", critique of presentations, and visit follow-up. The benefits of this program include that *(i)* the Nano Ambassadors are very familiar with the environment they are being sent to, *(ii)* the cost of this program is low compared to other high school outreach programs, since the students have their parents' homes to return to, *(iii)* the students' parents are indirectly targeted (e.g., one can envision discussions at dinner tables about nanoscience that would never occur otherwise), and *(iv)* compared to normal summer jobs, this program is attractive and motivating to IU students. This program will also be a valuable recruiting tool as *(v)* college students can serve as role models who inspire high school students to pursue STEM degrees while also *(vi)* feeding the "pipeline" of scientists at the high school level. *(vii)* The program also enhances the training of undergraduate researchers by putting high value on effective communication and reinforcing scientific concepts. As the old motto goes, the best way to learn something is to teach it yourself.

Columbus New Tech Collaboration. My laboratory also has a collaboration with Columbus New Tech which involves yearly visits to their chemistry classes during their unit on molarity. New Tech schools follow an inquiry-based model of learning which develops problem-solving skills and has been shown to promote students' science literacy and confidence.[50] Thus, our contribution is to introduce nanoscience through demonstrations and discussion. The students then help undergraduate and graduate researchers in my laboratory by preparing metal nanoparticles. In spring 2011 the project involved analyzing how bromide concentrations altered the size and shape of silver nanoprisms.[35] Samples were characterized by microscopy at IUNano and the results shared with the class by students from my group via Skype. Afterwards, a New Tech student was so excited that he drove to IU to see the microscope (see **ASSESSMENT PLAN**). This collaboration will continue with real research projects and provides the perfect opportunity to test other resources that will be distributed in our *Nano Ambassadors'* teaching kits. With support from IUNano, five more high school teachers will implement the nanoprism project in 2012.

Graduate/Post-Doctoral Training. These programs require involvement of graduate students/post-doctoral scholars in undergraduate and high school education. Besides reinforcing their understanding of nanoscience concepts, these activities enhance graduate/post-doctoral training by improving students' ability to communicate complex ideas in a manner suitable for the general public – a critical need.

EDUCATIONAL PROPOSAL: *(continued)*

ASSESSMENT PLAN: *Define expected outcomes of your educational plan. How will your evaluation design provide information to improve your project as it develops and progresses? How will you determine whether your stated project objectives are being met according to the proposed timeline?*

The educational model outlined as *Nano Ambassadors* was piloted with support from NSF in spring 2011 as *Energy Ambassadors*. Undergraduate Adam Richter returned to his former high school to discuss his photocatalysis research. Survey data analyzed with help from the IU Center for Innovative Teaching and Learning indicated that 70% of the students are now more inclined to seek out college research opportunities, with ~60% stating that they were unaware until Adam's visit that undergraduates could be involved in research. As one student put it, "Adam made it seem very interesting and a good opportunity." These results are encouraging as studies show students, especially those from underrepresented groups, are more likely to pursue careers in science if engaged in research early on.[51] Similar surveys will be collected for *Nano Ambassadors*. Adam's parents also mentioned the program when visiting IU, providing evidence that parents can be targeted. 3 Ambassador Trips are scheduled for spring 2012 and reflects the recruitment of two more undergraduate researchers into my laboratory. It is my vision that these pilot programs serve as a template for a larger IU Science Ambassadors' Program, in which other IU researchers adopt a similar outreach approach. After enough anecdotal evidence of the program's effectiveness is obtained, a chemical education article describing it will be submitted. Researchers at IU will also apply for support to transform the program into a service learning course and fully evaluate the model by tracking students and their career paths long term. Significantly, this program may serve as a model that could be adopted by other universities. From the collaboration with Columbus New Tech, survey data from the 100 students participating in the 2011 project found that 60% planned to pursue an internship or college degree in a STEM field after the nano project, up from 30% beforehand. Survey data will continue to be collected from these annual trips to assess students' attitudes about science and the effectiveness of the program. The nanoscience-themed coursework is approved by Indiana's Department of Education and will be distributed via *Nano Ambassadors* and IUNano's *Project-Based Learning Workshop*. Similar survey data will be compiled from those teachers implementing this project. Significantly, these efforts help meet the broader goal of building a scientifically literate public that is supportive and curious about science, while equipping student scientists with the necessary skills to be effective communicators - or ambassadors - of science.

Identify departmental or institutional colleagues who might play a role in this educational endeavor (as mentors, collaborators, etc.) as appropriate and describe the role they will play.

CALM and web-based resources. To reach people broadly, all developed resources will be posted on my website. I will also use an IU-based computer tool (CALM) that provides students with individualized questions on a given topic to distribute coursework developed with Columbus New Tech. Participants from 29 states, including those from ~125 Indiana high schools, use CALM.

IU's Nanoscience Center. The collaboration with Columbus New Tech is on-going and supported by the Outreach Director of IUNano, Jill Robinson, who distributes developed activities to other high schools through a two week *Project-Based Learning Workshop* for ~20 high school teachers per year, where I have guest lecturered for the past 2 years. See Letter of Collaboration 2.

Underrepresented STEM Groups. As highlighted by my leadership in IU's WIS groups, I am committed to providing a positive climate for research and increasing diversity in higher education. Currently, my group consists of 7 graduate students, 5 of whom are women, including a Hispanic-American. If supported, I will be further empowered to engage more women/minority students in research/educational activities. Additionally, both I and my students often collaborate with the IU chapters of ACS (of which I am the local president), NOBCChE, and SACNAS in promoting education/outreach activities.

LETTER OF SUPPORT: *Include a letter of support from your Departmental Chair, Dean or Provost that endorses your educational proposal and indicates why you are the appropriate faculty member to undertake this project. Insert this letter as Page (9a) of your application.*

LIST OF REFERENCES: *(Annotate the proposal with a list of references from the primary literature. Include all authors and titles. If more space is required, attach a maximum of one additional page. Use Arial 10 or 11 point font.)*

(44)Eubanks, L. P.; Middlecamp, C. H.; Heltzel, C. E.; Keller, S. W. *Chemistry in Context*; 6 ed.;Peterson, K. A., Ed., McGraw-Hill Science: New York, 2009.

(45)*An Inconvenient Truth.* Dir. Guggenheim, D. 2006. DVD.

(46)Easterbrook, G. "Ask Mr. Science: The Moral Flaws of Al Gore's *An Inconvenient Truth*" *Slate* **24 May 2006,** http://www.slate.com/id/2142319/ (accessed 20 October 2009)

(47)Skrabalak, S. E.; Steinmiller, E. M. "Introducing global climate change and renewable energy with media sources and a simple demonstration" *National Meeting - American Chemical Society,* **2010,** CHED:1454.

(48)Skrabalak, S. E.; Steinmiller, E. M. P. "Introducing global climate change and renewable energy with media sources and a simple demonstration"; Middlecamp, C. H., Jorgensen, A. A., Eds., In *Sustainability in the Chemistry Curriculum*; ACS Books: 2011, p In press.

(49)Walton, P. H. "On the use of chemical demonstrations in lectures" *U. Chem. Ed.* **2002**, *6*, 22.

(50)Brickman, P.; Gormally, C.; Armstrong, N.; Hallar, B. "Effects of Inquiry-based Learning on Students' Science Literacy Skills and Confidence" *Int. J. SoTL* **2009**, *3*, 1.

(51)"Recruitment and Retention of Women in Academic Chemistry" **2003,** Royal Society of Chemistry, http://rsc.org/ScienceAndTechnology/Policy/Documents/RecruitmentandRetentionofWomen.asp (accessed 13 July 2009).