AC 2010-1716: INTENSIVE IMMERSIVE RESEARCH EXPERIENCES FOR UNDERGRADUATES AND TEACHERS: UNDERTAKING CREATIVITY AND INNOVATION, DIVERSITY OF THINKING, AND ENTREPRENEURSHIP

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Intensive Immersive Research Experiences for Undergraduates and Teachers: Undertaking Creativity and Innovation, Diversity of Thinking, and Entrepreneurship

Abstract

One objective of National Science Foundation efforts is the training of the future work force in scientific and technical fields. In summer 2009 research experiences for undergraduates (REUs) and teachers (RETs) were developed and implemented introducing participants to leading edge research currently underway. These experiences were intended in part to fulfill the mission to create a diverse pipeline of future practitioners and educators in the Biomaterials field.

The Research experiences for undergraduates and teachers were six weeks in duration and ran concurrently. K-14 teacher participants derived from middle schools and community colleges, and undergraduate participants came from both the lead home and partnering institutions. Each REU and RET was teamed with a research mentor (i.e., lead researcher) and an graduate student. REU and RET participants had primary research responsibilities which were carried out over a five-week period. In the remaining sixth week, participants rotated through each laboratory to gain familiarity with all research areas. In addition to scientific research; weekly technical programs, enrichment activities, and trips were conducted, the goals of which were to foster creativity and innovation, diversity in thinking, and entrepreneurship; and to broaden participant imagination in the area of Biomaterials.

RETs also participated in professional development sessions centered on classroom instruction and designed to help them translate their new scientific knowledge into a one-week inquiry-based teaching module. Modules were aligned with the state's K-12 Science Curriculum introducing K-12 students to the basic concepts of bioengineering. Additional module goals included increasing K-12 student 1) knowledge of math and science; 2) awareness of and appreciation for the field of engineering; 3) ability to link this knowledge to real-life experiences; and 4) capacity for scientific engagement in the classroom. RETs were able to implement a portion of the module with high school students at the end of the summer.

Entrance and exit interviews were performed to assess the impact of the intensive research experiences upon REU and RET understanding of the Biomaterials field and upon their ways of thinking about creativity and innovation, diversity of thinking, and entrepreneurship. Seven REUs and five RETs participated in the entrance interviews; five REUs and four RETs participated in the exit interviews. Survey questions were subdivided into five topics: bioengineering, diversity, innovation, entrepreneurship, impressions from the research experience, and short-/long-term career and academic goals. A sixth topic addressed participant individual learning goals, quantified on a goal attainment scale of -2 to +2 (M = 0). Parsimonious interpretation of assessment data suggests that REU/RET research activities netted gains in participant understanding of bioengineering, diversity of thinking, innovation, and entrepreneurship, including a significant change in self-assessed proficiency levels relative to individual learning goals (t (.05, 6) = 2.9).

This paper will discuss the general strategy of the intensive research experiences, provide an overview of the teaching modules and development methodology, and report in-depth assessment results from entrance and exit interviews.

Introduction and Background on Creativity, and Innovation, Diversity of Thinking and Entrepreneurship

The ability to produce ideas, innovations, designs or products that are both novel and functional is an essential component in engineering and the basis for creativity. However, while creativity is a necessary facet in development and innovation, researchers such as Kazerounian & Foley [1] indicate that the engineering curriculum do not explicitly encourage creativity. It is an accepted fact that analysis, as taught in many academic curriculums, is not a very good means of generating originality or divergent thinking with is the cornerstone of creativity.[2, 3] However, few attempts are being made to facilitate student's experiences and innovation by teaching creativity.

Creativity or creative aptitude seems to depend upon the mysterious "institution" or innate characteristics of the individual. Yet, it has been well document in research [3, 4, 5] that creativity is not just innate, but a learned behavior. Thus, one can increase levels of creativity by practice. Cropley and Cropley [6] demonstrated that by engaging in creative exercises, engineering students innovate more and their designs were more elegant and creative than students in the control group. Similar results have been obtained by Charyton. & Merrill [7], and is consistent with results of Amabile, et.al.[8]

Enhancing the creative process for participants is of particular interest to our educational program. Enrichment activities within the supplied research experience will provide participants with some exposures, that are intended to assist in the development of divergent thinking while enhancing their fluency, flexibility and originality in the subject area of biomaterials.

Introduction to Summer REU and RET

The Research Experience for Undergraduates (REU) was organized to occur over a six week period during a summer. Also, during this six week period, a concurrent Research Experience for Teachers (RET) was also held. Both RETs and REUs participated in activities where a RET along with a REU worked in teams. Also, there were individual activities focused specifically and separately on RET interests. The purpose of these research opportunities was to contribute to creating a diverse pipeline of future practitioners and educators in the biomaterials field.

REU/RET Joint Activities

The REU and RET participants were assigned to work together in teams. Each team undertook a different research activity. The basic team structure was: a lead researcher mentor, a graduate research assistant, a REU participant and a RET participant. The team then collaborated to perform the assigned research. This primary research experience was conducted for five weeks.

The remaining week was a rotation through the research labs. This allowed the REUs and RETs to gain familiarity with all the research areas. This rotation week occurred nearly midway through the six week program.

The research conducted is meant to ultimately contribute to applications of metallic biomaterials in the following areas: craniofacial and orthopedic applications; cardiovascular devices; and biosensors for implants. The actual more narrowly focused research that was conducted consisted of the following: DC magnetron sputtering of magnesium-titanium coatings, pore structure characterization of porous magnesium, extrusioin of magnesium wires, pulsed laser deposition of Mg and Mg-alloy thin films, fabrication and characterization of TiN nanowires, Paclitaxel (Taxol) embedded polyesterurethane (PEUU) coatings on titanium substrates using direct-write printing, TiN as a biometallic material, four point resistivity measurements, MgO plus Fe thin film composites for biosensor applications, and titanium dioxide photo catalyst.

In addition to the scientific research, the REUs and RETs jointly attended a weekly professional development series during the six weeks. This activity consisted of: technical programs, enrichment activities and trips. The goals of these activities were to stimulate: creativity and innovation, diversity in thinking, and entrepreneurship; and broadening the imagination of the participants in the biomaterials area.

During the six week program various technical seminars and enrichment activities were given. The following technical subjects were presented in seminar format: Laboratory Safety, Principles of Atomic Forch Microscopy, Introduction to Thin Film and Nanotechnology, and Computational Modeling and Simulations in Materials Processing and Nanoengineering. The following enrichment topics were carried out. During the opening program, a diversity icebreaker/mixer activity was done to establish interactions between participants to facilitate team building and later team work. Also, seminars on: intellectual property and patient rights - The How and Why of Data Collection, a case study in biomedical ethical issues and dilemmas, funding sources and technical grant writing, a presentation by the state's Biotechnology Resource Center, oral presentation skills, a plant trip to a producer of ostomy and wound supplies, and a trip to an incubation center for entrepreneurship were done. These once to twice a week programs were done to provide experiences related to creativity, innovation, diversity of thinking and entrepreneurship outside and in addition to what was observed by doing the research. Besides the above, the REU/RET team worked together to produce presentations on each team's research that was given during a joint closing program.

REU Organization and Structure

The summer program's REU component consisted of seven undergraduate student participants in an intensive immersive research experience. The seven undergraduates had the following backgrounds. They were from both four year institutions and a community colleges. Their majors were biology, chemistry, chemical engineering, mechanical engineering. The participants were assigned to research in the area of metallic biomaterials.

RET Organization and Structure

The summer program's RET component consisted of three community college teacher and 2 middle school teacher participants in an intensive immersive research experience. The 3 community college teachers taught in the areas of biology, physical science and nanotechnology education. The 2 middle school teachers taught middle school language arts and science.

RET Module Development

Clinical faculty from the University's School of Education worked with RETs to facilitate the development of teaching modules. The purpose of the teaching modules was to bring inquiry-based learning opportunities to students predicated on scientific knowledge obtained through the summer research experiences. Using a hybrid format of classroom-based instruction and virtual seminar, the clinical faculty aided RETs in producing their individual teaching modules. As part of this effort, an online learning community was open to RETs, where they could access various resources associated with the ERC, including the virtual seminar, instructional handbook, inquiry-based classroom activities, and collaborative discussion. A full array of RET teaching module related products, including the instructional handbook, are accessible online.

Assessment of REU and RET

REUs and RETs participating in the six-week research experience were asked to volunteer for entrance/exit, one-to-one interviews. The interviews were conducted by an advanced-level graduate research assistant, specifically trained in dynamic, interpersonal communication, and supervised by faculty. Survey questions were open-ended in nature and were designed to encourage RETs and REUs to explore their thinking surrounding "research and development in a multidisciplinary environment that values diversity of thinking, innovation, and entrepreneurship." Survey questions were subdivided into topics such as bioengineering, diversity, innovation, entrepreneurship, impressions from the research experience, and short /long term career and academic goals. A sixth topic addressed participant individual learning goals. Parsimonious interpretation of assessment data suggests that REU/RET research activities netted gains in participant understanding of bioengineering, diversity of thinking, innovation, and entrepreneurship, including a significant change in self assessed proficiency levels relative to individual learning goals.

Once the interviews concluded, tape recordings were transcribed into a word document, and responses were subsequently aggregated according to specific questions. Data were subsequently analyzed for keywords. Institutional Review Board approval and Informed Consent were obtained prior to data collection.

The purpose of the entrance and exit interviews was to assess the impact of the intensive research experiences upon REU and RET understanding of the biomaterials field. Seven REUs and five RETs *(n=12)* participated in the entrance interviews. Five REUs and four RETs *(n=9)* participated in the exit interviews. Mean age for undergraduates was 21.5 years. There were five male undergraduates and two female undergraduates. Four undergraduate students described themselves as African American; two, Caucasian; one, Asian. Undergraduates derived from western, northern, and southeastern regions of the United States. Six reported US citizenship, and one reported permanent residency in the US. Also participating in the six-week research experience were five teachers. All of the teachers were permanently licensed in their state. Five teachers stated they had tenured/career status, and one teacher was permanently licensed with less than four years experience. The mean age of teachers was 39 years. There were three male teachers and two female teachers. Three teachers described themselves as Caucasian; one, African American; one, Asian. Every teacher derived from the southeastern United States and reported US citizenship.

Discussion of REU and RET Assessment Results

Figures 1 through 4 show changes in participant perceptions in bioengineering, diversity of thinking, innovation and creativity, and entrepreneurship. Descriptive data were analyzed for keywords. Keywords included: **Bioengineering:** Engineering, Human Body, Bioengineering, Biology, Biologic Sciences, Biomedical; **Diversity of Thinking:** Creative thinking, "Out of the Box," Connecting New Ideas, Original Problem-Solving; **Innovation and Creativity:** Creative, New, Idea, Revolutionize, Novel, Original; **Entrepreneurship:** Business, Product, Marketability, Ownership, Small Business

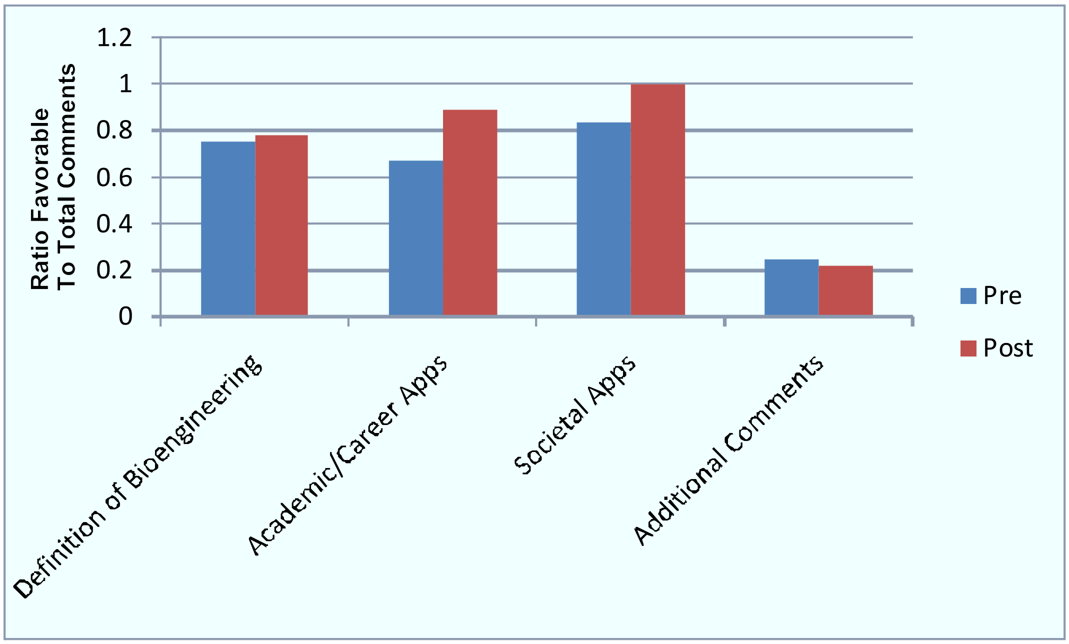

Figure 1. Participant Pre-/Post- Perceptions of Bioengineering and Its Application to Their Academic/Career Goals and Societal Problems. Keywords: Engineering, Human Body, Bioengineering, Biology, Biologic Sciences, Biomedical

Participants were also asked to talk about their perceptions of the REU/RET program upon their future academic and career goals. In every case but one, participants agreed at exit interview that the intensive research experience for undergraduates and teachers forwarded their academic and/or career goals, as well as their "dream" goals. The exception related to one respondent who indicated that his/her primary focus was upon biology, not engineering. It is notable that both undergraduates and teachers could link their research experiences with their future academic/career and "dream" goals. In other words, for undergraduates who wish to pursue graduate work in bio-engineering, the connection between their goals and the research experiences is largely intuitive. For teachers, the link may "feel" less obvious; yet, RETs made strong connections between their summer research and their future goals. For example, one participant stated: "It has opened my mind up to a Masters, not in literacy. It's possible that I would look for something in science education or maybe even a particular science." Yet another said: "There is a possibility of co-writing a grant. I would like to do more research at the community college."

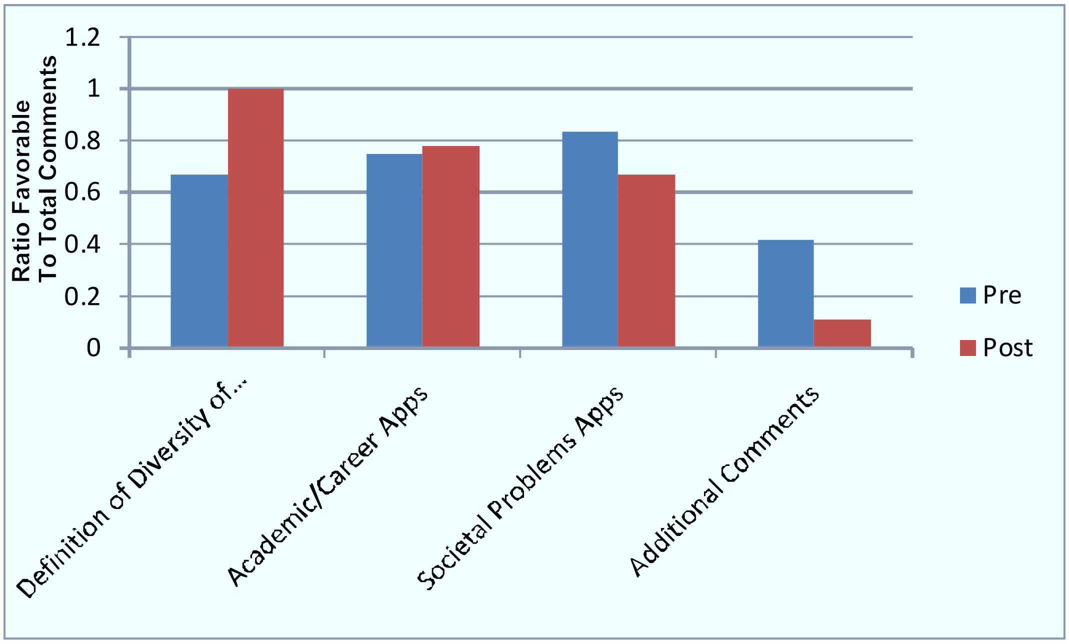

Figure 2. Participant Pre-/Post- Perceptions of Diversity of Thinking and Its Application to Their Academic/Career Goals and Societal Problems. Keywords: Creative thinking, "Out of the Box," Connecting New Ideas, Original Problem-Solving.

As part of their entrance/exit interview experiences, participants were asked to identify at least one individual learning goal for the six-week research experience. In every case except one, participants identified more than one learning goal. There were twelve participants available for entrance interviews. As well, there nine participants available for exit interviews; and of these, seven participants provided goal attainment scores related to their individual learning goals. Once each participant identified his/her goals, the participant was then asked to self-assess current proficiency levels using a Goal Attainment Scaling. Goal Attainment Scaling is a method for quantifying an individual's assessment of his or her proficiency level[9]. Using a five-point scale (-2 to +2, where 0 is average), participants were asked to score their proficiency level for each individual learning goal during both entrance and exit interviews. A composite score was subsequently computed for each participant, and then standardized as *t-scores* $(M = 50; SD = 10)$. Using SPSS 17.0, a paired t-test was computed (critical $t_{(.05,\ 6)} = 1.9431$; two-tailed) to compare pre-/post- GAS scores. A t-value of $2.9_{(.05,6)}$ was obtained.

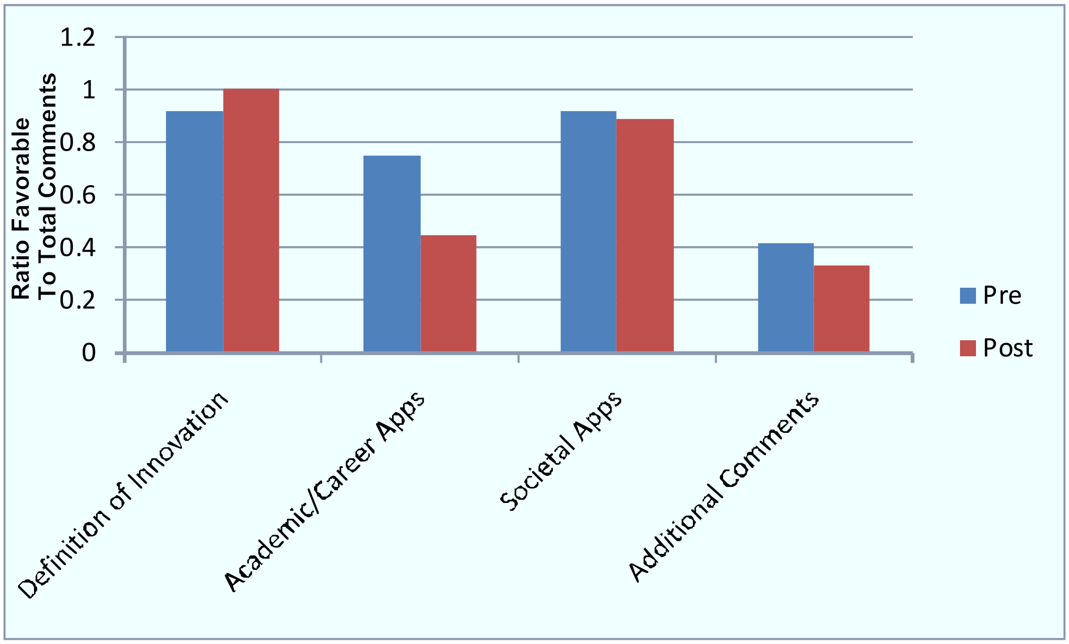

Figure 3. Participant Pre-/Post- Perceptions of Innovation and Creativity and Its Application to their Academic/Career Goals and Societal Problems. Keywords: Creative, New, Idea, Revolutionize, Novel, Original

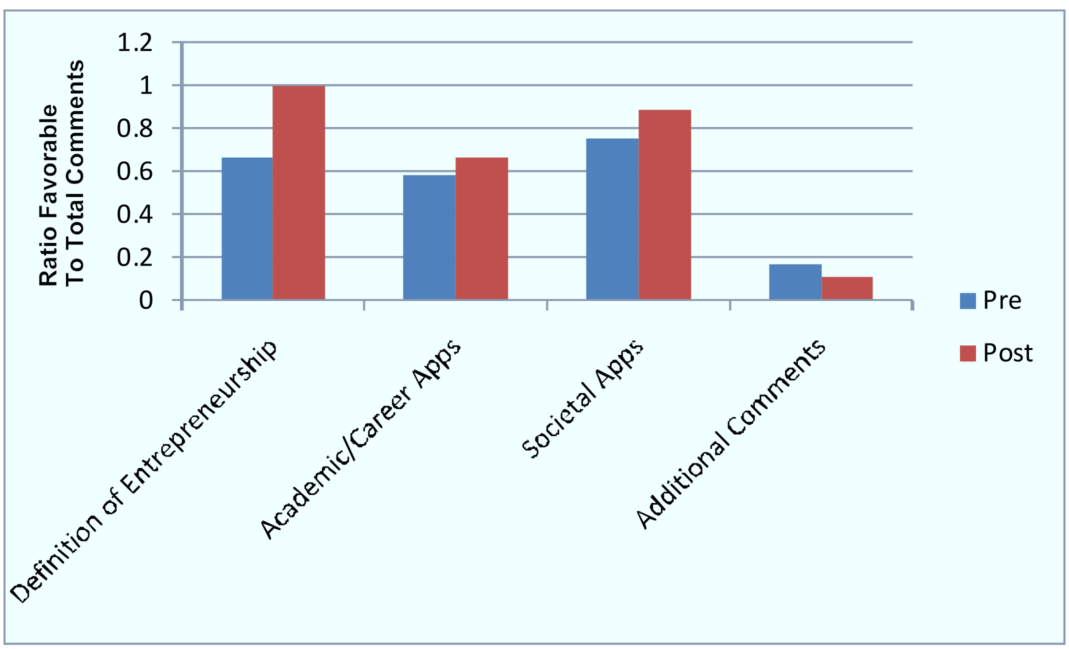

Figure 4. Participant Pre-/Post- Perceptions of Entrepreneurship and Its Application to Their Academic/Career Goals and Societal Problems. Keywords: Business, Product, Marketability, Ownership, Small Business.

Benefits of Concurrent REU/RET Programming

There were both logistical and content benefits for both the organizers and participants of the concurrent REU/RET program where the participants functioned in teams. For the organizers of the REU/RET programming, each could benefit and leverage a common set of core activities to eliminate some duplication of effort. Secondly, the collective pool of participants is more diverse ranging from young adults of community colleges and universities to actual K-14 teaching practitioners all working together within advanced laboratories in a university setting. The participants therefore have the opportunity to share and appreciate their differing experiences from their own background where their uniqueness is valued.

Other benefits of doing the concurrent REU/RET program with REU/RET teams was that the same faculty mentor and research topic could serve both REU/RET to minimize impact on laboratory resources and personnel. However, the teamed REU/RET participants don't duplicate effort because each has some aspect of non overlapping individual interest to fulfill from the research experience. Finally, during the technical seminars and other enrichment activities, the diversity of the REU/RET participants enabled more varied input into the comments, discussions and interactions that occured.

Suggestions and Recommendations

Since creativity is not just innate but can be a learned behavior [3, 4, 5]; and by extension so may innovation, diversity of thinking, and entrepreneurship be learned, activities should be done to incorporate any one of these aspects besides what is done directly within the research. The program presented undertook the following list of activities during the six week program as enrichment to address creativity, innovation, diversity of thinking, and entrepreneurship:

- Opening program: a diversity icebreaker/mixer activity was done to establish interactions between participants to facilitate team building and later team work;
- Seminar: intellectual property and patient rights -The How and Why of Data Collection;
- Case Study: Biomedical ethical issues and dilemmas;
- Seminar: Funding sources and technical grant writing;
- Presentation: State's Biotechnology Resource Center;
- Plant trip: Ostomy and wound supplies producer;
- Trip: Incubation center for entrepreneurship.

It was found that within a six week research internship program none of the topics for creativity, innovation, diversity of thinking and entrepreneurship could be developed in detail. Therefore, one of these may be selected as a single focus during a particular research internship program. However, during subsequent summers a different enrichment focus may be selected. So, if there are repeat participants, the cyclic changes in the enrichment topics would help keep the REU/RET programming interesting for participants who return.

Appendix: Extended Discussion of REU and RET Assessment Results

Participating in the six-week research experience were seven undergraduate students, one of whom will matriculate into his/her master's program in fall 2009. The mean age was 21.5 years. There were five male undergraduates and two female undergraduates. Four undergraduate students described themselves as African American; two, Caucasian; one, Asian. Undergraduates derived from western, northern, and southeastern regions of the United States. Six reported US citizenship, and one reported permanent residency in the US.

Also participating in the six-week research experience were five teachers. All of the teachers were permanently licensed in their state. Five teachers stated they had tenured/career status, and one teacher was permanently licensed with less than four years experience. The mean age was 39 years. There were three male teachers and two female teachers. Three teachers described themselves as Caucasian; one, African American; and one, Asian. Every teacher derived from the southeastern United States and reported US citizenship.

As part of their entrance/exit interview experiences, participants were asked to identify at least one individual learning goal for the six-week research experience. In every case except one, participants identified more than one learning goal. There were twelve participants available for entrance interviews. Also, there were nine participants available for exit interviews; and of these, seven participants provided goal attainment scores related to their individual learning goals.

Once each participant identified his/her goals, the participant was then asked to self-assess current proficiency levels using a Goal Attainment Scaling (GAS). Goal Attainment Scaling (GAS) is a method for quantifying an individual's assessment of his or her proficiency level [9]. Using a five-point scale (-2 to +2, where 0 is average), participants were asked to score their proficiency level for each individual learning goal during both entrance and exit interviews. A composite score was subsequently computed for each participant, and then standardized as *t-scores* (M = 50; SD = 10). Using SPSS 17.0, a paired t-test was computed (critical $t_{(.05,\,6)} = 1.9431$; two-tailed) to compare pre-/post- GAS scores. A t-value of $2.9_{(.05,6)}$ was obtained. This t-value suggests with 95% confidence that participants' individual perceptions of individual learning goal proficiency significantly increased between entrance and exit interviews.

Following are themes and trends from the REU/RET Entrance Interviews:

Bioengineering. Participant introduction to the *bioengineering field* appeared tied to individual developmental level. For instance, several participants indicated they had known about bioengineering for many years, whereas others reported having learned about it in recent years during high school or post-secondary education. Generally speaking, participants broadly defined bioengineering as scientific study linking biology, engineering, and medical (or other practical) applications. Participants intuitively seemed to believe that knowing more about bioengineering could be beneficial to their current and future career goals. On the other hand, most responses tended to lack specificity in application, suggesting that participants were less certain about how bioengineering would directly impact everyday professional life. The exception to this trend was in those cases where participants envisioned themselves pursuing graduate degrees in bioengineering. Participants demonstrated great enthusiasm for ways bioengineering, particularly nanotechnology, could benefit society. Stated ideas included: bone regeneration, cardiovascular therapy, Pulse Laser Deposition utilization, medicine delivery systems, and diagnostic procedures.

Diversity of Thinking. In general, responses to the questions pertaining to *diversity of thinking* informed a wide range of ideas, with little focus upon how diversity of thinking impacts the scientific process. When asked to define "diversity of thinking," participant responses ranged from sharing ideas, to multidisciplinary collaboration, to learning from others, to racial/ethnic differences, to open-mindedness, to positive communication, to multiple approaches. Participants appeared to believe that engaging in diverse thinking could be useful to their present and future career goals; however, they seemed reluctant or uncertain about ways diversity of thinking would specifically benefit (or not) their academic and/or career futures. Participants did not appear to make the critical link between diversity of thinking and new science. When responding to the query about diversity of thinking and its impact upon society, participant answers were broad and varied, ranging from appreciating different cultures improved teaching, to diverse thinking could lead to productive collaborations, to no response.

Innovation. In general, participants seemed much more comfortable discussing the concept of *innovation*. In almost every case, participants were able to offer a definition for the term and link this definition to their academic and/or career goals and to ways innovative thinking could benefit society. Examples of term definitions follow:

- I think according to what I think, innovation would be something that revolutionizes the society. Something that has not occurred before. Something that is also for the betterment of society. A unique idea maybe.
- Well the concept of innovation, I mean, from a scientific prospective, your really looking at new novel techniques that are going to advance humankind. How's that?
- P.T. Barnum quote, "If you put two things together that have never been put together before, then you'll make a million dollars" probably a billion dollars today. Putting things together, that have never been put together before.
- Finding a new way of doing an old thing perhaps, or finding a new use for something we already have. Making things better.
- Innovation is partly coming up with new ideas. The other side is improving existing ideas.
- Innovation is coming up with an idea that has not been thought of or taking an idea and implementing it in a new way.
- Innovation is higher level of thinking, is synthesizing concepts and ideas. It is thinking of applications to the real world domestic and internationally. Innovation is novice thinking.
- I believe innovation is a new idea.

Though they often could not concretely describe how innovation would positively impact their future; in almost every case, participants informed their belief that innovation was necessary in obtaining their academic and/or career goals. Participants were able to identify several areas where innovation could benefit society, including medicine delivery systems, biomedical materials, alternative energy sources such as bio-diesel and hydrogen fuel, and improving solar cell efficiency.

One participant concluded this part of his/her interview with the following observations: “Innovation is the key to success. Without innovation and originality, a person will not be as successful as he/she wants to be. Innovation focuses on individuality, as well as originality. It develops your own style. Without innovation one can’t reach the fullest potential, because something new is not from you. You won’t prosper, because it's not yours.”

Entrepreneurship. Participants appeared to struggle with defining the term *entrepreneurship* and linking same with their academic and/or career goals or societal benefits. In about half the cases, participants stated that entrepreneurship is associated with business, marketing, and making money. Only one respondent indicated his/her research experience could relate to entrepreneurship.

Participants seemed even less certain when addressing queries concerning academic and/or career goals; in many cases, respondents did not indicate any relationship between their academic and/or career goals and entrepreneurship. For instance, when asked about the relationship between entrepreneurship and academic and/or career goals, one respondent stated: “I don't think I can use science as one of the ways to be an entrepreneur. But, it would be more based on my hobbies and what I like. It would not be based on what I do for my living. So, I could think of like starting a gift shop or starting a shop which would have like decorative pieces or greeting cards. But I can't think of anything related to what I do for my profession.”

In the few cases where participants were able to make some connection between entrepreneurship and academic and/or career goals, the links were general and broad in scope (e.g., “One way that would be beneficial, if you find a project that you particularly want to do, you know an invention of some sort, but maybe the lab won’t fund it. So you have to find some other way on your own to fund it and work on it your own time. So it's basically your own little career. So it's beneficial when it's something that you really want to do, but no one else wants you to do it. So you have to do it own your own.”).

A similar trend evolved when discussing entrepreneurship and benefits to society. Participants either could not, or were reluctant to, connect these two concepts, or again, connections were general and broad in scope. For example, when posed the question, one respondent stated: “Probably not, I mean, I think it's really not an area that I think too much about. I mean, you know I just don't think that way. I'm not looking for, okay how can I be an entrepreneur within the science world. I'm looking at this primarily from a business prospective. I don't think that way.” However, in one case, the response to this same question produced the following: “Bone scaffolding, or screws that hold damaged bones together, but dissolve once the job is done and could be absorbed by the body. You would need a company to produce and distribute them. That would be useful to society by benefiting the employees and the government through taxes. Everyone could benefit.”

Perceptions of Research Experiences. Participants seemed to have a good understanding of the upcoming research experiences. In almost every case, respondents provided thoughtful answers to questions concerning purposes of the ERC and Education and Outreach (E&O). RET’s appeared to agree that one of the E&O purposes was to help public school teachers bring cutting-edge scientific concepts back to the classroom. Another respondent provided a substantive response as follows:

> The ERC, its goal is to bring together a diverse group of people from different areas, science and teaching areas to, I think first for the teachers, they want to teach children from K-12 about science research and engineering…So, they are trying to bring teachers over here so they can take the experience to the classroom…to expand the amount of people who are exposed to science in the high schools, elementary schools, and middle schools to get them more interested in research and science. So that when they go to college, its in their minds. As far as the students, it's for, to open the idea of entrepreneurship, innovations and different types of collaborations that we haven't done in diverse engineering research applications. This is a way, a place where we can sort of dip our toes into different things. I'm a chemistry guy, but I'm going to something that's bioengineering working with other students that are from other engineering backgrounds. And I am taking what I learned here back to my campus, my research, trying to expand what researchers are doing here to other campuses and universities and collaborating with other campuses to improve the quality of research.

On the other hand, participant descriptions of the desired proximal and distal outcomes of the ERC Education and Outreach (E&O) were more global in scope and did not precisely mimic the E&O vision is described next.

Short- and Long-Term Goals. In almost every case, participants envisioned linking their upcoming research experiences in the ERC to their short- and long-term goals. REUs and RETs alike identified furthering their education as one of their goals, and they reported that the research experiences would be beneficial to this end. Similarly, RETs saw value in these experiences in enhancing their pedagogy. Responses were overwhelmingly positive in nature, suggesting that participants believed the experiences to be important, personally relevant, and meaningful.

Following are themes and trends from the REU/RET Exit Interviews:

Bioengineering. By and large participant responses informed significantly greater understanding of the field of bioengineering when contrasted with entrance interview data. Of particular interest is enhanced language discrete to the field of bioengineering. Some bioengineering definitions included:

- I defined bio-engineering as applying engineering techniques in developing biological compounds.

- Bio-engineering is the enhancement or alteration of a person or animal's physiology through engineering and the design of devices that can interact with or become part of a person, animal, or plant body for the purpose of healing or enhancement of functioning.

- It is a new field between biology and engineering. It uses mechanical and life sciences to improve health and medical care.

- Bio-engineering is the manipulation of molecules and materials to determine their properties and determine useful applications.

Likewise, participants could more comfortably relate the bioengineering field to their academic and/or career goals and to societal benefits. Participants with graduate studies aspirations maintained a similar exit interview opinion to that expressed in their entrance interviews. One teacher noted: “As a teacher it pays to know something about many topics. Depending on the level that I teach it could show up in the curriculum. It is not currently in any of the curriculum that I have taught, but I imagine that as technology increases, it will be.”

Many participants agreed that bioengineering science could forward the clinical utility of heart stents. Additional uses included cranial facial applications; “bone implants, making them lighter and more efficient;” and “construction of a jaw bone template that is scalable, 3-D, and segmentable.”

Diversity of Thinking. In their entrance interviews, participants seemed to struggle with the concept of diversity of thinking, demonstrating broad and varied ideas, establishing little if any link between science and diversity of thinking. By contrast, exit interview data suggest enhanced understanding and appreciation for this important connection. In almost every case, participants linked diversity of thinking with one or more of their research experiences. For instance, one respondent indicated the diversity of thinking included a multi-disciplinary approach to problem-solving. Another participant talked about what he/she learned pertaining to medical heart stents, incorporating “mechanical engineering, physics, chemistry, and medicine, and, of course, they’re messing with biology, so all of that is interwoven into a project.” Still another proffered that diversity of thinking should be encouraged and that “compartmentalized thinking is problematic;” and another, “A cure for something uses diversity of thinking to make all the pieces of a cure. Someone here in the US might have one piece. Someone in Russia will have another piece. All of the Nobel Prizes go to people with teams from all over the world.”

Innovation. Similar to their entrance interview responses, participants informed a good understanding of innovation. Several participants were able to exemplify innovation with concrete research experiences. One respondent stated: “One of the things the lab, I'm in, is using is the technology of a printer to print medicines in specific patterns. That is using technology that we already have in a different way to solve a problem we are having.” Still another participant observed: “What we are working on in the lab, with nanotechnology; it will be huge for society. Eventually there will be tiny machines that can go into the body and inject something directly into red blood cells. It's the wave of the future;” and still another: “In a group like this of innovative thinkers, it is amazing how one person can have an idea and it seems like someone else is on the same wave-length.”

Entrepreneurship. Though entrance interview data suggested participants struggled with the entrepreneurship concept, exit interview data demonstrated significantly enhanced participant understanding of the concept and how it related their research experiences and to the purposes of the ERC. Participants could provide concrete examples taken from REU/RET activities. One participant noted that: "Entrepreneurship is taking something from the lab, some research, and making it mass-produceable; creating some specialized business in order to implement research into something more practical in the world." Another comment was: "Taking something done in the lab and growing it into more than just a journal article. The research I worked on in the ERC was to make a usable portable detection device. Taking the idea and making the device itself; then, give the blueprint of how to produce it, and have it produced on a wider scale."

When asked if participants could link entrepreneurship with individual academic/career goals, one respondent stated: "More in the past few weeks than before, I would like to start my own nanotechnology company." Another participant stated: "I'll start my own nano-bioengineering company, and I'll employ people. They will buy houses and pay taxes and shop at Costco, and Wal-Mart and all over. They will pay taxes, and hey, everyone benefits. And, they will send their children to the University!" And yet a third response was: "My goal was never to go into business. It is important for my career however. It is important for my students to understand entrepreneurship. I hope to inspire a few to pursue entrepreneurship, stoke the entrepreneurial fire."

Concerning the link between entrepreneurship and societal benefits, the following comments were proffered:

- Entrepreneurship should be emphasized more in high school, maybe even junior high. It should be encouraged.
- I see the link between science and entrepreneurship.
- I have thought that with what's being done here, looking at biochemicals such as hydroxyapitite, alloys created in thin films, and 3-D printing centering. These are things that have never been put together in the ways that are being put together now.
- Finding the right composite mixiture to simulate human bone.

Perceptions of Research Experience. In their entrance interviews, participants informed great excitement and positive expectations for their upcoming research experiences. During exit interviews, these positive expectations were validated as participants endorsed their research experiences, citing the importance of the ERC's vision and associated work. Exit data varied from the entrance interview inasmuch as most participants were able to describe in concrete terms ways in which their research experiences forwarded the proximal and distal goals of the ERC's Education and Outreach program. The substance of participant comments, together with the concrete examples provided, suggests that the research experiences forwarded the vision, proximal and distal goals of the ERC E&O. There were essentially no negative observations concerning the research experience.

General comments follow:

- As part of the National Science Foundation grant, the ERC is trying to open its doors to teachers in the hopes that we might take some of our knowledge back to the classroom and encourage young people to take part in science. It is also opening up to high school students and giving undergrads a chance to do research.

- As teachers, we are having a chance to observe in the lab but we are also trying to get a handle on what's going on in the lab and what does bio-engineering and nanotechnology really mean. For the undergraduates, they were more hands on because they already have the science background and understand of what's going on and are able to do more.

- The research experience has been good. It is hands-on with some experiments and seminars about the idea of research techniques. We also had a tour of the different labs to see what other professors are working on and how the projects are interrelated. Each lab is working on something, but they are related together so that the collective efforts can form more than just the labs working by themselves.

- The lab experience has been a great mental workout. It's going to improve the way I teach science overall, because it's been a great science experience. However, I think as far as directly impact the next generation of scientists, me spending time in a lab is not going to have that much affect.

- The purpose of the research is for the students to get a better understanding of bio-engineering research and get them interested in doing it. It is also developing a network among the students. The teachers gain knowledge about bio-engineering that they can implement into their classrooms.

- Part of how the ERC is funded is that they must do education and outreach. It is a way to hand the mantle off to the next generation of scientists. As far as education, it makes sense to educate educators. They are able to help develop methods of education that can be used. I'm really enjoyed the inquiry based method.

- The vision of the ERC is to get all ages (high school, middle school, and elementary school) aware of the bioengineering field. This will help to bring more minds in and hopefully get more people interested in the PhD program. They are also trying to build partnerships with schools such as ____, one in ____, and another in ____ I think.

- Take students and teachers and expose them to other types of research. The teachers will take what they are doing back to their classrooms to get the students more interested in research and science. For the students, it provides the broadest perspective for bioengineering to encourage them to go into it. It also encourages collaboration with other campuses.

- The vision is to inform the community about the ERC and the work in bioengineering that is being done here. This will include recruitment and highlighting the value to the community and state of the University. The research is noteworthy nationwide as well as worldwide and they want to let people know.

Comments concerning proximal and distal goals included:

- The immediate outcome would be camp this summer, with the high school students learning about nanotechnology and bio-engineering. Also the teachers having something to take back to their classrooms this year. In the long-term, modules to be disseminated to teachers for use in the classroom without training or many extra materials based on the work we've done here this summer.

- The proximal goal because most of the people here are from this local area, is to establish a network within the local area. The distal goal would be to expand beyond the state and work with campuses through-out the country.

- The proximal goal is to get the word out. It is a great program. Be proud of the University because they are adding something to the community. This will help with recruitment. The long-term goal is recruitment and growth. There will be the formation of companies from the research that employ people here.

- It advanced its proximal outcomes because the teachers were able to create teaching modules for their students. For me the proximal was getting the experience working in bio-engineering. The distal goal was expanding it beyond this university and provide the opportunity for collaboration that could be continued over coming years. It satisfied both the distal and proximal goals.

- It helped the proximal goal by informing the community through the schools. Some of the participants are interested in enrolling in the program. It supports the distal goal by helping student recruitment for program and public support

- It satisfies it [vision, author added] by reaching out to middle school, high school, and community college students through the RET program. They have all the bases covered without going too far. If you try to do too much in a limited amount of time, it can dilute the overall objective.

- The research does satisfy the vision because the RETs are doing lesson plans and the high school students are visiting next week. The students will see the research being done in bio-engineering. Undergraduates get to see the focus for research available in the Ph.D. program here.

- The research experiences do advance the proximal and distal outcomes because the program has been a catalyst for undergraduate students to become more enthusiastic about research. The RETs who are preparing to return to their schools will teach the students here for the summer camp during the last week.

- It satisfied the vision through the hands on experience. It needs to be better organized. There were a lot of aspects that need to be worked out. For example, they should set up some kind of temporary parking pass instead of telling people to just find a parking place on the street. The professors did not understand what the participants were supposed to be doing. There needs to be more of a plan. I spent the first three weeks doing basically nothing from 9 to 11 everyday because no one was here. The research was fun, but maybe the days need to be shorter.

Short- and Long-Term Goals. In every case but one, participants agreed that the intensive research experience for undergraduates and teachers forwarded their academic and/or career goals, as well as their “dream” goals. The exception related to one respondent who indicated that his/her primary focus was upon biology, not engineering. It is notable that both undergraduates and teachers could link their research experiences with their future academic/career and “dream” goals. In other words, for undergraduates who wish to pursue graduate work in bio-engineering, the connection between their goals and the research experiences is largely intuitive. For teachers, the link may “feel” less obvious; yet, RETs made strong connections between their summer research and their future goals. For example, one participant stated: “It has opened my mind up to a Masters, not in literacy. It’s possible that I would look for something in science education or maybe even a particular science.” Yet another said: “There is a possibility of co-writing a grant. I would like to do more research at the community college.”

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