Creating a Pipeline into Biomedical Engineering

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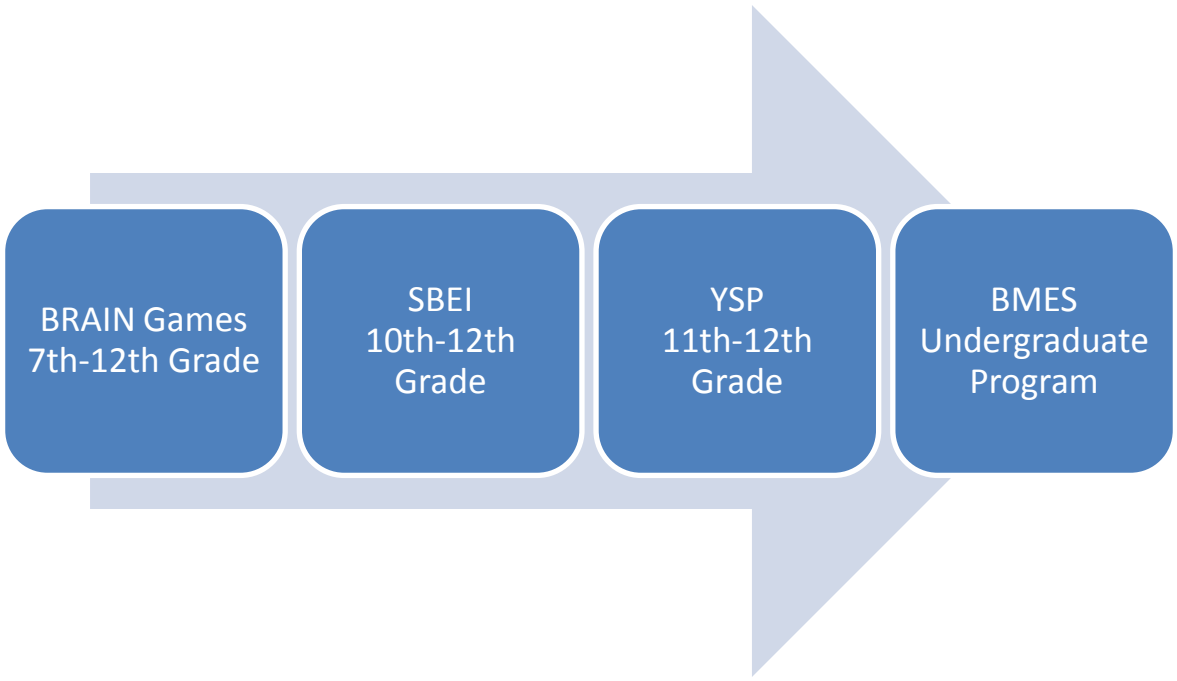
Miss Heather Rae Aschenbrenner

Coordination of Pre-College Summer Programs to Create a Pipeline into Biomedical Engineering

Introduction

Current political and academic discourse is riddled with a call for more students to graduate and enter into Science, Technology, Engineering, and Math (S.T.E.M.) career fields, with hopes of improving the United States' economic standing in the global economy[1]. At the same time, there is a waning interest among students in STEM fields; significant research has been conducted looking at ways to increase interest. Traditional education methods used in the past leave room for improvement when it comes to encouraging students to pursue science careers[2]. Educators are seeing students with considerably different characteristics than previous generations[3]. Today's students are digitally literate, connected, immediate, experiential, social, prefer teams, achievement oriented, value engagement, value experience, visual and kinesthetic, and impact driven. All of this suggests that a change is needed in the way science is presented in K-12 education.

Engineering has successfully been used as a tool to increase student confidence in science and mathematics[4]. Therefore, we posit that students will become more interested and likely to pursue careers in STEM fields if they are engaged in science curriculum in ways that allow them to be active participants in their learning. In an effort to respond to the lacking diversity in the STEM fields and worker shortage[5,6], the Engineering Research Center for Revolutionizing Metallic Biomaterials (ERC-RMB) has developed a series of impactful educational outreach activities. These include short term (one-day) workshops, one week programs, and multi-week experiences aimed at improving overall scientific understanding, as well as engendering interest in STEM. We began with one week programs, known as the Summer BioEngineering Institute (SBEI). We then developed the six-week research intensive Young Scholars Program (YSP). One day workshops, now known as Bioengineering Recruiting and Interactive Network (BRAIN) Games, were developed as a way to get underserved students interested in the above noted programs and STEM in general. Later, due to lack of funding, the SBEI was temporarily suspended. It is our hope that funding sources will be identified that can revive this program. For this purposes of this communication, we will discuss these programs as students would ideally process through them and into the Bioengineering (BMES) Undergraduate Program at North Carolina Agricultural and Technical State University (NC A&T). A graphic display of that progression is featured below.



BRAIN Games

BRAIN Games is a one-day workshop targeting middle school and high school students. The workshop is designed to engage students through active participation in scientific modules. We define modules as hands-on educational activities that are fun, but also teach STEM concepts. The modules incorporated in BRAIN Games were designed from the educational manual, "Teaching Engineering Made Easy 2"[7] and from the curriculum development of our Research Experience for Teachers (RET) participants. The RET program operates concurrently with the YSP, and has each classroom teachers immersed in bioengineering research with the goal of developing an educational module by the end of the experience. Eric Craven participated in the RET program in 2013 and 2014. In addition to using his module on Thin Films[8] at the summer installment of BRAIN games, he was also able to present at the 2014 National Educators Workshop. This module consisted of an introduction to thin films, followed by activities such as: Profilometer in a Box, Nail Polish and Water, and Soap Bubbles. These provide concrete, real world examples of thin films and insights into how to measure them. Another RET participant, Donald Sweeper also employed his module on Physical Validation[9] during BRAIN Games and presented at the National Educators Workshop. This module provided guidance for CAD teachers to introduce the concept of physical validation by focusing on designing an ACL screw. Students are introduced to the problem of ACL injuries and repairs. They are given a block of wood with a rubber band attached by a screw. After performing a pull test, the students examine their rubber band, then work on the design changes needed to produce less damage to the ligament.

Generally, students participating in BRAIN games rotate through three to four modules during the workshop. The modules are taught by RET's and/or graduate students in the ERC-RMB program. To encourage active participation, students are given points for participating and correctly answering content questions during each module. As BRAIN games is a relatively new

addition to our program, satisfaction questionnaires are the only means of assessment as of this publication. A schedule of the events can be found in appendix A.

In addition to the modules, participants are given the opportunity to discuss continuing education in STEM programs via a panel discussion. Undergraduate, graduate, YSP participants, and industry leaders serve on the panel and are encouraged to speak candidly and truthfully in response to the participants' questions. The day concludes with presentations from professors at NC A&T who describe the potential collegiate paths to pursue STEM degrees and the distribution of prizes to the students who answer the most questions correctly in their respective groups.

Summer Bioengineering Institute:

One extensive outreach experience that will be the focus of this paper is the Summer Bioengineering Institute (SBEI) held on the campus of NC A&T. It is a weeklong day camp for rising high school seniors, juniors, and sophomores. The overall goal of this program is to expose and further engage underserved and underrepresented high school students, at a critical cross-road in their education, to the wonders of science and engineering. This program is especially unique due to the level of collaboration between two universities (NC A&T and University of Pittsburgh (Pitt)) and the ERC-RMB. While it is not unique for two universities to work together, this collaboration has followed a trajectory very different from other partnerships. Pitt developed their summer outreach program with a strong emphasis on the knowledge, skills, and autonomy of undergraduate interns. Each year the interns decide on a theme for the camp. Then, they individually develop an activity that will provide participants with hands on bioengineering based activities. Once the program had been successfully run at Pitt it was used by ERC-RMB. As the bioengineering program at NC A&T became established, an effort to include their undergrads in the camp began. In 2012 and 2013 interns from NC A&T traveled to Pitt in order to take part in the module development process. The interns from both schools, along-side master teachers, worked over the course of ten weeks, to create modules or activities for camp participants (campers). Approximately half of the modules or activities are taken from a collection of academically tested modules, from for ready use in the classroom. These modules are learning activities that cover a wide variety of topics associated with biomedical engineering, including but are not limited to the use of stem cells, blood vessel synthesis, gene expression, prosthetics, bone augmentation, and the impact of bone decalcification.

The SBEI was offered for five consecutive summers from 2009-2013. Since 2013 was the most recent offering, we will focus on activities from that year. As in years past, the camp at NC A&T was one of three camps offered over the summer of 2013. Two camps were held in Pittsburgh and involved one week for middle school students and one week for high school students. The third 2013 camp, held in North Carolina, involved only high school students. The camps have been well populated, ranging between 13-20 participants. The concept for the SBEI as applied at was developed for , as a part of the 2+2+2 Life Science Pipeline Project[10]. The coordinators for the camp have successfully recruited and advertised for this camp by posting flyers and links to application forms on the ERC website. In addition, our university's Division of Research and Economic Development (DORED) authored a press release that was published on the institution's website. The SBEI also benefited from collaborating with the coordinator of the

YSP, who personally contacted 7-10 different schools aiming to recruit students. The application deadline was rolling from May to June, until capacity was reached. NC A&T's continuing education program, created in a writable PDF application and a Google document. The application, modeled after another program, consisted of a form requesting contact information, standard testing scores, demographic data, and details on scholarly endeavors as well as extracurricular activities. Applicants also submitted a personal handwritten statement reflecting on their interest in biomedical engineering. The application packages were subjected to an evaluation based on grades, SAT and ACT scores, academic level of the mathematics and science classes taken, as well as special circumstances. Lastly, care was taken to ensure a diverse pool of students participated. After being accepted to the camp, participants completed an additional online registration form, parental release forms, and paid a $75.00 registration fee.

While we refer to the SBEI as a one-week camp, we have developed a unique timeline running from Friday to Friday (no activities on the weekend) to best accommodate administrative tasks, such as: parental consents, campus tours, pre-assessments, and obtaining campus IDs. This schedule allowed ample time for these activities without sacrificing educational time. This increased the amount of camaraderie among campers and between campers and camp counselors.

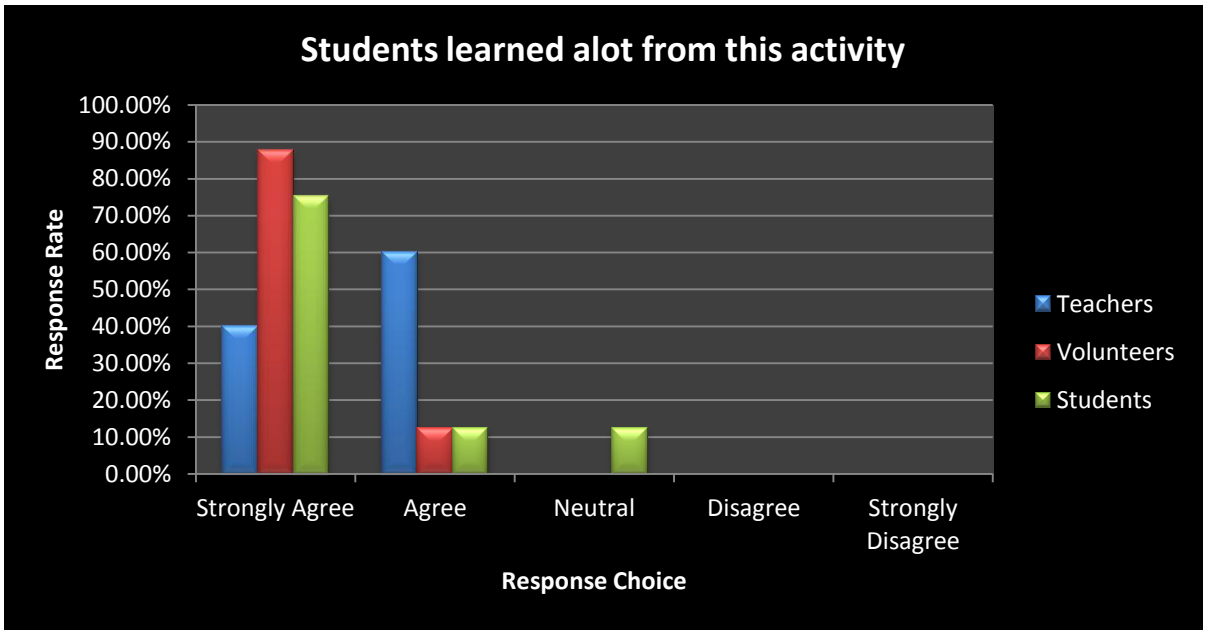
Campers were in teams of up to 4 participants per undergraduate counselors and teachers to complete modules. As noted in the schedule (Appendix B) , campers reported to a lab on the campus of at 9:00AM, began working until lunch in the campus cafeteria with the counselors, and then returned to the lab to work until 4:30PM. Prior to starting each module campers participated in interactive discussions on the topic. As campers completed activities, special emphasis was placed upon the importance of teamwork, collaboration, and "thinking outside the box". As in an actual research laboratory, campers would arrive at the lab and continue studies or activities from the previous day, it should be noted that the complexity and difficulty of the modules increases as the week progresses. Other activities included informal mentoring with the counselors to discuss preparing for post-secondary education. On the last day of the camp, content and satisfaction post-assessment, as well as a focus group with the undergraduate counselors were held. Lastly, campers, counselors, and staff participated in the ERC-RMB end of the summer awards recognition ceremony. Each SBEI camper received a certificate recognizing their participation. In addition, several campers gave testimonials about their experience in the camp.

YSP

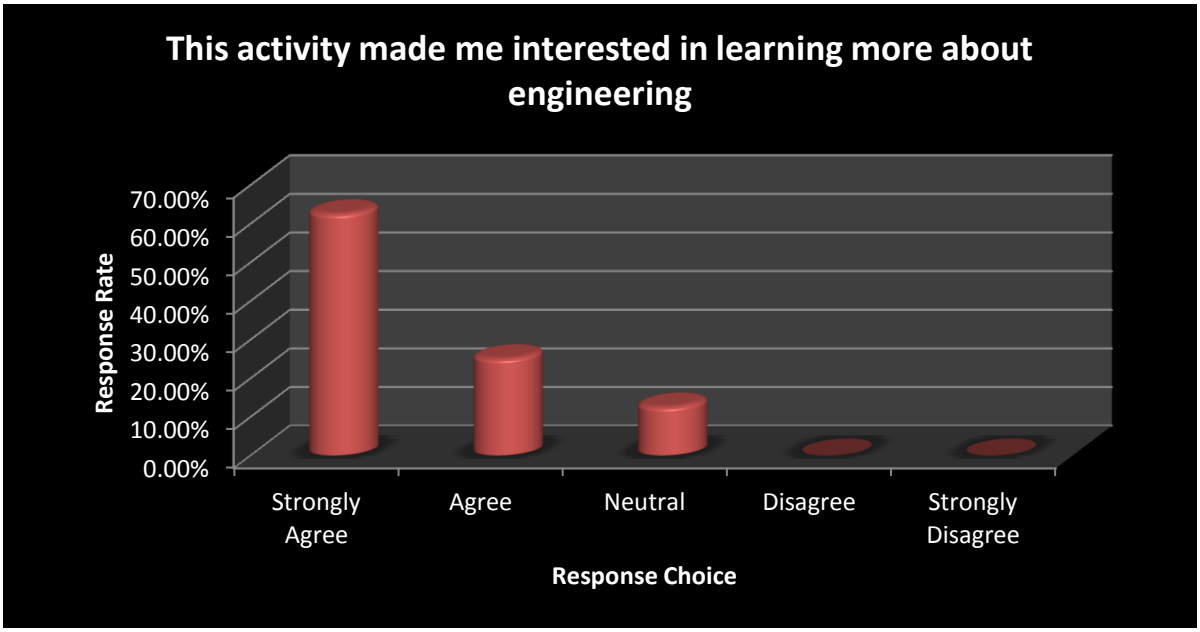
The Young Scholars Program (YSP) is a dynamic, research intensive experience for outstanding rising 11and 12graders in Guilford County, NC and the surrounding areas. It is a six-week program during which students are teamed with Research Experience for Undergraduates (REU) and RET participants. These triads have hands on research experiences in university laboratories working alongside University faculty and principal investigators. The YSP provides time in research labs, as well as, additional seminars, workshops, and field trips (Appendix C). Special care is given in selecting participants who can function in a highly independent and technical environment. YSP participants are monitored closely, but encouraged to contribute to furthering research projects, and actively taking part in all aspects of the program.

Program Results

BRAIN Games
The following charts contain questions asked of those participating in BRAIN games.

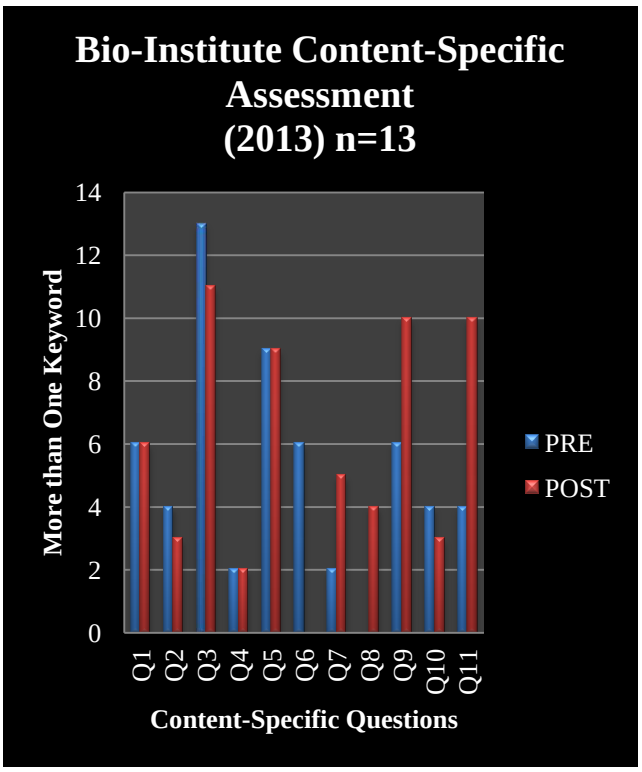


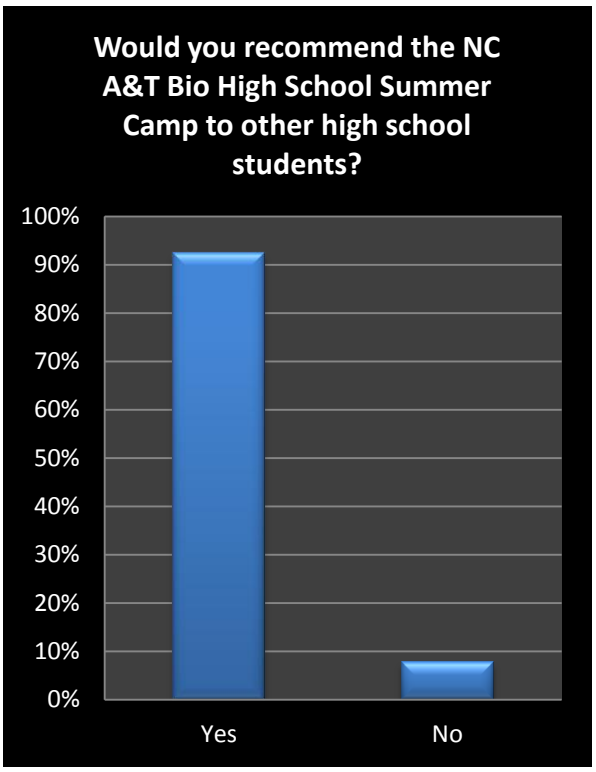
Teachers, volunteers, and students reported that students seemed to learn a lot from their participation in BRAIN Games.



The majority of students indicated that the activities increased their interest in learning about engineering.

SBEI


Bio-Institute Content-Specific Assessment (2013) n=13
More than One Keyword
14
12
10
8
6
4
2
0
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Content-Specific Questions
PRE
POST


Would you recommend the NC A&T Bio High School Summer Camp to other high school students?
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Yes
No

Content Questions and Keywords used to evaluate responses

Questions	Keywords
Q-1: What is tissue engineering?	Tissue, engineering, creating, regenerating, growing, organic matter, making, cell function, building, forming, examining, manipulating, rebuilding, repair
Q-2: What do you think is going on in the process of human development? List as many processes as you can.	Growing, cell division, regeneration, differentiation, cells dividing, reproduction, produce cells, development, protein synthesis, mitosis, mutation, maturity, specialization, gene expression, tissue building, decoding genome, homeostasis, metabolism, increase muscle mass
Q-3: What are tissue made of?	Cells
Q-4: How do cells or tissues communicate with each other?	Signals, mRNA, DNA, orbiting, electric shocks/impulse, hormones, chemical receptors, proteins, paracrine, autocrine, contact dependent, neuron, synapse, endocrine, nerves, gap junctions, extracellular matrix (ECM)
Q-5: What are cells internal set of instructions called?	DNA, nucleus, genome, chromosomes, genes
Q-6: All cells of the embryo contain the same set of instructions. Based on this idea, how can different cells arise with different structures and functions?	DNA, Extra Cellular Matrix, growth factor, signals, chemicals, cellular interactions, instructions, stem cells, differentiation, gene expression, specialization, codons
Q-7: What two repair processes are used by the body to heal a wound?	Scabbing, scarring, regeneration, mitosis, platelet, red blood cells, homeostasis, clotting, swelling
Q-8: What are three approaches used by tissue engineers to fabricate (grow) a new tissue?	Scaffolding, cell, stem cell, regeneration, imprinting, growth factor
Q-9: What cells are most commonly used when trying to grow a new tissue?	Stem cells, yeast
Q10: Where might scientists find stem cells?	Embryos, body, people, umbilical, bone, skin, blood, tissue, unborn babies, fetus, placenta
Q11: What do you think eventually happens to an implanted scaffold?	Degrades, degenerates, disappears, breaks down, dissolves, go away, decompose, integrated into body

During the SBEI, participants maintained or increased their knowledge in most of the content questions. However, there were questions where participants did not gain content knowledge. Possible explanations for this include: test fatigue, lack of interest in content, less focus on that

content area. The vast majority of participants indicated that they would recommend the program to other students.

YSP

Nearly all of the assessments for the YSP are aggregated with the concurrent REU and RET programs. However, there were focus groups conducted for each program which provide some insight into the unique experiences of participants in each group. When asked what they learned in the program, participants listed extracting keratin, how to operate a CT scanner, and magnesium alloy anchors. The aspects of the YSP that were the most interesting were the ability to shadow a researcher and see what work is done on a daily basis and learning how much individual and creative work went into performing a research project (ex. Creating your own program software). Each year YSP participants are amazed at the level of trust and respect given to them in the program. They find that they are treated as equals not only by their fellow REU and RET participants, but also by the faculty mentors and other program staff.

While increased content knowledge and interest in the field is beneficial, outreach programs also serve as a significant recruiting tool for the Bioengineering program at NC A&T, and can do so at other institutions. Since the inception of the pre-college programs through ERC-RMB, the Bioengineering Department at NC A&T has recruited a total of four students, who are former participants in the previously described outreach activities. One of the two students in the current class of 2016 participated in both the SBEI and the YSP, while another student in the same class, participated in the YSP. Both students are underrepresented minorities, and prime examples of the impact of providing a series of programs to high school students can have on student major selection. A participant from the summer 2012 SBEI is registered as a first year student, in the Bioengineering class of 2017 at NC A&T . She stated that the camp "…answered questions about the opportunities within the field…" and in answering these questions, highlighted the resources available on campus that she did now know existed[11]. After the most recent 2013 summer bioengineering camp a student participant indicated that the camp "…opened his eyes…" to the possibilities of bioengineering and specifically peaked his interest in biomechanics. He later applied for the bioengineering program at NC A&T for fall 2014 admission[12]. In both of these cases, the students indicated that participating in the SBEI led them student to pursue bioenigeering.

Limitations

While this paper is intended to focus on a model successive outreach programs, it is important to note that there are several limitations to the study. These programs are funded as part of a bioengineering research intensive project. Connections were later made that they serve as an introduction to STEM and NC A&T that could benefit the bioengineering program. Improvements and data collection could have been more targeted if that was the stated goal of the programs from the beginning. The limitations to BRAIN games and the program's assessment include: no information on knowledge change is available. One strength of the SBEI is the interactions between undergraduate interns and campers. However undergraduate interns often have little experience with pedagogical concepts. This can cause campers to miss the content knowledge in the modules because they are more interested in the activity than the

concept it represents. While modules have been developed for several years as part of the SBEI and RET programs, very little concern has been given to evaluating their efficacy and publishing them. This provides road blocks in being able to share the positive results of both BRAIN Games and SBEI. The YSP assessment results are thickly intertwined with the REU and RET co-hort. While the funding agency is satisfied with the results of these programs being reported in aggregate, it makes an evaluation of the individual program much more difficult. All of these programs have the goal of increasing interest in STEM careers, which is far removed from any high school experience. This longitudinal data is difficult to collect and the programs are just now old enough for any meaningful information collection to begin.

Conclusion

In conclusion, the NSF ERC-RMB has created a series of summer programs that have effectively introduced and reinforced biomedical concept for high school students in the state of North Carolina. Pre and post assessment of student perceptions, interests, and even content knowledge is needed when implementing such programs. Information from these assessments not only helps program coordinators and educators to understand the student participants but to also understand the efficacy of presented modules. An additional benefit to these programs is the recruitment of participants to the host institution undergraduate programs.

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Appendix A

National Science Foundation
Engineering Research Center: Revolutionizing Metallic Biomaterials
North Carolina A&T State University

Start	End				
Tuesday, July 29, 2014 (Proctor Hall)					
8:45	9:00	**Registration/Rules/Refreshments –** *Room 311*			
9:00	9:10	**Welcome: Dr. Matthew McCullough, Moderator** **Opening statement: Lois Deve, Administrative Director**			
9:10	9:55	**Eric Craven Room 314a**	**Donald Sweeper Room 312**	**Cindy Nelson Room 314b**	
10:00	10:45	**Kent Boyles Room 312**	**Chantel Simpson Room 314b**	**Eric Craven Room 314a**	
10:50	11:00	**Break**			
11:00	11:45	**Donald Sweeper Room 312**	**Cindy Nelson Room 314a**	**Chantel Simpson Room 314b**	
11:50	12:45	**Lunch with the Young Scholars**			
12:50	1:35	**Cindy Nelson Room 314a**	**Eric Craven Room 314b**	**Kent Boyles Room 312**	
1:40	2:00	**Close Out Session with Content Post-Assessment** **Opportunities Overview** **Room 311**			

Appendix B

PTEI
ADVANCING REGENERATIVE MEDICINE

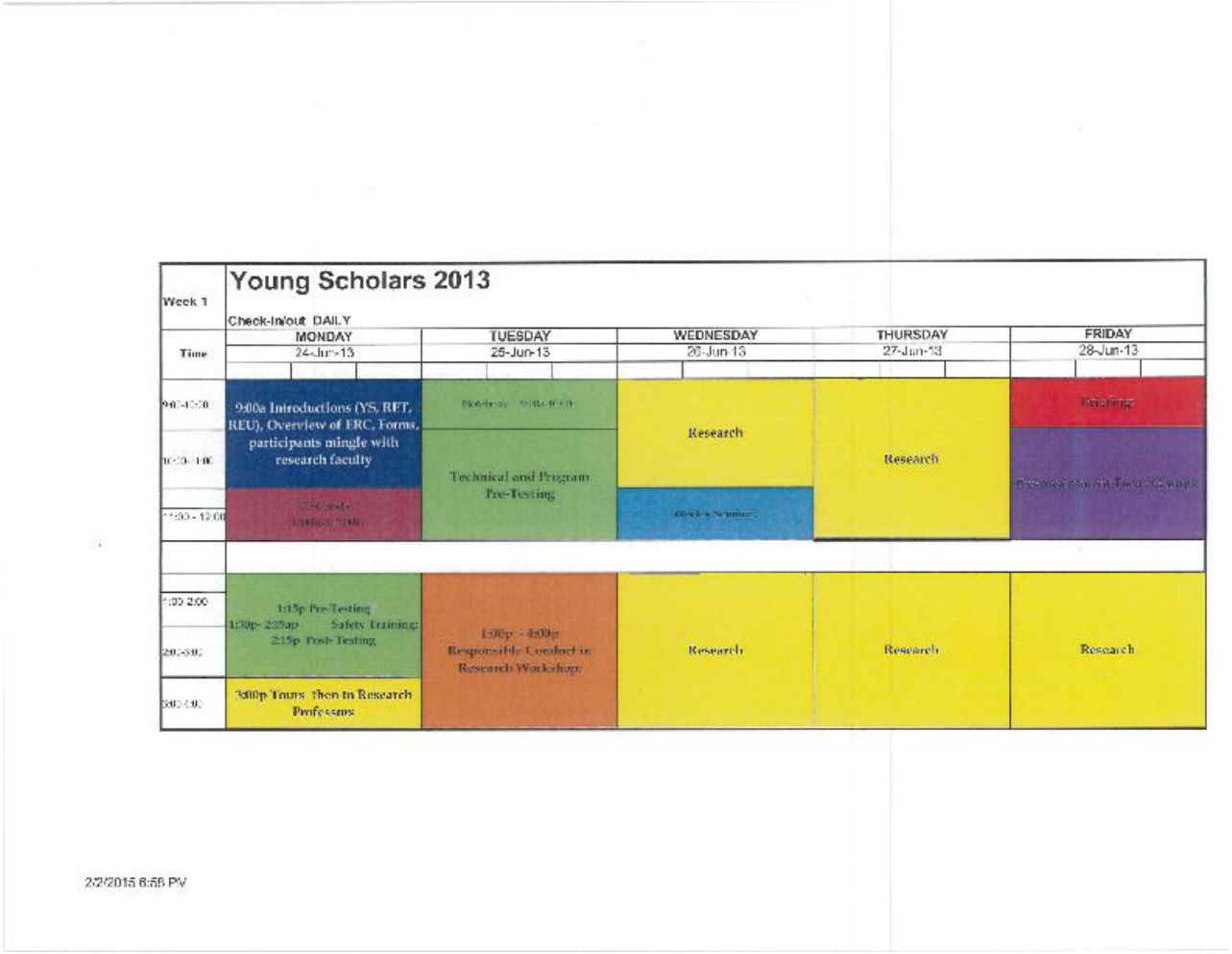
North Carolina A&T Camp

SCHEDULE OF DAILY ACTIVITIES
July 29th to August 2nd, 2013
8:30 am to 4:30 pm daily

Monday (July 29th)		
Time	**Activity**	**Filler Activity/Bldg**
8:30 - 9:30	Introductions - What is our mission? Meet your counselors What comprises our bodies? What are the structural components of our bodies and how do they allow us to move (perform)? Challenge Questions	Distribute Photo release
9:15 - 9:45	Human Performance: (Dr. Steve) Broad jump contest + hop scotch contest + balance contest	
9:45 - 10:45	Chicken Little Dissection + Instability	
10:45 - 11:45	Bone Calcification (Tyler Bowe)	
11:45 - 12:45	LUNCH	
12:45 – 1:15	Creation of TE company flag, handshake and TE company slogan	
1:15 – 2:15	Intro to pipetting (Prof. Smith)	
	Tissue Extract Challenge: "I got skills!" (Prof. K)	
2:15 – 3:15	Stem Cell Culturing demonstration (Prof. K)	
3:15 – 4:30	pGLO Transformation (Dominique Saddler)	
Tuesday (July 30th)		
8:30 - 9:30	Immunology runs its course (Mike Coury)	
9:30 – 10:00	Transformation Review	
10:00 – 10:45	Skin the ultimate defense (Nina Maxey)	
10:45 – 11:45	Medical Immunology (Prof K)	
11:45 – 12:45	LUNCH	
12:45 – 1:15	Stem Cell Seeding Game	
1:30 – 2:00	Cell Seeding Challenge Activity	
3:00 – 4:00	Bone Grafting - Crystal Hill	
4:00 – 4:30	Bioethics Discussion	
Wednesday (July 31st)		
8:30 – 9:30	Bone Strength Competition (cont'd)	
9:30 – 10:15	"Ghost Hearts" (Rasheda Toomer)	
10:15 – 11:00	TEBV activity construction	
11:00 – 11:45	Medical Immunology – Data Review	
11:45 – 12:45	LUNCH	
12:45 – 1:45	Exploring ECM (Hannah Smith)	

1:45 – 2:15	TEBV testing	
2:15 – 3:30	Prosthetics & You – Hannah, Ahmed & Laura	
3:30 – 4:30	Introduction to DNA (Prof. K) DNA capsule	
Thursday (August 1st)		
8:30 – 9:30	DNA extraction (Prof. Smith) Molecular Biology – How Does it Work? (Prof. Smith) Electrophoresis intro and pour gels	
9:30 – 10:15	"Ghost Hearts" - Review	
10:15 – 10:45	TE Guest Presentation (Tom Shupe & Joan Schanck)	
10:45 – 11:15	Mentoring Session – Round 1 (Undergraduate view)	
11:15 – 11:45	Load gels	
11:45 – 12:45	LUNCH	
12:45 – 1:30	Bone Calcification Testing	
1:30 – 2:00	Stem cell extraction game View gel results	
2:00 – 3:15	Prosthetics & You (cont'd)	
3:15 – 4:30	Young Scholars Presentations & Counselor Focus Group	McNair/IRC
Friday (August 2nd)		
8:30 – 9:15	Post Assessment (Courtney Lambeth) General Wrap-up (gel results) Final company scores and presentations	
9:15 – 10:45	Mentoring Session - Round 2 (Professor & Grad Student View)	
10:45 – 1:00	Summer Program Closing Ceremony (boxed lunch to follow)	McNair Hall

Appendix C



Week 1	Young Scholars 2013				
	Check-in/out DAILY				
Time	MONDAY 24-Jun-13	TUESDAY 25-Jun-13	WEDNESDAY 26-Jun-13	THURSDAY 27-Jun-13	FRIDAY 28-Jun-13
9:00-10:00	9:00a Introductions (YS, RET, REU), Overview of ERC, Forms, participants mingle with research faculty		Research	Research	
10:00-11:00		Technical and Program Pre-Testing			
11:00-12:00					
1:00-2:00	1:15p Pre-Testing 1:30p- 2:15ap Safety Training; 2:15p Post- Testing	1:30p - 4:00p Responsible Conduct in Research Workshop	Research	Research	Research
2:00-3:00					
3:00-4:00	3:00p Tours then to Research Professors				

2/2/2015 8:56 PM