
AC 2011-1610: ARE WE GROWING THE NEXT GENERATION OF BIO-ENGINEERS? AN ECOLOGICAL ASSESSMENT OF ONE BIOINSTITUTE SUMMER CAMP

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Are We Growing the Next Generation of Bioengineers?

Overview

Scientific understanding, engineering solutions, and technological innovations have led to substantial growth in economies all over the world since the Industrial Revolution¹. According to the National Academy of Science¹, fewer American students are choosing to obtain higher education in science and engineering than students in other countries. This powerful fact alone indicates that increased Science, Technology, Engineering and Mathematics (STEM) education is critically important to the current educational system, thus ensuring that the United States maintains the human capital necessary to growing its economy, solving the problems faced by a 21st century society, and maintaining a quality of life comparable to which Americans have grown accustomed.

More troubling, students in secondary education are taking fewer challenging courses in math and science than their abilities indicate they are capable of successfully completing¹. One reason for this apparent shying away from math and science may be the lack of science instruction in elementary classrooms due to increased attention to high stakes testing in Language Arts and Mathematics². Marx and Harris² further suggested that the decreased time devoted to science education means that today's students, in comparison with the adult scientists of today, are deprived of important early experiences in science which naturally lead to an interest in the field, encourage curiosity in the world around them, and facilitate the imagination necessary in the early stages of innovation. Emdin³ explains that even with increased attention to urban student engagement, there remains little true interaction between a student and the science curriculum. Sadly, this could be due to the encouragement of behaviors involved in science without the accompanying cognitive involvement marked by asking questions, discussing concepts, or voicing disagreements with controversial material³.

Interventions supported by the No Child Left Behind Legislation² and the National Academy of Science¹ primarily focus on increasing the numbers and quality of classroom teachers. This paper will serve to suggest and provide support for another option in changing students' view of STEM fields, through a week-long bioengineering commuter summer camp for high school students.

Theoretical Perspective

Borrowing from the field of child development, Bronfenbrenner's Person-Process-Context-Time (PPCT) ecological theory was utilized as a foundation for assessment planning. PPCT ecological theory posits that development results from "multidirectional and interactional processes," occurring over time, between developing individuals and the context in which they learn, work, and live. Though Bronfenbrenner's Person-Process-Context-Time (PPCT) model has been used in child development research, it is rarely seen, if ever, seen in educational research. One possible reason for the absence of truly ecological studies related to STEM education may be associated with the perceived complexity of the PPCT model. In response, it is here argued that though complex, the PPCT model affords unique opportunities to discover both more obvious and nuanced information surrounding the learning process. Moreover, the PPCT's multi-tiered

design allows for mixed research methodology and triangulation of data. Following is an overview of the PPCT model.^{4,5,6,7,8}

Bronfenbrenner^{4,5,7,8,9} is traditionally recognized as the theorist who forwarded the notion that human development occurs in context. However, Bronfenbrenner's most recent writings indicate that in addition to context, proximal processes (i.e., ongoing human interactions over time), person characteristics, and time effects also must be considered. Bronfenbrenner's ecological theory indicates healthy development is dynamic and continuous, separate from discrete developmental milestones occurring at particular points in time. To conduct ecological research, Bronfenbrenner proposed the PPCT model, a model which facilitates systematic study of the following: (a) person characteristics (b) proximal processes; (c) over-arching, as well as immediate, contextual influences; and (d) time effects.

Bronfenbrenner^{4,5,7,8,9} theorized that individuals bring important *person* characteristics to their developmental activities. Furthermore, human beings influence their environments, while environmental factors simultaneously influence human development. Bronfenbrenner identified three subsets of person characteristics, including *force*, *resource*, and *demand*. One person characteristic related to a student's educational development is the student's *willingness* to engage in the educational experience. This characteristic is referred to as a *force* characteristic. Force characteristics are related to a person's "disposition," and Bronfenbrenner and Morris⁷ further referred to force characteristics as the "shapers of development." Bronfenbrenner and Morris⁷ further divided force characteristics into two sub-categories, calling them either "developmentally-instigative" or "developmentally-disruptive." Developmentally-instigative characteristics are behavioral in nature and can "set proximal processes in motion and sustain their operation" (p. 1009). Over time, developmentally-instigative characteristics tend to (a) evolve into increasingly more complex activities, (b) bring about restructuring of (or creation of new) environmental features, and (c) encourage healthy development. As may be expected, the reverse is true for developmentally-disruptive characteristics. Given the behavioral nature of force characteristics, measuring them through direct observation makes sense. In this study, camper willingness to engage in camp learning activities was triangulated through camper self-report and counselor observation.

Another person characteristic related to student's educational development is referred to as *resource* characteristics. These person characteristics describe a person's innate abilities such as intelligence, talents, and gifts⁷. Resource characteristics include "biopsychological liabilities and assets" which enhance or impede a student's ability to engage effectively with his or her learning environment. An example of a "biopsychological asset" is the student's cognitive ability, enhancing or impeding his or her ability to assimilate and accommodate information and learning schemata. For this study, resource characteristics were indirectly measured through change in camper learning and understanding of technical content (i.e., tissue engineering).

The third person characteristic related to student's educational development is referred to as *demand* characteristics. Demand characteristics are largely biological and fixed, inviting or discouraging environmental reactions "of a kind that can disrupt or foster processes of psychological growth"⁷. An example of a demand characteristic is race/ethnicity. Of interest to this study was the camp's designers and administrators intention to serve underrepresented

student populations. Consequently, most campers were students with minority status. Given this perspective, it is reasonable to assume that the bioengineering camp was designed to “foster processes of psychological growth,” and thus indirectly and positively impact student STEM development as measured through self-report.

The concept of *proximal process* is central to ecological theory. Proximal processes are interactions occurring between a developing individual and the “persons, objects, and symbols” within his or her “immediate environment.” Moreover, proximal processes constitute the “engines of development”⁹. Healthy human development occurs in the presence of “patterns of exchange of information, two-way communication, mutual accommodation and mutual trust”⁵. Proximal processes can be measured either through direct observation or self-report. In better circumstances, multiple methodologies are utilized to measure proximal processes. For purposes of this study, proximal processes or “multidirectional and interactional processes” were triangulated through camper self-report and counselor focus groups.

Bronfenbrenner¹⁰ posited human organisms may be metaphorically conceived as systems nested within other systems. *Context* is specifically defined as the differentiated layers of environmental influences, ranging from over-arching contextual influences called macrosystems (e.g., race/ethnicity) to more immediate influences found in microsystems (e.g., classroom)^{4,5,7,8,9,10,11,12}. Each context has particular characteristics that impact the developing student and his or her proximal processes in specific ways. For purposes of this study, perceptions of contextual influences and ways they impacted camper development in STEM education generally, and bioengineering, specifically, were measured through camper self-report and counselor observation.

The last component of Bronfenbrenner’s model is *Time*. Bronfenbrenner^{5,7,9} has called this component the chronosystem. The examination of time effects may be done in two ways: (a) the study of development relative to a particular historical setting, and (b) the study of development by gathering data across at least two points in time. For purposes of this study, data were collected six months post summer 2010 bioengineering camp completion. As well, data from the summer camp’s first year (summer 2009) were compared to data collected summer 2010.

Ecological research requires systematic study of person characteristics, proximal process, contextual influences, and time effects. With this philosophical perspective in mind, a mixed-methods design was implemented to measure change in student understanding of (and interest in) **science, engineering, and medicine**, as well as their knowledge of tissue engineering and regenerative medicine.

Camp Description

The summer camp originated as part of the Education and Outreach activities of an Engineering Research Center (ERC) awarded by the National Science Foundation. The development and refinement of this summer camp was been guided by this ERC's Education and Outreach vision: to train future engineers for industry, research and development in a multidisciplinary environment that values diversity of thinking, innovation, and entrepreneurship and evolved from the collaboration of two geographically distant campuses that allowed for the shared use of

content, faculty, and mentors. Professors, science teachers (who were also participants in the University's RET program), and undergraduate bioengineering students served as camp instructors and individuals from outside of the camp as guest speakers. Efforts were taken to make science a non-threatening place by relating it to real-life situations. The camp included various learning environments ranging from traditional classroom teaching with little interaction, to group discussions about concepts and hands-on demonstrations.

The content of the camp revolved around biomedical engineering and more specifically tissue engineering which focuses on creating replacement tissues and organs for individuals with compromised functioning. In order to reach our Education and Outreach vision and provide instruction in tissue engineering, two specific goals for the summer camp were devised: introduce students to bioengineering and encourage them to pursue a baccalaureate degree in tissue engineering.

Assessment

Assessment methodology included pre-/post- written assessments and focus groups. Campers completed both pre- and post- written assessments in both general and content-specific areas. General assessments determined the overall quality of the camp experiences. Data from general assessments allowed for researcher interpretation campers' *force* characteristics, or willingness to engage in the camping/learning experience. Likewise, content-specific assessment data were utilized to evaluate camper *resource* characteristics or innate abilities as measured through understanding and learning related to Tissue Engineering and Regenerative Medicine concepts. Finally, *demand* characteristics were indirectly measured by campers' appreciation for, or lack thereof, for the camping experience. Counselor observations were also considered when studying the effects camper demand characteristics had upon the camp learning environment.

One criticism of the PPCT model relates to difficulty in measuring “multidirectional and interactional processes.” Indeed, measuring proximal processes challenges the ecological researcher. Nonetheless, to assess for proximal processes, camper observations through self-report and camp counselor focus group observations were triangulated to get at proximal processes. From these various perspectives, not only a sense of the “multidirectional and interactional processes” came to the fore, but a “feel” for the camp’s positive environmental – or contextual – influences evolved as well. Thinking chronosystemically, data were collected from camper parents six months post the camp experience. Camper families were contacted via email and surveyed utilizing surveymonkey. As well, data gathered from this same camping experience in summer 2009 were utilized for comparison. IRB approval, including camper and parental informed consent, were obtained prior to data collection.

Results

Bioengineering summer camp participants ranged from 14-17 years old ($M\ Age=15.5$), and most participants reported having just completed the 9th grade ($n=7$). Participants were predominantly male ($n=11$) and African American ($n=14$). See Figure 1. All participants indicated that they (a) held US citizenship and (b) planned to attend a 4-year college. Further, most participants ($n=11$) stated they intended to pursue degrees in either bioengineering or STEM-related disciplines. See

Figure 2. The majority of participants ($n=10$) indicated that they learned of the Bioengineering summer camp through one or both parents. Most participants (82%) stated they had prior experience with science experiments and/or science fairs.

Participant Distribution by Race/Ethnicity

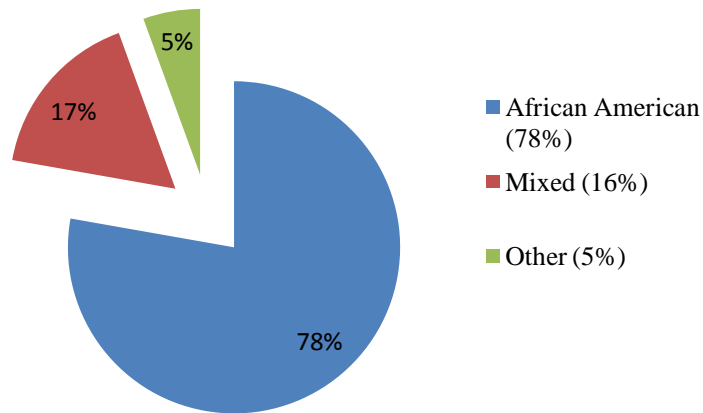


Figure 1

Distribution of Participants' Areas for Future Study

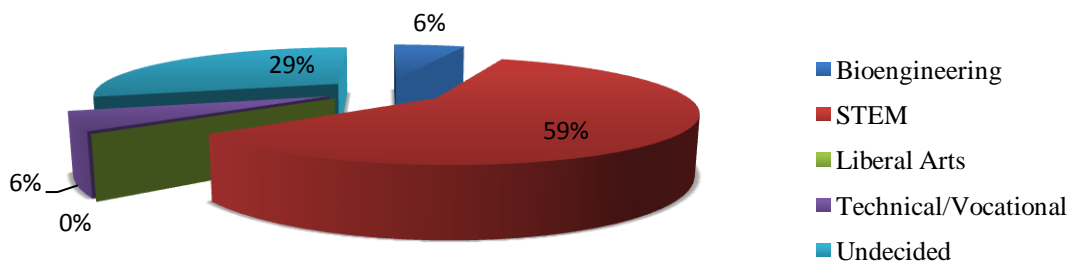


Figure 2

Twenty-six per cent of the participants reported that they hoped to learn more science through their participation in the Bioengineering summer camp, whereas 23% stated they wanted to increase general knowledge and skills. Most participants strongly agreed or agreed that they were taking part in the Bioengineering summer camp experience in order to learn more about “biomedical and skin engineering.” See Figure 3. Likewise, they strongly agreed or agreed that they were interested in science and engineering prior to participating in the Bioengineering summer camp.

Top Reasons Participants Chose to Attend the Bioengineering Summer Camp

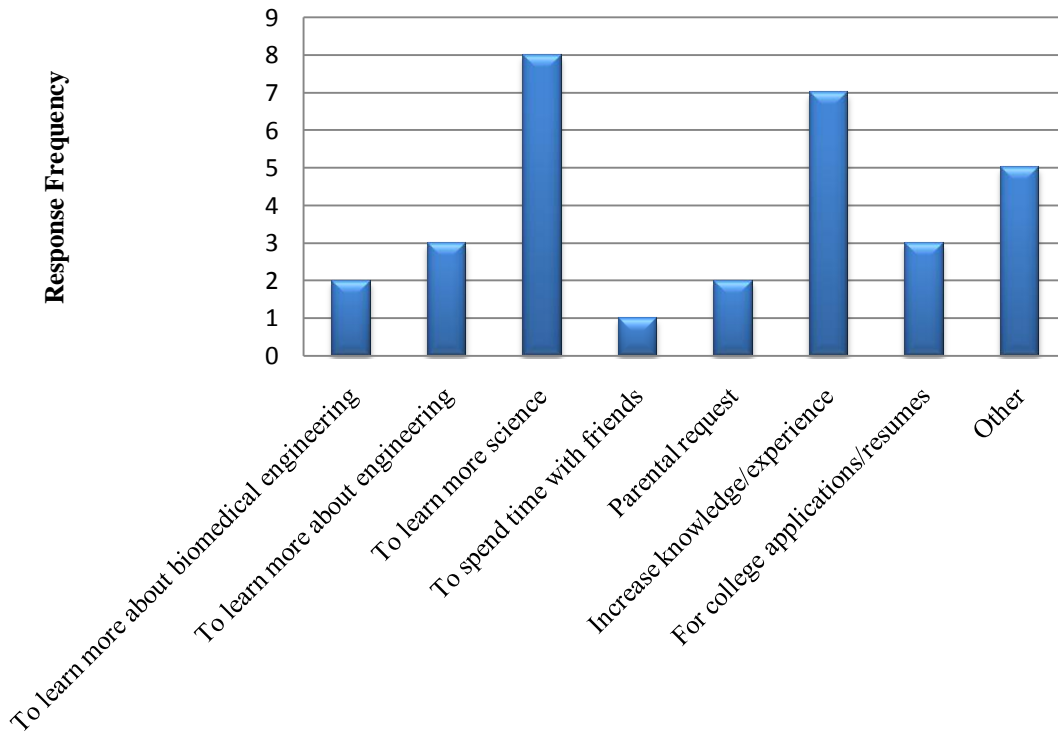


Figure 3

Data suggested that at the beginning of the Bioengineering summer camp participants demonstrated an elementary understanding of the definition of tissue engineering, and regenerative medicine. By contrast, post-assessment data revealed that participants experienced a substantive change in understanding and learning related to (a) the meaning of tissue engineering, (b) what makes up tissue, (c) how tissues or cells communicate, (d) DNA, (e) ways to grow new tissue, (f) where stem cells come from, and (g) the fate of an implanted scaffold. See Figure 4. Though participants established an adequate and positive trend in understanding and learning across all concepts, four topics remained challenging, specifically: human development processes; internal cellular instruction; human body repair processes; and three approaches to fabricate new tissue. See Table 1.

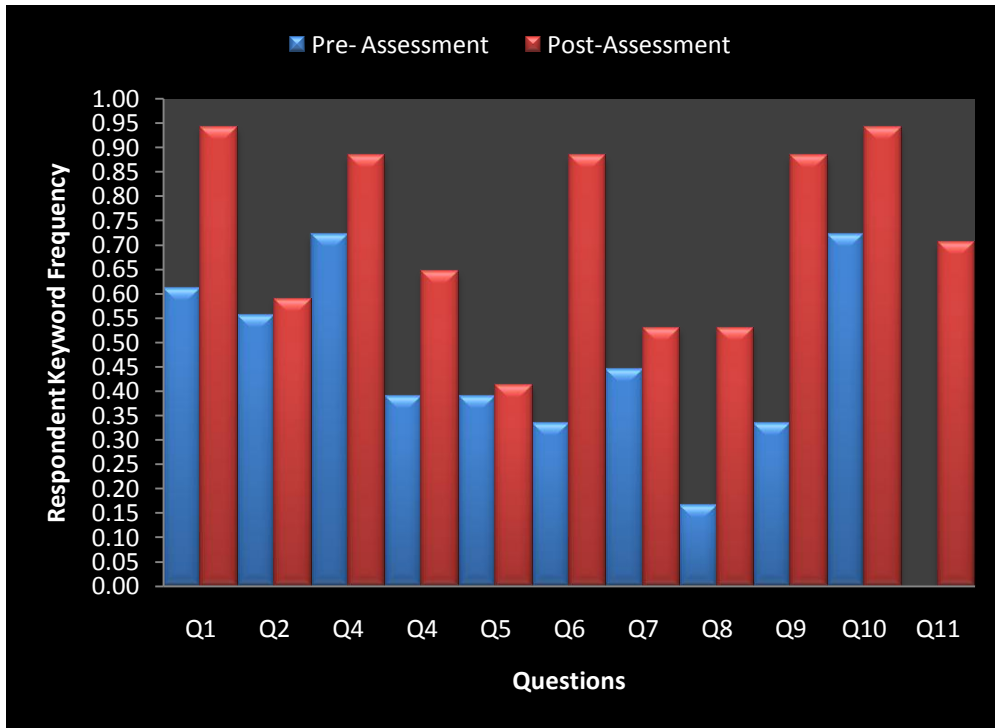


Figure 4 2010 Bioengineering Summer Content-Specific Assessment Results

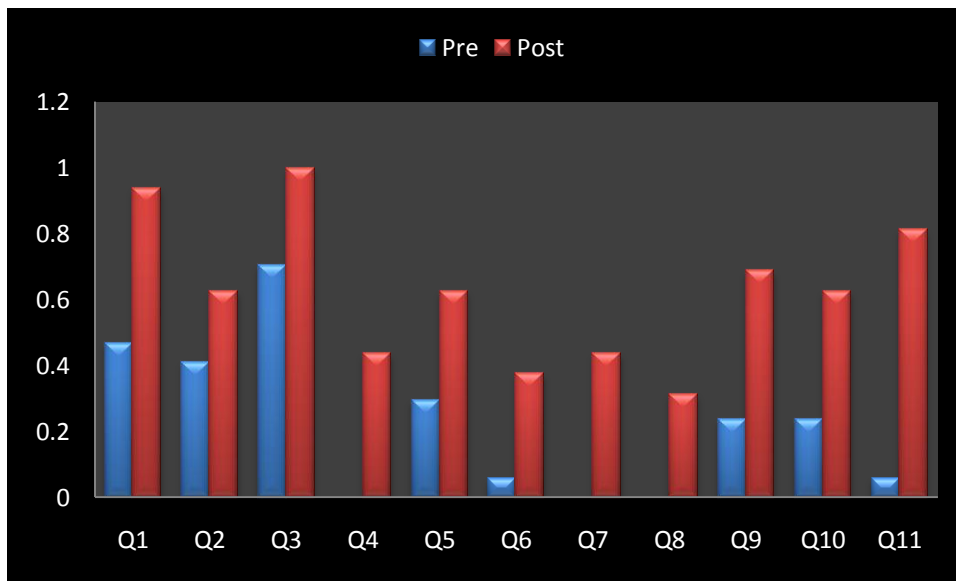


Figure 5 2009 Bioengineering Summer Camp Content-Specific Assessment Results

Questions	Keywords
Q1: What is tissue engineering?	Tissue, engineering, creating, regenerating, grown, organic matter, making, cell function

Q2: 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.
Q3: What are tissues made of?	Cells
Q4: How do cells or tissues communicate with each other?	Signals, mRNA, DNA, electric shocks, hormones, protein synthesis
Q5: What are cells internal set of instructions called?	DNA, nucleus
Q6: 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, mitosis, mutation, maturity, interactions, instructions, stem cells
Q7: What two repair processes are used by the body to heal a wound?	Scabbing, scarring, regeneration, mitosis, platelet, red blood cells
Q8: What are three approaches used by tissue engineers to fabricate (grow) a new tissue?	Scaffolding, cell, stem cell, growth factor, regeneration, imprinting
Q9: 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
Q11: What do you think eventually happens to an implanted scaffold?	Degrades, degenerates, disappears, breaks down, dissolves.

Table 1 Content Specific Questions and Responses

Camp counselor focus group discussions suggested that camp participants may have lacked some foundation knowledge in order to understand the material. Still, camp counselors indicated that the students seemed to become more interested in science as the camp progressed. Below are quotes from the discussions:

- Last year the students did seem a little more prepared.
- I think in the beginning, when we asked the kids what their interest was in science or what they wanted to pursue, a couple of them said it really wasn't a science career. But like you said, I think the kids were a little bit cooler. They put up a little bit of a wall, but as the week went on, they kind of dropped that wall. They believed in some of the things that we were doing and looked at it from a different standpoint. One of the girls said, "You know what, I never really like science, but this camp is making me think about it."
- I can't really compare the two groups, but since I was a camper last year, I can agree with what they were saying about not being as prepared. I can say that I didn't know that much. I was one of those kids who was on the fence about science classes. After this camp, I was really inspired. I did my senior project on nanotechnology.

Following the camp, participants were contacted six months later to provide feedback on the camp's impact on their view of science. Camp participants (n=4) completed the follow-up survey. Of these, all either Agreed or Strongly Agreed that they could see the value of the summer camp as it relates to STEM education. When asked if they would participate in the Bioengineering summer camp if asked again, all participants indicated that they would.

Participants in the follow-up survey also reported that they had a better understand of creativity, innovation, diversity of thinking, and entrepreneurship and could see a connection among these concepts and cell biology, bio-engineering, and scientific discovery and innovation. When asked about the greatest strength of the camp, all responses related to the hands on activities they took part in.

Discussion

With parsimony, results from the summer camp suggested that the camp was successful in encouraging students to consider careers in bioengineering. A review of data from the 2009 bioengineering summer camp¹³ informed notable differences between 2009 and 2010 camping cohorts. Campers in 2010 demonstrated higher content knowledge after taking part in the camp than did their 2009 counterparts. (See Figures 4 and 5.) These differences may be partially explained by counselor observations suggesting that 2010 campers possessed greater content knowledge prior to coming to camp. If so, then indeed, theoretically-speaking, it is reasonable to say that 2010 campers varied from their 2009 counterparts as a function of their *person* or *force* characteristics, whereby they brought more developmentally-instigative behaviors and preparation to their learning experiences. On the other hand, differences in demonstrated learning between camp cohorts may be attributed to camp designers', administrators', and counselors' *person* characteristics. In other words, this was the second year for designers, administrators, and counselors of the bioengineering summer camp; and thus it can be logically assumed that much about their approach to leading and directing the camp had significantly and positively evolved from the year before.

Bronfenbrenner would argue that efforts on the part of camp designers, administrators, and counselors to serve under-represented populations likely and positively impacted the *contexts* in which campers found themselves when they arrived at camp. In other words, the majority of students were African American; and though the camp was a multi-university collaboration, the campus on which the camp was housed was a Historically Black College University. This position is supported by students' general assessment of the overall camping experience, suggesting that campers were comfortable within their learning environments. Logically-speaking, finding oneself in a "comfortable place" supports willing engagement in the *processes* and *interactions* of camp learning activities.

Campers were not stratified according to grade level. Partial explanation for the decision to treat campers en masse was practical in nature, whereby camp designers strived to distribute resources equally among participants. Speaking more theoretically, taking an inclusive approach to camp design was intended to enhance the effects of proximal processes. By their nature "multidirectional and interactional processes" seek to capture every "teachable moment," including ones inspired through "peers" (i.e., campers), "mentors" (i.e., camp counselors), and "teachers" (i.e., camp instructors).

In focus groups, camp counselors noted that campers were initially "cool" to the camp experience, yet became increasingly more engaged with camp activities as the week progressed. These observations suggest that something was occurring within the camp experience that was positively influencing camper participation and learning. It could be argued that campers were

intentional about “taking away” as much from the camp experience as possible; or that they had particular interest in STEM-related learning; or that they were simply bright and energetic kids. Likewise, it could be said that camp designers and counselors were more experienced. After all, this was the second year of the camp. Camp designers’ desire to encourage participation among campers of minority status, whereby camper *demand* characteristics “invited” learning and development, could have been the most influential factor. In all probability, Bronfenbrenner would surmise that it was the synergistic effects of “all of the above” which most reliably explains the camp’s positive outcomes, including both camper and parental appreciation for learning and enthusiasm for the Bio-Institute, immediately following, and six months post the camp experience.

Given its complexity, some may wonder why use the PPCT model as an underpinning for assessment, and they may also argue that such complexity poses considerable threat to research design. These are legitimate comments, and perhaps the best response to these observations is to redirect our attention to the complex nature of assessment itself. Though potentially controversial, connecting programmatic assessment with student learning outcomes has obtained significant acceptance in assessment practices. (Dr. Courtney Bell, personal communication, NSF Discovery Research K12 PI Meeting, November 10, 2009, Washington, DC). In a series of white papers, the Educational Testing Service outlined some of the tough assessment problems currently facing higher institutions^{14, 15, 16}. Of importance to these discussions is the expectation that learning communities will develop and execute a *multi-dimensional* assessment plan, grounded in scholarship yet programmatically discrete, whereby student learning outcomes are identified, described, and “linked back” to programmatic objectives, mission, and vision¹⁷. Given this charge, implementing a correspondingly sensitive and nuanced model for assessment – such as Bronfenbrenner’s PPCT model – appears mandated.

Future research should include further discovery related to assessment of student learning and the Person-Process-Context-Time model. Efforts should be made to probe camp instructors and parents concerning effects of “multidirectional and interactional processes” upon camper learning. Developing an instrument to measure camp activity observations would be useful to PPCT data collection. Finally, continued comparisons among camper cohorts will provide relevant information concerning time effects.

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