Engaging Students In an Integrated Ecology, Technology, Engineering, and Mathematics Curriculum: A Florida Summer Program for Gifted Secondary Students

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Abstract: For over five years, faculty from the University of North Florida (UNF) and regional school districts have collaborated to create unique learning opportunities related to science, technology, engineering, and mathematics (STEM) topics for gifted and high-achieving secondary students. Within these summer learning experiences, through either residential or day camps, campers worked with science, technology, engineering, and mathematics faculty in university labs and settings. The design and implementation of these experiences involved post-secondary and secondary personnel and engineering, science, education, and mathematics faculty across several colleges. The purpose of this paper is to describe the critical components related to building partnerships between and within post-secondary and secondary school systems.

Introduction

This paper is a description of the critical components related to building partnerships between and within post-secondary and secondary school systems. An important part of this discussion is our design priorities of this program and how they connect to these partnerships. After having conducted this program for several years, we felt it important to step back and take stock through a multi-faceted examination of the camp: looking at it's priorities and goals, functions and operations, and lessons we learned. In our experiences, conducting the camp has been a matter of pragmatism and expediency. To this point, our activities have been focused on planning and implementing, but not reflecting. This examination will lead to more intentional curriculum design that to address our missions, goals, and objectives. This examination will lead to important implications for the future of the program.

To begin, we will discuss the rationale for conducting this program of this nature. Next, we will connect our program design to the national curriculum priorities outlined by important reform-oriented documents including *Science for All Americans,* the *National Science Education Standards,* the *Common Core State Standards,* and the *Next Generation Science Standards.* In making this connection, we will make clearer the rationale behind the goals for the program and our approach to the design of the curriculum. Next, we will share some of the key collaborative components that make meeting these design commitments possible at a university setting. These include addressing the issues of working across colleges and departments within the university, and with local and regional education agencies. Finally, we will discuss some of the lessons we have learned from our experiences and ideas for future program development. We believe this paper will be of interest to a higher education audience because it outlines necessary elements to insure successful collaborations, both within universities and those between universities and local schools, and key STEM education reform efforts.

Background

The camp team has evolved through time, but what has stayed consistent has been a relationship between post-secondary personnel at the university and those in the secondary schools in the surrounding counties. The most current iteration has been lead by one member of the Foundations and Secondary Education Department and one from the Mathematics Department. The education faculty member's area of specialty was secondary science education and was a high school science teacher for five years. The mathematics faculty member has been involved in secondary education through teachers' workshops, student enrichment programs, and mathematics curriculum work for 30 years.

The summer camp is a cooperative effort among three colleges and the public schools from the four surrounding counties. Most recently, we have worked with a consortium of school districts in the northeast Florida region. This consortium serves rural and suburban students.

Past and present staff members of the camp have included mathematicians, engineers, chemists, biologists, science/technology educators, gifted education specialists, and senior undergraduate and graduate students from multiple disciplines. They have met and planned with the gifted coordinators for the four counties and with faculty members from the School of Engineering, and the Departments of Mathematics, Chemistry, Biology, Leadership, Counseling and Instructional Technology, and Foundations and Secondary Education at UNF. These meetings and communications resulted in the construction of the major content components of this camp.

Another critical component of the summer camp staff has been undergrad and graduate students. In the recruitment of graduate and undergraduate students special attempts have been made to hire students with education majors or strong content backgrounds. The duties of these students have varied from serving as counselors, working through logistics and camper oversight, to running teaching sessions. These sessions have included modules on robotics and discussions about engineering clubs on campus.

Historically, the summer camp staff has judged students applications for the summer camp. A minimum of four of the following criteria have been used in the evaluation of applicants:

- Verification of meeting criteria for gifted student status
- Scores in science and/or mathematics on nationally norm referenced achievement tests
- Self-nomination essay
- Academic criteria of grade point average
- Letters of recommendation

Special consideration has been given to include students from *underrepresented groups* in the gifted programs in the surrounding counties. The selection effort also specifically targeted schools and teachers in underrepresented areas in these counties in order to recruit gifted and high achieving minority students. The campers we have worked with have been from rural, suburban, and urban schools.

The university campus has robust collaboration, together with expert instructors, state-of-the-art Mathematics, Chemistry, Biology, and Engineering labs. The design and coordination experience of the camp staff has provided these gifted/high achieving campers with a wide variety of challenging and fun activities in both classroom and lab settings. The unique exploration and learning experiences that have been provided by the camp would not otherwise available during the academic year in a regular or gifted classroom setting in the typical secondary classroom. Because of the highly specialized nature of the university labs and the intensive personalized attention given to each camper, the camp size has been limited to 30-40 students.

Rationale and Need

Gifted students have been traditionally underserved by the educational system. In their report, "Preparing the Next Generation of STEM Innovators," the National Science Board (NSB) of the National Science Foundation identified a pressing issue in STEM education today when it said that

> far too many of our most able students are neither discovered nor developed, particularly those who have not had adequate access to educational resources, have not been inspired to pursue STEM, or who have faced numerous other barriers to achievement. (NSB, 2010, pp. 5-6)

Even more at-risk are high-achieving students of lower socio-economic status. These students often slip academically from elementary to high school and are more likely to drop out of school than their higher income counterparts (Wyner, et al., 2007).

Gifted young students in the county school districts surrounding the university have a continuous need for a well-designed programs in science, technology, engineering and mathematics The higher education institutes in this region, including the university, have provided, independently and collaboratively, several camps for underachieving and average performing middle and high school students in the past. Many of these camps were designed without addressing the needs for gifted/high-achieving students of the region in the areas of science, technology, engineering, and mathematics. Because of the lack of such programs, a small number of these gifted young future scientists have found summer refuge and perhaps a future home in out-of-state institutions. This project is innovative in that it immerses these gifted students in situations encountered by professionals in the field and it utilizes the college-level laboratories, challenging activities, and instruction.

Florida standardized test scores provide evidence for the need for programs to aid local students in integrating math and science. While the scores have been variable, there has been an identified focus on improving student learning opportunities in the STEM areas.

Program Goals and Design Commitments

Informed by the national STEM reform efforts in education, the major program goals are to provide students with the opportunity to (1) participate in scientific hands-on experiences in the STEM areas, (2) engage in activities that help them understand the nature of science, and (3) see connections between the STEM content areas. This comprehensive and integrated approach seeks to achieve the following objectives:

- Increase students' depth of content knowledge;
- Provide students with university-level scientific research experiences and skills;
- Foster an awareness of leadership characteristics;
- Enhance problem solving skills;
- Build career awareness in mathematics, science, and engineering;
- Increase mathematics and science academic achievement;
- Foster interpersonal skills;
- Increase awareness of the relevance of mathematics, science, and engineering to everyday problems; and
- Foster the understanding and use of technology in learning mathematics, science, and engineering.

To accomplish these goals, our design commitments include:

- A multi-disciplinary approach to math, science, and engineering content
- A focus on problem solving
- The examination socio-scientific issues
- Providing opportunities for under-served populations

There are multiple commitments that influenced the design of the summer camp. First, we were committed to a multi-disciplinary approach to curricular design. There are many national calls for subject matter integration within K-12 instructional contexts (American Association for the Advancement of Science, 1990; National Research Council, 1996; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; NGSS Lead States, 2013).

Berlin and White (1994) clarified the meaning of curricular integration in their *Integrated Science and Mathematics Model*. In this model they identify six requirements that broadly define integration: ways of learning, ways of knowing, process and critical thinking skills, content knowledge, attitudes and perceptions, and teaching strategies. A key purpose of science education is to give students a means of understanding and acting on important issues by developing strong decision-making skills when they encounter real-world problems. Bring these skills and perspectives will give students a foundation to base decisions as citizens (National Research Council, 1996). The camp team members have built curricular connections to create a cohesive integration and meaningful links

between activities. A reflection period at the end of each day has helped students create mindful connections and extensions about the activities they experiences.
Second, as part of this curriculum design, we focused on moving beyond just factual information toward application of knowledge and skills toward problem solving. Students were provided challenging hands-on scientific and educational opportunities not available in their schools and originally designed for college level courses. As a result, students have had the opportunity to (1) develop problem solving skills, (2) stretch their thinking, (3) work in a team format and as individual with advanced scientific principles in realistic contexts, (4) make choices while solving open-ended problems, (5) develop independence as learners and (6) enhance leadership skills. The focus of many of the projects will be to integrate different aspects from science, technology, engineering and mathematics thus providing students with powerful cross-disciplinary perspectives.

Reform efforts have emphasized the use dialogical processes within science instruction; however, science is often understood to be a set of routinized practices that lead to single, correct answers that rarely lead to or are connected to real-world issues and concerns (Garii & Rule, 2009). Additionally, many teachers rely on the assigned textbook for curricular development and instruction, as the complexity and amount of knowledge embedded within science curricula can be overwhelming (Herbel-Eisenmann, 2007). While science offers myriad implications within real-world situations and problem and can foster introductions into the gray areas and uneasy possibilities, these are not typically found in typical secondary classrooms (Bishop, et al., 2006; Garii & Rule, 2009). Unfortunately, the literature also indicates that science teachers still follow more traditional approaches to their instruction (Aikenhead, 2006; Davis, 2003; Jenkins 1992), and we hope to counter these experiences by providing campers with real-world problem solving activities. Because we value the inclusion of socio-scientific issues the curriculum, and see its value to students, the summer camp is designed to allow students to see the usefulness of science and engineering to solve broader societal issues.

Finally, we were committed to an underserved school population — gifted and talented students. The university camp team members are experienced faculty that has worked with gifted students in the past. In addition, the gifted specialist has conducted in-service training for participating faculty on implementing *Florida's K-12 Framework for Gifted Learners* (Weber, et al, 2007).

To summarize, the summer summer camp is innovative in that it immerses students in situations encountered by professionals in the field and it utilizes the university's state-of-the-art laboratories. The focus of the camp activities has been to engage students in real-world problems by integrating different aspects from science, technology, and mathematics through inquiry-based projects and activities. These activities, designed to meet the ambitious and influential vision set by the American Association for the Advancement of Science (*Science for Americans*, 1990, and the *Benchmarks for Science Literacy*, 1993), National Council for Teachers of Mathematics (*Principles and Standards for School Mathematics*, 2000), and the National Research Council (*National Science Education Standards*, 1996), the Common Core State Standards (National Governors Association Center for Best Practices & Council of Chief
State School Officers, 2010), the Next Generation Science Standards (NGSS Lead States, 2013), and state-level documents like the Next Generation Sunshine State Standards (e.g. the Nature of Science and physical science standards). They have provided gifted secondary students with challenging, hands-on scientific and educational opportunities not always available in their schools, as they focus not only on college level scientific content, but also often-overlooked "science as process" components. These activities will provide students with powerful cross-disciplinary perspectives.

Curriculum and Teaching Strategies

The summer camp teaching strategies have been based on introducing campers to a variety of challenging, yet fun and interesting, projects that relate to their daily lives in the areas of mathematics, chemistry, biology and engineering. The modeling, discovery, and hands-on approaches were the cornerstones of all teaching strategies. In these approaches, campers conducted their own independent research as well as work together in their group projects. To enhance campers' communication skills, students presented their findings to class during and after each project as an individual or as representatives of their teams. The activities in this camp were designed to (1) promote inquiry, (2) enhance personal reflection and metacognition, and (3) increase student awareness of the role that collaboration plays in scientific activities. For example, campers were engaged in a continuous format of planning, developing and reflecting on their findings and discoveries. Also, campers reflected on their roles as future scientists and leaders in the area of mathematics, physics, and engineering during their writing, research, and reading experiences and discoveries.

Projects for the summer camp have been specifically selected to help campers make connections and see the interrelation of these disciplines and how they relate to their daily lives. Campers have also been instructed to maintain and provide a scholarly portfolio for their daily activities in the camp. Each portfolio included lab reports, findings, summary, and conclusions for every project as well as pre- and post-test assessments. The aims of the wide variety of teaching strategies and assessment types were to help students:

- Build the skills and knowledge in mathematics, science, and engineering and leadership that expand beyond the secondary curriculum;
- Enhance career awareness in mathematics, science, and engineering;
- Become an effective team player capable of working and researching independently or with minimal supervision;
- Become a successful communicator of ideas and knowledge;
- Expand their understanding of the role of a leader and the skills that leaders possess;
- Explore the relevance of their mathematics, science, and engineering experiences to their everyday lives;
- Understand and use technology in learning mathematics, science, and engineering effectively;
- Use the skills of mathematicians, science, and engineers in the field solving real world problems; and
- Enhance leadership characteristics, vocabulary, inquiry techniques, and understanding of the content.

As an example of the types of activities we used to accomplish these objectives, we will describe a recent summer camp in 2013. Water ecology (integrated biology and chemistry) was the theme, with the specific problem of assessing the health of bodies of water. The engineering modules were connected to general issue of watershed health (especially anthropogenic factors related to engineering) through personal and societal water use and waste generation. Both engineering and water ecology modules involved fieldwork and data collection. The overview of the daily schedule for a four-day, residential camp is listed below.

Group A	9:00-12:20	12:30-1:30	1:40-5:00	5:10-6:45	7:00-8:15	8:30-9:30
Monday	Water Ecology Module	Lunch	Engineering Module	Engineering Enrichment	Dinner	Movie
Tuesday	Water Ecology Module	Lunch	Engineering Module	Engineering Enrichment	Dinner	Pool
Wednesday	Water Ecology Module	Lunch	Engineering Module	Engineering Enrichment	Dinner	Movie
Thursday	Water Ecology Module	Lunch	Engineering Module	Departure		

On days one and two, campers were put into research teams and learned about methods of assessing the health of bodies of water. Teams visited lakes on campus to take water samples to analyze. In the engineering modules, they focused on water use and were assigned the task of keep track of their personal water consumption.

Campers focused on waste production and its effect on aquatic ecology, on days three and four. In the biology module, campers completed their data analysis and drew upon their engineering knowledge to create a plan meant to improve the health of campus water bodies. As part of this activity, campers worked in their research groups to create watershed remediation plans designed to improve the health of the water bodies (with data analysis to justify this plan). They presented these plans, for evaluation and peer critique during the last session of the camp. This activity was meant to give campers experience communicating their ideas in science and modifying conceptions based on new information and data shared during presentations.

During time outside the ecology and engineering modules, campers completed engineering, math, and science enrichment activities. These activities were hands-on and problem-based and centered on robotics using LEGOs. Other activities included visits to the labs used by college engineering clubs. These were of high-interest to the campers as reflected on evaluation surveys. Additionally, students used civil and environmental engineering content to develop remediation plans for the local watershed.

In summary, the approach made our objectives achievable because of the strength of the university built on:

- The university's successful history with outreach educational programs and summer camps which extends over 40 years of collaboration with local public schools;

- The extensive experience of the university team in conducting the research with and monitoring/coaching of gifted students in a team/camp format and as well as working with students individuals;

- The university's previously designed mechanisms to integrate students' and faculty members' daily reflections and feedback into our assessment procedures; and

- The university's modern and state-of-the-art laboratories and technologies that provide a hands-on scientific environment for these future scientists to go beyond the traditional gifted school setting and activities.

Key components the camp structure and resources have included a depth and the breadth of faculty members experience with, authentic interest in, and commitment to public school students who are underrepresented, economically disadvantaged, and gifted. Additionally, the physical facilities and equipment, in particular the labs and technologically enhanced classrooms, have provided a rich and accommodating environment to challenge and motivate students in their discoveries, particularly in the engineering, chemistry, biology, mathematics and simulation projects. Finally, the outstanding commitment and willingness of the university faculty and staff, particularly the engineering faculty to provide in kind donation of their time and services in order to alleviate costs associated with the camp has been important in meeting the goals of the camp.

Curriculum and Teaching Design Lessons Learned

Through the time we have conducted the summer camp, some key design elements have emerged to help our program be (and remain) successful. The first has been gathering input from campers and staff. This goes beyond just the typical after-event evaluations. We used input as formative assessment to make adjustments during the camp session. The second element relates to resources and our commitment to keep costs to campers low. We have been fortunate to find outside funding and have camp staff willing to provide their expertise and facilities at discounted rates. The third element was a developing a sense of team among the camp staff. There was a shared mission and responsibility to camp operations and curriculum. The final component was the intrinsic appeal of campus life. Allowing campers to experience living in a dorm, eating in the dining hall, and working with undergrads and university faculty in impressive facilities had a lot of appeal to the campers.

The first important design element has centered-on gathering input from participants and team members. We asked for daily student input using multiple communication modes and instruments. A key instrument in this data gathering has been the Plus-Minus-Interesting (PMI) chart. The chart allowed students to share things they liked about the camp, things they didn't, and what they found interesting. We've been able to use this chart as a formative assessment tool to make adjustments to camp activities and operations. We also met with the teachers daily to gather information. Faculty met daily to discuss curriculum implementation and adjustments during the camp.

As an example of input gathering and adjustments made after the camp, faculty met with key district personnel to share evaluation findings. As part of this reflection and discussion, the team identified a student desire for an applied biomedical component. As a result of this discussion, this component was added to the newest iteration of the camp. Campers had the option of completing applied biomedical modules that included DNA analysis and large mammal dissection. Similar to the water ecology modules, at the end of the camp session, research teams presented their findings to their peers for discussion and critique.

Another key aspect relates to resources. With our commitment to working with under-served populations, keeping student costs down has been a priority. We have consistently sought internal and external grants to cover expenses.

We have also worked with departments and faculty team members who are willing to donate rooms and equipment at little or no cost. Faculty team members have also under-valued their contributions to the program to keep budgets low.

A third critical part of the program is a notion of teamwork. As faculty developed the curriculum, there is a sense of shared responsibility. Planning and development of content coverage and activities has been a common endeavor. As all team members brought different expertise, they have had input in materials.

One surprising finding was the appeal of campus life to students. We often take our work setting for granted and since the excitement of being an undergrad is a distant memory, teachers and faculty may overlook this appeal. Living a university life, for example using the recreation facilities, having access to cutting edge facilities and faculty, and meeting science, engineering and mathematics undergrads were popular aspects of our residential camp. We believe these experiences opened students eyes to what college was like.

Conclusion: Steps in the Future

There are several ideas the team has focused on to further develop the approach to future camps. These include

- Continuing the seeking government funding to maintain access for student of low socio-economic status,
- To better understand the effectiveness of the camp, conducting more systematic data collection to better assess student understanding of both content and process understanding of science and mathematics,
- Further developing a focus on “soft skills,” like collaboration, within the curriculum,
- Providing greater time for students to work together in college-level, non-academic activities to help with their socialization.

While we feel it is a strength that we have been able to keep costs low (the last several camps were at no cost to campers), we believe that it is important to charge a nominal fee. We feel that may have the effect of giving greater buy-in and commitment on the students’ and guardians’ part as they might have more “skin in the game” if they have to contribute some financial resources to the program.

As a second step, we believe we need to conduct more systematic data collection. Most states focus on standards and standardized assessment, we need to collect longer-term data about how our program affects student performance. Working with school districts, we plan to gather student achievement data, course selection, and college attendance as indicators of our impact.

As another component students need more instruction and practice working in teams. This is a more accurate representation of how scientists often work. While we had students in teams, we did little to build team skills (the “soft skills” employers often look for in high school graduates). As part of these skills, students have a difficult time actively judging work from others. Proposed activities might include instruction on how to discuss data, critique data models and explanations, and create effective presentations to share with other working groups.

Our final modification relates to the overall student experience in our camps. We often forgot that we were working with high school students (though they met and exceeded our expectations for work ethic and quality). While academics are important, students wanted more time to step away from their work and explore the campus. In the future, we hope to provide students more experience with these aspects. In the future, we plan to add more time devoted to campus tours and using recreation facilities.

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