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Bowman Creek Academy: An Immersive STEM Experience (Work in Progress)

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Comments from Reviewers

- **A reviewer commented on the rewrite -done**
- Thank you for making changes to the manuscript to address comments, the study is much easier to understand and is logical for inclusion as a work in progress. I feel the paper would still benefit from inclusion of the survey results you make reference to in the outcomes section. Even if this data is preliminary, it gives context to the reader on the success of the program. I look forward to hearing more about this program in the conference setting.
- **A reviewer commented on the rewrite -done**
- Framed as a work in progress, the limited evidence is acceptable. The future development of the academy will be of interest, though division members would be interested in survey response data, examples of participant work, and reflective commentary on the success and challenges of the camp.
- **A reviewer commented on the rewrite -done**
- Please check the Author's guide for correct formatting. Recommend survey data be presented in a table in the Outcomes Section.

Bowman Creek Academy: An immersive STEM experience (*work in progress)*

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Abstract

Bowman Creek Educational Ecosystem (BCe2) is a partnership that pilots community-engaged, sustainable projects to address real world challenges in the Southeast neighborhood of City Y, a mid-size city in the Midwest. In an effort to create a more immersive and engaging experience for high school students, BCe2 developed Bowman Creek Academy (BCA). BCA is a week-long academic program that engages high school students with STEM (science, technology, engineering, math) education through scientific exploration and community resources. Serving as a catalyst to promote scientific innovation, BCA equips students with the necessary resources and guidance that are currently lacking at the K-12 grade level. During developmentally impressionable years, community resources and affordable platforms provide an environment where youth can explore STEM interest without limitations to time, formatting, or financial restraint. The basis for being a STEM education catalyst is to provide an accessible, affordable, and rigorous curriculum for students to learn how science and technology can directly impact their communities through resources around them. Each day of the program is developed around a facet of environmental science and engineering with guidance from industry professionals, local university professors, and community leaders. Immersive experiences have proven invaluable for inspiring high school students to reconsider STEM fields as a viable path for higher education or skills training. The BCA pilot year consisted of 10 students from 6 regional and national high schools. In 2018, BCA will seek to expand across City Y and explore the idea of creating cohorts throughout the city for other STEM focuses. Whereas the pilot year focused on environmental science and engineering, further cohorts may focus on healthcare and community health enhancement.

Background

Bowman Creek Educational Ecosystem (BCe2) pilots community-engaged, sustainable projects to address real world challenges in the Southeast neighborhood of a mid-size city in the Midwest. BCe2 partners local interns, city government, community organizations, and members of the Southeast neighborhood to create practical and sustainable environmental solutions to problems facing the city. A sandbox of innovation, BCe2 turns creative and analytical thought into action through its many community-driven and intern-led projects, such as Integrated Stormwater Management, Urban Sustainability, and Ecosystem Revitalization.

As a community-driven partnership, BCe2 seeks to expand its work to more groups in the community, particularly youth. Thus, Bowman Creek Academy (BCA) was developed—a week-long academic program in the summer for intermediate and high school students centered on topics in environmental sustainability. BCA revolved around two main ideas: anyone can contribute to creating a sustainable environment and youth have an empowering voice to create an impact on their community.

Non-formal learning environments, even through short bursts such as a week-long engagement, allow students the opportunity to experience real-world problems and develop viable solutions in a more relaxed environment. While many benefits can be drawn from textbook learning, BCA hopes to further assess how this environment improves a student's experience and overall attraction to STEM fields.

To this end, the program was able to design hands-on activities to engage youth in STEM topics to develop passion and vigor for ecological sustainability. The topics and activities centered around sustainability mimicked those researched and deployed by the larger BCe2 community. While this gave the students real-world examples to learn about, it also provided insight to the interworking of BCe2, furthering the organization's mission of widespread community engagement. The novelty of local connections is imperative to the BCe2 organization as a whole and especially BCA. BCe2's vast list of local connections used by BCA allowed the students to become more knowledgeable to the opportunities their city provides. Moreover, these local connections have their own research and methodologies that can be extremely beneficial to furthering the student's education in respective STEM fields. By intertwining STEM themes with interactive community experiences, BCA is better able to engage high risk students and equip them with the knowledge on how science and technology can directly impact their communities utilizing resources around them.

Program Development

To create BCA, extensive organization and planning were required throughout the 2016/2017 school year. Selecting the target demographic was the first step. It has been statistically shown that the level of STEM confidence and interest from the end of intermediate school to the end of high school decreases drastically [1]. BCA recognized the deficiency in STEM education through past years of community engagement and selected high school students as the target demographic for the program.

In order to focus the educational research and feedback channels of the Academy, the following research questions were developed:
1) Is a non-formal learning environment beneficial to engaging students' interests in STEM fields?
2) What are the primary mechanisms of engaged learning?
3) How can intermediate and early high school students best be engaged in place-based learning?

The overarching objective was equipping BCA students with the knowledge and empowerment to make a difference in their neighborhoods. BCA decided to focus on two pillars: environmental sustainability and youth empowerment. By drawing on the research questions, an hourly breakdown of the technical aspects of the program was created. This breakdown set the community-based activities regarding environmental sustainability BCA would perform and set feedback mechanisms to critically evaluate the learning outcomes and goals of the week's activities.

Day 1: Welcome, Biotechnology	**Day 2:** Urban Sustainability	**Day 3:** Internet of Things	**Day 4:** Green Infrastructure	**Day 5:** Outdoor laboratory, BCA Closing ceremony
Morning: Welcome, team building activities Afternoon: DNA extraction, chemical reactions and testing methods	Morning: Education and introduction to native tree nurseries Afternoon: Visit BCe2's constructed native tree nurseries	Morning: Arduino presentation, Arduino workshop Afternoon: Presentation and demonstrations by local engineering firm	Morning: Education on the benefits of rain gardens, construction of rain garden Afternoon: Continue and finish the installation of the rain garden	Morning: Experiments led by nearby highly selective university environmental monitoring research site Afternoon: BCA closing remarks and reflection

When choosing activities that would most enrich a student's experience, BCA chose to imitate projects that were completed by paid interns as part of the BCe2 internship and involved current BCe2 interns to lead the effort. This was beneficial, as BCA could rely on two years of research and projects completed by BCe2 for methodology, topics, and activities. This logic provided a deeper insight into BCe2 for the BCA students, as well as created a non-formal peer-led learning environment. Peer-led scenarios allowed for deeper connection, liveliness, and attentiveness throughout the week (Preszler et al. 2009)[2]. The cost of the program was free for students with free or reduced lunch or $25 otherwise, for the whole week.

The initial pilot of the program comprised of 10 intermediate and high school students, and 6 BCe2 interns. The participating students came from area intermediate and high schools, as well as a few students from regional intermediate and high schools. The participants were chosen on a first-come, first-serve basis and mostly from low socioeconomic area intermediate and high schools.

The BCe2 interns from the " Ecosystem Revitalization team" were chosen to lead the Academy as part of their participation in the BCe2 internship program. Intern backgrounds ranged from technical STEM fields to education. Interns received leadership, diversity, and project management training at the start of the internship.

Program Execution

Day 1: Biotechnology

The first day of BCA, Monday, provided a lively start to the week. The main focus of the day was team building and biotechnology. Couples with group bonding activities, the peer-led atmosphere allowed the students to connect to the BCe2 interns and provided quicker student engagement in the program. With the day's focus area of biotechnology, BCe2 interns guided students through DNA extraction methodologies and used hands-on experiments to demonstrate the lesson. Students combined common household cleaning products in order to extract DNA from a strawberry and analyzed the extracted DNA. The second experiment of the day showcasing biotechnology was to create a simplified "elephant toothpaste" with dish soap, active yeast, and hydrogen peroxide, creating a chemical reaction. Moreover, BCA educated students on pH balance by changing the blue pea flower tea into a pink color by mixing in acidic lemonade. These experiments gave students insight into the intricacies of DNA and how it can be used to further scientific innovation, opening up the previously unexposed world of biotechnology as a viable field of study. Thus, the first day created a precedent of a positive and academic environment for the rest of the week.

Day 2: Urban Sustainability

On the second day, BCe2's Urban Sustainability team led the students to explore one of BCe2's fundamental projects: native tree nurseries. BCe2's home city has looked to BCe2 to increase the city's urban tree canopy coverage. As a response, BCe2 has planted 3 tree nurseries, utilizing vacant lots to develop the trees over a five year period, before being extracted and replanted within city limits. By growing the trees locally and nurturing them from 2" tree whips, this will save the city over $16 million over a 20 year period. BCe2, in collaboration with the city's parks department, then transports these trees to various locations throughout the community. BCA's goals for this activity was to educate the students on the necessity of trees, learn how native tree nurseries operate, and discover essential best practices for tree conservation. Instilling sustainability ethics in the minds of high school students can plant the seed for increased leadership and advocacy for the environment.

Day 3: Internet of Things

The third day demonstrated how students can incorporate the digital world into the environment to develop effective sustainability. Students were able to learn about Arduino technology with a hands-on experience led by BCe2's Arduino Technology team. Arduinos, programmable microcomputers used to monitor, alert, and trigger reactions in a system, have been used by the Arduino Technology team for various sustainability projects. For example, BCe2 interns have researched installing Arduino technology with ultrasonic meters and pressure sensor tape in

order to measure the volume of water entering a system; this could help argue the effectiveness of green infrastructure in an urban city. BCe2 interns apart of the Arduino team led a demonstration for the students to computer program different functions on Arduino technology, with goals to provide insight into the growing STEM field of computer programming. As part of the Arduino day, students then visited a local engineering firm, which uses Arduino technology to create efficient, eco-friendly, and smart infrastructure to reduce combined sewer overflow (CSO). This firm provided a tour through its laboratory so students could view the projects and designs that the firm is constructing, as well as a presentation on the overview and mission of the engineering firm. This experience allowed students of BCA to become more immersed in what the city has to offer, become more knowledgeable about the plight of their city's sewers, and learn ways to reduce water usage, in turn reducing CSO into the water supply. One student said, "It was amazing to learn about computer science because now I have discovered another part of science that fascinates me and I think I will begin to learn more about what computer science has to offer and try to expand my knowledge on the topic." This comment represents the success of the day's activities in exposing students to a new and sometimes inaccessible STEM field of study

Day 4: Green Infrastructure

The fourth day provided an opportunity to put newfound knowledge into practice by having the students install a rain garden at a local community college and partner of BCe2. As a part of BCA, students were taught about the importance of rain gardens as well as the benefits, guided by the Urban Sustainability team comprised of BCe2 interns. Residential rain gardens use runoff from downspouts to redirect the water from entering the sewer system, and directly into the groundwater aquifers. The installation of a rain garden was one of many positive aspects of BCA in the students' and parents' minds, as it provided each student the ability to contribute to tangible evidence of what they have learned and turn learning into action. Students were also able to come away with the notion that plants can be solutions through a combination of nature and engineering to increase efficiency.

Day 5: Outdoor laboratory and BCA Graduation

BCA's last day gave the students a chance to learn from and network with a nearby highly selective university environmental monitoring research site. The site allows researchers the control of a laboratory but the real-world experimental value of the natural environment, using controlled watersheds that mimic nature in order to conduct research into a variety of environmental engineering topics. This is just one prime example of having the benefit of local connections when conducting BCA, as it provides further research and understanding into environmental studies being conducted in the student's hometown. This in turn, while also garnering further interest in STEM, leads to a greater city appreciation. BCA visited the site of the research site to learn how it works and provides a test bed for education, performing multiple

experiments using the site's simulated watershed. One of the experiments was to measure the flow of pink dye in the controlled rivers to obtain the velocity of the water in the river. They also modeled moving organic material through the river to measure the retention of organic material in certain areas and obtain the instantaneous retention rate at various points along the river. This experience provided another opportunity for hands-on learning for the students and for experimenting with unique aspects of STEM education. The final day provided interesting insight into the work that environmental engineer researchers do on a day-to-day basis in hopes of garnering interest into the field of environmental engineering.

Outcomes

BCA has demonstrated a unique approach to the fields of science and technology by giving BCe2 interns the opportunity to lead high school students through exciting, educational paths that they procured through an open and casual setting. This gave students more in control in their own learning experience, guiding them deeper into the intricacies of scientific exploration. In order to create the most valuable program possible, BCA has orchestrated several different methods on how to best analyze BCA's final impacts on the students. BCe2 interns were not only tracking the student's excitement and internal validation but steadily measuring any and all quantitative data of how the students academically developed and performed within the BCA program. BCe2 interns found their approach to be successful by measuring students' incentive by incorporating discussion and worksheets that track the student's individual progress and interests throughout the week.

As the days went by, BCA began to see an increase in the length and diversity of their survey responses and overall excitement for their upcoming days, a sign of a more engaged group as the week progressed. This progressive engagement was exemplified in deep discussions by the students and more involved experiments being conducted. Although some of the students had an idea of what they wanted to do in the future, many were still unsure about their options and what careers could best utilize their strengths. To spark interests in possible STEM fields, each day was spent focused on a different facet of science intertwined with feasible ways to get started in the scientific community as students. *This brought several challenges as well as successes to BCA. It was difficult to instruct the students on specific STEM fields, like computer science or biotechnology, that BCA students had little to no knowledge, in short period of time. While the plethora of research gathered by BCe2 proved beneficial in this area, having to explain years of research quickly was difficult. However, this allowed BCA to pinpoint the most important aspects of BCe2's research to highlight to the students to give them a better scope of the STEM fields. This information gap, though difficult to navigate, was successfully conquered by explaining key analysis and findings that would gauge the most interest in that specific STEM field.*

One of BCA's most successful days were when students explored the "Internet of Things" and discovered the uses of Arduino programming accompanied by a trip to a local engineering firm. Students enjoyed being able to have an activity that they could build themselves. By the end of the day, nearly all of the students requested more information on Arduino kits and asked if they would be able to get one to take home and experiment independently. Even the most uninterested of the students used all of their survey time to recount what they could create if they had their own set of Arduino components.

Replication

In order to replicate these results, it is imperative for BCA to provide a relaxed environment, engaging experiments, and guided expeditions to unique scientific projects. While most STEM programs have more rigid structures for the students to follow without room for questioning, BCA has the rare advantage of students teaching students. One technique interns used was allocating additional time after an experiment to conducting the experiment again and clear up a misunderstanding about the experiment. For example, if the student was curious as to why elephant toothpaste needs a certain amount of hydrogen peroxide to grow larger, interns can replicate the experiment and ask them what outcome they expect and why, then explain about electron transfer and chemical equilibrium. This approach not only strengthens the student's knowledge of the experiment but also gives them the personal motivation to question what they see and approach situations with a scientific perspective and uninhibited curiosity.

BCA also strives to shows students that scientific careers and research are feasible and beneficial to all, shown through activities regarding research projects conducted by their peers. Being a part of BCe2, BCA had the unique opportunity to view different projects conducted by BCe2, allowing the students to be fully immersed in student-led research projects and see the day-to-day lives of STEM professionals. This in itself can be a deciding factor in career direction and higher education choices [3]. When students are surrounded by those who have an appreciation and value for STEM fields, students are more likely to choose a STEM-related career and feel more connection to how they can contribute. Being student-led, BCA gave high school students the ability to find role models in the interns, looking to them for inspiration in personal life as well as career choice[4]. Being around STEM majors and professionals who highly value STEM fields at BCA, students will better be able to examine their options and discerning STEM fields for educational and career opportunities.

Conclusion and Future Direction

2017 was the first year the Academy was offered. A unique advantage of BCA's structure and strong suit was the low student to intern ratio. This provided a personalized learning experience and added to the students' academic freedom.

As BCe2 moves into its fourth year, Bowman Creek Academy aims to increase its presence in the BCe2 organization. In the future, BCA hopes to expand its partnerships in the city, allowing students to be able to visit and learn from even more groups and organizations throughout the city. A further goal is to modify BCA to the current projects of BCe2. While BCA was modeled after the projects of BCe2's 2016 summer internship, many more programs and ideas were researched in the 2017 summer internship. BCA hopes to develop new and exciting activities imitating the new projects BCe2 has taken part in to provide more insight to students.

Further, the following supplemental research questions will be developed and implemented.

1. How does BCA change attachment to place and perception of opportunity for participants in their community?
2. How does BCA change perception of opportunity to students in late intermediate school to early high school (age 11-15) in STEM fields and career pathways? Does this increase their attachment and excitement about STEM fields?
3. How can BCA create a scaffolding effect in which participants apply for the BCe2 internship and choose STEM fields in subsequent years?

Another hope for BCA would be to increase the amount of partnerships it harbors and decrease barriers to participation. One partnership could be with more intermediate and high schools throughout the city, in order to attract an even more diverse and talented group of students. That being said, BCA hopes to continue to work with intermediate and high school students to maintain the level of comprehension on BCA curriculum and tangible ways to directly influence their surrounding community. To attract more students, more outreach and advertising throughout the city can be conducted, as advertising was centered more on the southeast side of the city. Another mechanism for increase participation would be to provide transportation.

By having increased youth involvement, we are able to creates a more inclusive, accepting, and dynamic community. BCA hopes to continue to spur youth empowerment through peer-led environments to contribute greatly to their community in their youth and their careers, invariably leading to a more engaged community.

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