When Traditional Research is Delayed: Bridging the Gap between K-12 and the University through LAZARUS

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Abstract

LAZARUS is the Lab for the Analysis of Zombie Activity and Research into Undead Simulations. LAZARUS began in 2014 through a Texas Tech University (TTU) and Lubbock Independent School District (LISD) partnership, aimed at engaging K-12 students with rigorous research in a unique way. This partnership was the initial driving force in the conceptualization and creation of a super-computer known as the Schoenberg Cluster. With hopes of immediately being assembled and used as a high-power super-computer, the Schoenberg Cluster took time to build because of delays in design, coding, and building. During this delay, LAZARUS became a community engagement and outreach tool used within K-12 districts across the state. LAZARUS has been used to engage underrepresented and underserved students in STEM, with emphasis on Hispanics, rural students, females. LAZARUS provided a unique opportunity through technology allowing exposure and access to ideas and resources that are usually inaccessible for these students and districts, because of cost, distance, and expertise of teachers. Using the LAZARUS project as a guide, additional best practices will be given to replicate and utilize similar approaches for future traditional research to be expanded to engage the community.

Introduction

Supercomputing is an ever-advancing multidisciplinary field that looks to solve massively complex problems. The backbone of supercomputing is a supercomputer-a series of processing units placed in parallel that can act, calculate, and model independently. Super-computers are used by researchers that need to analyze big data sets or create complex models and simulations. LAZARUS is the Lab for the Analysis of Zombie Activity and Research into Undead Simulations. This lab was founded initially at Texas Tech University (TTU) in 2014 and came about due to a TTU and Lubbock Independent School District LISD partnership from a National Science Foundation (NSF) STEM Fellows in K-12 Education Program (GK-12) grant. The partnership formed from the GK-12 grant led to LAZARUS's initial conceptualization with the idea of matching a popular culture concept (zombies) with advanced mathematical modeling and simulations. The ending result was a research-focused and created LAZARUS Schoenberg Cluster super-computer that could model high-level mathematical concepts such as random walks and circle packing. Results from this type of "zombie research" could be used in various avenues including, epidemiology and public health. In addition to the Schoenberg Cluster, LAZARUS also contains a 3D printer, coding materials, and several sets of textbooks, which help undergraduate student researchers learn to code. The LAZARUS research team has steadily amped up research efforts in modeling and simulations and has recently reached the apex of what the Schoenberg Cluster super-computer can accomplish. As a direct result, the use of LAZARUS and the Schoenberg Cluster as an outreach tool has dwindled.

From the beginning of this research endeavor, once delays in using the Schoenberg Cluster to conduct university-level research were realized, LAZARUS was leveraged as an engagement resource collaboration point for TTU and LISD. This initial effort expanded to include outreach and engagement of other regional K-12 schools. In this broader application, one of the points of emphasis for outreach and engagement for LAZARUS was to help explain high-level mathematical concepts to K-12 students through the pop-culture reference of zombies. The other point of emphasis for outreach and engagement was to appeal to the students by differentiating the physical design of the Schoenberg Cluster from other box-mainframe super-computers. The idea was to make the Schoenberg Cluster aesthetically pleasing and evoke intrigue and interaction from K-12 students. This article will examine the development of LAZARUS as an outreach and engagement tool from its conceptualization through the NSF GK-12 grant, its physical creation by the STEM Center for Outreach, Research & Education (STEM CORE), initial funding from other NSF and industry grants, and its effort to connect complex mathematical, computer science, and coding concepts to K-12 students and schools, all while benefitting the research of undergraduate and graduate students. Finally, this article will establish best practices and innovative applications, making computer science, and coding more accessible within K-12 environments.

Background

Science, technology, engineering, and mathematics (STEM) education continues to be a national concern for K-12. As of 2015, a Pew Research Center report (Pew, 2015), which polled several people connected with the Association for the Advancement of Science (AAAS), reached the following conclusion: "[while] science holds an esteemed place among citizens and professionals, both the public and scientists are critical of the quality of STEM subjects in grades K-12" (p. 5). In a national study using a decade's worth of data, Chen (2009) found that STEM majors tend to be male, Asian, or from more advantaged family backgrounds—the opposite of what one would expect in a nation where underrepresented minorities (URM) will soon combine to be the majority. Among URMs, Hispanics are the key focus of where improvements are needed in STEM career preparation and readiness (NSF, 2017; USCB, 2011). When considering Hispanics, one of the exacerbating issues comes from the areas these students may come from. Hispanic population growth is a factor that has slowed the population decline in rural areas (USDA, 2005). According to Census Bureau Director John H. Thompson, "Rural areas cover 97 percent of the nation's land area but contain 19.3 percent of the population (about 60 million people)" (USCB, 2016). The challenge in the K-12 system for STEM education is how to reach students. Students from both URM groups and rural areas, like rural Hispanics or females, have had to contend with compounding disadvantages. Often, teachers from rural schools are teaching a variety of ages and subjects to meet the needs of their schools. Understanding how to reach this group and other similar groups to promote and sustain diversifying STEM learning efforts is a critical question for educators and researchers.

Engaged scholarship has been an effective tool for solving this STEM interest dilemma. According to the 2010 Lemelson-MIT Invention Index, an annual survey that analyzes perceptions on invention and innovation, 66% of students point to activities such as field trips to places where they can learn about STEM as one of the best ways to get them interested in STEM (MIT, 2010). LAZARUS offered a unique approach as engagement, field trips, and hands-on learning activities for K-12 students were developed *long before* the research centered components were functional.

LAZARUS increased STEM interest and interactions in rural areas and amongst URMs. TTU is in Lubbock, which is in the Llano Estacado of the United States. This region encompasses the northern part of Texas and the eastern part of New Mexico. The Llano Estacado is primarily a rural region with numerous rural communities and has a population of approximately 1.3 million. Lubbock is the largest city within the Llano Estacado and is centrally located in a 37,000 square mile region. Lubbock is known as the "Hub City," as it is the primary economic and health care source of the region. As such, TTU is the educational center of this region, particularly in STEM. The demographics of the Llano Estacado have continually shown increases in the Hispanic population. Towns and cities located in the Llano Estacado have anywhere from 28%-50% Hispanic populations. Based on this growth and enrollment, TTU has recently been classified as a Hispanic Serving Institution (HSI). Based on this regional structure, TTU is uniquely positioned to promote STEM engagement within a rural and Hispanic context.

Building Relationships

LAZARUS's genesis emerged from a long-term relationship between LISD and TTU through an NSF GK-12 grant. The NSF GK-12 grant was designed to present graduate-level STEM research in a K-12 teacher-friendly format. This encouraged hard science and engineering topic discussions and discovery for K-12 curriculum and professional development for teachers. Content-focused graduate students also gained professional development through communication and partnership while exploring and explaining complex research topics with non-researcher teacher educators. The initial interaction and collaboration between a TTU graduate fellow on the GK-12 grant and LISD teachers propelled the formulation of the LAZARUS Lab. Notably, this partnership defined essential needs for LISD teachers and students for STEM engagement. These needs included: advanced mathematical modeling, big data analysis, visualization and simulation, and hands-on exploration. Collaboration between TTU and LISD led to LAZARUS's conceptualization to meet these needs and afforded scholarly engagement opportunities as LAZARUS was delayed in reaching its full research maturity. The LISD and TTU partnership anchored the connection from LAZARUS to the community and allowed for expansion to multiple ISDs and the broader community.

The establishment of LAZARUS was then two-fold: providing a service to the LISD K-12 community (outreach and engagement) and providing a service to TTU students, graduate students, and faculty (research). Forming LAZARUS helped fulfill both aims and was mutually beneficial for both TTU and LISD. In meeting the needs of LISD, TTU was able to expand its outreach efforts with other K-12 regional schools and other informal STEM groups, providing an opportunity to view the building and design process. Most minors are not allowed in any type of traditional lab because of safety requirements, so finding appropriate STEM activities on campus were usually relegated to a visit of a computer lab in the summer or an undergraduate class during the academic year. These limited access options made bringing K-12 students to campus to learn about and engage with STEM ideas challenging. Further exploration of these STEM concepts through an online platform that could be accessed directly from K-12 schools and classrooms helped address the needs of the district's teaching and learning mathematical models, simulations, and big data. With the continued partnership LISD and additional K-12 schools, the growth of LAZARUS was leveraged as a STEM outreach and engagement tool. This extra work furthered the connection of LAZARUS with the community by developing an interactive social media strategy and online simulation platform.

Figure 1. K-12 Students on a field trip learning about LAZARUS

Social Media

The social media strategy employed during the building and development of LAZARUS detailed the conceptualization, the final build, and use of the Schoenberg Cluster. The aim behind LAZARUS was to design an interactive and fun Schoenberg Cluster. The whole LAZARUS Lab and the Schoenberg Cluster was made visually attractive and unique, which is unusual for a traditional super-computer. With this intent, social media accounts on Twitter, Flicker, If This Then That, and Facebook were created before the super-computer was even wired or programmed. These social media platforms gave the community, including K-12 students and teachers, the opportunity to interact with the project team and see how the Schoenberg cluster was being conceptualized, designed, and built.

These social media interactions were compounded with LISD K-12 field trips that showed off the Schoenberg Cluster before it was fully functional (See Figure 1). Not only did the added visually pleasing components capture interest of students and teachers alike, but it also allowed those who were interested in LAZARUS to continue to engage with the lab after leaving TTU campus.

For example, students were able to tweet LAZARUS, and cause the lights in the room to flash; or know that every time TTU football team scored a touchdown, the lights in LAZARUS would change and flash red and black (See Figure 2). Students could follow undergraduate and graduate student researchers posting blogs, videos, tweets, and progress updates on LAZARUS as development continued. LAZARUS even live-tweeted conferences that researchers attended that had direct impacts on the Schoenberg Cluster. Because of the large amount of exposure LAZARUS had before even becoming a functional super-computer lab, it began gaining popularity across Llano Estacado and across the nation through social media outlets and posts. LAZARUS's visual interest and the Schoenberg Cluster gained momentum

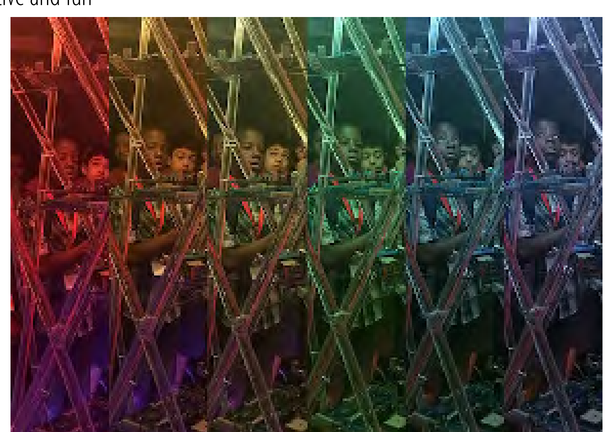

Figure 2. Example of LED light effects on Schoenberg Cluster

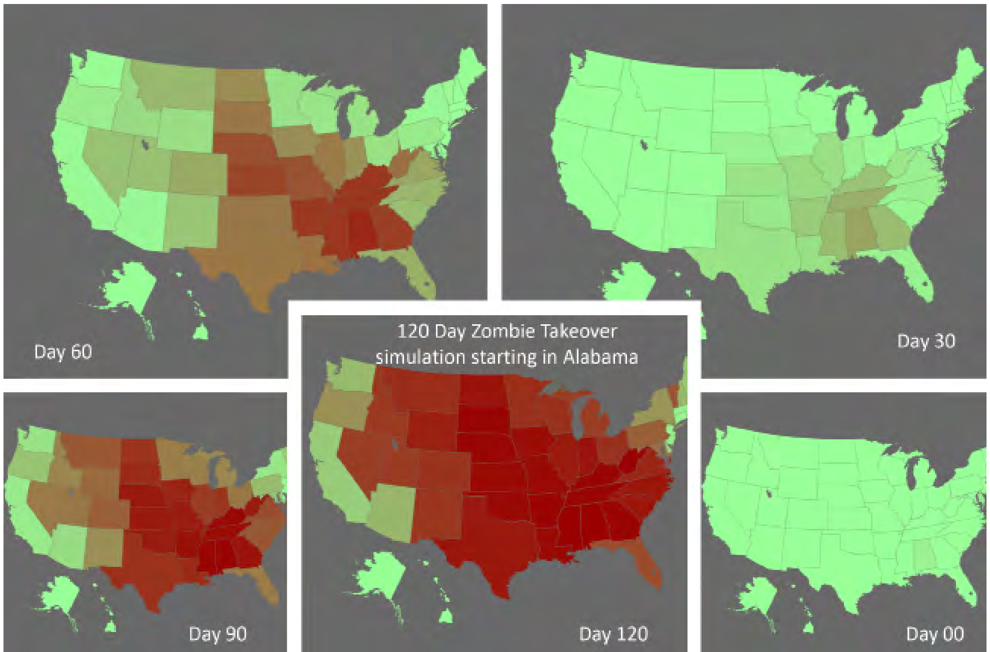

Figure 3. Screenshots from an online simulation showing a zombie outbreak starting in Alabama.

through advertising campaigns picked up across the university's realm of influence.

Online Simulations

After the Schoenberg Cluster became fully functional, the aim of keeping students engaged was not only attained through social media, but through students' ability to run their own simulations on the computer through a separate online platform, which was designed and redesigned by undergraduate students on the project (See Figure 3). This digital platform and simulations allowed students and teachers from across the globe to access LAZARUS. The simulations allowed the user to adjust factors such as city population and square footage, number of zombies present, the percentage chance of infection, and many other factors. Enabling the users to run their own simulations over and over again in quick succession, while changing various factors, allowed the students to see how one small change could drastically affect the likelihood of zombie wiping out the city. While this portion of the simulation took a long time to code and get working correctly with LAZARUS, students loved to "play" and run simulations once it was completed.

Team Construction

Social media and online simulations helped strengthen the relationships with TTU, LISD, and the wider community. In the conceptualization and building of LAZARUS, university-level relationships also had to be developed. The opportunity to create LAZARUS could not have happened without various multidisciplinary partnerships. Often in Higher Education, silos between disciplines exist that prohibit departments and colleges from interacting. LAZARUS was an exception to this siloed approach. Support for LAZARUS was seen through eight different departments across the TTU College of Arts and Science and Whitacre College of Engineering. This multidisciplinary approach was a necessity based on the magnitude and complexity of LAZARUS in research and outreach. Content knowledge for the creation of LAZARUS was needed in mathematics, engineering, marketing, administration, coding, and website design, along with varying skill levels from faculty and staff to graduate students to undergraduate students.

Along with this diverse knowledge base, funding for LAZARUS was needed across departments. Various departments supported the hiring of undergraduate students to design the Schoenberg Cluster case, donated physical space for LAZARUS, and provided administrative support to purchase supplies and components. As with content knowledge coming from different sources, so did financial support. Different institutional entities, such as STEM CORE, CALUE, and the University Career Center, made it possible to fund LAZARUS along with three various NSF grants, the support of LISD, and an NVIDIA education grant.

Innovations in Delayed Traditional Research

Building a super-computer like the Schoenberg Cluster within a lab like LAZARUS is a daunting task and something a single department research team would not tackle on their own. Meeting the LAZARUS project's research and engagement objectives were at the forefront of the initial construction of the super-computer. Further, in understanding this delay for academic contributions, the project team took a proactive step in constructing LAZARUS to make it an engagement STEM tool, which could also be beneficial for LISD. Along the way, this targeted engagement led to outreach with many K-12 schools and districts, field trips, and social media interactions.

Engaged Design, Construction, and Implementation

The driving force in this project was the special design of LAZARUS and its pop-culture function. The Schoenberg Cluster was designed unlike any other super-computer i. It had its computing nodes placed within a hyperboloid structure, which is atypical of the mainframe, box structure of most super-computers. Along with its visually unexpected structure, other features like electronically controlled colored LED lights that blink and change color based on use or outside occurrences gave it a personality of its own. Beyond its high-power computing ability, LAZARUS is a uniquely designed super-computer specializing in the "wow" factor. The LAZARUS design made

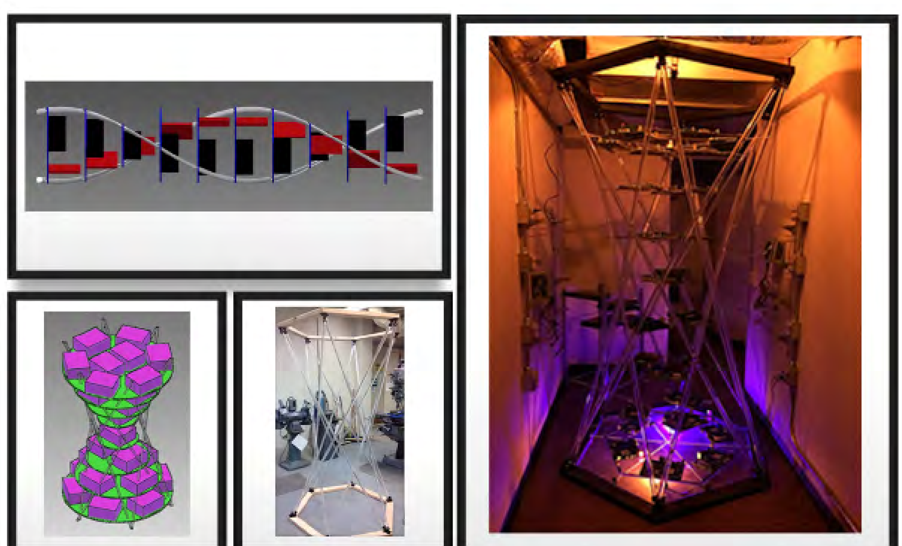

Figure 4. Initial concept to final assembly. A) Double Helix Concept, B) Hyperboloid Concept, C) Test Build, and D) Final Assembly

it an interesting point of discussion for groups that have visited. It also provided a valuable learning experience for the undergraduate engineering students that brainstormed, simulated, and actualized its unique design. Most engineering students do not have the opportunity to go through the full design process. They discuss, conceptualize, and make plans but frequently do not get to carry them out in a real-world application. Our engineering students went through different design iterations of LAZARUS, from a visually appealing but infeasible DNA double helix design to the intricate hyperboloid design in brainstorming (See Figure 4). These students created 3D models of the hyperboloid structure and proceeded to load it with components to test its feasibility with finite element analysis (FEA). From there, the design team was able to determine a design that met the typical requirements of sizing and loading of materials and mechanics and thermomechanical issues from heat generated by computer components. These students also worked with real-world constraints placed on design by the space that was donated for LAZARUS.

The space has a low ceiling, which changed the dimensions of the hyperboloid structure and required careful consideration for in-place construction of the structure. Furthermore, the space donated is in a lower-level room in the Mathematics building, which was known to flood. Students considered this in their design and properly raised the bottom level of nodes above the floodplain. The physical design and construction of LAZARUS gave the undergraduate researchers a tangible experience in the engineering design process.

The purchasing, assembly, and wiring of components and coding for LAZARUS gave our mathematics graduate and undergraduate students an experience in computer engineering that they would not have gained from their computer science courses. These students were able to use hands-on experimentation to explore different coding languages and systems to determine the best fit for the Schoenberg Cluster. In addition, the Department of Mathematics and Statistics was able to develop an undergraduate course on coding and computer science in the mathematical sciences. LAZARUS also hosted biweekly seminars, allowing users to engage with experts about how to best conduct their research while using the Schoenberg Cluster.

Outreach and Engagement Results

In its infancy and before large-scale use of LAZARUS for research projects, its distinctive design and pop culture function made it an engaging topic on supercomputing. It provided numerous opportunities for engagement with LISD, other K-12 districts, and the public. During campus tours, K-12 school field trips, outreach events, recruitment events, and academic summer camps, LAZARUS was a popular site to visit. With these visits, our team had the opportunity to discuss the design and build of LAZARUS, the unique functions of LAZARUS, and the far-reaching applications of zombie simulations related to epidemiology and public health. While most of these interactions were one-time on-campus interactions, teachers and students were encouraged to look up LAZARUS on social media and use the website to get more information and continue to engage after visiting. These interactions were usually a full-day, where students would see LAZARUS for several hours.

K-12 student visits traditionally comprised of three elements: (1) A faculty presentation outlining the foundational mathematics concepts underlying the first iteration of the zombie outbreak models, (2) A graduate student presentation introducing basic principles of high-performance computing—specifically the benefits of graphics processing unit (GPU) clusters, and (3) an in-person tour of the lab facility where students had the opportunity to touch and feel specific components of the Schoenberg Cluster. The faculty presentation introduced students to basic concepts from graph theory, Markov processes, and an analytical method referred to as *random walks*. Ultimately, both the large-scale cluster models and the smaller-scale online models leveraged these concepts as the underlying machinery for outbreak simulations. The graduate student presentation introduced K-12 students to the battle of oxen versus chickens—the idea that when addressing a computing-intensive problem, researchers can opt to seek out bigger and faster traditional processors (the oxen) or to restructure their problem so that it can be approached by dividing the burden across an incredibly large number of weaker processors (the chicken). In the end, the graduate student helped visitors understand that when moving a boulder, an endless supply of tethered chickens will ultimately out-pull a limited supply of very powerful oxen—often at a significant cost saving.

The lab facility tours focused on placing K-12 students as close to the actual computing cluster as possible. Students could see and touch individual computer components such as hard drives or GPUs while the machine was working because of the unique case design. Thankfully, the small risk of a student damaging the cluster in these encounters was never realized. Students often made their first concrete connections between computer components they had only seen mentioned in writing and the actual work of computers—both personal and high-performance. Students were also able to touch the unique case design, exploring the types of materials and challenges for designing the case around real-world parameters. Discussion of the case design complexities offered students a unique perspective on the intricacies of research and productive failure. While the complexity and depth of content were adjusted to account for the sophistication of the particular student group, these foundational concepts formed the core of each presentation.

In the initial 2-year period where LAZARUS was primarily categorized as an outreach tool, over 600 students from the surrounding school districts visited. Within these visits, over 2/3 of the students and teachers who visited LAZARUS were from school districts that were primarily Hispanic or were underrepresented groups. Over half of the students who visited were from rural school districts as well. Over 30 international K-12 students came to TTU that got to work with and experience several research components and applications of LAZARUS. Within these groups, LAZARUS outreach has focused on engaging Hispanic and rural students and has focused on engaging girls, who are underrepresented, in STEM concepts and coding. LAZARUS was used annually for female-centered outreach programs like Tech Savvy and Emmy Noether Day, aimed at middle school and high school girls. LAZARUS had

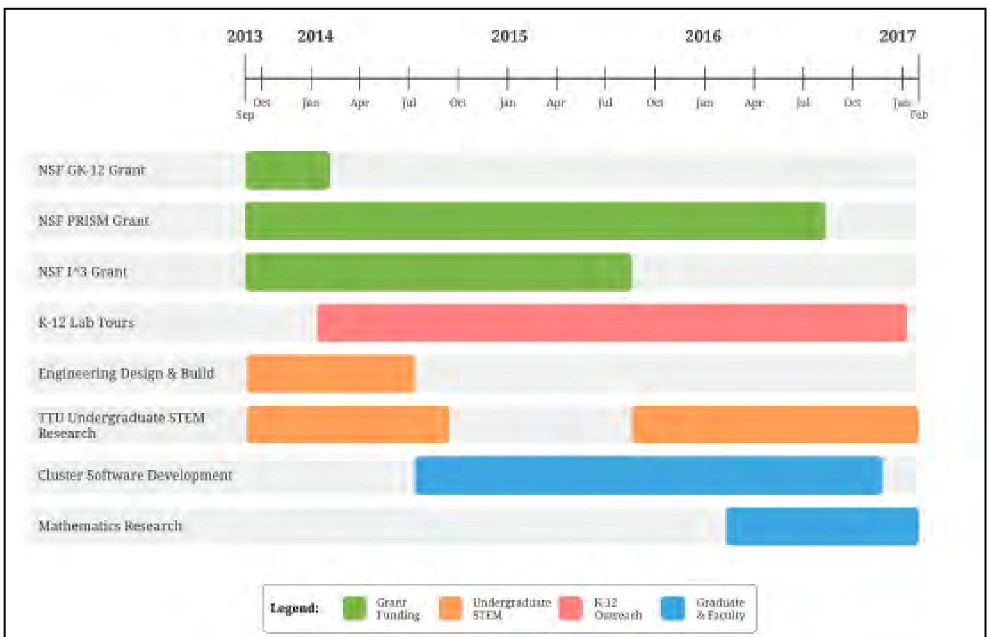

Figure 5. Summary of engagement

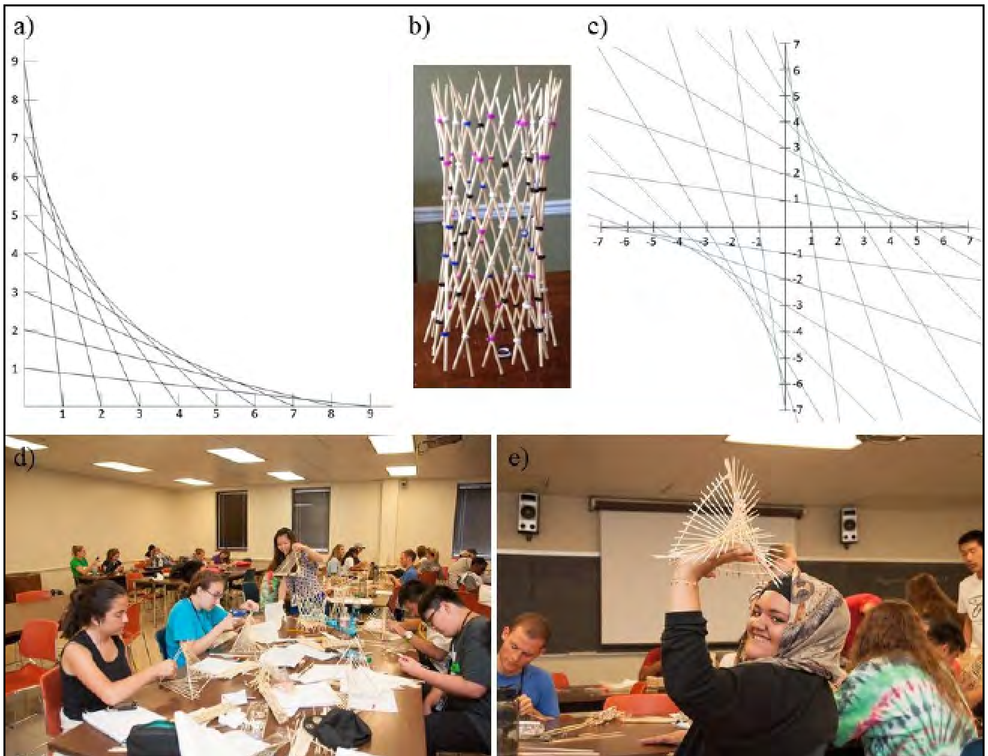

Figure 6. Hyperboloids in 2D and 3D space. a) drawing of hyperboloid in quadrant 1, b) bamboo construction of one-sheet hyperboloid, c) drawing of mirrored hyperboloid in quadrant 1 and 3, d) and e) student bamboo constructions of hyperboloids

the opportunity to introduce them to high-performance computing, high-level mathematical concepts, and an introduction to coding. Below is a graphic representation of the classifications of K-12 students who interacted with LAZARUS (See Figure 5).

Several people from industry came to view and learn more about LAZARUS, including a Texas Senator and representatives from the National Science Foundation. Furthermore, specific programs concerning LAZARUS were also developed for high school and undergraduate students in various disciplines across campus. Those activities highlighted programming of the cluster (teaching the basics of coding), mathematical modeling of random walks, biomathematics, and engineering design. One such program discussed the geometric function of hyperbola's and hyperboloids, mainly how they can be created with a series of straight lines that intersect in a dedicated pattern. High school students participating in these activities learned this in 2D space through demonstrations on a chalkboard. The basic construction of hyperboloids in 2D space can be made by drawing intersecting straight lines in quadrant I on the x-y plane. By mirroring these lines in quadrant 3, a 2D representation of the LAZARUS structure can be created (See Figure 6). In 3D space, a one-sheet hyperboloid is similarly formed by intersecting straight lines in the x, y, and z planes. The lines and points of intersection make an appearing curved surface. With this knowledge, students received experiential learning in 3D space when they were tasked to build a hyperboloid using bamboo skewers and rubber bands. By taking straight bamboo skewers and fixing them at certain points, these curved surfaces can be seen in 3D space. Based on this principle, students could create the basic hyperboloid of LAZARUS and other ornamental arrangements (See Figure 6). The physical hyperboloids the students constructed were theirs to keep serving as a reminder of their newfound geometry knowledge and the LAZARUS build.

While the original intent was to leverage LAZARUS and the Schoenberg Cluster to catalyze sustained K-12 engagement, most K-12 student encounters were not effectively maintained after the students returned to their schools. Students were exposed to various academic and career pathways where they might encounter high-performance computing, mathematics, biology, and statistical modeling. They were allowed to physically connect engineering and computer science concepts through their in-person lab tours and up-close encounters with the Schoenberg Cluster. However, attempts to sustain engagement with school groups once they left the TTU campus failed to extend beyond one or two encounters. The project team attributes this limited engagement window to school limitations on student access to social media and web-based video platforms from school-based networks and a series of key project team turnovers as the Schoenberg Cluster began to transition into its originally intended active research support capacity.

The one potential exception to these limitations is the web-based zombie outbreak simulator. While detailed web analytics were lost during a web server transition, K-12 teachers and students have reported anecdotally that this interactive simulation offered an opportunity for continued discussion and exploration long after lab visits. Plans are currently underway to revitalize the community-engaged mission of the LAZARUS project, and the team is placing an intentional focus on developing curriculum pieces that help classroom teachers make follow-up connections between the LAZARUS content presentations and grade-appropriate subject matter in their respective classrooms. Enhanced web-based simulations will serve as a key element in this renewal work.

Learned Best Practices & Replication

Outreach and engagement for LAZARUS have been a unique resource, based on availability and project location, which came about because of the collaboration with LISD. The resources available defined the Schoenberg Cluster's design and construction, and the project location led to engagement with rural and high URM schools. While these demographics are specific to the location, fundamental concepts can be repeated for successful STEM outreach and engagement activities learned from LAZARUS. These concepts include engagement strategies with supercomputing, resource usage strategies, presentation and outreach strategies, and location-based adaptations.

Engagement Strategies

Supercomputing is an important field of STEM. It is all-encompassing in that it can be used in science, mathematics, or engineering. It will also be a driver for future advancements in big data analysis, machine learning, and artificial intelligence. With such importance, advancing and introducing supercomputing to a new generation of scientists and engineers from the K-12 ranks is imperative. LAZARUS provides examples of introducing students to supercomputing, and these examples are replicable. The initial concept for LAZARUS was based on the pop-culture phenomenon of zombies, and the project grew from there. While zombies are much less popular now than in 2014, other pop-culture phenomena could also be leveraged by combining with supercomputing. For example, popular science fiction shows, like Black Mirror, that use artificial intelligence, robotics, and simulations, provide several applications that would use supercomputing. Models, algorithms, and coding could be used to educate students within this science-fiction context. Along with supercomputing as an engaging component, LAZARUS used the super-computer design as a point of engagement for LISD. Making a unique design for the super-computer is something that can be done with all super-computers. A unique design serves two purposes: 1) an aesthetically engaging component and 2) visibly accessible super-computer components. Aesthetics are important because they draw the eye to the super-computer and inspire design, function, and innovation to students.

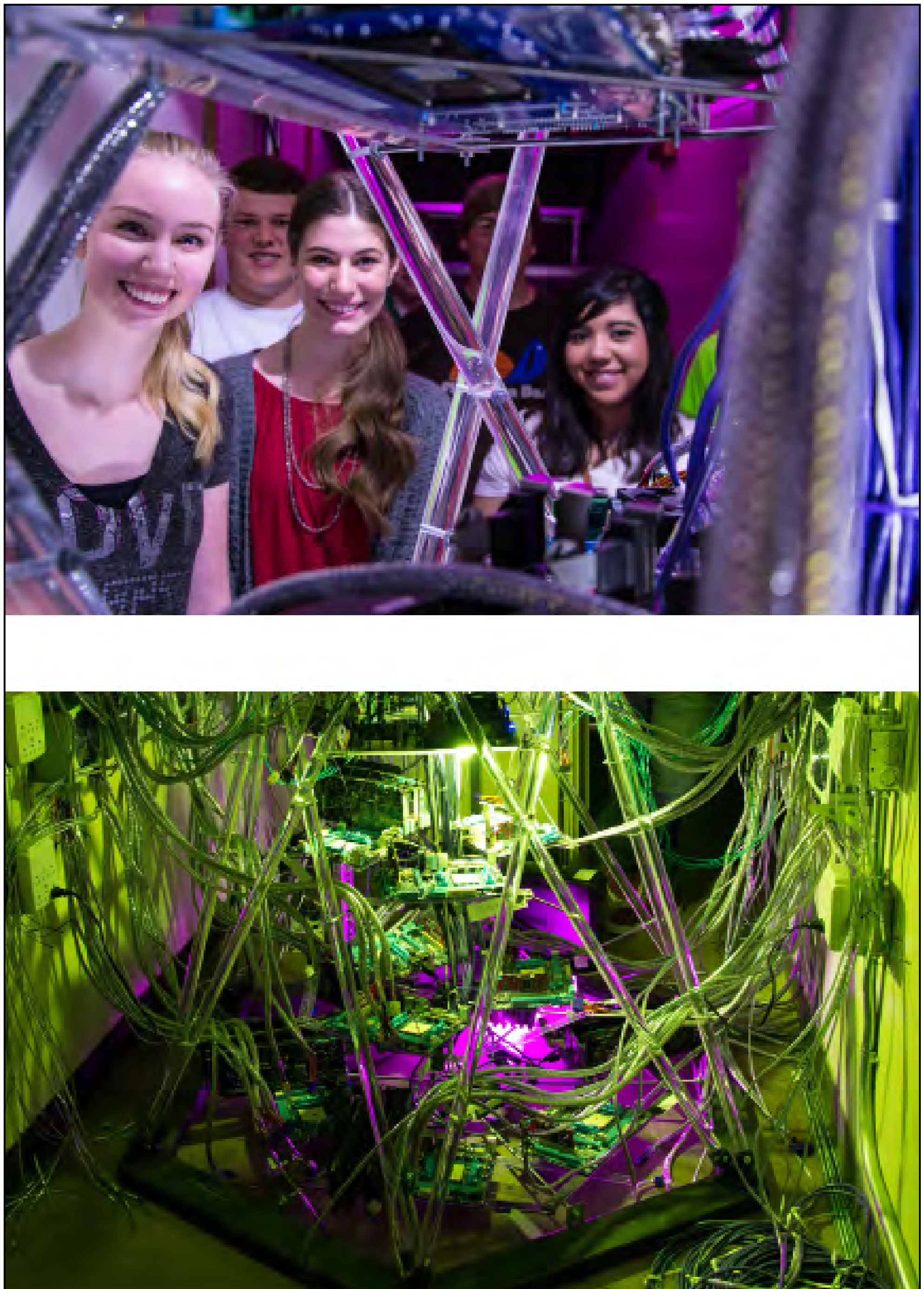

Figure 7. Sightlines for LAZARUS. Students looking through Schoenberg Cluster (Top) and Up-close view of processing unit and graphics card (Bottom)

Drawing the eye to the super-computer is not difficult and does not have to revolve around expensive computer components or structures. A basic sightline, framing, and inexpensive color-changing LED lights can be very impactful. Being able to see components is important in that it can teach the students how the super-computer works. LAZARUS was an intentionally designed super-computer with visible components, so you can point to the nodes, their processing units, graphics cards, etc. (See Figure 7). This visibility allows you to explain what each component does, how they are related, and how they function within the programming and coding aspects.

Resource Usage Strategies

LAZARUS was provided with ample resources based on funding from research grants and an industry grant. These grants helped develop a partnership between TTU and LISD and helped to purchase the components of the Schoenberg Cluster and fund undergraduate and graduate student involvement. Student involvement can be leveraged in any project where there is a tangible result. STEM education and training grants exist that can specifically be used for undergraduate training and involvement, along with partnerships with other departments across campus. Overall, creating opportunities for students to participate in research and involving them in outreach and engagement makes for a more enriching experience.

Presentation and Outreach Strategies

LAZARUS was leveraged in several different ways to increase outreach engagement to various groups. LAZARUS was used as an institutional focus for higher education research, an institutional resource for data analysis, and a tool used for any graduate student or faculty member. This helped gain academic and non-academic departmental backing to provide resources, such as physical space and faculty involvement. Also, the various institutional partners all were promoting LAZARUS in their fields of influence, causing the popularity to increase drastically. Simultaneously, LAZARUS' reputation grew in K-12 and regional realms, but it was also integrated into pre-existing outreach programs on TTU campus. LAZARUS was also promoted from all these different institutional groups, attained social media and media highlights, word of mouth advertising, and engagement from different departments, colleges, and ISDs. LAZARUS was even featured in a nationally aired commercial during peak college football season! Replicating a program with LAZARUS's popularity requires a professional and coordinated effort of publication and promotion across various spheres.

Repeatable Strategies

While the exact replication of LAZARUS as a concept is highly unlikely, there are several components and lessons learned in the creation of the LAZARUS project that could offer favorable applications to other programs. An outreach and engagement program, whose target is aimed at heavy research, can be made approachable by the community through the use of several key suggestions:

- Complex research ideas should be applied to a popular, approachable topic
- An interactive component of the project should be developed and be kept simple for enhanced usability and free access
- Community engagement and outreach can be created and leveraged at a low cost and be used as a stopgap before all research components have been implemented
- An intentional focus can increase the community engagement and development of outreach through identifying developmental partners

In addition to the above suggestions, many adaptations can be made to this model of community engagement and outreach to fit various geographic and social environments. For example, because of the rural and secluded nature of TTU, the engagement with the community was focused on engaging rural students that didn't have access to resources. However, the same argument could be made for many highly urban K-12 students, so the premise is the same. Focusing on open-source resources, free or low-cost activities, and easy access to these opportunities for students will help provide a much-needed service to the community, school districts, and informal STEM groups. Finally, hosting a similar project to LAZARUS is an attractive and innovative way to engage and recruit prospective students looking at attending the university. Allowing students to experience the intrigue of an uncommon lab, both in visualization and research aims, captured several students' attention and was the "tipping point" for several attending the university.

Conclusion

The development of LAZARUS was a multidisciplinary endeavor created by an initial partnership between TTU and LISD. K-12 schools and LISD continue to have access to the LAZARUS simulation platform for learning. The College of Arts and Sciences and Department of Mathematics have used LAZARUS as a simulation and modeling tool for graduate-level research. The TTU College of Engineering helped design and construct LAZARUS applying mechanical and industrial/manufacturing knowledge. Interdisciplinary approaches enrich the learning experiences of those who work on and use LAZARUS and could be used as an outreach and engagement component that touches on hot topics in STEM. Advancing fields like big data analysis, machine learning, and artificial intelligence are interdisciplinary fields that could function within LAZARUS. The future of STEM is dependent on these fields, and LAZARUS provides an important introduction to K-12 students and schools through outreach and engagement activities similar to the activities detailed here.

LAZARUS provides a case of a research project in its infancy being expanded into a STEM outreach and engagement tool. The concepts and ideas formulated and carried out with LAZARUS provide some basic and replicable practices that can be used to increase engagement in various STEM disciplines. Further, based on TTU and the surrounding area, the LAZARUS project provides insight into how research can be leveraged to engage K-12 students and schools. Key conclusions based on this work include:

- STEM research projects can and should be used as tools of outreach and engagement to increase STEM interest of K-12 students
- Outreach and engagement can provide valuable learning and training experiences for faculty, graduate and undergraduate students
- Setup and success of such a project requires multidisciplinary and institutional support
- STEM researchers should consider the design and construction of projects for engagement, access, and capabilities

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