ENGAGING HIGH SCHOOL WOMEN IN ENGINEERING DESIGN
USING CYBERINFRASTRUCTURE

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ABSTRACT
Without a doubt, the current generation of secondary school students is very familiar with information technology. Text messaging, e-mail, and social networking websites are a normal means of communication. There is also increasing recognition of the need for diversification in the engineering workforce and increasing the number of graduating engineers in the United States. This has created an opportunity to leverage leading edge Cyberinfrastructure in an outreach program targeting secondary school students. This paper demonstrates the implementation of a targeted outreach program that engages high school students in engineering design over a two-week period using state-of-the-art digital design repositories and motion simulation equipment.

KEYWORDS
Digital Design Repositories, Women in Engineering, Engineering Education

INTRODUCTION
One of the most difficult challenges in attracting students to engineering is conveying the idea that relating theoretical and analytical results to real-world phenomena can be interesting and engaging. This challenge is complicated by the fact that the stereotype of an engineer in society at large is a man in a dress shirt with a pocket protector and glasses. While there are some engineers who might fit this description, this image is reinforced by media and advertising using caricatures of male engineers or scientists. Research on society’s perception of engineers shows the development of the male stereotype at an early age that is difficult to change as children mature [1-6]. As a result, young women can find it difficult to foresee a career in engineering or find role models who have been successful in an engineering field [7]. Research has shown that these perceptions are not permanent, with pronounced reversals of perceptions after structured, engaging interactions with researcher and engineers who do not fit the stereotype [8].
In 2000, the Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development recommended “aggressive, focused intervention efforts targeting women, underrepresented minority, and disabled students at the high school level, at the transition into postsecondary education, and at the community college transition into four-year colleges and universities” [7].

While in the past several years, there have been a significant number of programs targeting increased participation by women in science and engineering careers [9], perceptions still exist that women are not suited to science or engineering [10,11]. While the issue of the inaccurate perception of engineers may not seem significant, when taken in concert with other workforce factors, developing a means of encouraging more women to participate in engineering takes on a role of national importance.

Innovation driven by advances in science and technology is a key component of the US economy [12,13]. However, this engine of economic development has multiple threats that will need to be addressed over the next generation. In 2003, the National Science Board reported [14] that the most significant threats to our science and technology workforce include:

- Flat or reduced domestic student interest in critical areas, such as engineering and the physical, and mathematical sciences
- Large increases in retirements from the S&E workforce projected over the next two decades
- Projected rapid growth in S&E occupations over the next decade, at three times the rate of all occupations
- Anticipated growth in the need for American citizens with S&E skills in jobs related to national security, following September 11, 2001
- Severe pressure on State and local budgets for education of the future S&E workforce.

Women represent 46 percent of the general workforce, but comprise only 19 percent of the science, engineering, and technology workforce [7]. A greater participation by women in science and engineering would make significant strides towards addressing this projected shortfall of scientists and engineers. Along with the need for increased participation in science and engineering careers, the ubiquitous nature of cyberinfrastructure-enabled frameworks (e.g., Facebook [15], MySpace [16]) has also increased the expectations of students when engaging them in a summer enrichment experience.

The increased expectations of learners has been recognized by researchers and national science advisory panels. As a result, recommendations have been made to increase the role of technology in learning environments [17,18]. In 2001, the President’s Information Technology Advisory Council (PITAC) set forth some recommendations for the development of technologies for education and training that use simulation, visualization, and gaming to actively engage students in the learning experience [19]. As part of their report, PITAC called for the development of educational experiences that provide learners with access to world class facilities and experiences using actual or simulated devices. Following the report, research has demonstrated effective means of increasing engagement in both pre-engineering and undergraduate engineering programs through the development of more inductive learning environments [9, 20, 21]. Equations and graphs are the language of engineering and such language is an abstraction of reality used to solve real problems. Using technology to provide students with an engaging, authentic experience that shows them how to work in a world of equations and graphs while applying the results to real-world products and systems can be a significant challenge.

Recognizing the need for increased participation in engineering and responding to the call for more authentic experiences for learners, a workshop program was developed by the New York State Center for Engineering Design and Industrial Innovation (NYSCEDII) in 2001 to introduce high school students to engineering design and visualization. This initial workshop program was similar to many other workshop programs in that it provided students with a two-week, intensive program of study. Early implementations of the workshop focused on the development of simple visualization models and robotics programming, using basic cyberinfrastructure. While successful at engaging students already interested in engineering, the program did not have an effective means of introducing students who may not have considered engineering as a potential career.

After five years, approximately 100 students, and fewer than 10 female participants, the workshop program was evaluated for its success in providing an engaging introduction to engineering and attracting new interest in engineering as a career. During the review, workshop programs at other universities [22, 23, 24] and secondary school outreach programs [9] were reviewed. As a result of the review, some key components were identified for inclusion in a redeveloped outreach program.

- The incorporation of a series of opportunities for students to see how engineers practice what they have learned in school.
- The opportunity for students to interact with role models in both formal classroom and informal settings.
- The use of more inductive teaching styles to engage students in learning.
- Students should have the opportunity to use leading edge tools and technologies to experience the excitement of ongoing research.
- Specifically marketing to a targeted group of students that is currently underrepresented in engineering.
- No program was found that coupled engineering design with cyberinfrastructure in an effort to encourage more diversity in engineering.

The new outreach program has been guided by these concepts, resulting in a comprehensive overhaul of the previous program. Fisher-Price, a toy manufacturer with a design facility in the
region, was recruited as a partner. The partnership with industry provided both access to role models in the form of practicing engineers and a relatable context (i.e., toy development) for the workshop program. Lessons were developed with the intent of immersing students in the use of the same tools that practicing engineers use on a daily basis. The design challenge for the workshop would require students to use state-of-the-art engineering design tools, allowing students to see that engineering is not a static field, but constantly evolving. Finally, to encourage greater participation by underrepresented groups, the workshop targeted a specific demographic, women in high school, to hopefully encourage participation by students who may not be actively considering engineering as a possible career choice.

OVERVIEW OF WORKSHOP

To recruit workshop participants, promotional materials were distributed to all of the high schools within a 30 mile radius of the university, including private and parochial schools. As a result of the outreach program, sixteen applicants representing seven schools were accepted. Five of the accepted students would be seniors in the Fall of 2007, four were rising juniors, and the remaining seven were rising sophomores. Of the sixteen students, only four of the students had taken physics classes.

The workshop curriculum provided a two-week educational program, with a total of 60 contact hours with the students. The program minimized traditional classroom instruction, favoring more inductive methods to engage the students in learning about engineering design. The curriculum was designed around a "Grand Challenge", where students were tasked with designing a roller coaster ride using a digital design repository. For the challenge, workshop participants would be split into teams of two students on the second day of the workshop. These teams would be used for both group-based learning exercises for the remainder of the workshop and for completing the design challenge. Teaming decisions were made to break up students from the same school and create teams with compatible members after a period of observation and interaction with a high school technology teacher.

Leading up to the challenge, the student teams would be guided through a series of exercises to introduce them to the following concepts:
- Conservation of energy
- Engineering design methodology and practice, including innovation in product design
- The development and application of simulation-based models in engineering design
- The use of cyberinfrastructure in engineering design
- Product dissection and reverse engineering
- Digital design repositories
- The role that research plays in developing new design methodologies

Some understanding of each of these areas would be necessary to respond to the design challenge. The schedule for the workshop program is shown in Fig. 1. The next section of the paper provides a description of each aspect of the workshop program in depth.

WORKSHOP CURRICULUM

**Workshop Welcome**

During the first day of the workshop, students were presented with a general overview of roller coasters and the principles that guide their design. Roller coasters are familiar to high school students and have been effectively used over the years to encourage greater participation by underrepresented groups, women in high school, to hopefully encourage participation by students who may not be actively considering engineering as a possible career choice.

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**FIGURE 1. WORKSHOP SCHEDULE**
to introduce conservation of energy principles in physics classes [25]. The overview presentation used this familiar experience to introduce students to the decisions that must be made during the design of a roller coaster. Students were also presented with the concept of constraints on design options that result from safety, cost, and space considerations. Following the initial presentation, students had the opportunity to meet engineers from Fisher-Price in an informal lunch that was accompanied by a “engineering fair”, with each engineer at a station presenting a representative project from their daily work. Rather than present students with a series of Powerpoint™ presentations, the students rotated amongst the stations, interacting with the engineers in a relaxed atmosphere. At the end of the presentations, the roller coaster design challenge was presented to the students and they began an active learning experience about energy.

Understanding Energy

In targeting freshmen and sophomores for the workshop, the likelihood that students would have any physics background was greatly reduced. Twelve of the students in the program had no physics background. As energy management is a key component of roller coaster design, the afternoon of the first day was devoted to developing students’ understanding of conservation of energy principles. Julia Goodwin, an engineering technology teacher from a local high school, participated as part of a National Science Foundation (NSF) sponsored Research Experiences for Teachers (RET) project in digital design repositories. Ms. Goodwin used her background and expertise to develop and lead the session on conservation of energy.

After a brief introductory presentation and exercises with online roller coaster simulators, students were provided with clear rubber tubes, tape, and marbles. Working in teams of two, students were asked to create basic roller coaster representations, including a simple bump and a loop. Figure 2 shows two students working on creating the simple bump model. Students would then test their “coasters” by releasing the marble into the tube and seeing if it would complete the track. Teams were then encouraged to experiment with designs of their own and asked to explain why the marble would or would not complete the path.

This simple exercise provided students with insight into energy management concepts. In addition to a greater understanding of conservation of energy, students also had been introduced to the decision making process necessary to complete the conceptual design of a roller coaster. In keeping with the lessons learned from previous workshop programs, the emphasis during this session was on active learning, rather than traditional lecture-based learning. A second focus of the workshop curriculum was to provide students with an opportunity to interact with practicing engineers multiple times during the program. The next section of the paper describes the interactions students had with engineers in industry.

Interaction with Practicing Engineers

Over the course of two weeks, the workshop incorporated multiple opportunities for students to interact closely with practicing engineers. Rather than limit the interaction to a lecture-style presentation on life as an engineer, more interactive exercises were developed to attempt to engage the students in the engineering design process and give participants a better idea of the challenges that engineers face on a daily basis. Over the ten day workshop, practicing engineers led four interactive sessions, with each session focusing on a different aspect of the engineering design process. For the sessions, production toys were used as examples of practical engineering design and manufacturing problems. Several young engineers from industry, the majority of whom were women, worked with the students to help them learn how a toy goes from a concept to reality, including such concepts as circuit design, product platforming, and manufacturing considerations.

An example session focused on how engineers solved the challenge of tracking two race cars on a track system, shown in Fig. 3. Students were asked to play with the cars and guess at how the toy worked. After some discussion, the engineers
showed students how a combination of electrical and mechanical devices controlled the cars and provided scoring for the game. Using an oscilloscope, students investigated how the track sensed cars crossing the start/finish line. The exercise culminated with a discussion of how the initial design concept evolved into the final product, including modifications to the design that were necessary to meet reliability requirements.

Building on this session, during the following day of the workshop, the engineers returned with more products and challenged the students with the task of explaining how the products worked. Each group of two students was provided with a different product and a sheet of questions about how the product’s features were designed and implemented. As seen in Fig. 4, students first used the toys and then, using simple hand tools, disassembled them. After the components were separated, students traced the internal electromechanical systems, following wires from switches to motors and sensors, and responded to their assignment sheet. The product dissection exercise provided students with the opportunity to immerse themselves in reverse engineering a product with the support of practicing engineers. During the dissection exercise, students asked the engineers to explain the reasoning for certain design choices. Upon completion of the exercise, a senior engineer pointed out aspects of the internals that were similar amongst multiple products, creating a product platform that would reduce cost and the time required to develop the product.

In addition to working with engineers who were early in their careers, the curriculum also provided an opportunity for participants to meet with potential role models on an informal basis. Several women engineers with leadership positions were recruited to participate in the workshop program. Every day during lunch a different host sat with the students and shared her experiences as an engineer. Mentors included:

- Women engineers in their first five years in industry from Fisher Price
- Julia Goodwin, a high school engineering technology teacher with experience in industry
- Jennifer Haggerty, a Mechanical Engineering Graduate Student
- Dr. Christina Bloebaum, a professor in Mechanical and Aerospace Engineering,
- Dr. Ann Bisantz, a professor in Industrial Engineering
- Ann Wegrzyn, Assistant Vice President of National Fuel Gas Distribution Corporation and an Industrial Engineer

In addition to the informal opportunities for interaction with practicing engineers, students were presented with the many different ways that cyberinfrastructure supports engineering design. The next section of the paper provides an overview of a series of seminars that students participated to develop an understanding of cyberinfrastructure’s role in engineering design.

Familiarization Sessions with Engineering Practice and Research Laboratories

A 2003 report by a National Science Foundation panel defined cyberinfrastructure as “infrastructure based upon distributed computer, information and communication technology” [26]. This formal definition of cyberinfrastructure provides a common nomenclature when discussing the use of information technology methodologies, tools, and hardware to solve problems in the growing knowledge economy. Engineering design is just one of many disciplines that benefit from the application of cyberinfrastructure. [27] To provide more understanding of how cyberinfrastructure fits into engineering, a series of seminars was incorporated into the workshop that introduced students to the use of cyberinfrastructure to solve a problem or complete a task in a product design process. A session entitled “Innovation in Engineering Design” introduced students to the concept that innovation can be a process driven exercise, aided by cyberinfrastructure.

A second seminar session presented student with the opportunity to use haptic, or force-feedback, devices to manipulate parts in a simple design interface. Using a Phantom™ device [28], students manipulated a part in a virtual assembly. The applicability of using haptic devices was reinforced during the engineering fair where the Fisher-Price engineers discussed how haptic devices are used in the modeling of new toys.

A third session, shown in Fig. 5, introduced students to the use of visualization and virtual reality in the design process. Working with a Powerwall™ system [29], students viewed immersive chemical plants, virtual product assemblies, and a virtual version of a sabretooth tiger. This session focused on how the math and computer programming used in the creation of video games also applies to the creation of innovative products. This session was followed up with an experience in developing virtual models using the Virtual Reality Modeling Language (VRML) [30], a programming language that is used to create virtual models that can be viewed using a web browser and a freely available plug-in.

FIGURE 4. STUDENTS DISSECTING A TOY TO INVESTIGATE THE INTERNAL SYSTEMS.
The final session on cyberinfrastructure in engineering design focused on the rapid creation of prototypes from product design data. Working with research staff, students discussed how design data is converted from images that can be seen on a screen into the data necessary to create a physical part that can be held and tested. A series of rapid prototyping approaches were discussed, including Fused Deposition Modeling (FDM), Stereo Lithography, and Selective Laser Sintering (SLS). Through these seminars, students had the opportunity to both see and experience how cyberinfrastructure has influenced product design and innovation. While these applications focused on the use of cyberinfrastructure to enable virtual product development, the next section describes how students learned about the use of cyberinfrastructure to enable physical simulation in the design process.

Interactive Simulation Development Using Cyberinfrastructure

One of the goals of the workshop curriculum was to provide students with the opportunity to use leading edge tools and technologies to experience the excitement of ongoing research. Many different varieties of simulations exist that can be used to demonstrate the engineering design process. Some simulations are purely numerically based. Provided with a set of numeric inputs, a simulation routine executes and provides an engineer with a result. A more engaging simulation might also couple some computer graphics, condensing the data into more intuitive graphs or other representations. Immersive simulations take this approach one step further, creating a world in which the simulation executes and the results are provided in an interactive manner that is seen as a part of the world. As these simulations immerse the user in a virtual environment and students are very familiar with the limited immersion of video games, the use of immersive simulations was seen as pivotal to the engagement of the students. In developing the educational program, the use of a physical simulation tool promised to involve the students in an authentic engineering experience.

Cyberinfrastructure for Physical Simulation

Physical simulation tools, including motion simulators, provide a graphical representation of a world and a means of experiencing travel through the world in a simulated moving vehicle through the use of a moving platform. This provides students with the opportunity to both see and experience the virtual version of their design first hand and in a safe manner.

A motion platform, (i.e., parallel manipulator [31], motion base, or Stewart Platform [32,33]) is a powered, mechanical, self-contained system for the execution of motion-based simulation and is described by the number of degrees-of-freedom (DOF) that can be simulated by the hardware. The Moog 2000E 6-DOF motion platform currently in use in NYSCEDII’s simulator facility also has an on-board computer that converts incoming messages into commands for the actuators that result in the movement of the top of the platform. This simulation framework was an extension of research into using physical simulation in road vehicle dynamics educations [34].

The simulation program provides the images that are displayed on a large (10' x 9’) screen, creates an audio signal for the sound system, and sends out position and orientation information for the motion platform. Using a basic washout filter [35], the dynamics model output states are converted into six degrees of freedom representing the position and orientation of the platform in space. Figure 6 shows a computer rendering of the layout of the facility, with the control booth, the motion platform, and the large scale display system.

Student Use of Cyberinfrastructure for Physical Simulation

While physical simulation is used in a wide array of fields, including flight and spacecraft simulation [36-39], driving and ground vehicle simulation [40-43], vibration isolation and tire simulation [44-46], medical and surgical simulation [47-52], large and industrial equipment training [53], and location-based entertainment [54-57], many of these fields require significant theoretical development before meaningful
use of a motion simulation platform is possible. However, in the case of location-based entertainment, the development of a ride experience that closely matches a rendered movie is an actual exercise ride designers perform in creating a new theme park attraction. Location-based entertainment is a growing industry with applications in theme parks and links to the video gaming industry, providing a familiar context for students.

As part of the overall context of roller coaster design, students were challenged with the task of matching the motion of the center’s Moog 2000E six degree of freedom motion platform with a simple roller coaster’s path. Students were provided with a profile of the roller coaster, shown in Fig. 7, and asked to create a motion profile that would give riders the impression that they were actually on the coaster. After a short introductory presentation in motion simulation, including the concept of degrees of freedom, students were asked to create a simple motion profile using Microsoft Excel. Students created a separate column for each degree of freedom (x, y, z, roll, pitch, yaw) and saved the output to a text file. An example file is shown in Fig. 8. This text file was then converted into a format that could be understood by the motion platform.

Using a program that simulated the motion platform, students could test their motions virtually before moving to the actual platform. Shown in Fig. 9, the virtual motion platform environment would allow students to load their ridefiles and execute them on a simulated motion platform. The virtual platform would then move through the prescribed motions, highlighting potential problems with specific actuator commands with the use of color cues. This process was used to screen out motion profiles that would be potentially unsafe to riders or cause problems with the equipment. Students also found it easy to imagine their ride on the platform and could change their ride file as a result. After iterating with the virtual version of the motion platform, students went to the physical simulation lab and loaded their ridefiles into the simulation program and experienced their designs.

Figure 10(a) shows two of the students experiencing their ridefile on the motion platform. Figure 10(b) shows the virtual roller coaster as seen on the display. Eight teams of students developed rides for the platform, each completing the double-bump exercise. A few groups experimented on their own to create motion profiles that might fit the roller coaster concept for the design challenge. The rides that each group designed were evaluated separately by a researcher in the application of motion simulation in engineering design and an engineer at Lockheed Martin with a background in location-based entertainment and electromechanical systems and an alumnus of the original workshop program. Building on the experiences in using cyberinfrastructure, the next section describes how students used digital design repositories to address the design challenge issued the first day of the workshop.
Virtual Product Development Using Digital Design Repositories

The concept of a repository for storing data is well developed in a range of fields, including the creation of digital libraries [58,59], education [60, 61] and software development [62,63]. As product design becomes increasingly a global enterprise, the need for networked, collaborative tools to support design innovation has become more pronounced. Over the past several years researchers have recognized this need and developed methodologies that build on advancements in repository design and leverage cyberinfrastructure to support engineering design [64-68]. While cyberinfrastructure to support tracking changes in product designs during detailed design and production have long existed [69,70], these new developments focus on the development of methodologies and cyberinfrastructure to support conceptual design early in the design process where few details exist for a specific product.

Working with Dr. Matt Stone (University of Missouri at Rolla), Dr. William Regli (Drexel University), Dr. Ken English (University at Buffalo), and Dr. Kemper Lewis (University at Buffalo), the three Research Experience for Undergraduates students developed a section of the digital design repository at UMR devoted to roller coaster design. The concept of a repository was introduced to students initially by presenting Facebook [15] as a repository of images. As an environment familiar to secondary school students, Facebook provided a relatable context for the idea of storing, reusing, and sharing information using a cyberinfrastructure-enabled framework.

Building on the familiarity of Facebook, the concept of a digital design repository was presented to the students. Two digital design repositories were presented, one at Drexel University [71] and one from University Missouri at Rolla (UMR) [72]. For the design challenge, the workshop students used the design repository from UMR, shown in Fig. 11(a). The repository contained models of approximately 20 different track sections, 3 stations were riders would get on or off the ride, and 4 different roller coaster train models. An example track section model is shown in Figure 11(b). Using these track section models as a basic set of components, the students were challenged to create a roller coaster that would be exciting to ride, fall within human rider tolerances, and would be designed with the laws of physics in mind.

Students worked in groups of two to develop an initial design concept for their coaster. Using Microsoft Excel as a simple analysis tool and information from the design repository, students calculated the amount of Potential Energy that would be created with an initial lift hill or initial Kinetic Energy that would result from a launch section of track. Using this information and information on elevation change and track length from the design repository, students calculated the available energy using Equations 1 and 2. The energy loss of 0.025% per foot of track was used to simulate a system with energy losses due to friction. With this information available, students could evaluate whether or not their coaster could climb a hill after traversing a distance along the track. Additionally, students used the spreadsheet to calculate the acceleration that riders would feel on different track sections.

The assembly environment students used is shown in Fig. 12. Students used ProEngineer™ to assemble their designs using part files from the design repository. As the students worked to create their designs, the workshop staff was made available in a ratio of 1 staff member for every 2 groups. During this period, if students requested the development of a new track section, the staff member would either work with the student to create a new section together or, if the section was more complicated, create it for the student. Constraints based on current design limits of
actual coasters were placed on the maximum height of the coaster (400 ft.) and maximum acceleration a rider should feel (4g). Most of the groups showed great enthusiasm in creating their designs, pushing back on the design restrictions. Many of the students found that the transition in the first drop had too small of a radius for people to safely ride the coaster. The limitation on the transition radius resulted in an effective maximum coaster height of 200 feet. Confronted by this real word limitation, students expressed frustration with the restrictions that were placed on their designs. This situation was used as a teaching opportunity for students to learn about the trade-offs that must occur as part of an engineer design process.

Although students started with a relatively small library of parts, the sample design shown in Fig. 13 demonstrates one of a wide range of possible design concepts. The student designs were evaluated by the workshop staff for creativity in concept, performance when compared to human tolerances, and whether or not a coaster train would complete the circuit. Each student group presented their designs at a session on the final day of the program where family and friends could come to see what the students had designed and ride the motion platform ridefile created as part of the physical simulation portion of the workshop program.

CONCLUSIONS AND FUTURE WORK

The workshop program was redesigned to more effectively target young women and provide them with an opportunity to see and experience state of the art engineering design through the use of cyberinfrastructure. The development and marketing of the workshop program as an all-women program resulted in more female applicants than the cumulative total of the previous six workshops, while using the same outreach path. This demonstrated the potential for greater outreach when creating a targeted program.

The redevelopment of the workshop curriculum focused on leveraging cyberinfrastructure and practicing engineers to provide a more engaging experience for workshops students. While the workshop included a significant amount of time spent on inductive learning activities, the findings of the review that led to the overhaul of the program were confirmed. Anecdotal data, from discussions with the participants and their families during the final presentations, gave the impression that there was a desire for even more informal learning activities. Informal feedback from participants and families also strongly supported the incorporation of informal opportunities for the participants to talk with potential role models.

The grand challenge format would have proven difficult to implement without a high ratio of staff to students while they worked on their designs. Students had varying backgrounds in computers, CAD, physics, and math. Having a large pool of support staff available to respond to questions and develop materials as needed created a dynamic learning environment where each group could experience learning at a level suitable to their experience. The frustrations that students had with real world limitations will present an ongoing challenge with any workshop program attempting to create authentic learning experiences for students. Real world constraints naturally limit design freedom, which can frustrate engineers of any level of experience. In future workshops, a session on how overcoming constraints drives innovation (e.g., New materials and designs were developed for roller coaster train wheels, as a result roller coaster designs could be taller and trains could travel faster without failing.)

Another additional benefit of the design of the workshop curriculum was the opportunity to incorporate ongoing research into the curriculum. Three undergraduate students participating in a Research Experiences for Undergraduates project, Mike Castellani (University at Buffalo), Jeremy Schueler (University of Missouri - Rolla) and Ayo Arumi (Drexel University) assisted in the development and testing of the digital design repository models and specialized interfaces that would be required for the workshop program. These undergraduate students worked in concert with Julia Goodwin, a local high school teacher participating as part of a Research Experiences for Teachers project, to develop instructional units that would be suitable for high-school students, but would still capture the essence of the ongoing exploration that is research in engineering design.

During the workshop, students also used Cyberinfrastructure that is part of ongoing research efforts. The use of a digital design repository in engineering education is a research effort that has been ongoing for several years as a partnership between Drexel University, Pennsylvania State University, University at Buffalo - SUNY, and University at Missouri - Rolla [68]. The motion simulation system is a component of multiple research efforts, including research in the use of simulation to treat Post Traumatic Stress Disorder [75] and to teach students about road vehicle dynamics [34]. The incorporation of research into the development and implementation of the workshop revealed to students that engineering design is a growing, dynamic field.

FIGURE 13. EXAMPLE STUDENT DESIGN
where creativity is important to success and problem solving.

The cumulative result of incorporating all of these components as part of a summer enrichment experience was the creation of a program that immersed students in the engineering design process. Using cyberinfrastructure, students were able to create and experience a motion simulation program and develop a virtual model of a roller coaster using leading edge digital design tools. In the future, the goal is to grow the workshop program to approximately 30 students per session to begin to investigate the effects of scaling the workshop from a small program to a large one. The mentor program will also be expanded, with hopes of having a different host each day of the workshop program. Finally, while the creation of the workshop program appeared to be a success, future versions of the workshop will include assessment components to more quantitatively measure the impact the program has on students’ attitudes towards engineering and their career choices.

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