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## ENGage LSU:

# HOW TO ORGANIZE AND IMPLEMENT AN ENGINEERING OUTREACH DAY FOR MIDDLE SCHOOLERS

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Although young children seem to have an inherent desire to explore STEM activities, most students lose interest in pursuing a career in these fields in middle school.[1] Exposing students to STEM experiences in middle school, and even earlier, can have a positive impact on their choice of career in the future.[2] For example, students who watched video interviews with STEM professionals increased their interest in pursuing STEM careers, most likely due to higher awareness of career options.[3] With the growing workforce demand for STEM professionals, it is important to reach children at this critical juncture in their development.[4] One reason for lack of interest is that most students do not have a good understanding of what engineers actually do. Since the petrochemical industry has such a large presence in Louisiana, students who do know a little about engineering lack awareness of the wide variety of disciplines within this large field. Many of these middle school students believe that an engineer can only get a job working in the petrochemical industry, resulting in missed opportunities to recruit promising students with interests in human health and the environment. Additionally, the majority of female students in engineering degree programs are pursuing majors in biomedical, biological, and environmental fields.[5] While 20.8% of all engineering bachelor's degrees in 2016 were earned by females, only 3.9% of graduates were African-American and 10.7% Hispanic; these numbers are far lower for women of color.[5] With the low percentage of females and ethnic minorities represented in STEM careers (14% and 5%, respectively)[6] and the high percentage of these underrepresented groups attending public schools in the East Baton Rouge Parish school district (87 schools and 42,000 students–89% ethnic minority; 81% African-American[7]), more students should be exposed to these types of engineering career possibilities. Universities can, and should, play a major role in increasing the numbers of students pursuing STEM careers, especially from minority groups, through community outreach and other educational events. In an effort to address this need, the authors have developed an outreach day (ENGage LSU) at Louisiana State University (LSU) that incorporated hands-on learning activities from a range of engineering disciplines including chemical, biological, mechanical, electrical, and environmental engineering. A hallmark of this outreach day is that all of the activities focused on bioengineering and nanoengineering with applications to clean energy and water, tissue engineering, disease diagnostics, and the development of new materials. The success of the outreach day was based on the involvement of young faculty members (11 in 2017 and 14 in 2018) partnered with undergraduate student leaders (17 in 2017 and 20 in 2018) who worked together to develop and implement hands-on activities to engage and excite the students.

## PROGRAM DESIGN

The design of ENGage LSU was the culmination of intense discussion between the authors and undergraduate leaders from the Society of Peer Mentors (SPM) at LSU. The goal was to construct a day that (i) had the highest impact for the middle school students, (ii) incorporated hands-on activities, (iii) exploited the expertise of the faculty in the College of Engineering (COE) at LSU, and (iv) utilized the research space in the university's new engineering building. The first step was to create a leadership team that consisted of the

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authors and three undergraduate leaders from SPM. This leadership team was responsible for naming the event, crafting the message and activities, and coming up with the program agenda (Figure 1A). The choice of date for the 2017 offering of ENGage LSU was dictated by the differences in spring breaks between LSU and the East Baton Rouge (EBR) Parish school district. The authors needed a day where the faculty and students were free from classes, but where the middle school students were still in class. Fortunately, the spring breaks between the two were different, which freed up faculty, students, and staff to participate in ENGage LSU. A similar approach was taken for the 2018 offering.

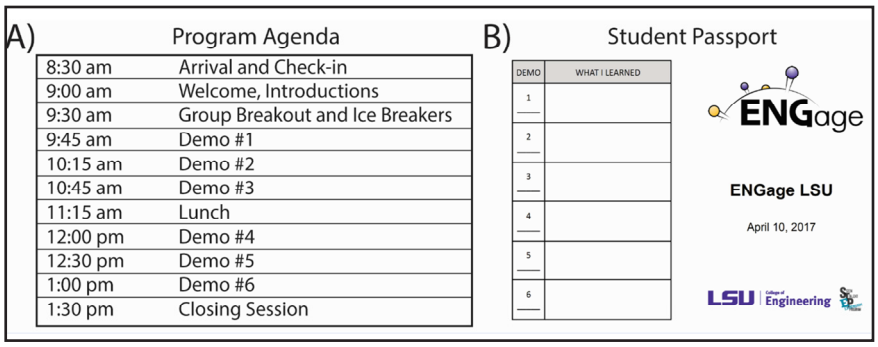


***Figure 1. Images of student passport.*** *Handout given to students at the start of the event giving the agenda of the program (A) and providing students with a passport to write reflections on each of the demonstrations they attended (B).*

The undergraduate leaders were also responsible for recruiting and training other peer mentors to act as group leaders for middle school students attending the event. Due to lab safety protocols and time restrictions for the schools, students had to be placed in groups (~8-14 students) and were only able to experience a subset of the possible activities. In 2017 there were 11 different demonstrations, 10 groups of students, and six time slots, which required that the team create a unique schedule for each group. A similar approach was taken in the 2018 offering for the 14 demonstrations and the 14 groups of students. Thorough planning included the order in which student groups moved around the building, which is quite large, and making sure that each group got to see a wide variety of activities. The leadership team devised a method of reflection for the students (Figure 1B) so the attendees could keep track of their activities and write down what they learned. Having a passport for students to record their experiences also enabled teachers to extend the teachable moments back in the classroom.

The authors then reached out to junior faculty in the COE to get tenure-track faculty members to participate in the event and lead the demonstrations. One advantage at LSU is the growth of the departments which correlates to a large number of assistant professors who are eager to develop outreach activities to educate the community. A mutual benefit for the participating faculty member is that this activity can be incorporated into the broader impact sections of their NSF proposals. For the 2017 offering, the authors identified 11 professors from five different disciplines including Chemical Engineering, Biological Engineering, Mechanical Engineering, Electrical Engineering, and Environmental Engineering with expertise in bioengineering/biomedical engineering and nanoengineering. In 2018, the number increased to 14 faculty with the addition of another engineering discipline: Construction Management. Some of these professors already had activities prepared while others required assistance, which was provided by pairing the faculty members with SPM members trained in K-12 outreach and hands-on activity development. The details for select activities are highlighted in Figure 2. The demonstrations were kept to ~20 minutes to allow for enough time for introductory lectures (~3-5 minutes), hands-on activities (~10-15 minutes), and a wrap-up (~3-5 minutes). The remaining 10 minutes in each demo slot was reserved for students to travel to the different labs in the building (~10 minutes) as outlined in Figure 1. The motivation for 10-15 minute activities was to keep the students engaged the entire time as well as to provide the attendees with the opportunity to participate in more activities.

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| **The Unbreakable Intravenous (IV) Fluid Bag: The Miracles of Plasticizers.** How do plasticizers alter the mechanical properties (e.g., flexibility) of polymers? Students will examine a plasticized poly(vinyl chloride) (PVC) intravenous (IV) fluid bag and a PVC pipe. The activity will explain why plasticizers, at the molecular level, alter the mechanical properties of plastic. |
| **Confused Colloids & Mad Magnetic Materials.** Particles which are 1,000 times smaller than human hair perform confused random motion. This random motion can be changed by electric and magnetic forces. Here we show how to form self-changing patterns and designs of the particles at liquid surfaces by applying invisible magnetic fields. |
| **Self-Cleaning Surfaces by Mimicking Nature.** Plants have been able to develop unique coatings that allow for self-cleaning to ensure their ability to convert light into energy. In this activity we will discuss how plants are able to dictate the motion of water in order to clean their leaves and how scientists are using these approaches for stain resistant clothing. |
| **Counting Cancer Cells.** How can engineers help doctors diagnose and treat patients suffering from cancer? A major challenge is the fact that no two cancers act the same, so a drug might work for one patient but not another. Our lab generates microfluidic devices that trap and detect single cancer cells to help doctors come up with personalized treatment plans. |
| **3D Bioprinting – Chocolate Demonstration.** We will explain how 3D bioprinting (3DBP) is different from 3D printing. In particular, 3DBP is able to provide complex patterns of vasculature and tissue architecture. We will use a widely available mixture as a bioink to produce fun structures–CHOCOLATE. |
| **Rapid Sand Filtration: A Simple but Important Water Treatment Technology.** How do simple materials like sand or charcoal pieces help remove small particles from dirty water? We will talk about how the sand filtration actually works and think about what it CAN/CANNOT remove from dirty water. |

***Figure 2. Titles and descriptions of select demonstrations given during the event.*** *Each activity was developed and led by an assistant professor within the College of Engineering with insight provided by the undergraduate peer mentors.*

Finally, the authors advertised the event to middle school teachers in the East Baton Rouge Parish school district and to local charter schools. This was accomplished by reaching out to contacts at middle schools that have established relationships with LSU in addition to contacting coordinators for local school districts. Planning began in January 2017, and the first outreach event was held in April 2017. Three charter schools in the Baton Rouge area (92 students) attended the 2017 outreach day. Planning for the 2018 offering started in August of 2017 that led to the participication of 5 East Baton Rouge Parish public middle schools and one charter school (6 schools; 165 total students) attending the 2018 outreach day.

## SUMMARY OF OUTREACH DAY ACTIVITIES

Due to the excellent planning by the SPM leadership team, the outreach days themselves went very well overall. During the welcome session the authors introduced students to different engineering disciplines and posed questions regarding the types of activities for which engineers are responsible. The welcome session also provided a good opportunity to give a pre-activity survey to gather baseline information on the students' interest and knowledge about engineering (see assessment section for more details). Prior to the outreach day, the authors asked the teachers to organize their students into groups of 8-10. The smaller group size allowed for more personalized interactions between the professors and students, and gave more opportunities for the students to ask questions. Another benefit of having small groups was that students could more easily navigate the lab space and interact with the demonstrations. Each group of middle schoolers was assigned an SPM guide to escort them to each demonstration around the building and to provide introductory and follow-up questions for each demonstration. Before going to their first location, though, each SPM guide led an ice breaker activity to get to know the students in their groups and to share a little about their experience as an engineering student as well.

A significant advantage of the outreach day was the strong commitment from the faculty participants. Each faculty mentor developed their own demo related to their on-going research efforts in the fields of medical diagnostics, tissue engineering, energy storage, water reclamation, and hard and soft materials. The demo included a title and description that was included in the student passport. Examples of a few of the demos are included in Figure 2, and images from the students performing the demos are shown in Figure 3. Every faculty member was assisted by graduate and undergraduate students working in their labs in addition to SPM members assigned to the faculty members. A strength of the activities was that some of them were performed in the faculty members' actual research labs, which gave the attendees a chance to see what an engineering research lab looked like. Not all faculty members have their labs in the main engineering building (Patrick F. Taylor Hall, PFT) due to the size of the LSU COE, so some of the faculty members gave demonstrations in classrooms in PFT. The authors decided to restrict the outreach day to a single building to reduce transporation time between activities. However, giving some demonstration in larger classrooms allowed for some more active demonstrations like the "Tumor microenvironment and drug resistance" activity in 2018 that let students participate in a tug-of-war to learn how cancer cells develop a resistance to drugs leading to relapse in cancer. The LSU COE provided safety glasses, and all students were told to wear long pants and closed toed shoes so that university safety regulations were upheld.

The student groups attended three demos, took a break for lunch (which the attendees brought with them), and then attended three more demos. One unfortunate aspect was that every middle school attendee was not able to experience all of the demos due to time constraints. The authors did their best to organize the students so that they were able to attend a mix of demos representing different fields of engineering (e.g., bioengineering, materials science engineering, and environmental engineering). An intent in future offerings is to increase the number and diversity of the faculty mentors; however, due to overwhelming interest from local area schools and limitations on bus availability, the authors expect that they will continue to have to cap the number of demos students attend. The final component of the outreach day was a concluding remarks session where the authors facilitated a discussion of new things that the attendees learned. This included a 're-ask' of some of the questions posed in the introductory session. As expected, student engagement and response was much stronger after the demos. This is especially impressive considering the students had

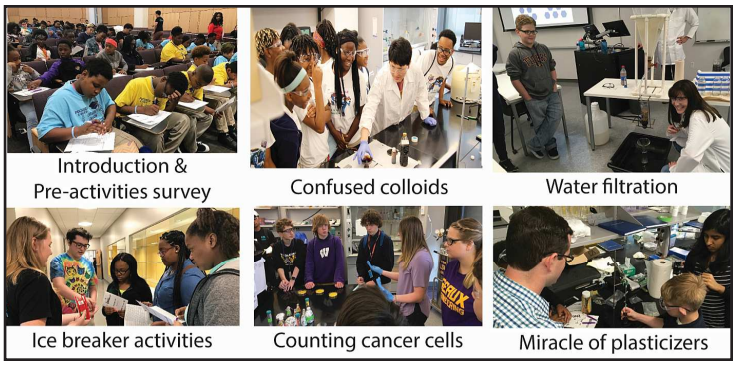


***Figure 3. Images from student activities during 2017 event.*** *(Left) Introductory events with the entire group followed by breakout sessions with peer mentors to get to know the groups. (Middle and Right) Images of students participating in the demonstrations that included both hands-on activities and learning about current methods in nano- and bioengineering.*

been going nearly non-stop for four hours! Finally, the students completed a post-activity assessment that will be discussed in the next section.

## ASSESSMENT

In 2017, three charter schools attended this inaugural outreach event, bringing 92 students, of which the majority were African-American and close to 50% were female. In 2018, six middle schools participated, bringing 165 students. Demographic data were collected from the teachers in 2018; 83% of students were ethnic minorities (mostly African-American) and 52% were female. Each student was given a short questionnaire during the welcome session to ascertain their general knowledge and interest in engineering prior to the event. All students also completed a post-activity survey to see if their interest or understanding changed after participating in this event. The same assessments were given in 2017 and 2018, so the students' reponses were combined for both years. One school arrived late in 2017, so pre-surveys were only collected from 67 students; only these students were included in the assessment so that pre- and post-comparisons could be made. In 2018, pre- and post-surveys were matched for 145 of the 165 participating students (one group had to leave early). Pairwise comparisons were made for each student to look for individual changes before and after ENGage LSU.

After the outreach event, 22% of students increased their level of interest in engineering, indicating that they wanted to learn more, and over half of the students (54%) showed an increase in confidence in their ability to become an engineer. Two additional questions were added to the survey in 2018 asking students whether they were planning to go to college and if they wanted to work as an engineer or scientist. 96% of students agreed with the first statement, and there was no discernable difference between their responses in the pre- and post-surveys. Alternately, there was a 56% positive increase in individual students' responses in the post-survey regarding whether they wanted to work as an engineer. Participants also increased their knowledge of biomedical and other less familiar types of engineering. Table 1 contains a summary of one question that was included on both the pre- and post-survey. Students were instructed to check off as many items from the list shown in Table 1 that they think engineers do. All possible choices were selected more often in the post-survey than in the pre-survey, but the largest increases were directly tied to specific demonstrations given during the event, as shown by the fold increase. For example, very few students initially thought that engineers help doctors diagnose and treat patients with cancer, work with things smaller than a human hair, and study the properties of plastics; students selected these responses 2-4 times more often in the post-survey. The large increase in students selecting these items in the post-survey shows that they left with a better understanding of the variety of engineering fields. The pairwise comparisons showed that students on average selected four more choices in the post-survey.

**TABLE 1**
**Comparison of pre- and post-survey responses to the question, "What do engineers do?"** Aggregate data for both 2017 and 2018 offerings of ENGage LSU (n=212).

| What do engineers do? (check all that apply) | Pre % | Post % | Fold Increase |
|---|---|---|---|
| help doctors diagnose and treat cancer patients | 22% | 82% | 3.8 |
| work with things smaller than a human hair | 28% | 81% | 2.9 |
| clean up oil spills | 24% | 61% | 2.5 |
| study the properties of plastic | 32% | 72% | 2.3 |
| drill for oil underground | 33% | 71% | 2.1 |
| make sure that packages arrive on time | 20% | 43% | 2.1 |
| build new internal organs for people | 35% | 73% | 2.1 |
| design systems to treat drinking water | 46% | 85% | 1.9 |
| develop processes to make chemicals | 50% | 89% | 1.8 |
| build roads and bridges | 58% | 87% | 1.5 |
| invent machines to do things in new ways | 67% | 91% | 1.4 |
| improve function of batteries and electronics | 66% | 82% | 1.3 |
| design cars and airplanes | 76% | 94% | 1.2 |

Students were also asked to list as many different types of engineering as possible both before and after the event. Table 2 shows the list of responses given to this question with the percentage of students who included each specific response on their pre- and post-surveys. The largest increase in responses was in biomedical engineering (3.5 fold increase), which is not surprising since many of the demonstrations focused on this area of engineering. On average, students named one more correct engineering discipline after the event with an average increase of 0.79. Values ranged from +8 to -6; nearly all of the negative differences were because the students named several types of engineers in the pre-survey, but did not answer this question on the post-survey. Although an increase of only one type of engineering may not seem like a lot, it is impressive that these middle school students were able to name an additional discipline in an open-ended survey question after only attending a 4.5-hour event. The results were very different when examining each school separately, however. As reported by the teachers from the two schools in 2017, one is a STEM Magnet and visits LSU regularly, while the other school had never visit-

**TABLE 2**
**Types of engineering fields listed by students on the pre- and post-surveys.**
Participants were asked to list all the types of engineering they could on both the pre- and post-survey. The fold increase between pre- and post-responses is in the third column. Responses coded as "other" included: technical, graphic, math, and physical. Aggregate data for both 2017 and 2018 offerings of ENGage LSU (n=212).

| Type of Engineering | Pre % | Post % | Fold Increase |
|---|---|---|---|
| Biomedical/Biological | 11% | 40% | 3.5 |
| Environmental | 3% | 10% | 3.5 |
| Industrial | 3% | 7% | 2.5 |
| Civil | 7% | 12% | 1.9 |
| Petroleum | 4% | 6% | 1.3 |
| Computer | 11% | 14% | 1.2 |
| Other | 28% | 33% | 1.2 |
| Mechanical/Aerospace | 43% | 50% | 1.2 |
| Chemical/Biochemical | 26% | 30% | 1.2 |
| Electrical | 17% | 17% | 1.0 |

ed LSU before and rarely, if ever, takes any sort of field trips. The majority of students from the magnet school were able to name more engineering fields after the event, while most of the other students struggled with this question. This trend was more apparent in 2018, with 5 underserved schools and one magnet school–only 29% of students from the underserved schools listed one or more correct engineering fields on the pre-survey, while 88% of students from the magnet school were able to do so. The students from the magnet school also named more engineering fields overall; several students were able to name 10-11 types of engineering, while no one from the underserved schools named more than five (the majority of students only named 1-3 fields). This demonstrates the need to reach out to underserved schools with diverse student populations to provide them with these types of much needed opportunities.

## CONCLUSIONS AND FUTURE WORK

To date ENGage LSU has been a tremendous success based on the assessment performed by the authors and the feedback from the teachers and principals from the three charter schools that attended. The authors observed a significant increase in student understanding with respect to different areas where engineers can make an impact, especially in the biomedical and environmental fields. Many of these students also increased their interest in pursuing a career in engineering as well as showed greater confidence that they have the ability to become engineers.

One major difference between the 2017 and 2018 offerings of ENGage LSU was the difference in planning periods. One lesson learned by the authors is that communication needs to occur much sooner, because most middle schools plan their field trips at the start of the academic year in August. During the 2017 offering of ENGage LSU, the late notice resulted in many schools wanting to attend, but not being able to because of a full field trip schedule. This was rectified during the 2018 offering that led to greater interest from a larger number of schools, especially those in the local public school system. In fact for the 2018 offering, a total of 320 students from nine schools initially signed up for the event. Unfortunately, the authors had to cap the number of students who attended at 200 due to limitations in the number of faculty members to maintain group sizes of ~8-14 students. There were only 165 students who participated because one school cancelled just before the event and most schools brought fewer students than they indicated on the registration form (due to illness, lack of permission slips, etc.). In future offerings, the authors will allow for 10-15% over the maximum number during the initial capping period in order to include as many students as possible. Due to this increased success, the authors worked with the LSU COE's Dean's Office to get additional financial support for ENGage LSU. For the 2018 offering, the COE provided meals for the faculty members and their helpers, snacks for the attendees, and 'swag' to give out to the middle schoolers.

Looking forward, the authors intend to continue to offer and grow the program. As such, if interest continues, the authors will examine the feasibility of offering the outreach day twice a year in both the spring and fall semesters. Based on the strong recruiting efforts for the 2018 offering and the excitement from the COE leadership, the authors consider this to be a strong possibility moving forward. Another possibility currently being explored is including faculty members from departments outside the COE such as Chemistry, Physics, and Biological Sciences with research expertise in the fields of bioengineering and nanoengineering. As the STEM fields continue to diversify and research projects become more interdisciplinary, the authors believe there is merit in expanding the activity outside of the college. This will provide more demos that will allow the authors to increase the number of attendees who can come per outreach day.

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