A Nanotechnology Summer Camp for High School Students: Activities Design and Student Feedback

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Abstract

For the past two years, Lawrence Technological University has hosted a nanotechnology summer camp program for high school students (Summer 2014 and 2015). The weeklong program is open by application to high school juniors and seniors. Students have the option to be residential or non-residential. During the five days the students learn about nanoscale phenomena, instrumentation, fabrication, and nanotechnology applications. Each day the activities follow a particular area related to nanotechnology: Monday - Introduction to Nanotechnology; Tuesday - Nanomaterials; Wednesday - Instrumentation; Thursday - Fabrication; and Friday - Energy. The unique feature of this camp is that it is team taught by six faculty from Biomedical Engineering, Biology, Physics, and Mechanical Engineering programs. Furthermore, current students at Lawrence Tech also participate and assist in the hands-on activities. Summer camp students are introduced to basic concepts of nanotechnology and also have the opportunity to use various nanoscale characterization tools such as the environmental scanning electron microscope and laser scanning confocal microscope. Student feedback was positive and indicated that the camp was successful, overall. The details of the camp activities, strategies for instructor-student interaction and exercises using sophisticated test equipment are discussed. The measures for student satisfaction and the results thereof will be highlighted. The authors will review the lessons learned during the past two years and share proposed modifications for future improvement.

Introduction

Within the last few decades there has been a remarkable amount of research done in the area of nanoscale (from a fraction of a nanometer to about 100 nm) science and engineering (NSE). The research has spanned all aspects of study including theory, simulations and experimental validation. These advances have opened exciting opportunities for scientific and technological developments in nanoparticles, nanostructured materials, nanodevices and systems. Increasingly the findings of these research have been incorporated into new products to render them desirable properties. The so called area of nanotechnology may be understood as the creation and utilization of functional materials, devices, and systems with novel properties and functions that are achieved through the control and restructuring of matter at the atomic, molecular and macromolecular levels.

Far-reaching outcomes for the 21st century are envisioned in both scientific knowledge and a wide range of technologies in most industries, healthcare, conservation of materials and energy, biology, environment, and education. At the same time, new dimensions of safety and ethical, social and environmental responsibility must be considered as nanotechnology based products become more common. There is a need to create the next generation of competitive workforce which understands and appreciates the potential of nanotechnology. One consequence of the recognition of this need is the inclusion of Nanotechnology in undergraduate education. Several academic institutions not only offer introductory courses in nanotechnology in their undergraduate programs but some, such as Lawrence Technological University, are taking the lead in creating minors and concentration in this field. The goal of these programs is to not only spark an interest in the students about this field, which may lead to pursuance of graduate degrees in nanotechnology, but to also open doors of high tech jobs which, alongside nanotechnology products, are becoming available.

Summer camps provide many high school students their first opportunity to learn about various disciplines in the science and engineering profession.[1-3] Universities and programs also use these opportunities to showcase their academic institution and attract students towards enrollment in the program.[4-6] Many programs, especially the ones with weeklong resident aspect built into the camp, also allow the students to explore the general college lifestyle and campus activities.[7] Other programs may focus on increasing female or minority participation in engineering.[8,9] Regardless of the specific circumstances, summer engineering program can be a great way to introduce engineering fields and expand student understanding of the college experiences.

Three years ago Lawrence Technological University created a taskforce to develop a minor in Nanotechnology for students from a wide range of backgrounds. The taskforce included faculty from various disciplines in the Colleges of Arts & Sciences and Engineering. A quick survey reveals that while many institutions (local or otherwise) offer Research Experiences for Undergraduates (REU) opportunities in nanotechnology, very few offer a summer camp which are typically focused on providing a broad overview of the field and are therefore, an effective tool for attracting high school students. Therefore, one of the actions taken by the taskforce was to introduce a summer camp in nanotechnology as a way to not only attract new students but also to develop nano-related learning modules, teaching resources and hands-on activities. Six of the taskforce faculty members took ownership of a particular area within technology and the weeklong summer camp was offered with ‘themed’ days. The involvement of multidisciplinary faculty not only reduced the burden of creating a new camp but was representative of the field of nanotechnology which blends engineering with chemistry, physics, biology, mathematics and many other fields of study. This was also an aspect much appreciated by the students that were involved in the summer camp.

Nanotechnology Summer Camp

The nanotechnology summer camp was initiated in Summer 2014 and was offered again in Summer 2015. The camp is weeklong (Monday through Friday 9AM-4PM) and is open by application to high school juniors and seniors. The students have the option to be residential or non-residential. Enrollment data showed that 5 out of the 16 participants are from out of state (31%). The goals of the camp are: (1) to stimulate the students’ interest in the area of nanotechnology, (2) to educate students (and parents) about the opportunities for industrial and research careers in this field, and (3) to attract students to the minor in nanotechnology which was recently launched at Lawrence Tech. During the five days of the summer camp the students learned about nanoscale phenomena, instrumentation, fabrication and nanotechnology applications. Each day the activities followed a particular area related to nanotechnology and was led by a different faculty from Biology, Physics, Biomedical, and Mechanical Engineering departments. An example schedule is shown in Table 1.

Table 1 Schedule of the Nanotechnology Summer Camp

<table>
<tr><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th></tr>
<tr><th>Introduction</th><th>Nanomaterials</th><th>Instrumentation</th><th>Fabrication</th><th>Energy</th></tr>
<tr><td>Day 1 Survey</td><td rowspan="2">Presentation: Nanomaterials</td><td>Presentation: Introduction of Microscopy Methods</td><td>Presentation: Introduction to Nanolithography</td><td>Presentation: Liquid Crystals</td></tr>
<tr><td>Presentation: Introduction to Nanotechnology</td><td rowspan="4">Scanning Electron Microscope: (i) Characterization of Nanofiber Scaffold; (ii) Characterization of Students’ own samples</td><td>Nanosphere Lithography Activity</td><td>Activity: Liquid Crystal Thermometer</td></tr>
<tr><td>Fact or Fiction Activity</td><td rowspan="3">Gold Nanoparticles (Colloidal Gold)</td><td rowspan="2">Presentaion: Ferrofluids</td><td rowspan="3">Activity: Preparation and Usage of Liquid Crystal Mixtures</td></tr>
<tr><td>Size and Scale Activity</td></tr>
<tr><td>Presentation: Matter at Nanoscale</td><td rowspan="2">Ferrofluid Activity</td></tr>
<tr><td>History and Timeline Explore Website</td><td rowspan="3">Electrospun Nanofibers for Tissue Engineering</td><td rowspan="4">Laser Scanning Confocal Microscope: (i) Characterization of Stained Cells and Drug-Delivery Particles; (ii) Characterization of Students’ Own Samples</td><td>Presentation: Piezoelectric Effect and Photoresistors</td></tr>
<tr><td>Activity: Surface Area to Volume Ratio</td><td>Presentation: Memory Shape Alloys</td><td rowspan="2">Activity: Piezoelectric Material</td></tr>
<tr><td>Presentation: Amazing Carbon</td><td>Memory Metal Activity</td></tr>
<tr><td>Activity: Graphene Exfoliation</td><td rowspan="3">Biodegradable Micro/Nano Particles for Drug Delivery</td><td rowspan="3">Cleanroom Visit</td><td>Presentation: Laser and Particle Image Velocimetry (PIV)</td></tr>
<tr><td>Presentation: Light Manipulation</td><td rowspan="2">Discussion</td><td>PIV Lab Tour and Demonstration</td></tr>
<tr><td>Build a Spectroscope</td><td>Exit Survey</td></tr>
</table>

A particular challenge of creating this camp was to make the complex concepts in nanotechnology accessible to high school students. As it can be seen in Table 1, for each topic a short presentation was given first, followed by a designed activity to provide hands-on experience. Many summer camps (at Lawrence Technological University and other places) are science based. The Nanotech summer camp also involves faculty from both science and engineering, and teaches both nanoscience and nanotechnology. In order to provide better engagement and dynamic interactions, current biomedical engineering students at Lawrence Tech also participated and assisted in the hands-on activities. This not only makes the camp manageable but also give the current students to act in the capacity of university ambassadors. The volunteering students also get experience with mentoring. The camp students get a chance to learn from college students which makes the atmosphere more relaxed and enjoyable for the camp students. The detailed description of each day's activities is presented in the following sections.

Day 1 - Introduction to Nanotechnology

A specific focus of the camp was to excite the participants about the potential of nanotechnology and discuss products and applications that incorporate nanotechnology for specific effects. Therefore, the activities on the first day were designed to serve as an introduction to the area of nanotechnology and to develop an appreciation of the nanoscale. During the second half of the day, activities were planned around demonstrations that use ideas and concepts that high school students are most likely to have encountered already in their coursework.

First, the students were made aware of the multidisciplinary nature of the nanotechnology which was reflected in the diverse group of faculty involved with the summer camp. Next, the presentation discussed books, TV shows and movies where specific reference to nanotechnology was made. Students were asked why most of the references in popular media were ominous in nature and all students correctly reflected that the reason is because 'nano' is too small. This perception was juxtaposed with scientific and economic aspects of nanotechnology which are overwhelmingly positive and optimistic.[10] The students participated in an activity where they were presented with various statements and asked to choose whether these statements were 'Fact or Fiction'.[11] These statements can be easily updated to reflect cutting edge nanoscience research. The activity is designed to generate discussion and interaction between students and with the instructor and provides an excellent segway into the discussion of nanoscale.

It is understandable that the perception of nanoscale can vary drastically since and object or a structure with dimensions less than 100 nanometers is too small to see with a naked eye. The camp students were given an Active Collaborative Learning (ACL) activity commonly referred to as *think-pair-share*. Each student was asked to first rank a list of 18 objects in the order of increasing size individually. After completing this task, the students worked in pairs to come to a consensus about their rank order. Finally, the instructor shared the correct ranking and the students used this to found the delta for individual and paired ranking orders (See Appendix A for the activity sheet). The results from this activity from year 2014 are shown in Figure 1.

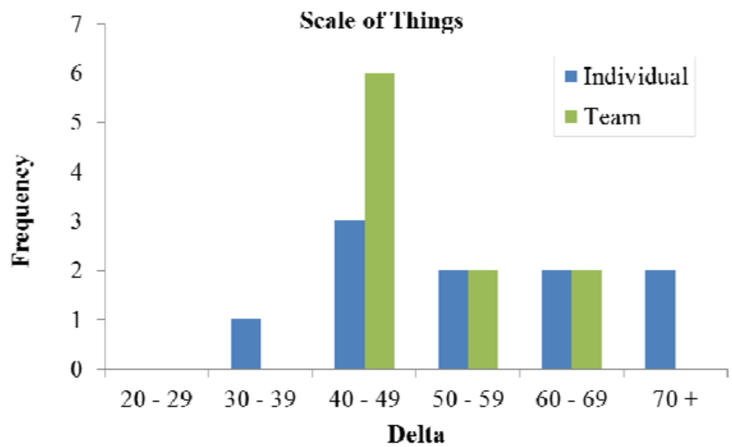


Figure 1. The frequency of responses from the Think-pair-share ranking activity are shown. The horizontal axis shows the sum of the differences between the student or pair chosen answers and the actual rank.

The results of the activity is indicative of lack of understanding of nanoscale particles as compared to things that students may already know of (bacteria, grain of sand). The activity was designed primarily to give an idea of the nanoscale. Furthermore, the ensuing discussion was tailored to highlight why nanoparticles have been researched for therapeutic applications and also raised issues of nanotoxicity. The idea of scale was reinforced through the video “Powers of 10” that shows the extreme of length scales, from intergalactic distance measured in light years to the sub-nanometer atomic nucleus.[12]

The next activity started with a presentation of historical artifacts (Lycurgus cup, Damascus sabre) that have embedded nanoscale particles. The students were provided with laptops and explored some of the other historical examples of nanotechnologies on Nano.gov website. Students learned that the interesting properties of these objects were to interesting physics at the nanoscale. One reason for these properties is the drastic increase in surface area-to-volume ratio (SVR) at the nanoscale. The idea was demonstrated with a simple rate of reaction experiment in which students compared the time it took an antiacid to dissolve in water if it was left whole, broken into pieces or crushed in a mortar. The fastest rate for the crushed sample, which has the highest SVR, was used to explain the *reactivity* of nanogold and the hue of the Blue Morpho butterfly.

The use of Graphene and other nanocarbons is becoming more common in consumer products. Students replicated the graphene derivation exfoliation technique, used by research Nobel winning research scientists.[13] Using a tape students exfoliated graphite flakes repeatedly until a monolayer was left (Figure 2). The graphene layer was transferred to a silicon chip with an oxide layer and was easily viewable with the naked eye.

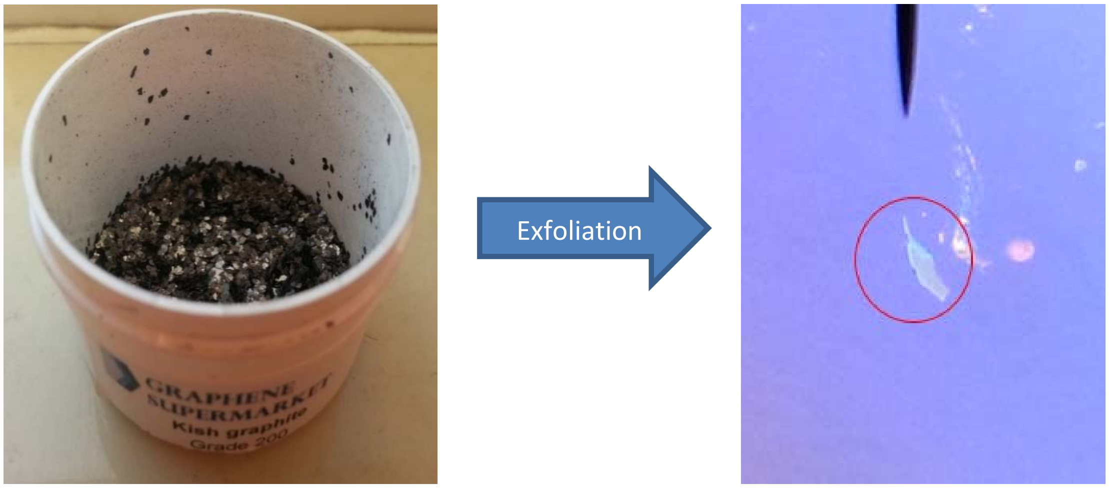


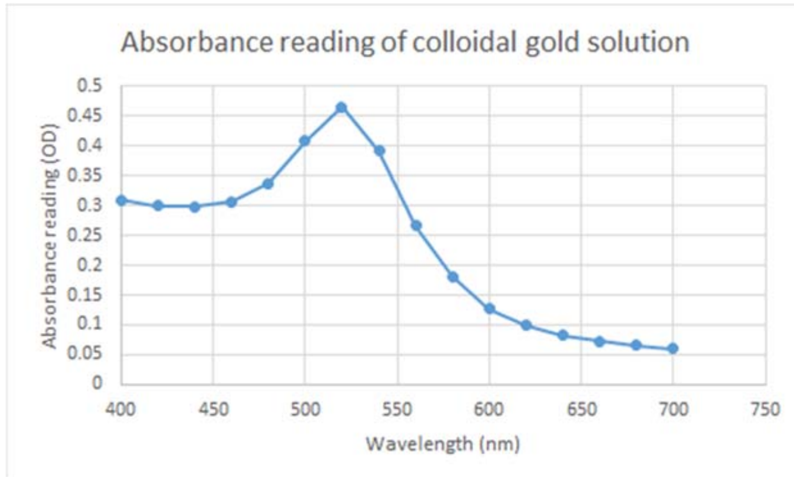
Figure 2. Micrograph shows a graphite flake (left) that was peeled to get a piece of graphite only a few atomic layers thick.

The final activity of the day revolved around the manipulation of light and the question posed by the famous Young's double slit experiment about the dual nature of light. The pre-activity presentation discussed ideas of diffraction and interference. The activity involved building a spectroscope to observe the spectra of various types of gas discharges. The tubes were made from mailing tubes with a CD as the grating material glued to one end of the tube. The grating caused interference of various wavelengths of light. On the other end of the tube, a viewing slit was created in construction paper to allow small amount of light to enter the tube. Students used their spectroscope to view the spectra of sunlight, florescent bulbs and various kind of lamps. The student enjoyed this hand-on activity and were able to take their spectroscope with them. The activity was useful because it showed how light in the visible spectra had wavelength in the nanometer range and how spectrometers can be used to identify different materials. The accompanying presentation showed how these concepts can be used to make polarized windows and get permanent colors through iridescence instead of pigments which are easily bleached.

Day 2 – Nanomaterials

The second day camp started with a brief presentation about nanomaterials, the cornerstone of nanotechnology. The students were introduced to the "top down" and "bottom up" synthesis methods for nanomaterials. Three types of nanomaterials were discussed on their synthesis, characterization and applications, followed by hands-on sessions where the students formed teams to conduct experiments related to these nanomaterials. Each team was led by a junior from Lawrence Tech who helped to ensure that all campers follow safety protocol when working in the lab. The team leaders also helped their teams' trouble shooting and data analysis during experiments when needed.

The first hands-on session was on the synthesis of gold nanoparticles and study of their unique optical properties. Following the Turkevich method,[14] the students added sodium citrate to boiling hydrogen tetrachloroaurate solution to obtain a colloidal solution containing nano-sized gold particles (Figure 3a). The students were excited to see the ruby color at the completion of the reaction. They shone a laser pointer through the colloidal solution to observe the "path" of light indicating reflecting of the laser by the gold nanoparticles. The students also tested the effect of adding electrolyte (such as sodium chloride) on the color of the colloidal solution. At the end, they measured the absorbance spectrum of the colloidal solution using a spectrophotometer (Figure 3b). As a take-home exercise, the students were also asked to estimate the amount of gold they synthesized in their experiment.



(a) (b)

Figure 3. (a) Students working in the chemistry lab; (2) Absorbance reading of colloidal gold solution.

Electrospun nanofibers were the second type of nanomaterials the students learned and practiced. After demonstration by the team leader, the students prepared their own biodegradable nanofiber samples collected on aluminum foils using different parameters. They could use these samples for electron microscopy characterization the following day. The students also learned about the application of these nanofibers in repairing ligament injury.

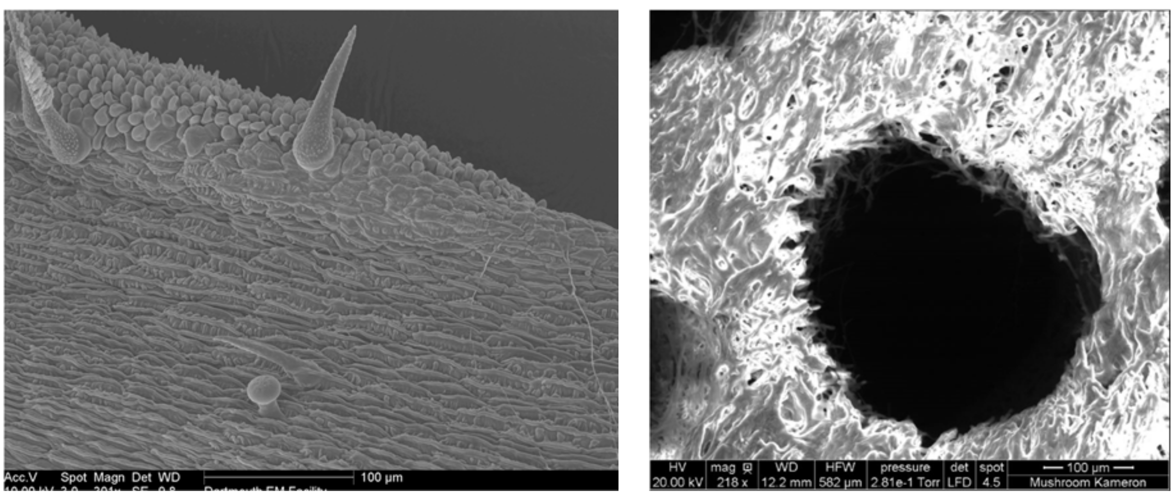
The theme of the afternoon session was micro/nano particles for drug delivery. The students first had some discussion on the advantages and disadvantages of different drug delivery methods. This led to the introduction of the concept of controlled release and how micro/nanoparticles could be used to achieve targeted and controlled delivery of therapeutic agents for enhanced effectiveness. The student teams made alginate beads by reacting sodium alginate and calcium chloride. The beads were loaded with a red food color dye ("drug"). The students then conducted drug release study of these beads in sodium citrate solution. The absorbance of the release samples was analyzed using a spectrophotometer. The team leaders helped their teams to plot the release curve.

Day 3 – Instrumentation

The third day of the camp concentrates on commonly used instruments in nanoscale characterization. The students were introduced to laser scanning confocal microscopy and environmental scanning electron microscopy (ESEM). The goal of this lab was to demonstrate how these instruments could be used to visualize and characterize nanomaterials. The day started with a brief lecture of different types of light microscopy, including phase contrast microscopy, fluorescence microscopy, and laser scanning confocal microscopy. This was then followed by a discussion of the different types of electron microscopes, including transmission and scanning electron microscope. Although the principles may seem abstract to high school students, the presentation was created with mostly schematics and photos, which made it very understandable and enjoyable. The lecture emphasized differences in scale measured by light and electron microscopes, and introduce students to different applications of each type of microscope.

After the presentation, students were divided into two groups of 5-10 students, each led by an instructor. During the morning, one group performed confocal microscopy while the other group performed ESEM. In the afternoon, the two groups were switched so the confocal group learned to operate ESEM and the ESEM group learned to operate confocal microscope.

To better engage students for SEM operation, students were asked a day before to select something they were interested to see. They brought flower petals, leaves, hair, dead ants, unknown worms, etc. The basic SEM operation was first demonstrated by the instructor; then, under the instructor's supervision, students took turns to load/unload specimen, scan images, optimize parameters or better resolution. The session was full of excitement and fun; there were quite a few wow moments, especially when students saw the compound eyes and hairy head of the ant, individual pollen stuck on flower petals. Some example SEM images acquired by students are shown in Figure 4.



(a) (b)

Figure 4. Examples images students took using the ESEM: (a) a piece of tree bark; (b) mushroom

The students also examined the nanomaterials obtained from Day 2 activity. In the confocal microscopy session, the students were asked to compare the size of the alginate beads with the size of mammalian cells which they had labeled with rhodamine-phalloidin and DAPI to visualize actin filaments and nuclei, respectively. They then discussed whether the size of their alginate beads were appropriate for drug delivery.

Day 4 – Fabrication

Before introducing the students to the concept of micro and nano fabrication on the Day 4 of the camp, what makes nanotechnology exciting, nanotechnology initiatives in US, applications and the career opportunities were presented.

Students had a mini lecture on micro and nano fabrication and then had a hands-on activity where they created masks with marbles and formed different patterns by using glitter. This activity mimics photolithography (Figure 5a).

During the remainder of the day the students also got to learn about ferrofluids and shape memory alloys through mini lectures and hands on experimental activities.

Day 4 at the camp is completed with a tour to the Smart Sensors and Integrated Microsystems (SSIM) Clean Room at Wayne State University, where the students got the experience fabrication activities related to MEMS, microsystems, microsensors and nano/micro integration technology (see Figure 5b).

(a) (b)

Figure 5. (a) Students mimic the photolithography process; (b) Students visiting the clean room

Day 5 - Energy

Last day of the camp had a theme of energy. The students were introduced novel materials with special functions (liquid crystal material, piezoelectric effect, photoresistors, etc.). Each topic was started with a brief presentation and team discussion of possible applications, followed by a hands-on activity for students to get better appreciation of the material behavior. There were usually three students in each team. The students were encouraged to form different teams to work with someone they did not collaborate in the previous days of the week.

The first topic was started with a question "What does LCD mean?" The students all heard about it at home or school however very few of them knew what the letters stand for. Because each camp student was equipped with a laptop which they may use during the week, many of them immediately started web searching and were reading about liquid crystal materials. After a short explanation and group discussion, the students were asked to prepare solutions at specific temperatures using the provided liquid crystal thermometer. This activity allowed students to see that the liquid crystal materials change color according to its environmental temperatures. The students were then given the necessary materials to prepare liquid crystal gel themselves. A step-by-step written instruction was provided to lead the progress (Figure 6a).

The students also had hands-on activities to learn about piezoelectric material and photoresistors. Presentation and video were first used to explain how piezoelectric effect and photoelectric effect happen. The room lighting was then turned off and the students worked in dark to exert pressure on a disk made of piezoelectric material to power up a small light bulb. Each team was also provided photoresistors and a multimeter. They measured the electrical resistance of the photoresistor under several lighting conditions (a fully illuminated room, a dimmed room, a dark room, and with the element completely covered in one's hand). The students saw the significant changes of the resistance performance. The students enjoyed both activities and had enthusiastic discussion about the possible applications of these special materials.

The last activity on Friday was about Particle Image Velocimetry (PIV), a laser based flow visualization technology. The students were first introduced light with different colors and energy, which are associated with their wavelengths. Presentation and videos were utilized to illustrate how PIV works to capture velocity field data. The students then visited the PIV Lab and were shown demonstrations of laser operation and flow analysis. During this activity the students were also trained with laser safety. Using a low intensity laser, the students also tried regular welding goggles / sunlight glasses to see their difference from laser protection goggles. The students learned the special caution and protection needed to be used when operating with laser system. An example of PIV image of water vapor flow out from a humidifier is shown in Figure 6b.

(a) (b)

Figure 6. (a) Students preparing liquid crystal material; (b) A PIV image of vapor flow out from a humidifier

At the end of the day, each student team was given 30 minutes to work together and prepare a presentation (5 minutes) to report out about their experience during the week. It was good to see that many students saved a lot of their images during activities in the previous days and shared their samples with other members. The students also summarized what they have learned, and were encouraged to recommend more activities for future nanotechnology camps. At the end of the camp, a certificate of accomplishment is presented to each student participant, and a group picture is taken.

Nanotechnology Summer Camp Resources

This section summarizes a list of equipment and tools that were used during the camp.

Environmental Electron Microscope (ESEM) Lab
Confocal Microscope Lab
Particile Image Velocimetry Lab
Chemistry Lab
Multimeters and other supplies
Absorption Spectroscopy - Demonstration Kit
Light Module Starter Kit
Ruby-Red Colloidal Gold Nanotechnology - Chemical Demonstration Kit
Methacryloxyethyl thiocarbamoyl rhodamine B, 100 mg
Nanoscale Drug Delivery Module Starter Kit
Ferrofluid Display Cell
Amazing Modern Materials - Multi-Demonstration Kit
Liquid Crystal Demonstration Kit
Chemistry, Physics, and Modern Materials - Multi-Demonstration Kit
Multi-Wavelength Laser Protection Glasses Goggles

Student Feedback

At the start of the first day of the camp, the students were handed a simple survey to specify their understanding of the field of nanotechnology (see Appendix B). Students were asked about their understanding of nanotechnology and the reason for their interest in the camp. The most common response was "*small objects*". A few student mentioned applications such as "*electron microscopes*" or technology used in *medicine* and *computers* while the risks of nanotechnology were absent from responses. The survey results were indicative of the perception of nanotechnology in general public that rely on newspapers reports and other media outlets to learn about an emerging technology.

In order to improve the student learning and collect valuable suggestions for future implementation, an exit survey was distributed to students to acquire their feedback and feeling about their camp experience. The full survey is shown in Appendix C. The students were asked to answer the following questions with scales 1 (least) to 5 (most).

- Please rate your overall satisfaction of the nanotechnology summer camp.
- How likely are you to recommend this camp to others?
- Did the camp help you get a better understanding of Nanotechnology?

The students also provided an evaluation to each activity they had during the week. They were asked that which day they learned most, and which day they enjoyed most.

The survey results indicated that the students were overall satisfied with the nanotechnology summer camp – with an average of 4.6 out of 5, as seen in Figure 7. One hundred percent of the students chose either scale 4 or 5 when asked about the likelihood of recommending this camp to other students (Figure 8). The majority of students felt that the camp helped them acquire a much better understanding of Nanotechnology – averaged 4.8 out of 5, as shown in Figure 9. 87.5% of the students chose the highest scale 5. One student mentioned that he/she would join Lawrence Technological University in two years.

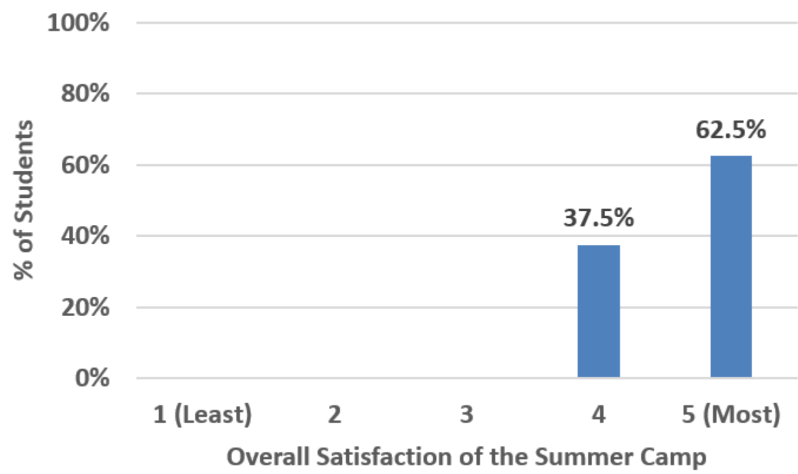


Figure 7. Student response to the question "Please rate your overall satisfaction of the nanotechnology summer camp."

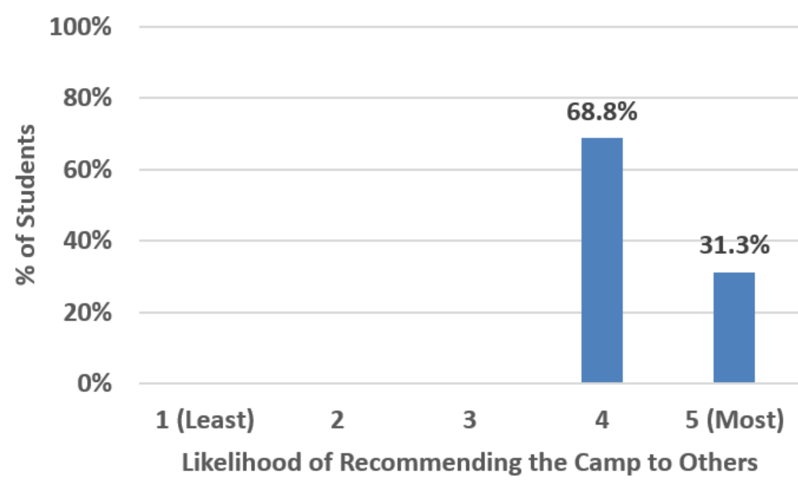


Figure 8. Student response to question "How likely are you to recommend this camp to others?"

It turned out that there were four activities the students enjoyed most (average feedback 4.8 out of 5): Biodegradable Micro/Nano Particles for Drug Delivery, Scanning Electron Microscope, Ferrofluid Activity, and Memory Metal Activity. Most of the students (39.1% of all responses) thought Day 1 of the camp was the most informative, and almost half of them (47.8% of all responses) agreed that Day 3 was the most fun. The results were expected because Day 1 was the overview and introduction session while Day 3 students got to practice the microscopes with samples they collected from all over the places.

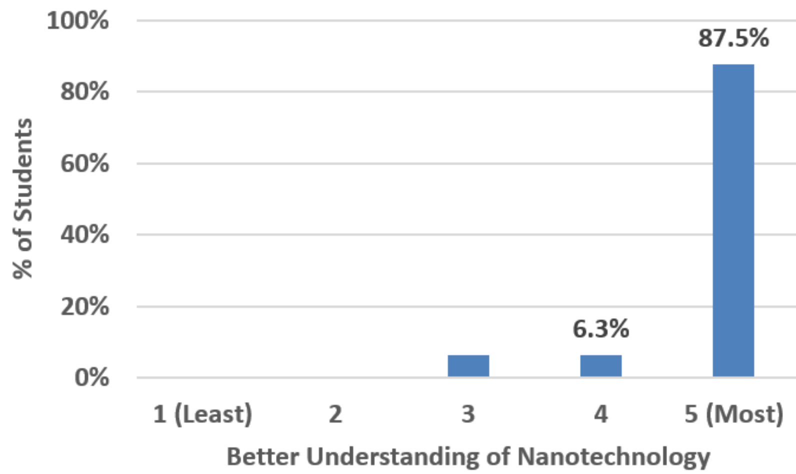


Figure 9. Student response to question "Did the camp help you get a better understanding of Nanotechnology?"

May students left written comments on the exit survey. Most of them were very positive. Some examples are shown below.

- "Having different people every day was really good being able to see the different backgrounds since nanotechnology uses so many science subjects."
- "I like all of it, and thank you – Might see me in 2 more years."
- "I had an overall good experience here and I learned a lot of new things that I didn't think I would know."
- "I liked that we had a lot of hands-on experience which is very good."

When asked recommendations for future improvement, some student preferred less lecture and adding more activities. Another suggestion was to "make sure to know the students' previous knowledge and experience" so that the instructor could avoid using terms they didn't understand, or spending time on materials they already knew. Therefore, it may be a good idea to add some more background questions on the Day 1 survey. Some students also would like to have more "scary or more dangerous" activities – the high school students are always looking for more exciting experience.

Other proposed modifications for future improvement include sending the introductory material to participants prior to the summer camp in order to enhance their scientific background and nanotechnology terminology knowledge. This will improve the understanding of presented concepts and related experiments during the week. Also, more direct assessment with technical questions will be conducted to evaluate the student learning besides their own perspective and satisfaction.

Conclusions

A nanotechnology summer camp program for high school students was developed and offered in 2014 and 2015. During the five days the students learned about nanoscale phenomena, instrumentation, fabrication, and nanotechnology applications. Each day the activities followed a particular theme related to nanotechnology, and team taught by six faculty members working in different areas. The survey results showed that the students' feedback were highly positive (overall satisfaction 4.6/5) and believed that the camp helped them significantly in understanding topics in nanotechnology (4.8/5). The most popular activity was the Scanning Electron Microscope when the students were amazed by how different things looked under high magnifications.

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Appendix A

Scale of Things

Objects	Individual		Pair		Actual
	Rank	Δ	Rank	Δ	
H - Atom					
DNA					
MEMS Gears					
Quantum dots					
Dust Mite					
Red Blood Cell					
E coli Bacteria					
Buckyball (Fullerene – C_{60})					
Human Hair					
ATP Synthase diameter					
Pollen Grain					
Length of Fibrinogen protein					
Intel CMOS Transistor (2011)					
Ant					
Carbon nanotube diameter					
Influenza virus					
Size of Au atomic nucleus					
Grain of Sand					

Appendix B

LAWRENCE TECH NANOTECHNOLOGY – SUMMER CAMP 2015

Day 1: Pre - Survey

1. What is the first thing you think when you hear Nanotechnology?

2. What do your perception of the nanoscale?

3. What made you want to attend a Nanotech summer camp? (Okay to circle more than one)
    a. Advised by Parent / Teacher / Mentor
    b. Heard about it on the News / Internet
    c. Personal Experience
    d. School Project
    e. Internship
    f. Other: ____

4. What are your expectations for the week?

5. How did you hear about the summer camp at LTU?
    a. Advertisement
    b. Email/Newsletter
    c. Facebook
    d. Family or Friend
    e. Newspaper or Magazine Article
    f. Website/Search Engine
    g. Other: ______________________

Appendix C

NANOTECHNOLOGY ENGINEERING SUMMER CAMP 2015

We hope you enjoyed the Nanotechnology Summer Camp. To help us improve the quality of the camp, please complete this survey. Thank you!

Statement	1 (Least)	2	3	4	5 (Most)
Please rate your overall satisfaction of the nanotechnology summer camp					
How likely are you to recommend this camp to others?					
Did the camp help you get a better understanding of Nanotechnology?					
How likely are you to pursue a minor or concentration in Nanotechnology when you get to college?					
Day 1					
Introduction to Nanotechnology					
Fact or Fiction Activity					
Size and Scale Activity					
Activity: Surface Area to Volume Ratio					
Build a Bucky Ball					
Build a Spectroscope					
Day 2					
Introduction to Nanomaterials					
Gold Nanoparticles (Colloidal Gold)					
Electrospun Nanofibers for Tissue Engineering					
Biodegradable Micro/Nano Particles for Drug Delivery					
Day 3					
Introduction to Microscopy Methods					
Scanning Electron Microscope					
Laser Scanning Confocal Microscope					
Day 4					
Introduction to Nanolithography					
Nanosphere Lithography Activity					

Ferrofluid Activity					
Memory Metal Activity					
Cleanroom Visit					
Day 5					
Liquid Crystal Thermometer					
Activity: Preparation of Liquid Crystal Mixtures					
Piezoelectric Materials and Photoresistors					
Particle Image Velocimetry Lab Tour					
Circle the day which was most informative	Day 1	Day 2	Day 3	Day 4	Day 5
Circle the day which you liked most	Day 1	Day 2	Day 3	Day 4	Day 5

Additional Comments and Suggestions to Improve the Camp: