

Getting Middle-School Students Interested in STEM Careers: Photonics, Lasers, and Optics; and Computer Networking

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Abstract

Baker College of Flint is now partnering with local middle schools to host half-day seminars intended to spark eighth-grade students' interest in pursuing a career in a STEM-related field. They attempt, in several hours, to expose students to a cooperative activity in a variety of areas. So far, we have presented half a dozen activities. Three more seminars are scheduled for early this year. (These seminars are in addition to more in-depth explorations offered to high-school students in our summer camps.) This paper describes the format and schedule of the seminars, several activities in optics and computer networking, and our plans to develop more activities and assessments.

Motivation

Our college has identified a need for more promotional activities that involve younger students. For some time, we had enrolled many 'non-traditional' adult students: those looking to upgrade or change existing careers. This trend peaked following the economic downturn of 2009 but has since largely ended. Our future enrollment is believed to depend mostly on 'traditional' students that continue their education immediately after high school, or even begin their college education during high school. Consequently, Baker College has strengthened relationships with local secondary schools, and renewed longstanding partnerships which have included robot competitions and summer camps. These schools include Carman-Ainsworth, Almont, and Beecher Middle Schools, and The STEMM Academy in Lapeer, among others. The seminars described here form a new part this promotional strategy, and are given to eight-grade students from Almont Middle School.

Format

Each seminar includes five activities, each from a different field of science or technology, and each with its own cooperative activity. Topics include: materials science; civil engineering; architecture; advanced manufacturing; electricity; computers and networking; and photonics, lasers, and optics.

For one morning, typically a Friday, about one hundred students visit campus, arriving mid-morning in several school buses. Seminars commence with a short orientation in a large classroom, where students are divided into five groups of about twenty each. Then each group starts with a different session, and rotates through all sessions in the same order, so that each

group attends each session. The sessions last only 22 minutes, with 3 minutes break in between. This is followed by a catered pizza lunch in the large classroom used for orientation. Students depart in the early afternoon.

Three seminars in this format were scheduled for winter and spring quarters 2016, most recently on Friday March 4.

Activities

One lesson involves the fundamentals of light: photonics and lasers. Baker College has an Associate of Applied Science degree in Photonics and Laser Technology, unique in our state, so we always try to feature it if we can. Several simple activities have been presented that fit within the short lessons yet demonstrate something worthwhile.

First, we start some videos to play in the background that are relevant to lasers. Since 2015 has been designated the “International Year of Light”, good promotional material has been created and posted on YouTube: “International Year of Light 2015 - Official Trailer” on the “Stichting FOM” channel, and “International Year of Light” on the “ouLearn on YouTube” channel, are perfect for a short session.

Safety

Any lesson with lasers, even the relatively safe hand-held laser pointers we use, should start with a few safety tips: don't point the beam near anyone's face; don't look directly into the beam, or even at a reflection; it is best to keep the lasers horizontal and near the surface of the table.

Prisms

We have several kits with optical prisms of various shapes (10cm diverging and converging lenses, equilateral and 45 degree right triangles, rectangles, and semi-circles). They are made of slightly smoky acrylic, so a laser beam going through the plastic is visible; with completely clear material, the beam would not scatter and would be invisible to the eye. These kits are passed out first, so students can play with various light interactions. Typically, students pile all the prisms into a single sculpture, then shine lasers on it so everything glows. This ‘looks cool’ but is not very educational. The instructor must explain that the shapes need to be laid flat on the table, and illuminated with horizontal beams by holding the lasers just off the table. Then the optical interactions are made more visible.

The rectangular prism demonstrates reflection and refraction;

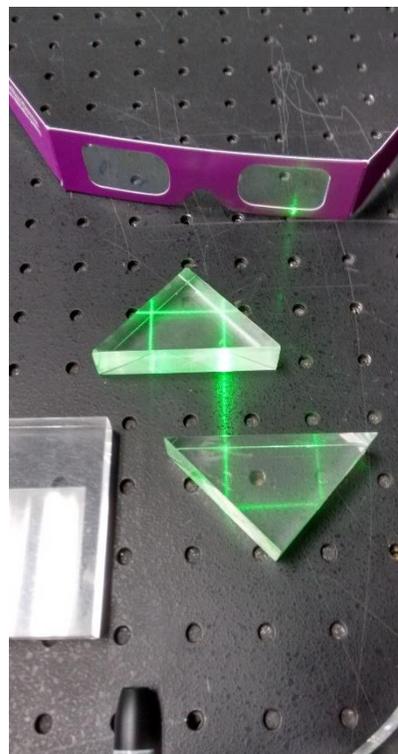


Figure 1

one can see how a beam bends toward a surface normal as the beam enters the acrylic. The instructor can explain this as the same thing that happens when a stick appears to bend underwater. The 45-degree right triangle can bend a beam twice, causing a complete U-turn. If students are interested enough, they can be challenged to arrange prisms in such a way as to shift a beam sideways without changing its direction. This can be done with two 45-degree right triangle arranged as a double Porro prism as in Figure 1. The instructor can then explain the application in binoculars. Best of all, shallow angles of incidence inside a prism give rise to Total Internal Reflection; the instructor can explain the most important application of TIR, which is fiber optics, the backbone of the Internet.

The two lenses demonstrate how refraction can be used to bend parallel beams of light to a single focal point. By laying the lens flat on the table (it is curved only in one direction), then holding the laser parallel to the optical axis of the lens and sliding it back and forth without rotation, parallel beams of light are sent into the lens, bent, and all converged at the focal point. Students almost never discover this on their own, but immediately understand it once they see it.

Diffraction Gratings

Cardboard glasses with diffraction gratings for lenses have become popular and inexpensive. They make everything viewed through them appear to have colored rainbow fringes. By themselves, they are fun toys. However, comparing the rainbow effects of various sources of light develops insight into the nature of light.

First, we ask students to look at the outside window; the continuous spectrum of daylight produces a continuous color fringe with - well - all the colors of the rainbow, as shown in Figure 2. Next, we ask students to look up at the ceiling light fixtures; the discrete spectrum of fluorescent lighting produces five individual colored images (red, orange, green, cyan, violet), as shown in Figure 3. Finally, we turn on our high-voltage gas discharge tubes and ask students to examine their colored light; the characteristic spectra of these tubes produce the signature colored lines of, in our case, hydrogen, helium, and mercury. In each case, the glasses spread these color images off to the side. For the gas discharge tubes, the effect is pronounced.



Figure 2



Figure 3

Time permitting, a laser pointer can also be shown through a diffraction grating to show interference patterns on a wall or screen. The instructor can explain the interference patterns, which are the basis of spectroscopy, and how they might be used to identify different materials.

Nonlinear Optics

Laser light is monochromatic; it contains exactly one color or wavelength. This can be demonstrated by shining a laser beam on surfaces of various colors. Green light shown on a green surface will be brighter than green light shown on a red surface, because the red pigment absorbs more green light energy. But the reflected light will still be green. Yet students, who in spite of instructions, tend to aim lasers at each other's clothing, might discover that green lasers sometimes seem to reflect yellow light. (This was discovered accidentally several times.) The instructor can explain that some chemicals in dyes, especially bright orange and pink dyes, absorb energy at the green wavelength, then re-radiate it a longer (yellow) wavelength. This is called non-linear optics. Students have fun 'testing' each other's clothing for the effect.

Tour

Time permitting, we show students various equipment we have in the lab that we cannot let them use: a high-powered fiber laser that generates the beam in a long yellow-clad fiber-optic cable; an argon-ion laser that produces blue-green light; and a neodymium-YAG system used to demonstrate nonlinear optic effects. We show them a picture burned into wood with the fiber laser by some of our AAS students, and talk about industrial applications of lasers.

Toys

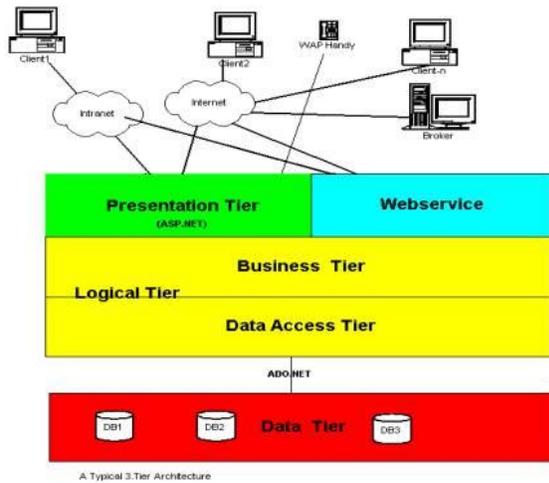
We have one laser pointer that is purple, and is good to introduce near the end of the lesson for novelty. We also have several optical gadgets that are more fun than useful: a laser pointer fitted with a diffraction grating that shows a bright rectangular grid of dots; a motorized multi-colored light designed for parties and stage lighting, and a light cube that shows animated patterns. These are very eye-catching, but we use them sparingly because they do not demonstrate basic optical effects.

Cyber Defense

For our Cyber Defense discussion, we diagramed a typical internet connection to a web site.

The purpose was to show students what transpires when their browser goes to a web site. The students were asked to go their favorite web site. We then had a discussion of what servers are involved to make the request from a user to the systems.

Figure 4 shows a typical three-tiered computer architecture which includes: Web Server (presentation tier); Application Server (logical tier); and Database Server (logical tier).



A typical page request comes from a client machine over the internet to the presentation or web service layer of the target website server. The request is then sent through the logical tier and finally to the database server.

The students then go to a web site for the demonstration. This includes the multiple network zones and how the traffic is sent between the systems and finally rendered within their browser. Figure 5 shows some finer details of actual web traffic.

Figure 4

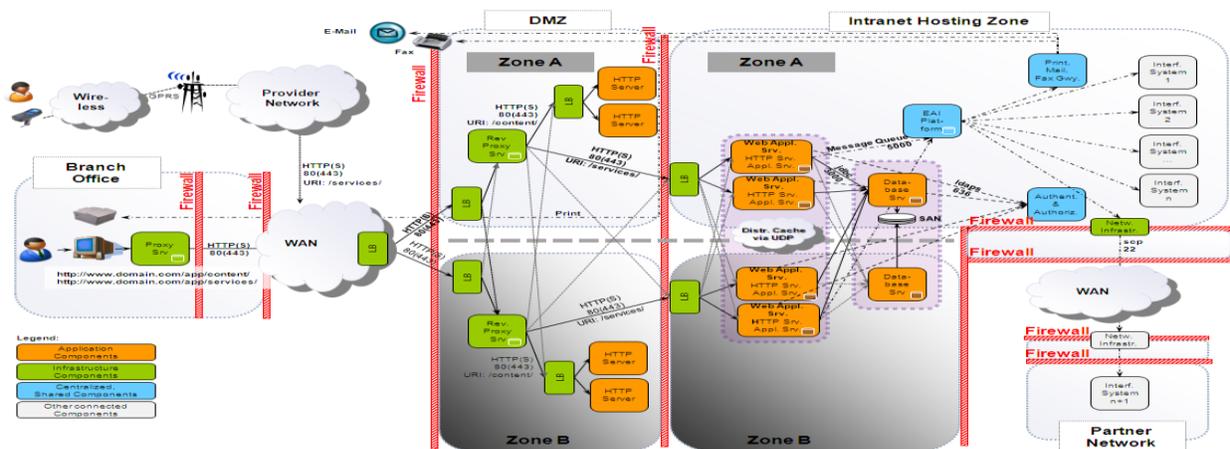


Figure 5

Future

Since more seminars are scheduled, more material can be developed. In the photonics lab, with our optical 'breadboards' we plan to put together a few permanent demonstrations with precise alignment. One good demonstration is a beam collimator that expands the diameter of a beam from a pinpoint to about one centimeter. This is for the purpose of reducing the divergence of the beam, at the expense of increased diameter. It uses a low-power helium-neon laser, two mirrors, a diverging lens, and a converging lens. With the collimator set up on an optical table, students can hold an index card in the beam to see the effects of the converging and diverging lenses. The system can be aligned by adjusting the mirrors so the beam reflects back along its original path all the way to the laser aperture.

Assessment

Future sessions will use surveys to record students' impressions before and after each seminar. This might give us ideas to improve our sessions, and help us determine the effectiveness of the seminars as a whole. We will pose statements, and ask the student to strongly agree, agree, be neutral, disagree, or strongly disagree. Pre-seminar assessment statements will include:

- I currently have a good idea of the type of career I want to pursue.
- I have already given thought to a career in a technology-related field.
- My current career plans are to go into _____ or _____.
- I am interested in learning more about possibilities in STEM-related careers.

Post-seminar assessment statements will include:

- Compared to this morning, I am more interested in a STEM career.
- I learned about things I had never even heard of until today.
- I learned more things about subjects I already knew about such as _____.
- My two favorite sessions were _____ and _____.

Several more seminars are scheduled for the winter and spring quarters.

Conclusions

This paper describes the motivation for outreach activities designed to influence young students toward pursuing STEM-related careers, as well as the format and content of a series of half-day seminars for eighth-grade middle school students. It describes the increasing cooperation between our college and local primary schools, and shows example activities in the fields of photonics and optics, and computers and networking. Finally, it summarizes some basic assessments that will be implemented to track the success of the format and provide ideas for improvement.

Biography

Mr. Ellis Love is an Instructor in the Department of Engineering & Technology at Baker College in Flint, Michigan. He teaches courses in Electrical Engineering and Electronics Technology. Prior to joining Baker College, he worked in the industry, mainly at Motorola. His areas of interest and study are embedded systems, and photonics and lasers.

Mr. Doug Witten is currently a Ph.D. student studying computer science and informatics. Doug received an M.S. degree in computer science from the University of Michigan - Flint and a Bachelors degree in computer information systems from Baker College. Doug is also an Adjunct faculty at Oakland University, University of Michigan - Flint, and Baker College. Doug's research interests are centered around Health Information Exchanges, message transport, networking and big data. In his spare time, Doug loves to play the guitar, spend time with his family and he is a rabid Michigan Football fan.

Dr. Pattabhi Sitaram is Associate Professor and Chair of the Department of Engineering at Baker College in Flint, Michigan. He worked in the automotive industry, primarily at General Motors, for fifteen years as crashworthiness simulation and methods development engineer, and a Subject Matter Expert for plastics, composites and foam materials. He has taught extensively at both undergraduate and graduate levels in Civil and Mechanical Engineering disciplines. His research interests include Finite Element Analysis & Design, Crashworthiness, Vibration, Structural Stability, and Plates & Shells.

Dr. Anca L. Sala is Professor and Dean of Engineering and Computer Technology at Baker College of Flint. In addition to her administrative role she continues to be involved with development of new engineering curriculum, improving teaching and assessment of student learning, assessment of program outcomes and objectives, and ABET accreditation. She is a founding member of Mi-Light Michigan Photonics Cluster, and is active in the ASEE, ASME, and OSA professional societies serving in various capacities.