Photonics Classes in High School

Pearl John, Laser Instructor, Columbia Career Center, Columbia, MO
Richard Shanks, Laser Instructor, Columbia Career Center, Columbia, MO

ABSTRACT

In continuing the development of a three-year high school photonics program, the Columbia Area Career Center (Missouri, USA) faces the challenges associated with introducing a new subject area to career technical education in the public school system. The program was established to address the severe lack of Laser Electro-Optical Technicians (LEOTs) in the local manufacturing industry. Its goals are to increase student awareness of the expanding job opportunities available in photonics and optics, teach skills needed for the field, and foster close ties with industry and post-secondary institutions. This paper examines the success of the program to date and outlines the problems associated with teaching an advanced curriculum at the high school level.

Keywords: high school, LEOT, laser, photonics, Columbia Area Career Center

1. INTRODUCTION

The three-year Photonics Program at the Columbia Career Center was initiated by Dr. Don Bristow, the Director of the Center, with the intention of training students to become Laser Technicians. As a result of providing industry with a 16-week LEOT Training Course, the Career Center decided to offer a high school course in Laser Technology. The aim of the program was to give the students a one-year head start in the field by speeding up the training process for LEOTs to address the urgent need for Laser Technicians in industry – generally throughout the nation, but particularly in Columbia where a multinational manufacturing company needed technicians.

This paper deals with the challenges faced and successes gained throughout the development of our three-year program to teach Photonics to high school students. The challenges faced by the Career Center and its instructors have been wide-ranging. We have needed to educate not only our students, but also our local community. In order to educate our students we have had challenges with regard to available curriculum, textbooks and equipment, and the developmental stage of students. In order to educate our public we have had to deal with issues such as the lack of knowledge of the field of photonics, funding problems, lack of knowledge of the program in the community, and a lack of diversity in the students who have been attracted to our program.

Are we succeeding in training technicians? If our program is succeeding, our successes have been the result of using Problem Based Learning techniques, working with Student Projects, using a team approach which has involved all supporting faculty at the Career Center, having a strong Advisory Committee, having support from Industry, having a safety committee, having an outreach Program, and most importantly attracting quality students to the program.

2. PROBLEMS/CHALLENGES

We face three broad challenges: First, the need to educate our local community about photonics; second, the lack of available curriculum and text books for our students; and third, the general teaching issues that relate to the developmental stage of the students.

2.1 Educating Our Public

Teaching our community about our Photonics program is proving to be an important task. This community consists of local teachers, administrators, businesses, school counselors, parents and students. Educating

Seventh International Conference on Education and Training in Optics and Photonics,
Tuan-Kay Lim, Arthur H. Guenther, Editors, Proceedings of SPIE Vol. 4588 (2002)

these groups has been necessary in order to ensure that we have enough students to teach, a diverse student group, financial and other support from local businesses, and support from the students' parents.

The Career Center administration and their instructors have worked hard to change the general perception of the local community toward technical and vocational schools. In the States, "Vo-tech" schools have generally been seen as non-academic and directed only at students who are not college bound, but, at the Career Center we are attracting more gifted students. Approximately 70% of the Career Center's students are now college bound. Career Center student enrollment figures continue to rise with this change in perception - last year's enrollment at the Center totaled 1564 students, while this year there were over 2000 applications. The Photonics Program now has over 100 students.

The Career Center relies on students from sending schools – our student population is assembled from 6 surrounding High Schools, and the students are transported to us for 90minute classes on a daily basis. We continue to have to educate the sending schools, parents and counselors about the new program to ensure that student expectations of the course are realistic. We have had our 15-year-old students coming into program at the introductory level thinking that they will be spending their time playing laser tag, and then finding the hard work a bit of a shock. It is necessary to ensure that counselors are fully aware of the academic demands of our program. We are also working with junior high school science teachers to encourage more of their students into our classes.

We are obliged by state requirements to ensure that we recruit students from minorities and encourage young women into the program, and we are happy to be working on this. The number of girls in the program is increasing from year to year, but we still have about 90% males in our classes. We are trying various initiatives to tackle these issues. These initiatives include, but are not limited to: demonstrations by our students in Junior High Classes; inclusion in local science competitions; newsletters to parents; talks to parents and prospective students on 'Back to School Night'; "Skill Expos'; professionally produced brochures; tours for Science Teachers, students, counselors and administrative staff; Adult Education; an Advisory Committee; and appearances on local television and articles in the press and on the radio.

While Photonics and Optics are an integral part of modern society, the industries themselves seem to be almost invisible to the general public. We continue to have to educate our community about not only our program, but also about the field of Optics and Photonics. Most people do not know what Photonics means.

We are aware that this lack of knowledge about the field is a general problem, not specific to our community, and we have taken part in a recent National Science Foundation (NSF)-funded joint SPIE and Optical Society of America (OSA) workshop whose goal was to develop a joint-society, long-range strategy to stimulate informal optics education programs. These initiatives would help raise the profile of the Photonics and Optics industry with the ultimate aim of solving the urgent need for more trained technicians.

2.2 State Approval for the Photonics Program

Recent improvements have been made to our curriculum as a result of the Missouri School Improvement Program, through which our school and program are accredited. The Columbia School Improvement Program has required an improvement in the documentation of our curriculum to ensure that a qualitative review of the best practices in schools is possible. We have had to ensure internal alignment between our Introduction to Laser Technology course and Photonics I & II courses with Career Center Electronics and Physics Technology curricula. As well as conforming our curriculum to the Center for Occupational Research and Development (CORD) Photonics Skills Standards, we have had to align it with the SHOWME standards – Missouri's own teaching standards. Dr Boyer-Stephens, the Career Center's Administrative assistant has been instrumental in accomplishing this task.

The 1994 Missouri Outstanding Schools Act led to the development of the A+ Program, which aims to encourage students to continue post-secondary education in a technical area in order to train the technicians that Missouri needs. The sending schools that supply our students have joined the A+ Program and now have very specific requirements for documenting our essential skills to ensure that student success is measurable. The benefit of the A+ program for students is free tuition at their local community college. This will be a tremendous benefit to our students, as our local college is beginning to offer a two-year Associates Degree in Photonics. Students will now be able to avoid the considerable amount of debt that an average American student amasses at college due to large tuition fees.

2.3 Curriculum Subject Matter

There is no available curriculum aimed at high school students for a three-year laser technology/Photonics program. The "Introduction to Laser Technology" course was originally designed by Neal Miller, based on the 1995 CORD's National Photonics Skill Standards for Technicians. The curriculum has utilized CORD's teaching materials – including "Principles of Technology Unit 13," "Introduction to Laser Technology" and "Geometric Wave Optics" and a variety of other educational materials from the Scientific Laser Connection, labs from "Lase" by Gareth Williams and Malcolm Cornwall, and a variety of labs and projects developed by the instructors. All three courses within the program are constantly being revised to meet the changing needs of the students. There are also no suitable textbooks available; materials tend to be either too simplistic or aimed at too high a level. However, we encourage students to use CORD material as their reference, augmented by trade journals, videos, publications and internet research.

2.4 Developmental Stage Of Students

As well as the difficulty obtaining suitable curriculum aimed at our students, we also have to deal with many general teaching issues that are unique to the educational developmental stages of the age groups we teach. This affects our curriculum, the way that we teach certain concepts, and the cost of our program. Our students are mostly in what has been termed a 'concrete' phase of learning. They require prompts that are more visual and tactile to help them learn, in comparison to older students in the more 'abstract' phase of learning. This issue is most evident in teaching mathematics.

2.5 Math

One of the most difficult aspects of teaching this program to this level of student is the math. At this level the students are very concrete in their thinking. The math does offer a means to initiate more analytical thinking; however, the majority of students expect math to be of the "plug-and-play" type. One of the difficulties is that the students are not experienced in using math as a language. From a very young age they are conditioned to merely solve problems as presented, when in our own classes they must be able to know what the solution means. For example, when they use the formula E=P/A, they at first see a "plug-and-play" type of formula. They don't readily see the relationships. The CORD material is presented in a way that requires a student to have an understanding of those relationships when presented.

The labs that accompany the CORD units are excellent and are used in this program; however, the students need to see applications for these labs. To make the labs carry more meaning, the program moves to holography as an application. Students are required to calculate the exposure times for their holographic film. The irradiance formula is revisited and analyzed to find a use meaningful to the student. The film used in the program is Slavich's PFG-01 material; with a film sensitivity of $100\mu J/cm^{2.}$ A PD200 Ophir power meter with a detector head with a know diameter of 1cm is used with this application. By making the units in the irradiance formula common to the film sensitivity, the students can see how the relationship,

$$P/A = \text{film sensitivity/time or } \mu W/cm^2 = (\mu J/cm^2)/\text{ seconds}$$

can be derived. More simply put,

$$P/A = f.s../T$$

Simple algebra derives,

$$T\ (\text{exposure time}) = f.s \times A/P$$

Since the film sensitivity (100 μJ/cm^2) and power meter (area of the Ophir detector head = 0.785 cm^2) are constants, the formula can then be further simplified to,

$$T=78.5\ \mu J/P.$$

The students are encouraged to derive this as a group with little help from the instructor. Upon completion the students are generally surprised, since this is the formula they had used the year before in "Introduction to Laser Technology," and they now understand where it came from. This exercise produces valuable learning. The students have a re-enforcement of information learned during the previous year, their derivation of the exposure formula re-enforces the irradiance formula, and they produce an actual product using their learning.

The students can now see math as a language that describes the real world and they can see how math is also like the tools they use to set up the equipment. This practical application is the key to enable the students to learn the math comfortably. The most difficult part of designing this curriculum is tying all the labs together using applications that the students find engaging. As of yet, not all labs are tied to applications; this is an ongoing effort.

2.5.1 Math Skills Specialist

One of the great benefits of working in the Career Center is the availability of our Math specialist, Theresa Yeager. Yeager has designed labs for all three courses in our program; utilizing laser/Photonics applications to help teach math required concepts. She has observed that,

"Many of our students are unable to see the value of taking more than the two required mathematics courses in high school. This attitude can initially be a problem. We also face a wide disparity in student mathematics ability levels. However, when students enroll in a course like lasers or phonics they develop a different attitude towards mathematics, because it is related to their course. This provides valuable motivation and immediate relevancy. I am always thrilled to see students who claim that they hate mathematics working diligently on mathematics problems with such intensity and determination."

2.6 Workplace Expectations

In the summer of 2001 the Columbia Career Center had several meetings to deal with in-house curriculum issues. One of the main issues that affects this program is what has been termed, "workplace expectations." Staff has always been mandated in a technical school to teach students the general skills that they will need in order to succeed in any workplace. Through some surveys and meetings, a school-wide standard was implemented. This standard is a compilation of the important issues raised by the instructors from various programs housed at the Career Center. This device can be weighted as the instructor sees fit for each individual program.

The workplace expectations as devised are behavioral in nature and address many issues. The areas covered are: 1). Attendance, punctuality, and preparedness; 2). Perseverance to complete quality work; 3). Openness, flexibility, & willingness to change; 4). Responsibility for own learning; 5). Responsibility for own language and behavior; 6) Independent and collaborative work habits; 7). Safe and efficient work environment. Each of these areas is addressed with two or three more criterion statements. Each instructor has the choice of using whatever part is most important for that particular program, usually set forth by the Advisory committee. These items are then tallied in an Excel format and used as a percentage of the students' grades.

2.7 Equipment

The cost of a program of this nature is a major investment. In the beginning, the program was funded through an Enhancement Grant, which was provided, by the State of Missouri and local funding. This grant was made available as the result of the Schools Improvement Act of 1993, which was developed, to help upgrade the technical programs serving high-demand occupations. The Missouri Department of

Elementary and Secondary Education (DESE) has been instrumental in seeing that the program has been funded through the grant. However, funding has recently dried up from this source because, while there is a documented need nationally for Laser Technicians, there is less documentation for a local need. Many companies are unwilling to document that they have a need for laser technicians for proprietary reasons. We are currently looking for alternative methods of funding. Our program has been very fortunate to have people who understand this problem and are willing to find the funding. This still does not help the program in terms of acquiring equipment. We live with fixed budgets and only acquire necessary items and then we must rely on industry equipment donations, which are few and far between. We must thank Newport Corp., Optoform, and Integraf at this time for their assistance; their help is greatly appreciated.

The equipment that we use in Photonics I & II is predominantly of industrial quality rather than educational. The students see the value of good equipment when trying to accomplish difficult tasks and ask for the better equipment. The careful handling, maintenance, and storage of equipment by students is critical in making the students responsible for their work. The proper handling of the equipment is stressed repeatedly, not only because of the cost of replacement but also because of the availability of use for the labs. The students realize very quickly the difficulty of completing a lab without the proper equipment; this awareness does spur better handling of the equipment. The students are given specific procedures for the handling of equipment, such as: the required use of carts which helps decrease breakage by reducing the distance the equipment could fall; the optics are never to held over concrete; students are to make sure that everyone around them is made aware that they have optics in hand; students are to ensure that they always mount optics as low to the table as possible, and never touch optics with flesh.

The maintenance of the equipment is completed whenever possible by the students. Often the equipment is repaired as part of a lesson plan especially if the item is needed for a particular lab. This adds a welcome troubleshooting component to any lab. The more difficult repairs are handled by the instructor after school hours sometimes with help from interested students or Advisory committee members. Strict guidelines for storage must be set for the students to follow. Specific places for each item must be marked, preferably with graphics of the equipment. The use of carts helps the students to keep their equipment organized and gives them a way to put the equipment in the proper place easily. The instructor must be vigilant on this point to give the impression that a clean equipment room is important. It is equally important that the instructor does not find equipment for the students so that the students will rely less on the instructor and work harder to keep the equipment in an organized fashion.

2.8 Safety

Safety is a primary concern and daily challenge. We have tried to work up to the best possible standards of safety. One instructor was sent on a Safety Training course by the Laser Institute of America (LIA) to become trained as a Laser Safety Officer. As a result of this training a Safety Committee was established with LIA's Dr. Ken Barat as an informal advisor. The Committee consists of students, parents, industry safety advisors and career center faculty. Career Center support staff, instructors and students now undertake a comprehensive Laser Safety training Program to raise safety standards in the lab. We are also currently in the process of developing a safety manual and our aim is to train students to reach Industry's safety standards. Tim Buol, the Chair of the committee believes that:

"The tools and habits we learn early (hopefully the right one's) carry over to future endeavors."

Regular tests, pop quizzes, safety competitions and the use of assistant Laser Safety Officers provide the core of our safety program. Students are tested academically on their safety knowledge, and practically on a day-to-day basis when working in the lab. All Introduction to Laser Technology Students take part in a quarterly safety competition for prizes and are awarded for having no safety infractions. The safety competition encourages the students to look out for the safety of their peers – if they see an infraction they are encouraged to report it. The competition is considered 'fun' and encourages responsibility, students help each another correcting each others mistakes before the instructor has a chance to see any breaking of safety rules. During holography projects each class assigns a Laser Safety Officer's assistant to ensure that students are safe during lesson times. We can never stress safety enough in our classes due to the age-group of our students.

3. SUCCESSES

The successes of the program include the fact that we have three consecutive years of Photonics Education available for our students. We also use Holography as an application to almost all areas of Photonics that we teach. We have based much of our curriculum on project work, inspired by Problem Based Learning (PBL) techniques in which the instructors were trained, and we have an excellent relationship with local industry. These are some of the strengths that we feel indicate that our program is successful.

3.1 Having a 3-year program allows us to revisit material at a higher level

One of the greatest benefits of the program is having three years of courses available to our students. USA education is based on a 'credit' system. In order to graduate from a Columbia, Missouri high school at age 18, a student must have accumulated 22 credit hours. Students are able to take up to 5 credits in laser technology that will have a tremendous effect on their schooling.

3.2 Revisiting concepts.

Each course that we teach builds on previous knowledge. Introduction to Laser Technology builds on the Science Curriculum Light Unit that students have had in their junior high schools. Our Photonics I & II courses benefit from the students grounding in Introduction to Laser Technology. This 3-year program allows us to revisit concepts taught previously at a deeper level. For example, both basic and advanced Holography is taught at the Introduction to Laser Technology level. Students make single-beam reflection holograms, Dennisyuk holograms, and diffraction gratings, and at the end of the year make split-beam reflection holograms. In order to calculate exposure times for their holograms students are provided with a formula. They produce the holograms in groups. In Photonics I, students make split beam laser transmission holograms using more advanced equipment. They also calculate exposure times by working out the formula for time and use an irradiance lab to derive the formula for time exposures. They use microscope objectives instead of concave mirrors to spread out the beams, and learn about advanced handling and cleaning of optics.

In Photonics II, students make split-beam laser transmission holograms to produce interferometric images for non-destructive testing methods. Students now have to produce set-ups individually, rather than in groups, calculate exposure times, use microscope objectives with pinholes in spatial filters and collimating mirrors. Each year a new set of skills and level of difficulty have been added to the holography projects.

We also teach irradiance and light-theory-based labs - including reflection, refraction, diffraction and polarization - at every level of instruction. In Introduction to Laser Technology, students graph the expansion of the beam over a set distance in comparison to white light. In Photonics I, the beam irradiance is calculated on a raw beam hitting a small portion of the detector head. Also, the beam is expanded using diverging optics to greater than the detector head, and irradiance is calculated at 4 distances from that point. In Photonics II, students use the irradiance and beam diameter to calculate and design optical systems. The same format is followed wherever possible to build upon previously learned knowledge.

3.3 Holography /Self Esteem & Motivation

Holography as a 'corner stone' for our Photonics Program because of the great benefits it provides for students.

Being able to make holograms is a great motivation for students. Students on the "Introduction to Laser Technology" course appreciate the creative freedom of being able to choose their own holographic subject matter. Students are encouraged to bring in personal, valuable objects – objects that have a story attached for their first hologram. Talking about their subject matter helps build a sense of community in the classroom. The last holography project involved students bringing in photographs of family or friends to use as a subject for shadowgrams. This personal approach strengthens the understanding that students are learning for themselves – learning is not being imposed upon them. It helps to break down the barriers between school and home-life.

The Photonics I & II courses allow a much greater degree of freedom to pursue holographic projects, due to the structure of the course and class sizes. Students are given one day a week to work on their own research projects and students work on their holography individually rather than in groups. Photonics students also have the opportunity of working with more powerful lasers and professional grade equipment

This element of the curriculum has proved most successful; last year two of our Photonics II students submitted research papers to the SPIE annual conference and Mike Walk gave his paper on Strain/Displacement via interferometry – testing a carabiner. Mike used holographic interferometry to non-destructively test climbing equipment to gauge when the equipment needs to be retired. Mike is a climber and wishes to provide a low cost service to voluntary organizations to test aging equipment. His project consisted of making numerous double-exposure, single-beam reflection holograms of the climbing equipment under different amounts of pressure to simulate different loads of weight.

Other student projects have included the design of a beam path enclosure to make high-powered lasers suitable for use in the classroom and other safety devices, shutters for lasers to use with holography, and the production of cylindrical and animated holograms. Last year two students helped in the writing of an educational web site, with the aim of publishing their research projects on color holography experiments. Students have also opted to try to build lasers and research light theory. Students have had to write an abstract for their research project for approval by their instructor, develop a product and write a paper that they present to their instructor and classmates at the end of the project. The freedom to do a research project fires student's enthusiasm. Another of the benefits of developing a research project in High School is that students will receive support and tuition with no extra cost if their project becomes marketable. This is in contrast to many colleges, which will help patent inventions, but may take up to 90% of the financial rewards.

The objectives for instruction in holography include, but are not limited to: safety training, understanding of light and wave theory, optics and equipment handling, communication skills, research skills, analysis of data and recording skills, problem solving and team-work skills. All of these skills are considered essential to the Photonics industry and holography is listed as one of CORD's National Photonics Skills Standards for Technicians .

3.4 Problem Based Learning.

Staff at the Career Center were trained in Problem Based Learning (PBL) by Dr. Maurita Miller. The recognizable issues in PBL are messy real life problems with a 'hook' to appeal to students. We have used this training to enhance our curriculum, and we base many of our units on solving problems.

3.4.1 Business & manufacturing project

One of the aims of the program is to foster knowledge of the real world. This is done in sever al ways, one of which is a manufacturing project. The students started the project in the Spring of 2001, four weeks before Mother's Day. The students started with a PBL (Problem-Based Learning) project and were given few parameters for the project. They were required to use a Carbon Di Oxide Industrial Laser System in producing gift items for Mother's Day; and they had to be ready to deliver the last product the Friday before Mother's Day. They were given no further information in order to encourage student-generated questions. The students were prompted to take control of the learning process and document their questions and discussions. The documentation was an effective tool for starting the project in an organized manner, giving direction to the project, and allowing the students to set the rest of the parameters needed to be successful.

The instructor was placed in the role of facilitator and the students became in-charge of the production. A leader was chosen; however during some rather heated discussions a new leader stepped up with solutions and a plan to everyone's satisfaction. From then on, the group had co-leaders. As the project continued, the students were given additional information as was appropriate. As an example, some of the students were doing more than others and complaints were beginning to arise. Since the students were going to share in the profits, inequalities were recognized. The facilitator explained that, to be fair, they would have to decide as a group on a standard that would be fairly applied to everyone and their work habits. The discussion was all that was necessary; all found something useful to do that would further the goals of the group and was acceptable to all. The facilitator was no longer the deciding factor in this area. Surveys were conducted for product viability and pricing. From this data, the students analyzed their market, what the market would bear, and what products would sell. A catalogue was devised and stands set up to sell the product by order. During this time the other students were learning the operation of the ULS 25 (CO_2 cutting and etching system, Universal Laser Systems 25W) and the associated Corel Draw program. The rest of the students had various duties including researching poetry, finding graphics, image manipulation, product finishing, public relations, advertising, and accounting.

Important objectives were achieved in this project that related to the students in a real world sense. The students got a sense of the difficulties of starting and running a business. In this project they each realized they had a job to do, but were not limited to that job. They found that each would have to do more than just his or her job to succeed. This project allowed them to function in roles that they don't normally assume in high school - to be employer and employee – and that allowed them to see both sides of these roles. They experienced a workplace and the difficulties of running it. Functioning with other people becomes critical in teamwork and is not always easy. The students found this to be one of the hardest aspects of the project. Conflict management then becomes a main teaching point. The students must develop a strategy for solving the conflict so that work can resume. They learned to respect each other's strengths and compensate for weaknesses to such a degree that they grew to rely on each other. Hardly anyone let the team down. The students saw how laser applications are applied in a 'real world' business sense and how to succeed in a team.

The project in one of the classes was completed with much success raising over $230 after expenses. All aspects of the project were documented in their logbooks. The students were assessed on logbook write-ups and daily productivity. In the wrap-up, the students expressed their satisfaction over a job well done, and talked of the difficulties in running a business. This was their first exposure to actually running a business, and they talked of the difficulties of timetables, product finish, employer-employee relations and customer satisfaction.

All the psychomotor skills - sizing materials, cleaning optics, focusing of unit, operation of system, product preparation and finishing - are of great use to industry. These are skills that industry expects, but not the only ones desired. Our advisory committee has told us on repeated occasions the importance of the students understanding business and recommended that they take a business class as part of post-secondary education.

One of the other great benefits of this project is the teamwork that must be present for success. Regardless of how well the students liked or disliked each other, they understood the necessity of working together. The incentive was there to work together because of the possibility of being paid. In all the classes this was found to be true, and they all were paid, albeit some more than others. Several of the students stated that they received great value from the experience. The same type of expression came from the classes that were less successful. Because their success was directly tied to the sale of product, the inadequacies could be seen very clearly. The students readily saw their errors and had solutions during wrap-up discussions. This project contained a myriad of problems requiring solutions before proceeding ultimately to the last product sold and delivered. Every class communicated during wrap-up about how their group could correct the mistakes "next time".

This is the real success of the project, since the students knew the project was not to be repeated for them. They did go beyond analysis and developed solutions for what were perceived as the problems encountered. The perception was formed that, had they proceeded differently at specific times during the project, they would have been more successful. This explains the occurrences of; "Next time…" and "If this project is done again…" in their logbooks.

By using applications that are real and engaging, the students start with very concrete concepts. This allows them to feel comfortable and confident. Once the students solve the first set of problems encountered in the project, they realize there will be more and start to anticipate the next set. The students had become accustomed to this and when the end came they went the extra step by explaining how their project could then be improved.

3.4.2 The Bridge Project

Introduction to Laser Technology students are given a project to construct a laser sculpture, a laser-light bridge in the classroom. Students are given a performance date and asked to design a structure to span the length and the height of the room. Several drawing projects and team building exercises are then given to the students to encourage their creativity and to help them prepare for the project. The motivation for the students is that they will have an audience. Audience numbers usually range between 50-60 people.

Once the project is outlined by the teacher the students are encouraged to think through the steps they will have to take to complete the task. With prompting from the instructor the students suggest that they will each have to take on a different role or perform a different job. The job titles chosen by the students usually include: Designer, Chief Engineer, Construction Manager, Safety Manager, Equipment Manager and Foreman. Students pick a leader and everyone is given a job by their peers. All students then work on individual designs for the bridge which are then judged, adapted and re-designed to make a single group design. Once the design is agreed upon, it is transferred to a floor-plan and students then establish what equipment is needed to realize the project. Next comes the measuring out and building of the structure. The project takes approximately two weeks of instructions for the 'every-other-day' classes and a complication is that all the four classes need the same equipment. Therefore students cannot leave their equipment out during construction but have to make it available for others. This encourages a sense of competition between the classes to see who will construct the 'best' bridge, it also trains the students to care for the equipment. Finally the bridge has to be built, displayed and put away within the 90minute class period, which takes an enormous amount of hard work. The project cannot be done by a few students, it has to be done as a team effort and there is a real struggle as students learn how to work together efficiently.

On completion of the project students feel a real sense of pride in their achievement. The bridges usually consist of at least 10 red and green Helium Neon lasers and an argon laser. Mirrors are mounted on magnetic bases attached to the ceiling and floor using a scissors lift. Students donned hard-hats and drove the lift around the room to attach mirrors to the ceiling. One year the students included a waterfall from scaffolding. The usual response from their audience is 'cool'.

The learning objectives for the project include, but are not limited to: safety awareness, teamwork, problem solving, measurement, leadership skills, research, beam alignment, goal setting and time-management. We believe the project is a success because of the usual benefits of problem-based learning: the teacher becomes a facilitator and students are then responsible for their own learning. Students are motivated to do a good job. The performance earns students respect from their instructors and peers.

3.4.3 Student Projects

The nature of the labs restricts the students to a narrow means of creativity and analysis. While this is good in the confines of the units being covered, it sometimes frustrates the students. They feel they are doing pieces of a puzzle with a predetermined end. This too is good in the confines of the material being covered. It was felt that they needed something more creative to accomplish or something that would allow the students to explore the area in the field that really excited them, hence the formation of student projects.

Fridays are dedicated to student projects, with a discussion on ideas, how to develop them, the scientific method, and research. Every day worked on the project is documented in the logbook for possible future reference (also this is a main portion of assessment) and this point is stressed. This is probably the best method for the students to see the value of the logbook. The logbook becomes the central coordination for the project. After a few Fridays spent on research and an idea has been formed, the students are required to write an abstract of fifty words concerning the project they want to accomplish. The instructor can check the validity of the project, equipment availability, and possible time constraints from the abstract.

One of our best successes in this area was with a former student, Mike Walk. Mike's project was to try and predict the possible breakage of a carabineer using interfermetric holography. Mike spent two years researching and producing his interfermetric holograms. Without the logbook to document his many successes and failures, the project would not have been completed. His dedication to work and documentation resulted in a paper presented in the year 2000 at the SPIE Conference held in San Diego, shortly after his high school graduation. All the students are encouraged to explore their chosen ideas as far as they can, some having better success than others, however, they all gain from the experience.

3.5 Logbooks

Another of the aims of the program is that students work toward becoming independent of the instructors. We want them to become world-class learners. Students have little exposure to independent learning at this age level and this makes any project difficult for them at first. In order to aid students learn strategies to help them with independent learning we focus on the importance of using documentation as a problem-solving tool. Through discussions with several sources a particular format for documentation was instituted.

The format was introduced to one of the instructors when he was a student under Pat Berger at Indian Hills Community College Technology Center, Ottumwa, IA. This format follows a precise structure: Title, Date, Name (author), Lab Partners, Objective, Equipment List, Procedure, Data, and Analysis. The students are required to purchase a composition book of either the wide rule or the grid format. Further requirements include: 1 the use of a ballpoint pen. 2 The use of straight edges for all drawings and graphs. 3 The elimination of personal pronouns. 4 Filling both sides of the pages with work. When used in this form and if strictly followed the logbooks become a legal document. Students are told examples of scientist's finally being acknowledged for their work after long-legal battles because of their log books. This alone is a great incentive for the students to do their best in the logbooks and the results are often excellent. However, a pretty logbook is rather useless without good data and a thoughtful analysis. The students can see this and work hard to accomplish this task.

The logbooks were discussed by our Advisory committee at the start of the program The consensus of the committee was one of approval, from industry members to parents. The industry members present related the importance of documentation and talked of the similarities of formats. The main difference was that the student's documentation was written in a logbook and industry used computers. Through further discussion it was revealed that industry also encouraged their employees to keep a logbook, as the information was often easier to retrieve. The members were impressed with the student's progress with documentation, as time elapsed. Documentation is an employability skill and is also helpful for the students when applying for post-secondary education.

In the summer of 2001 one of our students, Renee' Holzhauser (a junior at the time and a soon to be Photonics 2 student,) had gone to San Diego to tour San Diego University. Renee' took her logbook to show the professors her work. During the tour she showed them her logbook, the professors were visibly excited about her work. They were so anxious to have her attend the university they asked her if she would like to help unpack, set-up, and fire, a recently arrived laser. Renee' was very impressed with this and has plans to attend San Diego University in the fall of 2002.

The logbooks have many benefits including: improving written and language skills, fostering attention to detail, safeguarding student's work and providing students with their own reference material. The logbooks give the students something concrete to return to when the labs or material presented become too abstract. When students reach Photonics II, the logbooks have become an integral part of the everyday business and the students take great pride in the appearance and content of the logbooks. The process of documentation is taught over a two to three-year period. The logbook format is the first piece, making sure to write "Title:" and then the title of the lab, then "Name:", etc. After the students get a firm handle on this the next step is filling in the correct information in the first parts of the format. Next "Objective:" and "Procedure:" are stressed for a longer period of time. At first the objectives and proce dures are given, the procedures are stressed a great deal and re-enforced with standard operating procedures (SOPs) for turning on the lasers and developing procedures given to the students. As the labs become more difficult the students are required to write their own procedures and later their own objectives. The “Data:” portion of the write-up is also difficult until the students see the use of tables and graphs. The students see this very quickly the first time they have to explain the data to a third party with little understanding, i.e. the students explain the labs that day to any tour groups. The most difficult area for the students is the “Analysis:” and this is the part that is stressed most by the instructors. It is here that individual ideas are expressed and creativity is encouraged. They are required to think, which can be a challenge at times.

3.6 The Advisory Committee

The Missouri Department of Elementary and Secondary Education requires all technical programs at the secondary level to have an advisory committee. This advisory committee consists of people from industry, parents, students, former graduates, administrators, program instructors, instructors from post-secondary institutions, and other instructors that help the program. The committee meets once a quarter to discuss issues concerning curriculum, safety, future employment, post-secondary opportunities, and other issues that arise.

The advisory committee is one of our best resources. The help that members provide is immeasurable. Committee members provide feedback on general curriculum matters, lesson plans and other many issues. Members have also helped repair equipment.

The industry members of the advisory committee helped with the manufacturing project by stating the importance for students to have some business experience. Even though the skills learned from the project are not part of the National Skills Standards, the members felt the introduction of the project to be a very useful addition. All agreed that exposure to running a business would help the students later in school and in their future careers. In general the students that graduate from this program are college bound. The members agreed the major thrust should be towards preparation and articulation with local colleges.

Last year the company with representatives on our Advisory Committee offered two of our students an opportunity to job shadow their workers for a day. The offer was made to students who were 18 years or older. The job shadowing experience afforded the students a chance to see the work first hand and talk to technicians. The students returned to class and shared what they had learned with the other students, which was extremely beneficial for all concerned.

4. EXTRA-CURRICULA ACTIVITIES

The extra-curricula activities that our students take part in are extremely beneficial to individual student’s success. Our students are encouraged to mentor other younger students, compete in local competitions, and take part in organized outreach programs and sign up for our student organizations.

4.1 Saturday Science & Outreach

Every other year the Photonics program has taken part in a University of Missouri initiative called “Saturday Science”. The goals of Saturday Science are to encourage more young women to consider careers using science. Over the course of three Saturdays the Career Center invites approximately 100 8th grade students - 50% of which are girls – to make holograms. Three instructors have worked with up to 15 of our students to ensure that each Saturday Science student leaves with a hologram and a better understanding of the field of Photonics. The Saturdays are extremely beneficial to the program – they encourage the girls especially, to consider taking Introduction to Laser Technology. Our students teach others to make holograms, giving them a sense of pride and underpinning their own knowledge, and most importantly, they are paid for their work. A testimonial from one parent supports the belief that the Saturday Science experience is of benefit to our students;

> “The Laser Tech and Photonics Students were obviously proud of their accomplishments and of the curriculum and were eager to talk about their classes and teachers.…I am glad the Laser Technology presentation is part of the Saturday Science series. I was impressed by the knowledge and skills of your students and by how eagerly they

conveyed their interest in laser technology to the Saturday Science Group." Ann O'Dell. March 4 2001.

4.2 Student Organizations

4.2.1. SPIE High School Chapter.

The Columbia Area Career Center was the first institution in the world to have a high school student chapter. Membership offers the following opportunities:

Networking with Professionals, Help finding a Dream Job Money savings, special member rates on conferences, publications, and continuing education courses. Scholarships and Grants Information on upcoming events, Society news, critical technical resources for your career, An Exchange of ideas with fellow students, faculty, and professionals. Chapters can be used to attract speakers and are eligible for additional support from SPIE.

We currently have about 20 students involved in our SPIE High School Chapter and most of them are working on a group project to produce an Interactive CD Rom on Teaching holography to other students and teachers. This project has been given a grant by SPIE to help fund production. The CD includes film footage of students making holograms, safety information, information about holograms and holography theory, trouble-shooting and advanced set-ups. The students are learning – in essence another problem based learning project.

4.2.2. Skills USA/VICA

Skills USA-VICA is a national organization serving a quarter-million high school and college students and professional members who are enrolled in technical, skilled, and service occupations, including health occupations. Benefits for members include the following opportunities: Job contacts and networking, competing in the Skills USA Championships at the local, State and National levels, development of professional and leadership skills, and increased self-confidence, scholarships, awards and honors, recognition from peers, educators, and community leaders, access to a national employment network with job postings and job-hunting resources, a student professional newsletter, travel, meet new people and make new friends.

The students gain valuable experience learning how to run a professional organization. This is done through many meetings on the local and state level. The organization is student run and they are also responsible for the fundraising needed to operate the club and the trip to competitions. These competitions are among other students from technical schools. Many of the competitions require the students to stand and deliver in front of small audiences giving the students much needed exposure to public speaking. Also stressed in the club are employability skills and speakers from industry explaining the importance these skills. Our students have placed respectably in a number of these competitions.

5. CONCLUSION

Is our Program a success? Of course we like to think that it is, but how can we measure the effectiveness of our curriculum and our teaching? Officially, the Missouri Department of Elementary and Secondary Education assesses the effectiveness of the program by recording the number of students that we have in college, studying a related subject, in related employment or in the Military. Statistically 70% of the students graduating from our Photonics II program are studying related fields. Statistics are taken 185 days after the student graduates from high school. We currently have seven students taking an Associate Degrees at Indian Hills and two at Vincennes University; both institutions have an articulation agreement with us. We also have two students at the University of Missouri studying Physics and Engineering and one student studying optics at the University of Arizona. One of our first graduates recently began working as a Laser Technician. If we are successful, it is due to our team, working on behalf of the students and programs at the Career Center.

The most successful way to teach the students has been to use a curriculum that is modular in nature, building toward applications-based projects. Each unit covered by CORD's "Introduction to Lasers", uses labs that relate to one another. Adding projects to these units re-enforces the material covered. These projects also give students "real world" value to their work. Students see a product resulting from their studies instead of just a grade. Ideally all the units and lab work should support some laser application. The students would then see the relevance of the units. Textbooks at this level need to reflect this process.

Finally the best indicator of success comes from our students. Below is a testimonial from a former student, Zach Houston.

.

> "As a student at a the University of Missouri, it is only now that I realize how much I depend on what I have learned from the Laser and Photonics courses at the Career Center. These classes taught me more than just the logistics of lasers and everything I needed to get started in the field, but it opened a whole new world of discovery and possibility that I had not seen prior to my enrollment. The opportunities presented to me before I even graduated high school, are more than some graduate students get when they finish their Masters degree or doctors when they finish their PhD. It's not everyday that you can work with equipment that's worth more than your average car, or recreate the feeling that you know more than some college students do. Had it not been for the Photonics program I would not be able to finished some classes at the university with as much ease as I have. Nor would it be possible for a peer of mine to get published and speak to people that are old enough to be his parents and grandparents at an international conference held by the largest optical science society in the world. These opportunities can't be found anywhere else, and I highly recommend taking part in the only program of its kind in the nation, and come on, you get to play with lasers!"
>
> Zach Houston, graduated spring 1999

ACKNOWLEDGEMENTS

Dr. Don Bristow, Director, Columbia Career Center
Dr. Wanda McCampbell, Assistant Director, Columbia Career Center
Steve Chott, Director Technology Education, Columbia Career Center
Dr. Arden Boyer-Stephens, Administrative Assistant, Columbia Career Center
Teresa Yeager, Math Specialist, Columbia Career Center
Dr. T. Jeong, Professor Emeriterus, Lake Forest College
Pat Berger, Educational Director for the Laser Division, 3M
Neal Miller, Educational Consultant, Rocheport, MO
Tim Buol, Laser Safety Team, 3M
Dr. David Bryan, Optical Engineer, 3M
Bruce Allen, Regional Sales Manager, Newport Corp.
Mike Walker, Curriculum Consultant, Educational Development Project.
Missouri Department of Elementary and Secondary Education
Dr.Ken Barat, LIA safety Instructor. Laser Safety Officer, Berkley University California
CORDs National Photonics Skills Standards for Technicians
Jim Kyd, Electronics Instructor, Columbia Career Center
Bob Jewett, Construction Instructor, Columbia Career Center
Curt Lichty, Commercial Electricity Instructor, Columbia Career Center
Advisory committee members, past and present.
All of the staff at the Columbia Career Center, especially the secretaries.
And most of all our students, past and present.

Reference

1. CORD, *National Photonics Skills Standards*, Photonics Spectra, Pittsfield, Mass., 1995.
2. M. Cornwall & G. Williams, *LASE*, *Laser Applications in Science Education,* pp. 5, LASE Publications, Los Gratos, Cal., 1992.
3. Center for Occupational Research and Development, *Introduction to Lasers*, Center for Occupational Research and Development, Waco, TX, 1986.
4. Center for Occupational Research and Development, *Geometric and Wave Optics,* Center for Occupational Research and Development, Waco, TX, 1987.
5. Center for Occupational Research and Development, *Principles of Technology Unit 13,* Center for Occupational Research and Development, Waco, TX, 1987.
6. R. Dahl, *Laser Technology Modules 1-7,* Industrial Fiber Optics, Glendale, AZ, 1994.
7. M. A. Walk, "Strain/Displacement of a Carabiner via Interferometry", *Proceedings of SPIE*, pp. 409, SPIE, Bellingham, WA, 2000
8. N. Miller and P.John, "Public Education and the Electro-Optical Industry: A Strategic Partnership in Creating Photonics Classes for High School Students." *Proceedings of SPIE*, 3831SPIE, Bellingham, WA, 2000
9. P. John, "Advanced Holography in High School", *Proceedings of SPIE*, SPIE, Bellingham, WA, 2000