An Integrated Design Course in Laser Engineering

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Students pursuing a Bachelor of Science in Electrical Engineering at the University of Washington typically pursue a two year pre-engineering program and enter the Department of Electrical Engineering in Autumn of their junior year. During their junior and senior years, students must complete a core curriculum of six courses. In addition, students must take one elective course in each of two different breadth areas and at least three elective courses in one depth area.

These requirements make it necessary to construct breadth courses with good engineering science content as well as a significant design experience -- but which only consume a single quarter of the students' time. Furthermore, since resources cannot support both a breadth *and* depth version of a class, these classes must be detailed enough to serve as part of an in-depth sequence.

This paper will focus on the course Laser Engineering, which has been developed to meet these difficult requirements. The course includes a design project self-selected by the students. This paper will discuss the logistics of managing a self-selected design project format with limited economic and personnel resources. The discussion is oriented toward instructors who may be considering a similar self-selected design experience.

I. Introduction

The focus of the last four weeks of the quarter in the Laser Engineering class is the completion of a laboratory-based project where students design and construct some type of laser system. Design projects may be on any subject that relates to lasers. The only restriction is that the design project must involve the physical construction of something. "Paper" projects or software-only projects are not permitted in this course[1].

These design activities are performed in teams. Team selection is made by the students -- however, I reserve the right to break "loose wheels" from teams and put them in teams of their own[2]. During the first five weeks of the quarter, approximately 15-20 minutes is spent each Monday going "around the room" and having each student briefly describe their concept for a design project. Generally by the fourth week, approximately 70% of the students have decided on a reasonable project and have formed into design teams[3]. Table I summarizes the student design projects in this class over the past five years.

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1 It is quite easy to "lead" the students into a particular project direction. I have found that such projects are dramatically less successful than those the students select totally on their own.

2 Many studies show the value of NOT permitting students to form their own design teams. (See for example, Johnson D.W. , R.T. Johnson, and K.A. Smith, Active Learning: Cooperation in the College Classroom, Interaction Press, Edina, MN, 1991) However, in this class, the student-selected teams have been quite successful. Perhaps this is because the students clump together based on common interests in a design activity rather than past friendships or similar academic performance.

3 Of course, there are always a few that make their project decisions at the very last minute. I will typically "lock" the design teams on the day that the written proposal is due.

Table I - Student projects in EE 488 in chronological order from 1991-6

Paul Porath, *Optimizing the Collimation of a Diode Laser*
Suzanne DeBacke and **Stephanie La**, *Transmission and Reflection Holography*
Scott Karlson and Edward Smith, *Characterization of a pulsed Nd:YAG*
Richard Tolmie, *Scattering in Random Media*
Jeanette Clark, *Fiber-optic Communication Link*
Deanne McDowall and Jamie Brunner, *Characterization of a Carbon Dioxide Laser,*
Ron Newton, Scott Garat, Dan Nelson, Ken Wong, Jeff Fasen and Thom Johnson, *Two-color fiber-optic communication link*
Weston Roth, *Design and Construction of ND filters, Surface Plasmon Resonance*
Rob Olsen, Greg Bray, Marc Daoura and Aaron Spangler, *A Laser Raster Display System*
Molly Bryne and Kurt Myer, *Laser Unequal Path Interferometry*
Kris Merkel, S*cattering in the Oceanic Environment*
Jason Lattin, Mike Na and Nglia Lam, *Hole drilling using a pulsed Nd:YAG*
Art Tuftee, *Photorefractive Mirrors,* Rob Fenner, *Design and Fabrication of a HeNe laser*
Carrie Cornish and **Elizabeth Bruce**, *Design of an in-situ absorption meter for ocean optical sensing*
J.P. Xie, Alex Gailly, and **Mika Sato**, *Laser Doppler Radar*
Mark DeFranza, **Chien Tseng** and **Ming Chang**, *Low Temperature Photoluminescence*
Reg Nipius, Jiang Liang, and Andy Quang, *Lateral Shearing Interferometry*
Jack Peel, *Design and Fabrication of a Nitrogen Laser*
Alex Gailly, *Characterization of an Argon-ion Laser*
Joven Acosta, **Betty Wang**, and Nanlin Chang, *Photorefractive Keratectomy*
Les Gerads, Curtis Lipski, Bruce Qualey and Taylor Wang, *Optimizing a carbon dioxide laser*
Kris Merkel and Kyle Johnson, *Fiber Optic Interferometer*
Jennifer Gale and **Kathy Leung**, *Operation of an audio CD system*
Rick LeBold, Joseph Manakkil, **Lisa Pak Stec**, **Thao Tran**, *Non-contact Measuring of Skin Blood Flow Rate Using Speckle Phenomenon*
Cheryl Tornquist and **Wendy Bretz**, *Laser-Graph*
Craig Miller, Dennis Beardsley, Jeff Winters, **Christina Westlund**, *Laser Microphone Experiment*
Leslie Woitte and Richard Anderson, *Laser Seismograph Project*
Kelly Doser and **Pamela Roper**, *Laser Doppler Anemometry*
Victor Babbitt and Robert Tornay, *Spatial Phase Modulation Using Liquid Crystal Displays*
Rachel Kinghorn, **Anne Goerlich** and Greg Reynolds, *Laser Photobleaching*
Kris Eggehorn, Eric Johnson, Wei-Ting Chen, *Results of Laser Scattering on Water, Ice, Snow, and Pavement*
Robert Jordan, Robert Ober and Alex Tselnik, *A Fiber Optic Hydrophone*
Brian Adams, Tim Chinowsky, Chi-yen Wang, *Holographic Interferometry of Mono- and Bimetallic Pennies*
Andrew Lundberg and Nathan Horton, *Where is the Doppler Shift?*
John Martinson and Quinn Hamon, *Laser Doppler Velocimeter*
Ron Lowe, Scott Makos, Rick Sanghera, and Sean Weathers, *Laser Rastering*
Jennifer Allegretto and Steve Nguyen, *Holographic Neural Network*
Matt Amberg and Tim Hecox, *Holography*

II. Logistics

As can well be imagined, allowing the students to self-select a design project within the broad area of lasers is a logistical nightmare. For the first few years, the last four weeks were hellish. However, as the class evolved, I began to develop better ways of managing the self-selected design projects.

Some successful tricks include:

1. A dedicated room for the projects (the Photonics Teaching Laboratory)[4]
2. A well-established system for inventory management
3. Making past projects available as posters, Xerox copies, and (most recently) Web copies

1. The Photonics Teaching Laboratory

The EE 488 class is managed as part of the Photonics Teaching Laboratory. The Photonics Teaching Laboratory was initiated by a grant from the National Science Foundation (DUE-9151497). The laboratory supports self-directed design projects for Laser Engineering (EE 488), as well as organized formal laboratories for Fiber Optics (EE 465) and Photonic Devices (EE 400)[5]. The laboratory also supports EE 499 senior projects.

Physically, the Photonics Teaching Laboratory is a 500 sq. ft. room with numerous cabinets and tables. A single Photonics class (plus a random number of senior projects) uses the laboratory each quarter. The room is locked with a Simplex combination lock and there is a large scheduling white board outside of the door. In the Laser Engineering class, the scheduling white board is rarely used, because the projects can generally be run simultaneously. However, in the classes with organized laboratories, one laboratory set-up is made -- and students sign up for blocks of time to use the set-up. Resource issues have forced laboratory management in the direction of having one set-up and multiplexing the students' time -- rather than having many set-ups at a common time.

2. Inventory Management

There is one major difference between a self-selected design project in lasers and a self-selected design project in a field such as electronics. This difference is the cost of components. Optical components are deceptively expensive. By this, I mean that a typical optical component is *far FAR* more expensive than it looks. This leads to casual treatment by the students, and loss or damage of the components.

The first few years I ran the Photonics Teaching Laboratory, the losses were just absurd. We were losing approximately $5,000 each year in optical components. This was roughly divided between theft losses of HeNe lasers (at roughly $500 each) and casual losses of small (but expensive) optical components. This was

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[4] Some projects cannot be run in the Photonics Teaching Laboratory. However, I have found that the more projects which can be physically run in the same room -- the more successful the class is. The projects feed off each other, and students can learn from each others' projects as well as from the answers that I give to other groups' questions.

[5] I serve as instructor for the Laser Engineering class (EE 488), and overall manager of the Photonics Teaching Laboratory.

clearly unacceptable, and I began to explore ways of permitting students to engage in self-selected design activities -- and still get the parts back at the end of the quarter.

After some experimentation, I have found several successful ways to manage expensive optical components. At the moment, the laboratory maintains three classes of components:

- Components available from the Electrical Engineering Stockroom
- Inventoried components available in the Photonics Teaching Laboratory
- Uninventoried components available in the Photonics Teaching Laboratory

Components that are much more expensive than they look (for example, beam splitters and harmonic separators), attractive to steal (primarily HeNe lasers), or exceptionally popular (for example, power meters, oscilloscopes, and fiber optic chucks); are made available in the EE stockroom. Students formally check out the part and pay a nominal fee (typically $1-$5)[6]. The parts are listed on the Web and any Electrical Engineering student can check them out. There is a priority order for usage (1. undergraduates in a Photonics class, 2. graduate students in their last quarter where the part is essential to their thesis project, 3. undergraduates in any other class, 4. other graduate students).

Components that are expensive, but not exceptionally attractive to steal (for example, posts, rails, and breadboards) are made available in the Photonics Teaching Laboratory. The Laboratory has a Simplex (combination) lock and the students may check out parts on an honor system at any time. The combination is changed each quarter.

Inexpensive donated components (for example, boxes of lenses) and components that we have acquired through scrounge (for example, mirrors, lenses and irises) are also made available in the Photonics Teaching Laboratory. These components are not inventoried, but are still checked out on an honor system.

All Photonics Laboratory parts are marked with a distinctive automotive striping tape. Additionally, stockroom and inventoried components are each marked with a part number[7] and the replacement cost[8]. Inventory is run twice a year, in June and December. Inventory is typically announced two weeks in advance, and EMAILS are sent out regularly with messages like "Three more days until inventory"[9]. I *clearly* announce that parts not properly returned will be removed from set-ups[10].

The success of this system has been excellent. In two years of checking parts out from the stockroom -- we have not lost a single part. As an additional and unexpected advantage, damaged parts are more readily identified and can be repaired or replaced.

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[6] The psychology of this isn't clear, but it works. Having students pay a very small fee for a very expensive part results in more parts coming back.

[7] Giving each part its own number aids in locating the parts during inventory. More importantly, it also seems to have a very strong psychological impact. Something like "she knows I have THIS particular part".

[8] It's actually amazing how much this helps. You never even need to say anything.

[9] It turns out to be necessary for me to run inventory rather than a student or clerical worker.

[10] I rarely find it necessary to "raid" set-ups. It is known that I WILL, and the possibility is usually enough. Actually, at this point in the evolution ... merely seeing me walking around the building at inventory time with a clipboard is generally enough to send student scurrying toward setups.

Labeling parts with a specific number, putting a price on them, and inventorying them twice a year has dropped yearly losses of inventoried Photonics Laboratory components from roughly $5000 / year to $200 / year. (Interestingly enough, last year -- the only parts that were not returned had been checked out to a faculty member!)

3. Making past projects available as posters, Xerox copies, and (most recently) Web copies

I make past student projects available to the students in a variety of forms. All student teams are required to make a poster, and the best of these are mounted in the hallway on the 4th floor of the Electrical Engineering building. I maintain a file of past reports and have Xerox copies of these reports available in the Photonics Teaching Laboratory. In recent years, the use of World Wide Web has expanded dramatically in our department, and I now have students hand in their project proposals and reports on WWW using an electronic drop-box system[11].

These techniques have resulted in a steady improvement in project quality over the last few years. Each class sees the past work of the previous class and is motivated to do "one better". This "baseline raising" effect is especially obvious with the posters. Student posters from this class are routinely assumed to be graduate student work -- and visitors are always amazed to find that this is simply the final project in an undergraduate elective class.

III. Summary

The Laser Engineering course in the Department of Electrical Engineering at the University of Washington has both a strong engineering science component and a significant design experience. The self-selected design project offers exceptional motivation for the students, and a "baseline raising" effect has been observed by making past project reports and posters available to the next class. A managed inventory system with formalized check-out procedures allows good flexibility for the student projects while assuring that the majority of the parts are returned.

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[11] See http://www.ee.washington.edu/lasers/ee48894/title.htm