A.6 *Describe the major design experience that prepares students for engineering practice. Describe how this experience is based upon the knowledge and skills acquired in earlier coursework and incorporates appropriate engineering standards and multiple design constraints.*

OPT310 Optical Engineering Senior Design Fall Semester
The final courses in the Optical Engineering core are the Senior Design courses that provide the capstone experience. As a preparation for transition from academic to professional practice, constraints that are typically encountered in optical engineering practice are incorporated into the course. In the 4-credit fall course, students are formally introduced to the design process with in-class exercises related to fundamentals of the customer interview process. Through an in-class team exercise, students interview the 'customer' (the Professor) who has created an example product requirement. The class takes a previously defined Product Requirements Document (PRD) obtained from an early version of a real commercial product and edits it accordingly to reflect the requirements of the 'customer'. This role playing exercise is repeated in three class periods, during which time the students learn about how to deal with changing customer requirements and documenting them through a PRD. Students prepare a resume in a specific one-page style and submit as the first assignment. Fundamentals of the design process are discussed, including problem definition, concept generation and brainstorming, customer interviews, and concept selection. Potential customers and projects are identified and screened for projects with the potential for rigorous applications of the students' skills in optical engineering analysis, design, prototyping and development of specifications working closely with the customers. Potential customers can come from our Industrial Associates member companies, local and other Optics companies, as well as other community organizations such as the Rochester Museum of Science, UR, Rochester Institute of Technology, URMC, etc. The project will ideally require development and delivery of a physical prototype, although some projects may be purely design oriented, when it is not possible, practical within constraints or economically feasible to fabricate and deliver a hardware prototype. The students must consider and work through a range of creative solutions, and discuss the range of potential solutions with the customer. The customers help the students decide which paths are most promising.

All potential customers are given one class period to present their potential project to the class, and the class interviews the customer, taking notes. After having heard all of the customer presentations, students submit their resume together with a two page essay in which they detail which project team they would like to join, as first, second and third choice. The must detail which of their qualifications make them most suited to each project, and why they are specifically interested in the project. The Professor then creates the teams and assigns students to the teams according to their qualifications, special courses taken, prior work and internship experience, and their expressed wishes in their essay.

The fall semester course includes four lectures (In Fall 2014 presented by the University of Rochester Patent Lawyer Reid Cunningham) on:

- Fundamentals of Intellectual Property
- Patents and Trademarks.
- "Finding Inventions in Your Work"
- Google Patent Analysis Techniques
- "Things you really need to know before you graduate"

A three-part assignment is created with each student being assigned a specific US Patent number. The student must obtain a copy of the patent and analyze it in several ways, including Google Patent analysis. The written assignment is submitted and each student presents a five-slide PowerPoint summary to the class. In Fall 2014 each student was assigned a recent patent in the subject area of "laser pointer." Students analyze at least the Title, Filing date, Issue date, Inventor(s), Assignee, Abstract , Background, Summary, Description of the drawings and Detailed Description, Claims, References Cited, Referenced By, Classifications, Technical Field, etc. In class, we discuss the similarities and difference between different patents in the group. The patent analysis is augmented by several lectures by the Professor:

- Reviewing examples of Pre-Employment Industrial Intellectual Property Agreements,
- University of Rochester Intellectual Property Agreement, and
- "IP War Stories," including review of litigation cases that the professor has experienced as Expert Witness.

Second round of editing as a class team exercise on the Professor's imaginary product continues as the class edits the second revision of the imaginary Product Requirement Document. This exercise is a model for what they will do when they start interviewing their customers.

Students meet with their customers for the first time, then review in class their first version of their Product Requirements Document. Comments from Professor and class are recorded by the team with suggestions for areas of improvement and further questions to ask their customers.

Students meet with customers for a second time and review their second revised PRD in class. The first special topic lecture on Engineering Ethics is delivered with role playing. The class discusses ethical choices and then students write a five minute in-class essay. Real world examples are given where unethical behavior resulted in very bad consequences. The results are discussed in a follow-up lecture.

After Thanksgiving break, the final round of Product Requirements Documents are conducted in class, with preliminary plans, budget projections, and as much preliminary project planning as possible including potential large items that may need to be purchased. Students submit the final version of their PRD as their final exam.

OPT311 Optical Engineering Senior Design Spring Semester

The Spring Semester starts with an in-class review of an example of a good Product Requirements Document and the corresponding Design Description Document (DDD) that was done by a previous Optical Engineering Senior Design Team. Teams meet separately with the Professor to lay out their entire plan for the Spring Semester. Then teams begin regular reporting (every two weeks) on their progress. The class is encouraged to review each Team project critically and offer suggestions, help, ideas, etc. Written feedback from the Professor is given to the Team shortly after each class. The Team feedback is sent to all students in the class, so that they can monitor progress. Teams include their updated DDDs in their reviews, with changes from the previous versions highlighted. Teams are also encouraged to review their individual roles in the Team at each presentation and point out any changes.The Midterm Progress Report in the form of the DDD is presented in class and submitted as a Midterm exam. It is marked up and graded/commented and returned by the Professor.

In the Spring semester two Special Topics lectures are delivered along with in-class role playing and discussion:

- Sustainable Optical Engineering, and
- Lifelong Commitment to Learning

The Sustainability lecture includes Real World examples where new methods of Green Photonics are applied in a wide range of Optical Engineering areas, such as lead and arsenic-free glass selection in optical design, reducing carbon footprint in optics manufacturing, increasing efficiency and decreasing waste in manufacturing using optical technologies, increasing efficiency of lighting, etc. Examples of environmental damage caused by improper disposal of radioactive Thoriated glass (Kodak) and improper disposal of chemical waste generated by silicon solar cell manufacturing (in China) are reviewed.

The Lifelong Commitment to Learning lecture encourages students to become active in their community and professional societies, and gives a number of examples of how they can keep their education current as a professional, through attending conferences, taking short courses, teaching at local schools and community colleges, etc.

Reviews of Team Progress continue, and the Teams elect their representative to deliver their Team 90 Second “Elevator Pitch.” At the Spring meeting of the Institute of Optics Industrial Associates, each team had the opportunity to deliver their pitch to the Industrial Associates attendees. We rehearsed their pitches in class while recording them ‘shotgun style’ and then played the video back to the class, with comments, feedback, suggestions, corrections, etc. Each student introduced the team project, members and gave a short description of the project and results obtained so far. This particular exercise went extremely well, and the students and projects were extremely well-received by the Industrial Associates Member attendees from small and large companies, government labs, etc.

Teams then reviewed their final DDD and project results in class, and sent to the Professor the draft versions of the posters that were to be presented at the Hajim School of Engineering Annual Design Day. Teams submitted their final DDD as the final exam. The final DDD was marked up, graded and commented by WHK and returned to the students. The final grade was determined as one third Midterm DDD review, one third Final Project Presentation and Poster, and one third final DDD. Hajim School Design Day involves live demonstrations, computer simulations, posters, etc.

Overall, as a Capstone Experience in Optical Engineering, the team projects should involve rigorous optical design as well as an opportunity to use the considerable range of skills that they have acquired in the Optical Engineering undergraduate program. To varying extent, projects involved Code V and Light Tools, methods of Geometrical and Physical Optics, Radiometry and calculation of Photon Budgets, Optomechanical Design, Cost Estimation, Quantum Optics, MatLab coding and development of specialized software for running on Phablets, Laser Diodes, Visual Response Testing, Optical Materials Testing, Scatterometry, Interferometry, prototype development, Imaging Systems, etc. Appropriate engineering standards were applied in areas of lasers, eye safety, vision testing, etc. and students were instructed in shop safety. All projects were subject to multiple engineering constraints, and each Team had to consider alternative design possibilities. Projects involving prototype building were subject to cost constraints as given by the customer and/or Professor. Projects involving Optical Design were subject to constraints arising from the optical specifications as well as manufacturing cost.