# Inventive Problem Solving in Biomedical Engineering

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(or: Lobby of Gates-Hillman)  
**Office hours:** by request: best before or after class

## CLASS TIME AND LOCATIONS

- **GHC 5222**  
  5:30 PM to 8:20 PM, Thursday

**Prerequisites:** graduate student status in Biomedical Engineering  
(or permission of Instructor)

**Cross listing:** n/a

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  - 2-660 Surgery for Engineers | 9 units | Fall and Spring ......................................................... 9  
  - 42-699A Technological Innovation in Biomedical Engineering | 9 units | Fall ....................... 9  
  - 42-744 Medical Devices | 12 units | Fall ........................................................................... 9  
  - 42-699J Engineering in Medicine | 9 units | Spring ................................................................ 10
COURSE DESCRIPTION:
This course is aimed at discovering inventive solutions to some of medicine’s most difficult problems. It involves a theory of inventive problem solving known as “Triz” that teaches the student how to “invent on demand.” The structure of the course will follow a “flipped classroom” model: with reading assignments and pre-recorded lectures assigned before class and “homework” performed in-class. This allows students to learn the material at their own pace, and to translate theory to practice in a group setting with mentorship of the course instructor and teaching assistant, and teamwork of classmates.

Throughout the semester, specific problems will be assigned to the entire class on topics emphasizing cost saving (affordable health care act), medicine for under-resourced settings, rehabilitative medicine for children, and global health. A final project will be required of each student on a topic of choice (with instructor approval.) Each project will have an associated “client” from industry or healthcare who will serve as outside reviewer. The composition of the class will emphasize biomedical engineering students, but will also invite a limited enrollment of students from the School of Design, Tepper, and Heinz. Accordingly, there will be emphasis on multi-disciplinary teamwork, and networking. In summary, the goals of this course are to: develop formal skills in inventive problem solving, gain proficiency in teamwork and networking, to actually solve real-world problems in medicine, and last but not least… to have fun while learning.

Keywords
- theory of inventive problem solving
- cost saving – affordable health care act
- under-resourced settings
- global health
- networking, social network, professional network
- multi-disciplinary

COURSE OBJECTIVES:
The goals of this course are to: develop formal skills in inventive problem solving, gain proficiency in teamwork and networking, and to actually solve real-world problems in medicine. Students taking this course should achieve the following objectives:

1. Possess a set of innovation/invention tools that can be useful in designing a new product or solving a difficult problem.
2. Understand the key principles of Triz – a theory of inventive problem solving, including Resources, Contradictions, etc.
3. Gain proficiency thinking “outside the box.”
4. Solving a difficult, practical problem using inventive tools.
5. Gain experience working in an interdisciplinary team on a common design project.

TEXTBOOK
None, per se. Reading assignments will be provided electronically (e.g. on Blackboard).

SOFTWARE:
This course will use an invention software platform known as “Innovation Workbench” by Ideation International (Detroit, MI). A free software license will be provided, courtesy of Zion Bar-El, for the duration of the semester.
COURSE WEBSITE
All registered students will have access to the class website via Blackboard (http://www.cmu.edu/blackboard). Class announcements, course information, instructor information, course documents, and assignments are contained on this website. Website will also allow you to create your own home page, which in turn will provide some social networking capabilities. This website will be constantly updated with relevant information throughout the semester.

CLASS PROCEDURES
This course employs a “Flipped Classroom” model. Rather than listening to boring lectures for 3 hours, you will review most of the instructional material at home. And then you come to class to do “homework.” Nevertheless, since this is a 12-unit course, according to CIT guidelines, you will be expected to invest a combined 12 hours per week, for example:

- Contact Hours – 3/wk
- Reading and Lecture (at home) – 3/wk
- Homework Assignments (including term paper) – 6/wk

Lectures and “Lectures”
In a flipped classroom, the instructional material is generally reviewed at home. This will consist of: PowerPoint presentations (with or without audio narration), textual material (articles, book chapters, etc.), online videos (e.g. YouTube), and other media.) There may be quizzes or checklists associated with these.

The class session will begin with a review of the previous week’s assigned reading/viewing. In some cases, additional information and/or examples will be presented by the instructor or guest. The remainder of the class will involve exercises based on the material, which may include solving problems, presenting results to the class, and discussions. The Instructor, TA, and guest mentors will be available to assist you. Some exercises will be completed by each individual student, others may involve teams of two or more.

Reading Assignments and Quizzes
Associated with each reading/viewing assignment will be an online quiz, which must be completed before the following class.

Final Invention Report (Term Paper)
Each student will work throughout the semester on their own individual invention (or invention portfolio) of their choosing (from a selection of options provided during the semester.) It will include a thorough description of a biomedical problem, and a systematic approach leading to a brilliant inventive solution – using the tools and principles learned in class. A final report will be due at the end of the semester, along with an oral presentation. Further guidelines regarding the content, length and format of the report will be available on Blackboard¹. Periodic updates for specific milestones may occur throughout the semester. These updates will be graded as in-class exercises.

Mid-Term Exam
The mid-term will be given during class on the date indicated in the Course Schedule. It will be a closed-book exam, consisting of multiple-choice questions, essays, and inventive challenges. It will cover all the material from the preceding classes, and is

¹ BME42-699 Final Invention Report Guidelines [YYYY].doc
intended to gauge the student’s retention of the most important core principles and tools. The mid-term cannot be missed. Any scheduling conflicts with the mid-term exam must be submitted in writing to the instructor at least two weeks prior to the exam. As a general rule, the exam will abide with the Carnegie Mellon University Policies on Examinations.²

**Final Exam**

There is no final exam for this course. Students will however present their term project during finals week. The date will be determined by the Registrar later in the semester.

**Grading - 42-699 (12 units)**

The final grade for graduate students will be computed as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-class Exercises</td>
<td>30%</td>
</tr>
<tr>
<td>At-home Exercises &amp; Quizzes</td>
<td>20%</td>
</tr>
<tr>
<td>Mid-Term Exam</td>
<td>20%</td>
</tr>
<tr>
<td>Final Report (and presentation)</td>
<td>30%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Throughout the semester, the students will be able to view a running total/average of all grades accrued to-date on Blackboard.

The associated letter grade will be assigned according to the following scale (as per University Standards - http://www.cmu.edu/hub/reg/grading.html):

<table>
<thead>
<tr>
<th>Grade</th>
<th>Points</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>&gt;100%</td>
<td>Superlative</td>
</tr>
<tr>
<td>A</td>
<td>100-91%</td>
<td>Excellent</td>
</tr>
<tr>
<td>A-</td>
<td>90.9-90</td>
<td>Outstanding</td>
</tr>
<tr>
<td>B+</td>
<td>89.9-89</td>
<td>Great</td>
</tr>
<tr>
<td>B</td>
<td>88.9-81%</td>
<td>Very Good</td>
</tr>
<tr>
<td>B-</td>
<td>80.9-80%</td>
<td>Good</td>
</tr>
<tr>
<td>C+</td>
<td>79.9-79</td>
<td>Fair</td>
</tr>
<tr>
<td>C</td>
<td>78.9-71%</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>C-</td>
<td>70.9-70%</td>
<td>Poor</td>
</tr>
<tr>
<td>D+</td>
<td>69.9-69</td>
<td>Poor</td>
</tr>
<tr>
<td>D</td>
<td>68.9-60%</td>
<td>Passing</td>
</tr>
<tr>
<td>R</td>
<td>&lt;60%</td>
<td>Failure</td>
</tr>
</tbody>
</table>

**CLASS POLICIES**

**Attendance**

Needless to say, attendance is mandatory. At the end of each class, you will be turning in your assignments. Any scheduling conflicts must be presented to the course instructor or TA at least a week in advance. With their approval, you may receive full credit for the missed in-class assignment if uploaded to Blackboard on the following day.

**Assignments:**

Since homework assignments are performed during class time, they will be due at the end of the session. The TA will scan the hard copy so that students may keep the original for him/herself. The assignments will be reviewed by the instructor and/or TA, and a grade (typically on a scale of 0-10) will be posted within one week on Blackboard.

² [http://www.cmu.edu/policies/documents/Exams.htm](http://www.cmu.edu/policies/documents/Exams.htm)
**Class Decorum:**
Class sessions will start and end on time. If you are late, please enter the class without disruptions. If you must leave early, please make your exit as quickly and quietly as possible.

**Food and Beverages:**
Unless the building guidelines say otherwise, you are permitted to bring non-alcoholic beverages to class to keep yourselves hydrated. Food, on the other hand, is not permitted. 10-minute breaks will be provided during class time if you wish to get something to eat – outside of the classroom.

**Use of Laptops, Tablets or other Mobile Devices**
During Lecture Portion of Class: The use of laptops is permitted for the exclusive use of: note taking and demonstrations. Web-surfing, social networking, gaming, etc… is prohibited.

During in-Class Exercises: The use of smart phones or laptops is generally permitted and in fact might be necessary. Again, their use will be restricted to course-related activities.

Please keep in mind that these guidelines are necessary to maintain an environment that is conducive for learning.

**Accommodations due to Disabilities:**
If you wish to request an accommodation due to a documented disability, please inform the Course Instructor and contact Disability Resources (102 Whitfield Hall, 8-2013, lpowell@andrew.cmu.edu) as soon as possible. For ongoing documented classroom accommodations, a one-week notice is required.

**Academic Integrity:**
Students at Carnegie Mellon, because they are members of an academic community dedicated to the achievement of excellence, are expected to meet the highest standards of personal, ethical, and moral conduct possible. These standards require personal integrity, a commitment to honesty without compromise, as well as truth without equivocation, and a willingness to place the good of the community above the good of the self. Obligations once undertaken must be met, commitments kept. Rarely can the life of a student in an academic community be so private that it will not affect the community as a whole or that the standards above do not apply.

The discovery, advancement and communication of knowledge are not possible without a commitment to these standards. Creativity cannot exist without acknowledgment of the creativity of others. New knowledge cannot be developed without credit for prior knowledge. Without the ability to trust that these principles will be observed, an academic community cannot exist. The commitment of its faculty, staff and students to these standards contributes to the high respect in which the Carnegie Mellon degree is held. Students must not destroy that respect by their failure to meet these standards.

**Cheating and Plagiarism:**
Students at Carnegie Mellon are engaged in preparation for professional activity of the highest standards. Each profession constrains its members with both ethical responsibilities and disciplinary limits. To assure the validity of the learning experience a university establishes clear standards for student work. In any presentation, creative, artistic, or research, it is the ethical responsibility of each student to identify the conceptual sources of the work submitted. Failure to do so is dishonest and is the basis for a charge of cheating or plagiarism, which is subject to disciplinary action.

**Cheating** includes but is not necessarily limited to:
1. Plagiarism, defined below.

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3 Excerpted from Student Handbook, found at: http://www.studentaffairs.cmu.edu/acad_integ/acad_integ_text.html
4 Reproduced from http://www.cmu.edu/policies/documents/Cheating.html
2. Submission of work that is not the student's own for papers, assignments or exams.
3. Submission or use of falsified data.
4. Theft of or unauthorized access to an exam.
5. Use of an alternate, stand-in or proxy during an examination.
6. Use of unauthorized material including textbooks, notes or computer programs in the preparation of an assignment or during an examination.
7. Supplying or communicating in any way unauthorized information to another student for the preparation of an assignment or during an examination.
8. Collaboration in the preparation of an assignment. Unless specifically permitted or required by the instructor, collaboration will usually be viewed by the university as cheating. Each student, therefore, is responsible for understanding the policies of the department offering any course as they refer to the amount of help and collaboration permitted in preparation of assignments.
9. Submission of the same work for credit in two courses without obtaining the permission of the instructors beforehand.

**Plagiarism** includes, but is not limited to, failure to indicate the source with quotation marks or footnotes where appropriate if any of the following are reproduced in the work submitted by a student:

1. A phrase, written or musical.
2. A graphic element.
3. An idea derived from the work, published or unpublished, of another person.

Any disciplinary actions regarding charges of cheating or plagiarism will follow the procedures described in the “Carnegie Mellon University Undergraduate Academic Disciplinary Actions Overview” that can be found at [http://www.cmu.edu/policies/documents/AcadRegs.html](http://www.cmu.edu/policies/documents/AcadRegs.html).

**Collaboration vs. Cheating:** Collaboration is defined by Merriam-Webster’s Collegiate Dictionary (10th edition) as “to work jointly with others or together, especially in an intellectual endeavor.” Much of the work that is performed in this course (and in biomedical engineering as a whole) is collaborative in nature. Therefore, collaboration in this class is encouraged during the execution of the exercises. In addition, discussions regarding the content of homework assignments, lab reports, and the final project are also encouraged.

You are encouraged to discuss the course material, concepts, and assignments with other students in the class. **However, each student must eventually submit his/her own unique work (i.e. report, homework, etc).** If any collaboration was used to complete an assignment, record the names of the collaborators and the nature of the collaboration. Any attempt to submit work that is not the student’s own work will be considered to be an act of cheating and will be subject to prosecution.

**Expectations of Students and Instructors:**

The students have the right to expect the following of the instructor and teaching assistants:

1. A syllabus that describes class procedures, policies, and a course description.
2. Class sessions that will start and end on time.
3. Advance notice of any changes to the course schedule – preferably within 48 hours of the change, unless there is an emergency situation.
4. Access to the instructor and TA outside class.
5. Feedback on all assignments within two weeks (preferably one week).
6. Response to phone calls or e-mails within 24 hours during weekdays and 48 hours on weekends.
7. To treat students respectfully and courteously.

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5 Adapted from Howard Culbertson at Southern Nazarene University. The original list of expectations can be accessed at [http://home.snu.edu/~HCULBERT/contract.htm](http://home.snu.edu/~HCULBERT/contract.htm).
8. A learning experience that is rewarding, enjoyable, elucidating and contributes to your valued career goals.

The instructor has the right to expect the following of students:

1. Students will prepare for class by reading/viewing the instructional material assigned prior to class.
2. Students will inform the instructor if extenuating circumstances prevent attending a class.
3. Students will arrive to class on time.
4. Students will make an effort to engage in class discussion.
5. Students will ask questions, and seek assistance when needed.
6. Students will respond to email from Instructor or TA within 24 hours during the week and 48 hours on weekends.
7. Students will provide feedback (constructive criticism) to the course instructor and/or TA, or via the online Suggestion Box on Blackboard with recommendations or problems with course content or management – rather than “bottle it all up” for the end-of-semester course evaluation – whereupon it is too late to take corrective action.
8. Students will work together effectively in groups (if applicable) to successfully complete the assigned tasks.
9. Students will follow the code of conduct regarding academic integrity, cheating, plagiarism, and collaboration as outlined in the syllabus.
10. Students will conduct themselves like professionals.
11. Students will have fun.
<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
</table>
| 1    | Introduction & Overview  
Summary of Grand Challenges in Medicine |
| 2    | Introduction to Triz:  
Theory of Inventive Problem Solving  
(Resources, Contradictions, Separation Principles) |
| 3    | Innovation Workbench (Zion Bar-El)  
Triz-2: Anticipatory Failure Determination; Directed Evolution |
| 4    | Prescriptive Design Methods |
| 5    | Medical Challenges in Developing World |
| 6    | Medical Device “Events” and “Accidents” |
| 7    | Student Presentations |
| 8    | Human Factors Design  
**Mid-Term Exam** |
| 9    | Economic and Logistical Challenges of Healthcare in USA |
| 10   | Best Practices of Medical design  
(IHA, V&V, etc.) |
| 11   | Bio-Inspired Design |
| 12   | Challenges in Senior Care |
| 13   | Challenges in rehabilitative medicine and independent living |
| 14   | **No class – Thanksgiving** |
| 15   | Improvisation Workshop |
| 16   | Student Presentations |

For most current course schedule, see:
BME42-699_Inventive_Problem_Solving_in_BME_CourseSchedule.doc
(Note: old/obsolete schedules will be marked “obsolete” with date)
RELATED COURSES:
The following courses are considered complimentary to this course.

42-660 Surgery for Engineers | 9 units | Fall and Spring
This course explores the impact of engineering on surgery. Students will interact with clinical practitioners and investigate the technological challenges that face these practitioners. In addition to weekly seminars, all students must sign up for one of the three accompanying practicums: Clinical Neuroscience, Clinical Cardiovascular, or Clinical Orthopedic. Students will complete a final report on the practicum that will describe an important clinical problem that can be solved with a new technology or a significant optimization of an existing technology.

1. Clinical Neuroscience Practicum involves on-site experiences with a variety of neuroscience faculty: neurosurgeons, neurologists, neuro-interventionalists, neuro-radiologists, clinical neuro-physiologists, neuro-otologists and neuro-ophthalmologists. Direct contact will be at least 3 hours a week.
2. Clinical Cardiovascular Practicum involves on-site experiences with cardiology and cardiovascular surgery faculty: cardiac surgeons, thoracic surgeons, cardiologists, interventional cardiologists, cardiac perfusionists, and cardiac radiologists. Direct contact will be at least 3 hours a week.
3. Clinical Orthopedic Practicum This practicum involves on-site experiences with orthopedic faculty: shoulder surgeons, hip surgeons, knee surgeons, hand surgeons, sports medicine surgeons, and physiatrists. Direct contact will be at least 3 hours a week.

The final report of the practicums will involve the most interesting, innovative, important problem uncovered which in the view of the team can be solved with a technology or a significant optimization of a technology. The report form will be the NIH R21. Opportunities to collaborate with engineering students from an outside institution will be sought.

The Primary Instructor is Jim Burgess, MD, Department of Neurosurgery, Allegheny General Hospital. This course meets once a week for 3 hours in addition to the practicum held at the Allegheny General Hospital, transport provided.
Pre-requisite: Physiology.

42-699A Technological Innovation in Biomedical Engineering | 9 units | Fall
Developing innovative technologies in biomedical engineering requires understanding patents and intellectual property as well as understanding patient needs and market pull. This course will introduce students to technological innovation through discussion of case studies across biomedical engineering. Students will learn to read patents and analyze patent landscapes as well as discuss approaches to developing creative solutions that meet product and regulatory requirements. A team-based project will allow students to apply their skills in biomedical engineering and the tools in this course to proposing novel therapeutics, devices, or diagnostics that meet critical patient needs and have market potential.
Pre-requisites: Graduate status in CIT or MCS, or permission of the instructor.

42-744 Medical Devices | 12 units | Fall
This course is an introduction to the engineering, clinical, legal and regulatory aspects of medical device performance and failure. Topics covered include a broad survey of the thousands of successful medical devices in clinical use, as well as historical case studies of devices that were withdrawn from the market. In-depth study of specific medical devices will include: cardiovascular medicine (pacemakers, heart valves, vascular grafts, heart-assist pumps...), orthopedics (fixation devices, prostheses...), and general medicine (defibrillators, blood pressure cuffs, stethoscopes...) We will study the principles of operation (with hands-on examples), design evolution, and modes of failure. Additional lectures will provide basic information concerning biomaterials used for implantable medical devices (metals, polymers, ceramics) and their biocompatibility, mechanisms of failure (wear, corrosion, fatigue, fretting, etc.). Guest lectures will be provided by practicing engineers from regional medical device companies to provide real-world perspective of the development process.

In addition to a mid-term and final exam covering topics presented in class, students will prepare a written report that critically investigates a particular medical device that has been recalled by the FDA, of the student’s choosing. The report will include the design history, engineering analysis, and recommendations for future improvements (re-design). [Students enrolled in 42-744 will also be required to produce a lo-fi prototype, which they will present in class at the end of the semester.] The ultimate objectives of this course are to (1) provide students with a broad understanding of the medical device industry, (2) stimulate critical analysis of medical device design, and (3) convey practical knowledge and skills that are valuable for a future career in the medical device industry.
Pre-requisites: Graduate standing for MCS and CIT students. For non-MCS or CIT graduate students, a degree in a science or engineering.

42-699J Engineering in Medicine | 9 units | Spring
The main objective of this course is to bring together the principles of medical device innovation with the details of medical practice in the Intensive Care Unit (ICU). This will be achieved by: (1) a review of selected acute illnesses, and a recounting of patient cases seen in the ICU with each condition, (2) a brief description of currently used technologies and (3) study of the course textbook, “Biodesign”. Another objective is familiarizing the students with the skills needed by entrepreneurs. This will include concise writing, slide preparation for presentations, market and technology research (use of resources at the Pittsburgh Life Sciences Greenhouse is suggested), description of the Small Business Innovation Research (SBIR) program, and information on technology startup companies. Interaction in class will also be encouraged. Guest speakers will give some of the classes.