Putting the Capstone First:

Turning the STEM Curriculum Upside Down

Joe Pow
Associate Director
Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology

Megan Iafrati
Susan Kratzer
3rd Year Imaging Science Majors

Elizabeth Bondi
2nd Year Imaging Science Major

Victoria Scholl
2nd Year Imaging Science/Motion Picture Science Major
What is imaging science?
Why we're here...
Freshman Imaging Project: A New Pedagogy
Our Goal

• Provide first-year students with an experience which is:
  o More relevant
  o More engaging
  o More challenging
  o More motivating
  o More fun…

• In doing so, promote active learning
What does the literature say?

• Higher education should produce new frames of understanding by piloting new ideas and approaches to keep students’ learning on the cutting edge.

• Learning should be experiential and steeped in investigation from the very first courses.

• Learning should be personally meaningful for students and faculty, it should make connections to other fields of inquiry, and it should suggest practical applications related to the experience of students.

• Learning should take place in a community where faculty see students as partners in learning, where students collaborate with one another and gain confidence that they succeed, and where institutions support such communities of learners.
Other Existing Programs

- Colorado School of Mines
- Claremont McKenna College
- University of California Santa Cruz
- University of Michigan
- Drexel University
- Purdue University
- Western New England University
- University of Colorado at Boulder
Our Approach to PBL

- Student led
  - Non-traditional classroom
- Subjective grading
  - Attitude, effort, contribution
- Active learning
  - Adopt practices of STEM professionals
Implementation Strategy

• Students will:
  o Approach the project as a single design team
  o Self-organize into smaller groups which will focus on specific aspects of the project
  o Work in parallel using standard systems engineering practices
  o Scaffolded by a team of faculty and staff mentors
**Typical Academic Year Plan (Quarters)**

**Fall**
Plan/Organize/Prepare
- Define the problem
- Conduct lit searches
- Identify resources
- Define performance specs
- Plan and organize
- Develop critical skills
- Disseminate results

**Winter**
Concept Definition/Trades
- Conduct trade off studies
- Develop predictive models
- Build & test components
- Define interfaces
- Refine plans
- Continue dissemination

**Spring**
Demonstrate/Validate
- Integrate components
- Validate system-level performance
- Prepare for public demo at ImagineRIT
- Prepare for any follow-on summer projects

---

**Preliminary Design Review (PDR)**

**Critical Design Review (CDR)**

**ImagineRIT**
Innovation + Creativity Festival
RICHARD E.
Son of R.M. & M. STAYLOR
BORN July 14, 1877.
DIED July 13, 1878.
PTM Demo
FIGURE 9B-13 Laser scans of life-size normal (A) and abnormal (B) clay heads processed using specialized software that has allowed detailed and highly accurate curvilinear and volumetric craniofacial measurements.

T, tragion; N, nasion; SN, subnasion; GO, gonion; GN, gnathion
Phenotyper Demo
Array Demo
Desired Outcomes
From the Syllabus

- Students will demonstrate:
  - A general understanding of the foundational concepts of imaging science
  - More in-depth knowledge of at least one aspect of imaging science
  - A working knowledge of the principles of systems engineering
  - Proficiency in technical communication (oral and written)
  - An appreciation for the value of interdisciplinary teamwork in technical disciplines
  - Innovation and creativity in their approach to problem solving
The Big Question...

How *effective* is this pedagogy in meeting these objectives?
Program Assessment

• Extremely important
  o Achieving the desired student-based outcomes
  o Securing funding for this and other initiatives

• Initial approach
  o Collaborate with independent external evaluators
  o Credible and objective

• Lack of funding gave rise to backup plan
  o Limited to internal assessment using Honors Students
Program Assessment Challenges

• Limited resources = less rigor
• Sensitive to possible bias
• Lack of control data
• Hampered by small sample sizes
• Question of what data should be collected
Data Collected

• Enrollment and attrition
• Pre- and post-surveys about attitudes
• Student course evaluations
• Student peer evaluations
• Video interviews
• Focus groups
• Co-op, internship, or other relevant experiences
Our Data: Enrollment and Attrition
Attrition Rate
(Imaging Science Students Only)

First Cohort: 42%
Second Cohort: 33%
Third Cohort: 28%
Historic Attrition Rates

2005 Freshmen: 29%
2006 Freshmen: 43%
2007 Freshmen: 33%
2008 Freshmen: 60%
2009 Freshmen: 56%
Our Data: Course Evaluations
Section One: Student Data
Information about the student and his/her background

Section Two: General Questions
Effectiveness of the instructor and the course overall

Section Three: Laboratory
Value of the experiments and quality of equipment/facilities

Section Four: Comments
Open-ended questions asking for students’ ideas and opinions
How effective was the method of presentation of the course material?

116 responses
How valuable were the laboratory experiments?

116 responses
What is your overall rating of this course?

116 responses
Our Data: Surveys
1. How often in the past year did you...

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Occasionally</th>
<th>Frequently</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Support your opinions with a logical argument...</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>2. Seek solutions to problems and explain them to others...</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3. Evaluate the quality or reliability of information you received...</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>4. Take a risk because you felt you had more to gain...</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>5. Look up scientific research articles and resources...</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>6. Seek alternative solutions to a problem...</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>7. Accept mistakes as part of the learning process...</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>8. Seek feedback on your academic work...</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>9. Work with other students on group projects...</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>10. Integrate skills and knowledge from different sources and experiences...</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>
1. For each statement please indicate the extent to which you agree or disagree.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Not sure</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Listening to a variety of solutions to problems is important to advancing scientific ideas.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>2. In order to apply a method used to solve one type of science problem, the new problem must have similar characteristics.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>3. It is important for scientists to share their ideas with people in different disciplines (e.g. engineers, biochemists,...)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>4. Scientists can gain from exploring alternative solutions or courses of actions that build on the ideas of others.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>5. It is important to have a leader who can do all the required work to ensure a project is completed correctly.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
# Self Assessment

1. Using the scale, please indicate extent to which you feel ready to participate in...

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Somewhat</th>
<th>Moderately</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. scientific problem solving</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>2. a science research team</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>3. innovative thinking within a scientific problem solving context</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>4. work using scientific equipment</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>5. writing a scientific report</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>6. independent science research</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>7. using a variety of scientific and non-scientific resources to solve problems</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>8. contributing ideas to a scientific discussion</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>9. working with others to develop an approach to a problem</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>10. new and challenging contexts by building on your prior experiences</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>11. seeking untested and unique approaches to scientific work</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>12. developing new technology</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>
Student Prompt:

First Cohort Prompt: Please reflect on your experience and share your thoughts below. Topics to address might be the value of the experience, its significance to your learning and/or the challenges you encountered – but please share whatever you feel is important.

Second Cohort Prompt: The President and Deans of RIT are interested in your Freshman Imaging Science experience. They would really like your feedback and input as they consider whether to recommend this approach to other programs on campus.
"The value of a class such as this shouldn't go unnoticed. More than just basic knowledge, I've grown as a person. It's one thing to learn facts, it's another to gain a skill set."
"I now have the initiative to go out and explore what other types of opportunities exist for myself, and plan to make the best of my undergraduate education here at RIT because of it."
"Rather than being spoon fed information, students had to go out and find solutions to the problem on their own, mimicking the environment of working in the real world."
"It would be a disservice to not have opportunities like this for every student, because in scenarios like this, you can let a student really show their true potential."
"Due to the interest I had in this class, the collaboration, and the difference in experience from any other course, I wanted to do the work. I wanted to learn. Avoiding the ever-trudging 'learn for the test' class structure, this class made me motivated."
Our Data: Video Interviews
Our Data: Student Research
Research Experiences

• Student-led teams which designed and built:
  o Volumetric display
  o Schlieren camera

• Co-ops and internships at
  o Library of Congress
  o Idaho National Laboratory
  o Environmental Protection Agency
  o National Geospatial Intelligence Agency
  o Goodrich Aerospace
  o USC Institute for Creative Technologies
  o Mitre
Our Data: Anecdotes and Observations
From the Soph-Level Instructor:

I find all Freshman Imaging Project (FIP) students lack basic background, relative to previous classes, in at least one, and usually several, of the key imaging chain areas.

I needed to backtrack to cover introductory material that used to be covered using a traditional pedagogy. At the same time, to ensure FIP students wouldn't be completely lost (relative to traditionally prepared students) as they continued through the imaging science core curriculum, I attempted to cover most of the same material I had covered for pre-FIP students. This led to a sense of "cramming" during the 10-week quarter.
From the Soph-Level Instructor:

The last two classes of FIP-prepared students are more capable and confident in certain respects, relative to my previous (pre-FIP, traditionally-prepared) classes. Many students display in-depth knowledge in key imaging chain areas, from their project experiences. (Last year, some of these same students seemed bored by the pace of my class, overall.)

Overall, my impression is that FIP-prepared students are more comfortable in the lab setting (which is a critical component of my course as well as other imaging science core classes).
Audience Feedback
Dear Freshmen -

This looks great. Please don't forget you'll need to get it through the door.

Sincerely, Joe
Challenges Going Forward

• Calendar conversion
  o 2 semesters vs. 3 quarters
  o Class meetings are shorter
  o Class meeting time precludes after-class work
  o Timing of formal design reviews less favorable

• Class Demographics
  o Course now mandatory for Imaging Science and Motion Picture Science students
  o Limits ability to bring in students from other disciplines
The End...