RT19: Systems Engineering Capstone Experience

by
Mark Ardis
Stevens Institute of Technology

Annual SERC Research Review
October 5-6, 2011
University of Maryland
Marriott Inn and Convention Center
Hyattsville, MD

www.sercuarc.org
Acknowledgments

• Beth McGrath, Stevens Institute of Technology
• Chris Jurado, Stevens Institute of Technology
• Dr. Susan Lowes, Teachers College, Columbia University
• Sophie Lam, Teachers College, Columbia University

• Our sponsors at ASDR&E

• Our colleagues at the participating institutions
Building Education & Workforce Capacity in Systems Engineering

Research Question
What methods, approaches, environments, and materials lead to greater SE learning, career interest, and interest in DoD problems?

Role of mentors
Role of student projects

Approach
Develop course materials and other value-added SE inputs and conduct pilot courses in 14 diverse institutions; assess impacts on SE learning, career interest and interest in DoD problems among undergraduate and graduate students.
### Partners

#### Civilian Universities
1. Auburn University  
2. Missouri University S & T  
3. Penn State  
4. Southern Methodist University  
5. Stevens Institute of Technology  
6. University of Maryland  
7. University of Virginia  
8. Wayne State

#### Service Academies
1. Air Force Institute of Technology  
2. Naval Postgraduate School  
3. Air Force Academy  
4. Military Academy – West Point  
5. Coast Guard Academy  
6. Naval Academy
**Project Schedule**

**Phase I: Start Up**
- 2.5 Months
- March 1 – May 15, 2010

**Phase II: Pilot Implementation**
- 13.5 Months
- May 15 – June 30, 2011

**Phase III: Analysis**
- 3 Months
- July 1 – Sept. 30, 2011

- Letter of intent 3.15.10
- RFP Released 4.1.10
- Proposals Due 5.1.10
- Select Team 5.15.10
- Courses Start
- Develop Project Description
- Pilots Submit Interim Reports
- Final Report to Sponsor
- Workshop
- Pilots Submit Final Reports
- Final Report to Sponsor
- Workshop
Methodology: Measurement of Student Educational Outcomes

Required Common Assessments

- Pre/Post Survey
  - Knowledge of SE
  - Interest in SE Careers
  - Awareness of DoD problem areas

- Pre/Post Case Student Analysis (Bradley Fighting Vehicle)
  - Growth in SE approach/Analysis (semantic analysis)

- Weekly Blog Posts
  - Qualitative
  - Progress in level of sophistication of student analysis
  - Final blog post-cumulative
Measurement of Student Educational Outcomes

Customized Assessments

- Faculty-developed assessments unique to their courses
  - Comprehensive Rubrics
  - Student presentations
  - Peer reviews
  - Team reports

- PI Evaluation of course effectiveness

- PI Reports on DoD and Industry Mentors
DoD Problem Areas Addressed

<table>
<thead>
<tr>
<th>Problem Area 1: Low-cost, low-power computers</th>
<th>Problem Area 4: Immersive training technologies</th>
<th>Problem Area 2: Expeditionary assistance kit</th>
<th>Problem Area 3: Expeditionary housing systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.10%</td>
<td>28.60%</td>
<td>14.30%</td>
<td>21.40%</td>
</tr>
</tbody>
</table>
Disciplinary character of student body

- Students from multiple disciplines: 72%
- Students from the same discipline: 14%
- Students from multiple disciplines, plus a mandatory SE major on each: 14%
## All Institutions - By Class year

<table>
<thead>
<tr>
<th>Year 3 (undergraduate)</th>
<th>Year 4 (undergraduate senior)</th>
<th>Year 1 (graduate)</th>
<th>Year 2 (graduate)</th>
<th>Year 5 (undergraduate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>113</td>
<td>94</td>
<td>28</td>
<td>19</td>
</tr>
</tbody>
</table>

Number of Students, $n=264$
### All Institutions - By Major or Program

<table>
<thead>
<tr>
<th>Major/Program</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems Engineering</td>
<td>65</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>60</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>27</td>
</tr>
<tr>
<td>Computer Science</td>
<td>15</td>
</tr>
<tr>
<td>Industrial Engineering</td>
<td>17</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>3</td>
</tr>
<tr>
<td>Software Engineering</td>
<td>15</td>
</tr>
<tr>
<td>Engineering Management</td>
<td>8</td>
</tr>
<tr>
<td>Biomedical Engineering</td>
<td>1</td>
</tr>
<tr>
<td>Aeronautical Engineering</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>52</td>
</tr>
<tr>
<td>University/Academy</td>
<td>Mentors</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Auburn</td>
<td>Advisory board (5 SE professionals from govt. and industry)</td>
</tr>
<tr>
<td></td>
<td>Industry Mentor (automotive arena)</td>
</tr>
<tr>
<td></td>
<td>PhD TAs (support team)</td>
</tr>
<tr>
<td>Missouri S&amp;T</td>
<td>Boeing Company engineers: Dale Waldo, Louis Pape, Nancy Pendleton,</td>
</tr>
<tr>
<td></td>
<td>Robert Simmons and Robert Scheurer</td>
</tr>
<tr>
<td></td>
<td>Office of Naval Research: Pete Muller</td>
</tr>
<tr>
<td>Penn State</td>
<td>DoD Mentors: Col. Nancy Grandy, and Mr. Phil Stockdale</td>
</tr>
<tr>
<td>Southern Methodist</td>
<td>U.S. Marine Corps</td>
</tr>
<tr>
<td></td>
<td>Office of Naval Research: Pete Muller</td>
</tr>
<tr>
<td>Stevens Institute</td>
<td>Naval Surface Warfare Center: Eric Shields</td>
</tr>
<tr>
<td></td>
<td>Red Gate Group, Ltd: Joseph Barniak</td>
</tr>
<tr>
<td>U of Maryland</td>
<td>Lockheed Martin: Sandy Friedenthal</td>
</tr>
<tr>
<td></td>
<td>DoD Mentors: Dr. David Robie, Kim Watkins</td>
</tr>
<tr>
<td>U of Virginia</td>
<td>DoD Mentor: Bill Campbell</td>
</tr>
<tr>
<td></td>
<td>Northrop Grumman engineers</td>
</tr>
<tr>
<td>Wayne State</td>
<td>Army Shelter Expert, Claudia Quigley</td>
</tr>
<tr>
<td></td>
<td>Army TARDEC: Dr. Pete Schil</td>
</tr>
<tr>
<td>Military Academy</td>
<td>SRI/Sarnoff: Dr. Rakesh Kumar</td>
</tr>
<tr>
<td></td>
<td>DoD Mentors: LTC Joe Nolan, LTC Chris Vaughn [Joint Advanced Training</td>
</tr>
<tr>
<td></td>
<td>Technologies Lab]</td>
</tr>
<tr>
<td>Air Force Academy</td>
<td>DoD Mentors: a reserve AF Colonel, a retired USMC officer</td>
</tr>
</tbody>
</table>
Participants

![Bar chart showing participants by institution and semester]

Lines:
- Students Fall
- Students Spring

Institutions:
- SMU
- NPS
- Auburn
- MUST
- Wayne State
- Stevens
- PSU
- UVA
- Naval Academy
- UMD
- CGA
- AFA
- West Point
- AFT
How DoD problems were addressed

- One design problem broken into subsystems, each addressed by a separate team (one example)
- One design problem, with each team working on the entire problem (several examples)
- Several design problems, with each team working on a different problem (most common)
Student Prototypes
Would you choose a career in SE?

- Yes: 66%
- No: 15%
- Maybe/Don't Know/Unsure: 19%
Why Choose a Career in SE?

Problem-solving and intellectual challenge
“It seems like something that would interest me because it is not the same thing day after day and it allows me to be creative with my job. In addition, it’s very rewarding producing something that solves people’s problems.”

“I find thinking about complex systems of systems and their interactions both with the outside world and internally very interesting, and I am excited to work to help organizations improve efficiency.”

Interdisciplinary and project diversity
“... you're exposed to a wide variety of areas, not just one specific area. The projects in systems engineering vary much more than in individual engineering fields.”

Leadership opportunities
“I love working on huge projects and managing a whole lot of people. It's a pain sometimes, but it's so rewarding in the end to see the final huge project.”
Industry and DoD Mentors were Critical

“These individuals were vital to the success of the systems engineering capstone because they brought a level of legitimacy, relevancy, and real-world context to the problem that was a catalyst for student learning and mastery of course outcomes.” [Faculty]

“[Our mentor’s] industry experience allowed him to foresee debilitating problems; his managerial skills enabled him criticize in a gentle, useful manner; and his credentials as former vice president of manufacturing for a large motor company lent credence to his comments.” [Faculty]
SE Approach was Eye-Opening

“This is a different approach [compared] to engineering design approaches I was familiar with, where the focus was more on developing the best product with the most features. I believe that the systems engineering approach is a better one because the perfect useless gadget is still useless.” [Student]

“I was not aware of the amount of types of documentation that a systems engineering project required. The different competencies like requirements management and verification and validation showed how important organizational aspects are to a successful project.” [Student]
“Without a doubt, the greatest accomplishment of RT 19 is the demonstration that truly cross-disciplinary capstone design projects can be developed by groups of seniors at the undergraduate level.” [Faculty]

“[Our project] shows very well how teams of people from different backgrounds should communicate and work together. In the real job world almost all teams consist of people from different academic backgrounds so it is very useful.” [Student]
1. Fostering Systems Engineering Education through Interdisciplinary Programs and Graduate Capstone Projects. Jacques, David (Air Force Institute of Technology)

2. Integration of Systems Engineering Training Modules into Capstone Courses across College of Engineering Departments. Ellis, Darin (Wayne State)

3. SE Capstone: Experimental Learning in Distributed Classroom Environment for Systems Engineering Capstone Projects. Corns, Steve (Missouri University)

4. SE Capstone: Introducing Multidisciplinary Capstone Design to the United States Coast Guard Academy. Adrezin, Ronald (US Coast Guard Academy)

5. SE Capstone: Implementing a Systems Engineering Framework for Multidisciplinary Capstone Design. Sheppard, Keith (Stevens Institute)

6. SE Capstone: Introduction of Systems Engineering into an Undergraduate Multidisciplinary Capstone Course. Nemes, James (Penn State)

1. A Systems Engineering Approach to Micro Expression Facial Motion Capture with Structured Light. Bruner W., Chakravarthy, T., Jones, K., Kendrick, R., LaManna D. (Southern Methodist University)


Next Steps

- “Promising practices” by DoD site visitors informs selection criteria for second cohort of SE Capstone partners

- Final report/recommendations October 31, 2011

- RT-19A will study contexts for promising practices, deployable student products; sustainability and scale up models
Problem Area 5

• Assistive technologies for wounded warriors to facilitate rehabilitation and contribute positively to wounded warrior quality of life, including but not limited to:
  • application of haptic research
  • augmented reality
  • research from traumatic brain injury
  • bio-medical advances
  • hybrid assistive approaches (e.g., human-machine interfaces) and other leading-edge technologies
Promising Practices (1/2)

1. Fall semester tools/techniques/approaches SE theory course, followed by spring semester design project course

2. Cross-disciplinary student teams

3. Regular, direct involvement of mentors with student project teams

4. Established relationships with nearby DoD commands and facilities

5. Creative use of mentors from defense prime contractors
Promising Practices (2/2)

6. Structured design reviews with DoD and industry mentors serving as reviewers

7. Use of SE Ph.D. candidates as project advisors

8. Creative imposition of technical, budget, and schedule constraints by faculty to model "real world"

9. For civilian institutions that have on-campus ROTC units, established relationships with ROTC units for requirements analysis, use case testing, and solution viability
Questions?
Contact for more information

Mark Ardis, Co-PI
mark.ardis@stevens.edu
201 216 5143

or

Beth McGrath, PI
bmcgrath@stevens.edu
201 216 5037
This material is based upon work supported by the Assistant Secretary of Defense Research & Engineering (ASDR&E) office. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the sponsor.