The Social Web of Engineering Education: Knowledge Exchange in Vertically-Integrated Project Teams


Prepared for Presentation at the 2012 ASEE Annual Conference and Exposition, San Antonio, TX, June 10-13, 2012.
Active & Cooperative Learning Approaches


- Cooperative learning:
  - promotion of learning through providing cooperative incentives rather than competition (Bandura, A., 1974).

- Active learning (project-based learning):
  - creation of social communities that focus on applied problems; important for the development of professional capabilities (Prince, M., 2004).

- Positive active learning experiences are important for development of professional capabilities and retention of students in engineering programs (Litzinger, T., Lattuca, L. R., Hadgraft, R. G., and Newstetter, W. C., 2011).
Team Learning Environments

- Incorporate a range of possible learning opportunities.
- Increasingly relevant and used in engineering environments.

We ask:
- How do students engaged in engineering design educational experiences exchange learning and knowledge resources?
- How do the ways that engineering students interact in team network environments matter for the skills that they develop through this experience?
Undergraduates need Real Design Projects in which they Learn the Innovation Process

Large-Scale Research and Development Efforts Need Help at all Levels of Innovation
Program Architecture

- **Long-term, Large-scale Design projects:**
  - Large teams: 10-20 undergraduates; 1-4 grad students
  - Long-term participation – up to 3 years for UGs
  - Sophomores, juniors, seniors, grad students on each team
  - New students replace those who graduate
  - Teams are multidisciplinary & continue for many years

- **For-Credit Program:** Tech Electives; Senior Design

- **The Innovation Continuum:**
  - Research, develop, design, & deploy real solutions
Example: The eStadium Team at Georgia
Vertically Integrated Projects Program

eStadium Project – estadium.gatech.edu

Video and Data Capture

Web and Video Delivery Servers

Internet
The Social Network Perspective - 1

- A “social network” is a set of individuals or entities that are connected by sets of ties, which represent different types of relationships and access to resources (Wasserman, S. Faust, K., 1994).

- Instruction takes place within a defined and deliberately conceived network (project team) in which learners advise other learners.
In collaborative student teams, peer-relations (network ties) are a source of student learning (Gregory, R. D., 1994).

Structured peer-relations (networks) support student learning by

- enabling exchange of knowledge and expertise
- allowing for interactions between peers of different intellectual development
- providing advice (which fills gaps in their knowledge, to obtain information, and learn about opportunities in order to more quickly solve problems or take advantage of opportunities) (McGrath, C. A., Vance, C. M., & Gray, E. R., 2003).
Learners advise other learners, and gain in the process

**H1:** Students to whom other students turn for help in the student team environment will experience greater learning outcomes than students who do not.

**Learning is active**

**H2:** Those students who actively seek out advice and problem-solving help from their peers will report higher learning on a range of learning outcomes than those who do not.

**Learning is cumulative**

**H3:** Students who are engaged in long-term projects will report higher levels of learning than those who have been engaged for shorter periods of time.

**Learning is motivated**

**H4:** Students with higher levels of enthusiasm for the project will report higher learning outcomes.
Vertically Integrated Projects Program

Findings: Who knows who? and How?

I met this person through VIP:

<table>
<thead>
<tr>
<th>Georgia Tech</th>
<th>Purdue</th>
</tr>
</thead>
</table>

I met this person through VIP:
FINDINGS: **VIP Student Learning Networks**

- Ties show the exchange of technical information, including:
  - technical advice, advice about engineering concepts, advice about technical applications
  - overall ties that exchange technical information and average ties per person increased from one year to the next
FINDINGS: **VIP Student Learning Networks**

<table>
<thead>
<tr>
<th></th>
<th>Spr 10</th>
<th>Spr 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>All advice: Georgia Tech: All Students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of nodes</td>
<td>45</td>
<td>109</td>
</tr>
<tr>
<td>Number of ties</td>
<td>124</td>
<td>336</td>
</tr>
<tr>
<td>Mean centrality</td>
<td>2.75</td>
<td>3.83</td>
</tr>
<tr>
<td>EI-Index (team)</td>
<td>-.66</td>
<td>-.79</td>
</tr>
<tr>
<td>EI-Index (UG-G)</td>
<td>-.35</td>
<td>-.52</td>
</tr>
<tr>
<td>EI-Index (year)</td>
<td>.03</td>
<td>-.64</td>
</tr>
<tr>
<td>EI-Index (gender)</td>
<td>-.47</td>
<td>-.19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Spr 10</th>
<th>Spr 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgia Tech: Undergraduates Only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of nodes</td>
<td>33</td>
<td>93</td>
</tr>
<tr>
<td>Number of ties</td>
<td>77</td>
<td>245</td>
</tr>
<tr>
<td>Mean centrality</td>
<td>2.33</td>
<td>2.25</td>
</tr>
<tr>
<td>EI-Index (team)</td>
<td>-.66</td>
<td>-.80</td>
</tr>
<tr>
<td>EI-Index (year/VIP1)</td>
<td>.04</td>
<td>-.72</td>
</tr>
<tr>
<td>EI-Index (gender)</td>
<td>-.38</td>
<td>-.20</td>
</tr>
</tbody>
</table>

- Results show integration of women, and slight increase in cross team integration.
- Results show fewer ties that cross student ranks (UG-G) boundary.
What factors matter most in students assessment of skills gains?

- Series of multiple regression models:
  - \( \text{Skill} = f(\text{outdegree} + \text{indegree network variables} + \text{time on project} + \text{student rank} + \text{gender} + \text{institution} + \text{student enthusiasm} + \text{prior research/team experiences} + \text{student faculty team ratio} + \text{student rank}) \).
  - Model: tested on summary and individual skills.
### Table 5: Regression Models: Respondent Self-Reported Technical Skills

**How much has your VIP experience helped in the development of these other skills?**

Other skills: teamwork-related

<table>
<thead>
<tr>
<th>Variable</th>
<th>working on a multi-disciplinary team</th>
<th>working on a project team in my discipline</th>
<th>planning a long term project</th>
<th>managing a project team</th>
<th>resolving team conflicts or disagreements</th>
<th>collaborating on project team solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of VIP students sought for advice</td>
<td>0.05</td>
<td>0.04</td>
<td>0.07</td>
<td>0.03</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Number of VIP students asking for advice</td>
<td>0.02</td>
<td>0.02</td>
<td>-0.02</td>
<td>0.10</td>
<td>*</td>
<td>0.06</td>
</tr>
<tr>
<td>Georgia Tech</td>
<td>0.42</td>
<td>***</td>
<td>0.04</td>
<td>0.14</td>
<td>0.12</td>
<td>-0.04</td>
</tr>
<tr>
<td>Participated in project in 2009/2010</td>
<td>0.38</td>
<td>^</td>
<td>0.48</td>
<td>0.20</td>
<td>0.35</td>
<td>0.19</td>
</tr>
<tr>
<td>Team is new in 2011</td>
<td>0.05</td>
<td>0.08</td>
<td>0.03</td>
<td>0.12</td>
<td>0.08</td>
<td>0.04</td>
</tr>
<tr>
<td># of undergraduates per faculty</td>
<td>-0.03</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.02</td>
<td>-0.01</td>
<td>-0.03</td>
</tr>
<tr>
<td>female</td>
<td>0.17</td>
<td>-0.05</td>
<td>0.23</td>
<td>*</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Junior</td>
<td>-0.10</td>
<td>0.36</td>
<td>*</td>
<td>0.09</td>
<td>0.13</td>
<td>-0.08</td>
</tr>
<tr>
<td>Senior</td>
<td>-0.04</td>
<td>0.18</td>
<td>0.08</td>
<td>0.01</td>
<td>-0.14</td>
<td>-0.13</td>
</tr>
<tr>
<td>Student Enthusiasm for VIP</td>
<td>0.09</td>
<td>**</td>
<td>0.12</td>
<td>***</td>
<td>0.15</td>
<td>0.12</td>
</tr>
<tr>
<td>Research assistant for a faculty member</td>
<td>0.06</td>
<td>0.03</td>
<td>-0.03</td>
<td>0.28</td>
<td>*</td>
<td>0.18</td>
</tr>
<tr>
<td>Worked on a project team as part of your employment</td>
<td>-0.01</td>
<td>0.06</td>
<td>0.02</td>
<td>0.15</td>
<td>0.01</td>
<td>0.09</td>
</tr>
<tr>
<td>Control: Freshman or Sophomore</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adj R-squared</td>
<td>0.14</td>
<td>0.10</td>
<td>0.17</td>
<td>0.17</td>
<td>0.08</td>
<td>0.10</td>
</tr>
</tbody>
</table>

N = 133 for all models

*P<0.1=^, P < 0.05= *, P < 0.01 = **, P<0.001=***

**Tables of regression coefficients & significance.**

Cols = Skills
Rows = Vars
VIP Student Learning Outcomes: Technical Skills

How much has your VIP experience helped in the development of technical skills?

<table>
<thead>
<tr>
<th>Variables</th>
<th>Experimentation (Data analysis &amp; interpretation)</th>
<th>Engineerin (g design)</th>
<th>Programming and designing computing algorithms</th>
<th>Understanding comp/commun hardware and systems</th>
<th>Applied problem solving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef</td>
<td>Sig</td>
<td>Coef</td>
<td>Sig</td>
<td>Coef</td>
</tr>
<tr>
<td># of other VIP students sought for advice</td>
<td>.09</td>
<td>^</td>
<td>.06</td>
<td>.06</td>
<td>.23</td>
</tr>
<tr>
<td># of VIP students asking respondent for advice</td>
<td>-.11</td>
<td>-.02</td>
<td>-.09</td>
<td>.10</td>
<td>-.11</td>
</tr>
</tbody>
</table>

N = 133

*P < 0.1 = ^  *P < 0.05 = *  *P < 0.01 = **  *P < 0.001 = ***

- Do students who seek advice from others learn more than others who do not? Yes.
- Do students who teach others learn? Not necessarily.
Vertically Integrated Projects Program

VIP Student Learning Outcomes: Technical Skills

How much has your VIP experience helped in the development of technical skills?

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<th>Variables</th>
<th>Experimentation and data analysis &amp; interpretation</th>
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<td></td>
<td>Coef.</td>
<td>Sig.</td>
<td>Coef.</td>
<td>Sig.</td>
<td>Coef.</td>
</tr>
<tr>
<td>Participated in project in 2009/2010</td>
<td>.62</td>
<td>^</td>
<td>.74</td>
<td>*</td>
<td>1.31</td>
</tr>
<tr>
<td>Student Enthusiasm for VIP</td>
<td>.30</td>
<td>***</td>
<td>.30</td>
<td>***</td>
<td>.17</td>
</tr>
</tbody>
</table>

N = 133

P < 0.1 = ^  P < 0.05 = *  P < 0.01 = **  P < 0.001 = ***

- Is technical learning in VIP cumulative?  Yes.
- Are more engaged students learning more?  Yes.
**Vertically Integrated Projects Program**

**VIP Student Learning Outcomes: Team Skills**

*How much has your VIP experience helped in the development of team skills?*

<table>
<thead>
<tr>
<th>Variable</th>
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<td>*</td>
<td>.06</td>
</tr>
</tbody>
</table>

*N = 133 for all models*

\[ P < 0.1 = ^ {\text{^}} \quad P < 0.05 = \ast \quad P < 0.01 = \ast\ast \quad P < 0.001 = \ast\ast\ast \]

- Do students who seek advice from others learn more than others who do not? **Yes, for planning and dealing with problems.**
- Do students who teach others learn? **Yes, about managing.**
Vertically Integrated Projects Program

VIP Student Learning Outcomes: Team Skills

<table>
<thead>
<tr>
<th>Variable</th>
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N = 133 for all models

\[
P < 0.1 = ^ \quad P < 0.05 = * \quad P < 0.01 = ** \quad P < 0.001 = ***
\]

- Is learning in VIP cumulative? **Yes, but not for all**
- Are more engaged students learning more? **Yes**
Conclusions:

- In the VIP Program, undergraduates are gaining important technical, as well as managerial and collaborative skills through their experience.
  - Undergraduates show the development of important learning communities, and exchange of technical and other advice within and across teams.
- UG student development knowledge ties within and across teams.
- Proactive students that seek information seem to experience the most skill attainment.
- Personal motivation and engagement seems to be an important factor for reported skill attainment.
Next Steps:

- Expand/Refine evaluation framework:
  - Number of disciplines involved growing
    - Functions: Design – Discovery – Analysis -- ....
  - Extend data to incorporate faculty input on VIP processes, student learning, etc.
  - Extend student data to include psychometric metrics, and other activity and outcome metrics.
    - Include metrics on propensity to interact in groups, and other personality variables.
    - Incorporate other measures of skill gains
Vertically Integrated Projects Program

http://vip.gatech.edu
http://www.strath.ac.uk/viprojects

Julia Melkers, jmelkers@gatech.edu
Ed Coyle, ejc@gatech.edu
Extra Slides and Info:

Tools Used:
- UCInet for networking statistics
- NETDRAW to draw graphs
- Sawtooth Software for surveys

Model Strength: Adjusted R Square high

Psychometrics: Social Potency/Closeness
FINDINGS: VIP Student Learning Outcomes

- Participating on their VIP team has yielded important practical and technical skills.
- Skill development attainment has varied across institutions.

![Graph showing mean responses for various VIP skills](image)

Mean Responses: 1= not at all, 2= somewhat, 3=a great deal
Georgia Tech VIP Teams

- **eStadium (GT/Purdue/OSU/Morehouse)**
  - CEE, CS, CM, CEE, ECE, MGMT, Law
  - Wireless, Multimedia, Sensor Nets, etc

- **eDemocracy**
  - CS, ECE, ISyE, INTA
  - Election Monitoring System, Redistricting, Policy, etc

- **Collaborative Workforce**
  - CS, ECE
  - Multimedia Content; Collaboration Tech.; etc

- **Intelligent Tutoring Systems**
  - CS, ECE, ISyE
  - Learning Theory, Databases, GUIs, Ontologies, etc
Georgia Tech VIP Teams

- **GTRI Robotics Team**
  - CS, ECE, ME
  - Design and develop robot/unmanned systems

- **eCampus**
  - CS, ECE
  - Wireless, Mobile Apps, Databases, GUIs

- **Computational Structural Biology**
  - BIO, ChemE, CS, PHYSICS
  - Macromolecular Simulations, Algorithms, etc.

- **Cure Diabetes**
  - BME, MSE, ME
  - Develop new implantable devices for curing diabetes
Georgia Tech VIP Teams

- **USLI Rocket Team**
  - AE, ECE
  - Rocket design, instrumentation, construction and flight

- **Intelligent Transportation Systems**
  - CS, ISyE
  - Optimal control of transportation fleets; Tech Trolley

- **I-Natural**
  - CS, ECE, ME
  - Design of robots that interact with people

- **Brain Beats**
  - BME, CS, ECE, ME
  - Neural basis of human ability to maintain “rhythmic time”
Georgia Tech VIP Teams

- **AquaBots – New**
  - CEE, CS, ECE, ME
  - Navigation of underwater and surface vehicles, mapping and exploration underwater, etc.

- **Open Academic Environment – New**
  - CS, ECE, IC, CM
  - Web tools supporting learning and research collaboration

Adding 2 to 3 teams per year