The Use of Systems Engineering Principles to Improve Learning Outcomes in a Multidisciplinary Course

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Using Systems Engineering to Improve Learning Outcomes in a Multidisciplinary Course

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Modern Engineering Challenges
• Large scale problems
• Multidisciplinary aspects
• System hierarchy
• Complexity

Engineering education must be responsive

- Weinberg et. al. “A multidisciplinary model for using robotics in engineering education”
- Miller et. al. “A model curriculum for a capstone course in multidisciplinary engineering design”
- Roberts et. al. “Developing a multidisciplinary engineering program at Arizona State University east campus”
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Modern Engineering Challenges: An Example

• The modern vehicle:

  • Vehicle powertrain course
    100% mechanical engineering
    50% mechanical / 50% electrical
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**Introduction**

**Systems Engineering**

- Allows successful design of broad, risky, and complicated systems
  - Multidisciplinary systems

- Is a key component of sustaining U.S. competitiveness
  - Universities are developing and expanding systems engineering courses and departments

- Could improve learning outcomes for a multidisciplinary course
  - Vehicle Powertrains course at Colorado State University
    - Graduate level mechanical engineering course
    - Each week: 2 x 50 minute lectures, 1 x 50 laboratory
    - Focus on Matlab and Simulink model development
    - 12 laboratories, 2 exams, and 1 capstone project
    - 2017 class: 18 students, 2015 class: 20 students
A systems engineering lecture was given in the course

• Systems engineering is not an emphasis in the mechanical engineering curriculum
• Lecture given to coincide with the beginning of work on the course capstone project
• Systems engineering comprehension, retention, and perceived usefulness are evaluated
  ◦ Voluntary pre-lecture survey (16 of 18 responses)
  ◦ Voluntary post-lecture survey (16 of 18 responses)
  ◦ Voluntary end of course survey (18 of 18 responses)
• Systems engineering application in the course is evaluated
  ◦ Individual course capstone projects

Analyzed with:
1. Independent group t-test
2. Bootstrap group mean difference
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1. Course relevant concepts
   ◦ Defining the system boundary
   ◦ Requirements development
   ◦ Concurrent development
   ◦ Applying the V-model
   ◦ Resource management
   ◦ Configuration management
   ◦ Risk management
   ◦ Tailoring applied systems engineering
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2. Potential systems-level scopes for the course capstone project
   - Well-to-wheel analysis
   - Electrical grid power source considerations
   - Ride-sharing or non-vehicle ownership scenarios
   - Powertrain control optimization
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Figure 2 – Example of Hourly Marginal Fuels Data by Time of Day [Source: PJM, 2008]

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Student reported level of systems engineering knowledge

• “Before lecture” → “After lecture”
  ◦ T-test: independent response
  ◦ Group mean difference: Increase in systems engineering knowledge

• “After lecture” → “End of the Course”
  ◦ T-test: not independent response
  ◦ Group mean difference: some evidence that systems engineering knowledge increased
Student responses to the statement: “Development of modern powertrains requires a multidisciplinary approach”

- “After lecture” → “End of the Course”
  - T-test: not independent response
  - Group mean difference: strong agreement after the lecture and at the end of the course
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Student responses to the statement: “Is systems engineering useful?”

• “After lecture” → “End of the Course”
  ◦ T-test: not independent response
  ◦ Group mean difference: some evidence that agreement increases after completion of the course
Student responses to the statement “Implementation of systems engineering improves development of multidisciplinary systems”

• “Before lecture” → “After lecture”
  ◦ T-test: independent response
  ◦ Group mean difference: strong student agreement

• “After lecture” → “End of the Course”
  ◦ T-test: not independent response
  ◦ Group mean difference: some evidence for slightly stronger student agreement
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Student responses to the statement “systems engineering could improve performance in labs, homework, and/or exam prep”

• “After lecture” → “End of the Course”
  ◦ T-test: not independent response
  ◦ Group mean difference: some evidence that students disagree with this more after completion of the course
    ▪ Note: students still mostly agree with this statement
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Student responses to the statement “systems engineering could improve performance in the capstone project”

- “After lecture” → “End of the Course”
  - T-test: not independent response
  - Group mean difference: some evidence that students disagree with this more after completion of the course
The survey also had a section for comments from students

- “The split between mechanical and electrical engineering is much more prominent in education than in industry. Any course that bridges the gap is A-Okay in my view!”
- “Two lectures on systems engineering and its application to the class would be beneficial”

- Students perceived value in teaching systems engineering in the course
- Additional systems engineering content may be necessary
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Systems-level project scopes were evaluated and compared to the last time the course was taught

- Could be included in addition to the modeling, simulation, and design requirements
- All projects ended up with a systems-level scope
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Summary

• Systems engineering lecture given in our vehicle powertrains course
  ◦ Presented course relevant concepts (concurrent development, V-model, etc.)
  ◦ Presented potential systems-level scopes (well-to-wheel analysis, ride-sharing, etc.)

• Before lecture, after lecture, and end of course surveys administered
  ◦ Student knowledge about systems engineering significantly improved
  ◦ Students are confident in systems engineering relevance and that it will improve engineering development
  ◦ Students may have lost some confidence in their abilities to implement systems engineering after completion of the course
  ◦ One student directly suggested an additional lecture on systems engineering

• Student capstone projects evaluated
  ◦ Systems-level project scopes increased from 33% to 100%
Conclusions

• Inclusion of the systems engineering lecture improved course outcomes
• Students attribute benefit to the inclusion of a systems engineering lecture
• Inclusion of an additional systems engineering lecture focused on an in-depth example may further improve learning outcomes

• Overall: we were able to raise systems engineering awareness/understanding and the students attributed a benefit to this
Future Work

- Apply this same methodology to other multidisciplinary graduate-level courses
- Implement additional systems engineering course components
- Investigate the role of previous systems engineering education
- Develop additional techniques to evaluate improved learning outcomes
Systems Engineering + Multidisciplinary Courses = Success!

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2018 ASEE ANNUAL CONFERENCE & EXPOSITION
JUNE 24–27, 2018 | SALT PALACE CONVENTION CENTER | SALT LAKE CITY, UT