A New Paradigm in Engineering Education Using Two Disruptive Technologies: Simulations & Online Learning

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Cornell University
Outline

1. Backstory
2. Pedagogical framework
3. Hands-on simulation MOOC
4. A new paradigm
Swanson Simulation Program at Cornell University

- Established in 2000 with an endowment from Dr. John Swanson, ANSYS Inc. founder
- Department: Mechanical & Aerospace Engr.
- Goals:
  - To facilitate routine use of computer simulation in M&AE curriculum
  - To provide support and leadership to the community on simulation in engineering education

Advisory Committee

<table>
<thead>
<tr>
<th>ANSYS</th>
<th>ASME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boeing</td>
<td>NAFEMS</td>
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<tr>
<td>GE</td>
<td>Penn State</td>
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<td>MathWorks</td>
<td>CIMData</td>
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<td>PTC</td>
<td>DatapointLabs</td>
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### Swanson Simulation Program: Impact on Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Level</th>
<th>Enrollment</th>
<th>Software</th>
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<tbody>
<tr>
<td>MAE 3250 Mechanical Structures</td>
<td>Junior</td>
<td>150</td>
<td>ANSYS Mech.</td>
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<tr>
<td>MAE 3240 Heat Transfer</td>
<td>Junior</td>
<td>130</td>
<td>ANSYS Mech.</td>
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<tr>
<td>MAE 3272 Mechanical Lab</td>
<td>Junior</td>
<td>140</td>
<td>ANSYS Mech.</td>
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<tr>
<td>MAE 4272 Thermo-fluids Lab</td>
<td>Senior</td>
<td>160</td>
<td>ANSYS Fluent</td>
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<tr>
<td>MAE 4230/5230 Int. Fluid Dynamics</td>
<td>Ugrad/M.Eng</td>
<td>60</td>
<td>ANSYS Fluent</td>
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<tr>
<td>MAE 4700/5700 Finite-Element Analysis</td>
<td>Ugrad/M.Eng</td>
<td>50</td>
<td>ANSYS Mech.</td>
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<tr>
<td>MAE 4020/5020 Wind Energy</td>
<td>Ugrad/M.Eng</td>
<td>50</td>
<td>ANSYS Mech./ Flu.</td>
</tr>
<tr>
<td>MAE 4650 Biofluid Mechanics</td>
<td>Ugrad/M.Eng</td>
<td>20</td>
<td>ANSYS Fluent</td>
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<tr>
<td>BME 4490 Biomechanics Laboratory</td>
<td>Ugrad</td>
<td>4</td>
<td>ANSYS Mech.</td>
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<tr>
<td>MAE 6690 Biofluids</td>
<td>Ph.D.</td>
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<td>ANSYS Fluent</td>
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</table>
Simulation Examples from Cornell Courses

Thermo-Fluids Lab

Temperature Contours

Wind Energy
SimCafe.org: Free Learning Portal for Simulations

- Contains over 50 learning modules on FEA and CFD using ANSYS
- Has been critical for the integration of ANSYS-based simulations into courses
- Learning modules have a uniform structure

2016-17 Usage Statistics

<p>| | |</p>
<table>
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<tr>
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<tbody>
<tr>
<td>Pageviews</td>
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<tr>
<td>Unique visitors</td>
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<td>Countries</td>
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<td>Average session</td>
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The Simulation Blackbox

User inputs → Color pictures & other results

Garbage in → Garbage out

Garbage out → Garbage in

Novice thinking
What’s Inside the Blackbox?

User inputs → Mathematical Model → Numerical Solution → Selected variables at selected points → Post-processing

Physical Problem → Physical principles Assumptions → Hand calculations

Physical Problem → Experimental data → Color pictures & other results

Expert thinking
1. Mathematical model
2. Numerical solution procedure
3. Hand-calculations of expected results/trends
• Verification: Did I solve the model right?
• Validation: Did I solve the right model?
Uniform Process Across Courses

Problem Specification
1. Pre-analysis
2. Geometry
3. Mesh
4. Model Setup
5. Numerical Solution
6. Numerical Results
7. Verification & Validation

Just-in-time, problem-based learning

Novice > Expert thinking

cf. Just-in-case, content-based learning
Outline

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2. Pedagogical framework
3. Hands-on simulation MOOC
4. A new paradigm
MOOC: A Hands-on Intro to Engineering Simulations

- Holistic approach to teaching math/physics and hands-on simulations
- Simulation app: ANSYS Student
- 6 simulation case studies drawn from 5 engineering courses
- “Big ideas” sections
- Cuts across traditional boundaries
  - Common approach to problems involving different physics
  - Common approach to FEA and CFD
- A new kind of engineering course
MOOC Lectures and Assessments

- **Lectures**
  - Overlay chalkboard, PowerPoint, ANSYS
  - Self-recorded
    - Now edited by undergrad TA's
  - Four minutes long on average
  - Sage on the stage > Guide by the side
  - Bring in industry expert as needed

- **Assessments facilitate active learning & guided exploration**
## MOOC Statistics

<table>
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<tr>
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<th>Total</th>
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<tbody>
<tr>
<td>Enrollment</td>
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<tr>
<td>Countries</td>
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<tr>
<td>Verified certificates</td>
<td>2700</td>
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<tr>
<td>($49 each)</td>
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<tr>
<td>YouTube views</td>
<td>1.9 million (5.7 million minutes)</td>
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</table>

![Daily Learner Graph](image)
Top 3 Themes:

- Great course/Amazing
- Positive experience/I enjoyed learning
- Thanks

Secondary Themes in Comments:

- I gained a better understanding of the underlying math & physics
- The connection between math/physics to industry was effective
- Please provide more materials/courses of this kind
1. After this course, I'm going to do more "Verification and Validation."

2. In other courses I attended, the instructor was teaching how to do by just pushing buttons but now I know that there is no demon inside the computer to do the magic; it is just science. Now I know how the software is working, what is the theory behind the calculations and how to check if my model is correct.

3. The high quality of the introduction to problems (LOVE the big ideas pieces) and careful stepping through complex mathematics to get the learner to a point where the ANSYS task makes sense is very engaging. I have a good understanding of the mathematics but the way it is explained here would have made my acquisition of that understanding so much quicker. I [greatly] appreciate this course for the big picture and practical frame it puts over a very complex and what for me at times past was a bewildering area.
Instructor Comment

• I will be using ANSYS as a tool for a freshman project-based course. I was looking for a tutorial online that the students could use considering that they would have never used ANSYS before.

Yesterday I was lucky enough to stumbled upon your [course]. I signed up to take it and, having gone over the first section, I’m sold! =) You’ve done an amazing job! Also, it is exactly the sort of thing I was looking for! I wanted the students to know what is under the hood without having to go into so much detail that you never get to use the software!

The question I have is, would it be possible to use part of your course for my course?
A New Paradigm

- Holistic approach
- Multi-disciplinary
- Just-in-time problem-based learning
- Novice > Expert
- Embraces automation
  - Simulation
  - Online learning
- Sage on the stage > Guide by the side
- Scales well
  - One person teaches thousands, one person at a time
Disrupting Engineering Ed to Democratize Simulations

• Win-win
  – Learners
  – Employers

• Challenges
  – Cultural
    • Students are agents of change
  – Simulation app evolution

Pervasive Learning

Modular digital content (Simulation-based)

MOOCs

Courses

Freshman