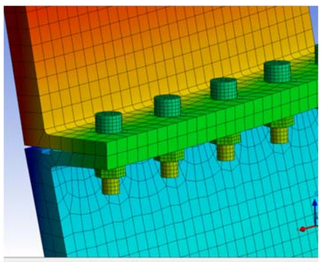
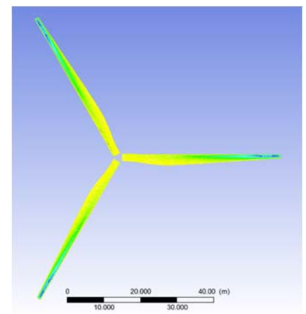
Cornell Engineering

Massive Open Online Courses (MOOCs) and Simulations: Creating a New Paradigm in Engineering Education by Combining Two Disruptive Technologies



Rajesh Bhaskaran
Swanson Director of Engineering Simulation
Mechanical & Aerospace Engineering

Fall 2016 Engineering College Council Meeting



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Outline

- History
- SimCafe
- Massive Open Online Course (MOOC)
  - Overview
  - Online lectures
  - Enrollment metrics
  - Student reactions
- Conclusion

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Swanson Simulation Program at Cornell University

- Established in 2000 with an endowment from Dr. John Swanson
- Department: Mechanical & Aerospace Engr.
- Original goal:
  - To facilitate the introduction and routine use of computer simulation in M&AE curriculum
- Additional goal (via input from advisory committee):
  - To provide support and leadership to the community on simulation in engineering education
- Endowment supports approximately one full-time position

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Swanson Program: Impact on Courses

	Course	Level	Enrollment	Software
1	MAE 3250 Mechanical Structures	Junior	150	ANSYS Mech.
2	MAE 3240 Heat Transfer	Junior	130	ANSYS Mech.
3	MAE 3272 Mechanical Lab	Junior	140	ANSYS Mech.
4	MAE 4272 Thermo-fluids Lab	Senior	160	ANSYS Fluent
5	MAE 4230/5230 Int. Fluid Dynamics	Ugrad/M.Eng	60	ANSYS Fluent
6	MAE 4700/5700 Finite-Element Analysis	Ugrad/M.Eng	50	ANSYS Mech.
7	MAE 4020/5020 Wind Energy	Ugrad/M.Eng	50	ANSYS Mech./ Flu.
8	MAE 4650 Biofluid Mechanics	Ugrad/M.Eng	20	ANSYS Fluent
9	MAE 5690 Musculoskeletal Biomechanics	Ugrad/M.Eng	20	ANSYS Mech.
10	MAE 6510 Advanced Heat Transfer	Ph.D./M.Eng	10	ANSYS Mech.
11	MAE 6690 Biofluids	Ph.D.	15	ANSYS Fluent
12	MAE 6640 Mechanics of Bones	Ph.D./M.Eng	15	ANSYS Mech.

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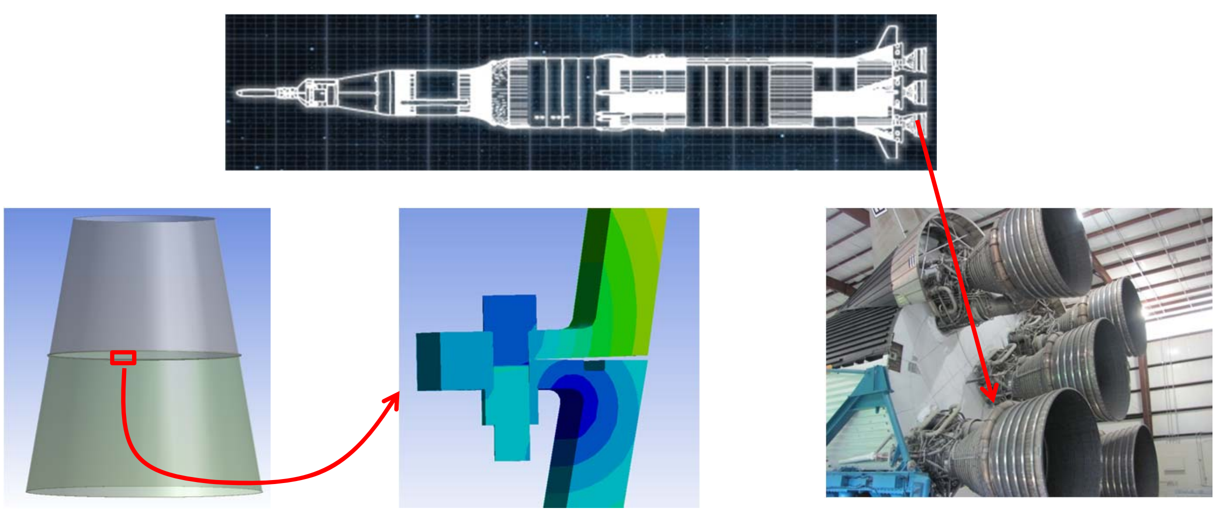
Simulation Example from an MAE Course

Bolted Flange on Rocket Engine in *Finite Element Analysis*



Swanson Program: Impact on Project Teams

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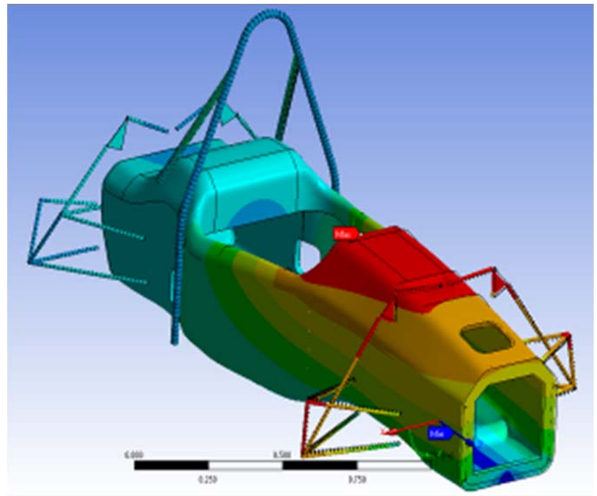
- Formula SAE Racing
- Baja SAE Racing
- Violet Satellite
- Mars Rover
- AIAA Design-Build-Fly
- CU Sustainable Design
- Cornell Rocketry
- Concrete Canoe
- Steel Bridge
- AguaClara



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SimCafe.org: Free Learning Portal for Simulations

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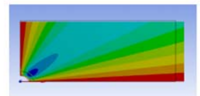
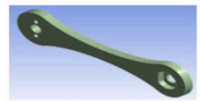
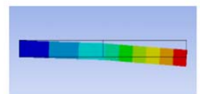
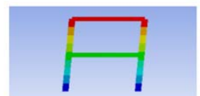
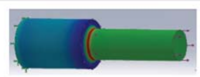
- Contains over 50 learning modules
  - Finite-element analysis (FEA) and Computational Fluid Dynamics (CFD) using ANSYS
- Learning modules have a uniform structure that connects fundamentals to hands-on practice
- Has enabled the integration of ANSYS-based simulations into 12 Mechanical & Aerospace engineering courses at Cornell

	Plate With a Hole	MAE 3250/ MAE 4700--5700
	Bike Crank	MAE 3250/MAE 3272
	Bike Crank: Part 2	MAE 3272
	Cantilever Beam	MAE 4700-5700
	Plane Frame	MAE 4700-5700
	A stepped shaft in axial tension	Prantil et al textbook

Simcafe Usage Statistics: July 1st, 2015 to June 30th, 2016

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Pageviews	2.1 million
Unique visitors	156,000
Countries	164
Average session duration (min)	10

Increase of 23% in pageviews from prior academic year

156 educational institutions had more than 200 sessions

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A Hands-on Introduction to Engineering Simulations

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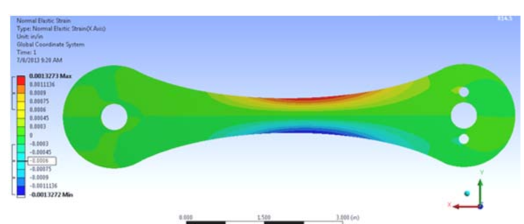
- Learning of fundamental math/physics alongside tool use & practical applications
- Case studies were drawn from 5 M&AE courses
  - Common approach to problems involving different physics
- Common approach to FEA and CFD

Simulation



MOOC: Approach

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6 ANSYS Case Studies

- 1 Conduction
- 2 Structural mechanics
- 2 Fluid dynamics
- 1 Fluid dynamics + Structural mechanics

Big Ideas

- What's under the blackbox
- Structural mechanics
- Fluid dynamics
- FEA
- CFD

Framing the Simulation Case Studies

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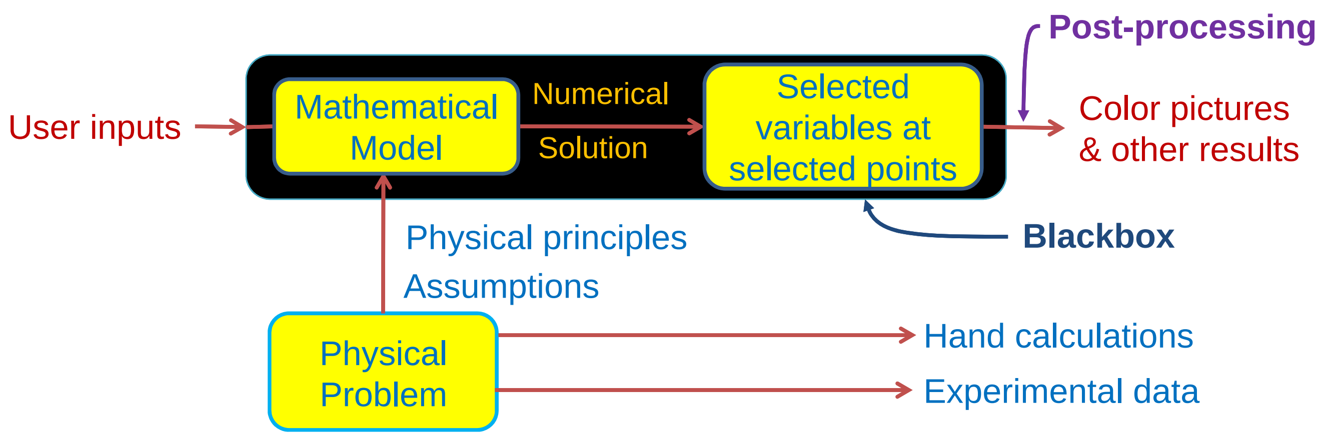
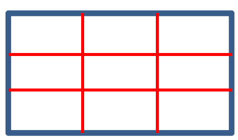
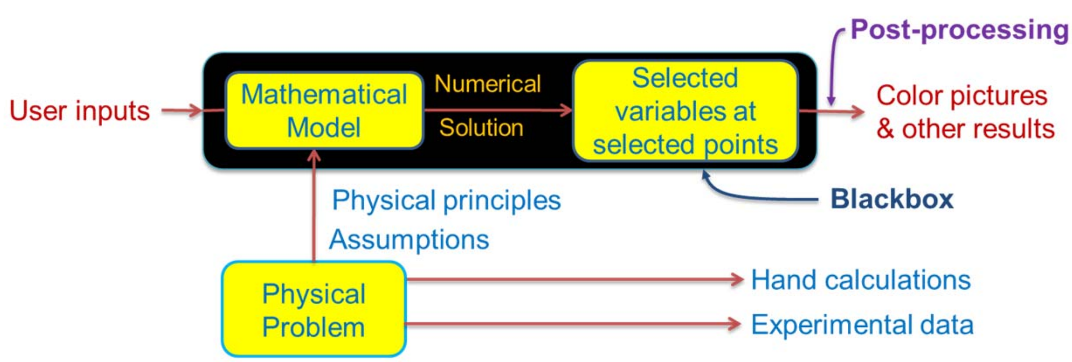
The Blackbox

What's Inside the Blackbox?





Pre-Analysis Section



1. Mathematical model
2. Numerical solution procedure
3. Hand-calculations of expected results/trends

Verification & Validation Section

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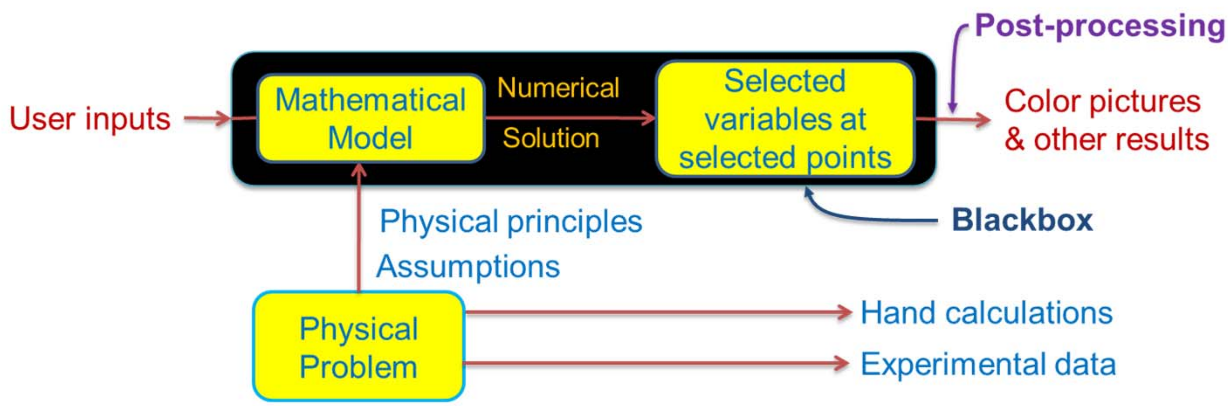

- Verification: Did I solve the model right?
- Validation: Did I solve the right model?

Student Comment

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- After this course, I'm going to do more "Verification and Validation”

- 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 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

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- 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?

Online Lectures

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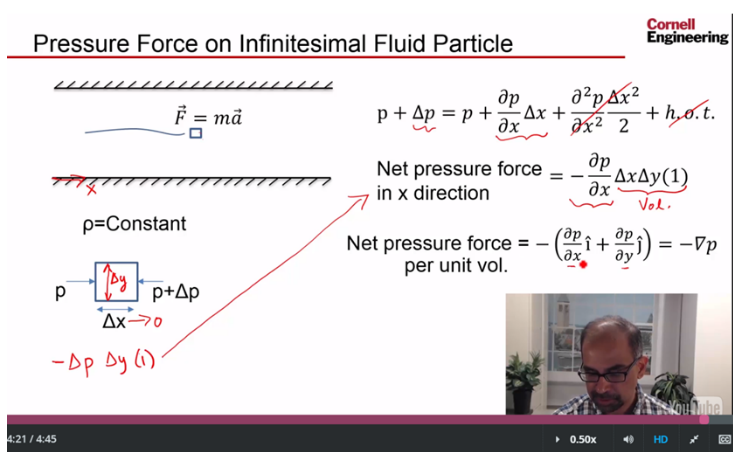
- Recorded in a self-service studio
- Can overlay chalkboard, Powerpoint, ANSYS
- Can bring in an industry expert
- Can chunk in a way that matches short-term memory



Enrollment Metrics

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- 25,000+ from 169 countries signed up
- 9,000+ actively engaged with the course
- 1,600 completed it
- 1,100 signed up for verified certificate paying $49 each
- YouTube stats:
  - MOOC channel: 480,000 views
  - Cf., SimCafe channel: 760,000 views

Geographic Distribution

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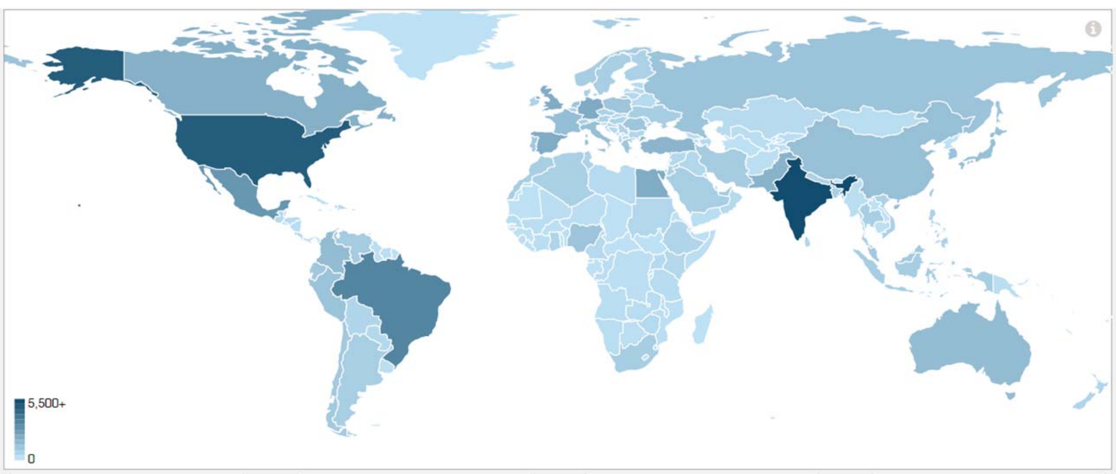

169	India	United Sta...	Brazil
Total Countries Represented	Top Country by Enrollment	Second Country by Enrollment	Third Country by Enrollment
	21% of students	17% of students	8% of students

Education Level

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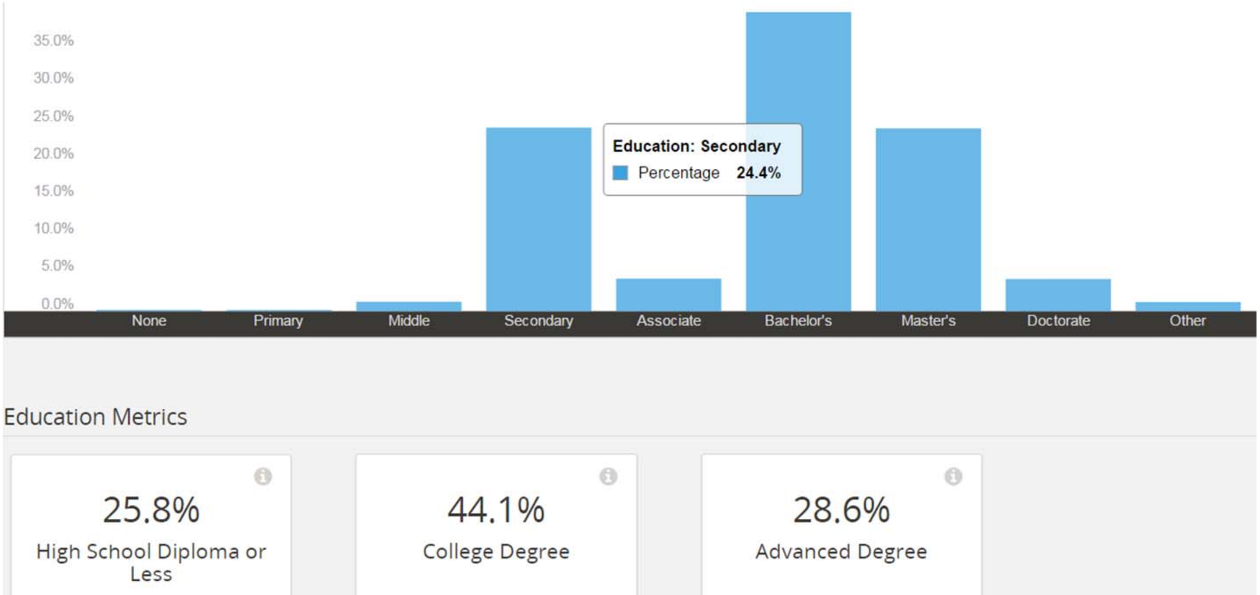

Please Rate Course **Materials**

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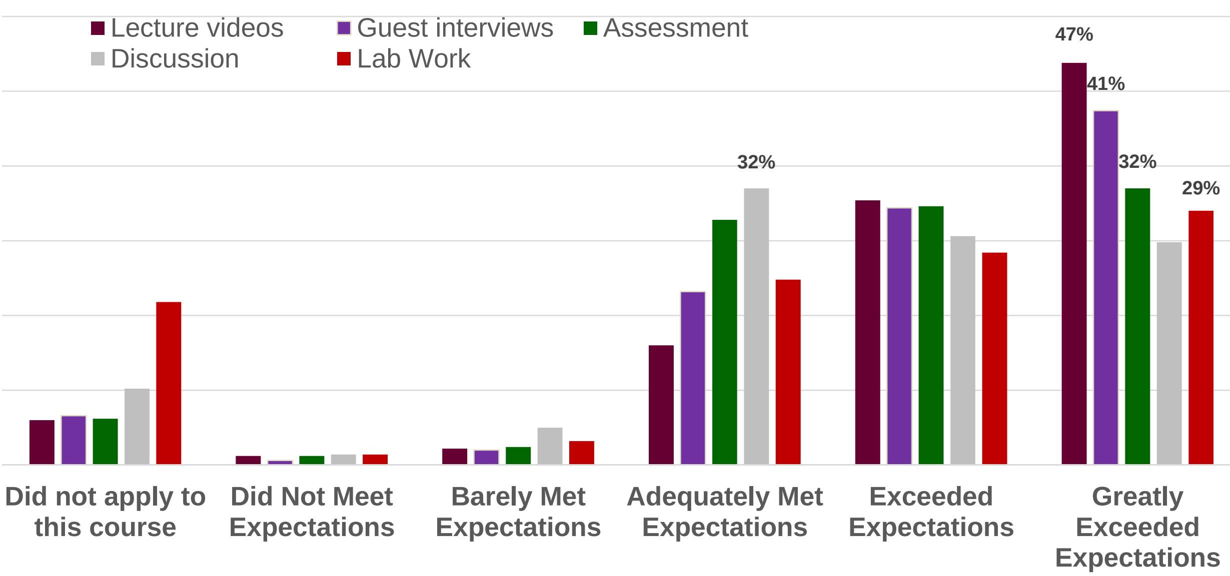
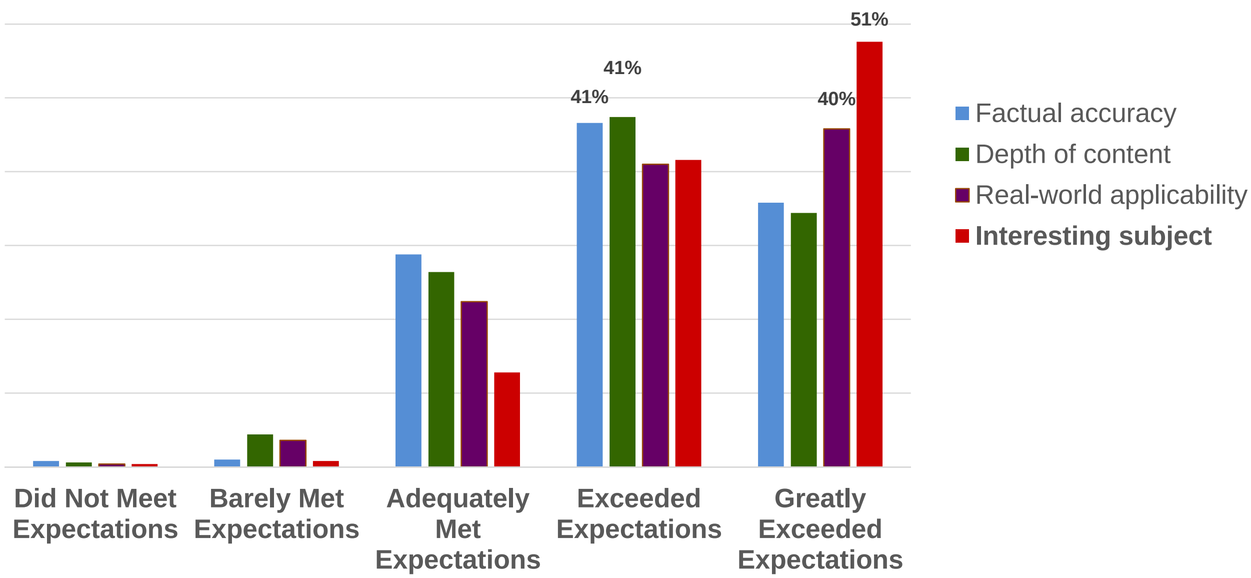


Please Rate the Course Content



Open Comments Analysis (by Dr. Kim Nicholson)

Top 3 Themes:

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

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

Open Comments Analysis: Word Cloud

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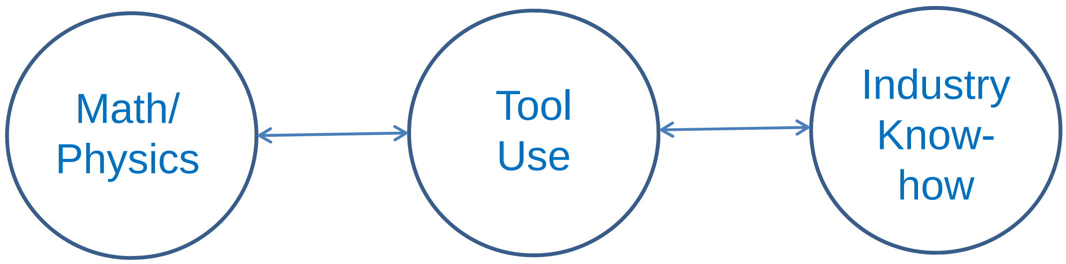
MOOC Demonstrates New Paradigm in Engr. Education



- Students gain:
  - Practical skills sought by employers
  - Better understanding of the fundamental math/physics
- Enabled by combining two disruptive technologies
  - Simulations and MOOCs

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How does this new paradigm disrupt status quo?

1. Integrative
   - Cuts across traditional boundaries
2. Flips the curriculum
   - Beginners are exposed to advanced material
3. Uses learning modes proven to be more effective
   - Hands-on, visual, case-study based, guided exploration in a numerical lab environment
4. Scalable
   - One person can teach thousands
5. Global
   - Faculty can run an international classroom sitting in the office
6. Customizable
   - Accommodates diverse audiences

Vision

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- Develop and disseminate the next-generation engineering curriculum
  - Simulation-based
  - Digitally delivered
- Enable the "democratization of simulation"
  - What is the limiting factor?
    - ~~Math models and numerical methods~~
    - ~~Hardware~~
    - ~~Software~~
    - People

Future Work

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- Develop a core simulation-based curriculum
- Increase awareness
- Crowd-source the teaching
- Facilitate integration of MOOC content into courses
- Support interested faculty