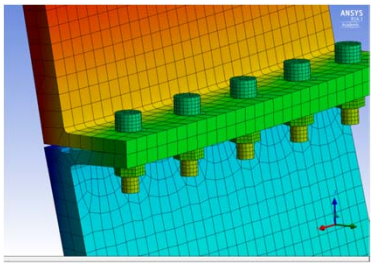
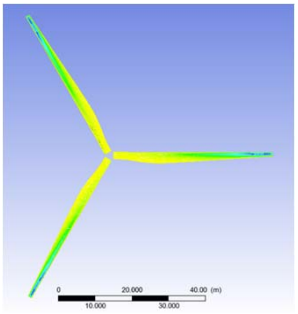
Massive Open Online Courses (MOOCs) and Simulations: Creating a New Paradigm in Engineering Education by Combining Two Disruptive Technologies



Rajesh Bhaskaran
Cornell University

Fall 2016 Engineering College Council Meeting



Outline

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

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Cornell Engineering

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Swanson Simulation Program at Cornell University

Cornell Engineering

- 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 one full-time position

Swanson Program: Impact on Courses

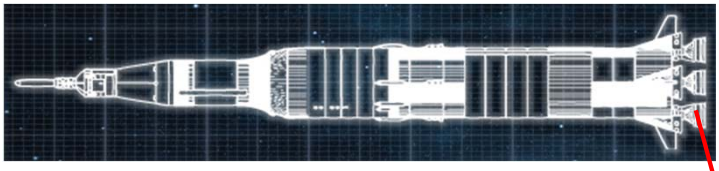
Cornell Engineering

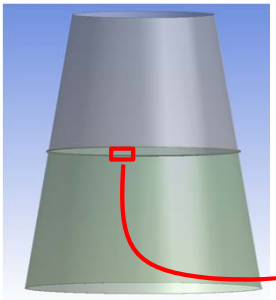
	Course	Level	Enrollment	Software
1	MAE 3250 Mechanical Structures	Junior	150	ANSYS Mech.
2	MAE 3240 Heat Transfer	Junior	130	ANSYS Mech.
3	MAE 3272 Mechanical Lab	Junior	140	ANSYS Mech.
4	MAE 4272 Thermo-fluids Lab	Senior	160	ANSYS Fluent
5	MAE 4230/5230 Int. Fluid Dynamics	Ugrad/M.Eng	60	ANSYS Fluent
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.

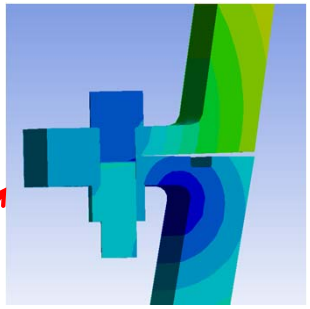
Simulation Exercises in Cornell Courses

Cornell Engineering

Bolted Flange on Rocket Engine in *Finite Element Analysis*



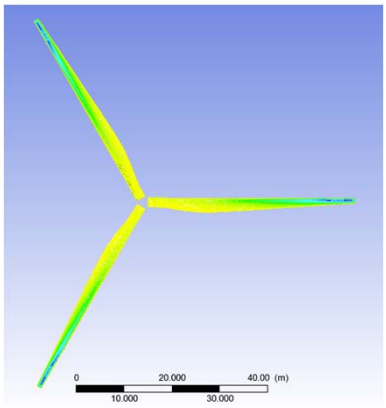




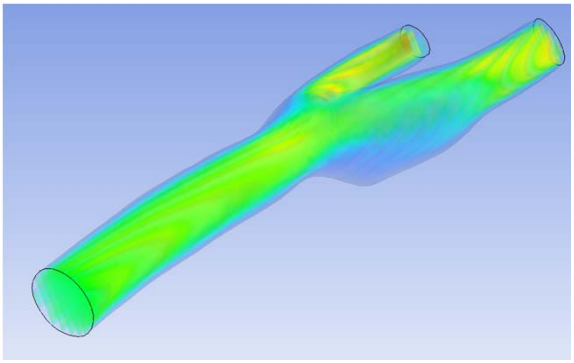
Simulation Exercises in Cornell Courses

Cornell Engineering

Wind turbine blade in *Wind Energy*



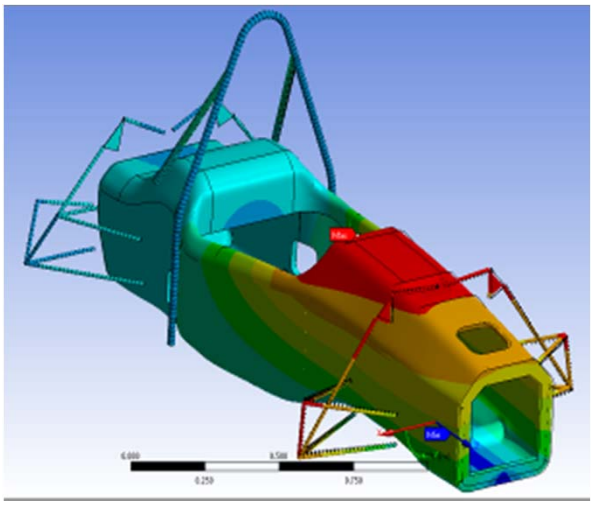
Bifurcating artery flow in *Biofluids*



Swanson Program: Impact on Project Teams

Cornell Engineering

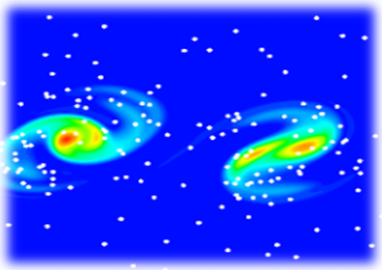
- Formula SAE Racing
- Baja SAE Racing
- Violet Satellite
- Mars Rover
- AIAA Design-Build-Fly
- CU Sustainable Design
- Cornell Rocketry
- Concrete Canoe
- Steel Bridge
- AguaClara

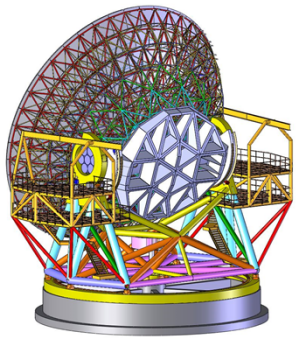


Swanson Program: Impact on Research Groups

Cornell Engineering

- **Zhang**: Pollutant dispersion
- **Koch**: Multi-phase flow
  - NSF grant outreach
- **Fisher**: Cookstove
- **Space Sciences**: CCAT, 25-meter telescope in Chile
- **Butcher**: Developmental bioengineering
- **James**: Computer graphics sound
- **Adie**: Optical coherence tomography
- **Baeumner**: Biosensors





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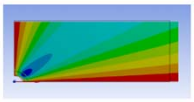
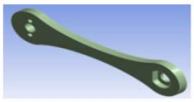
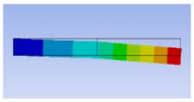
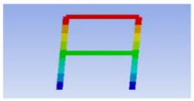
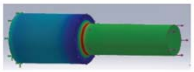
Key Resource: SimCafe

Cornell Engineering

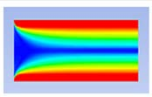
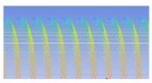
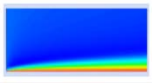
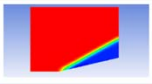
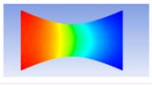
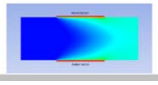
- Online portal for learning and teaching engineering simulations
- Has enabled the integration of ANSYS-based simulations into 12 Mechanical & Aerospace engineering courses at Cornell
- Also used by
  - Professors at educational institutions around the world
  - Students for supplementary learning
- Can be freely accessed at *simcafe.org*

	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 Contents

Cornell Engineering

- Contains over 50 learning modules
  - Finite-element analysis (FEA) and Computational Fluid Dynamics (CFD) using ANSYS
- Subject areas: Solid mechanics, fluid dynamics, heat transfer and dynamics
  - Textbook/canonical problems
  - Practical problems
- Learning modules have a uniform structure that connects fundamentals to hands-on practice

	Laminar Pipe Flow	MAE 4230/5230/4650/5650
	Turbulent Pipe Flow	MAE 4230/MAE 5230
	Flat Plate Boundary Layer	MAE 4230/MAE 5230/MAE 6510
	Supersonic Flow Over a Wedge	MAE 4230/MAE 5230
	Compressible Flow in a Nozzle	MAE 4230/MAE 5230
	Turbulent Forced Convection	MAE 4272

Simcafe Usage Statistics: July 1st, 2014 to June 30th, 2015

Cornell Engineering

Pageviews	**1.7 million**
Unique visitors	145,000
Countries	164
Average session duration (min)	10

Increase of 9% in unique visitors from prior academic year

130 educational institutions had more than 200 sessions

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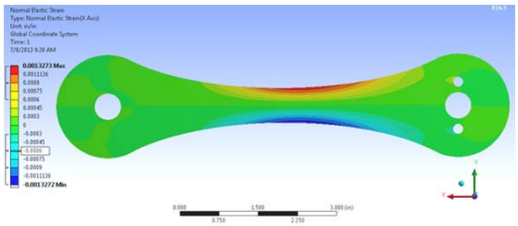
A Hands-on Introduction to Engineering Simulations

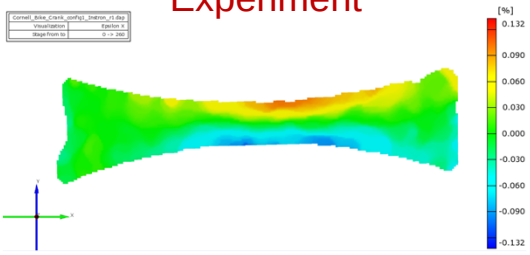
Cornell Engineering

- 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



Experiment



MOOC: Approach

Cornell Engineering

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

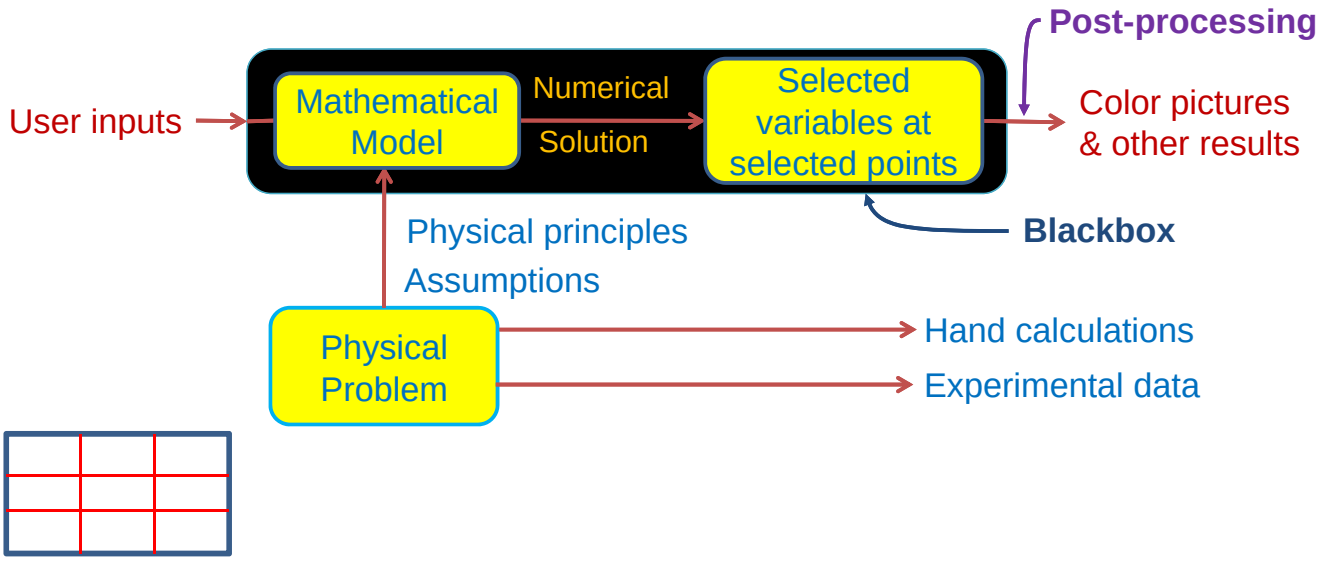
Framing the Simulation Case Studies

Cornell Engineering

The Blackbox

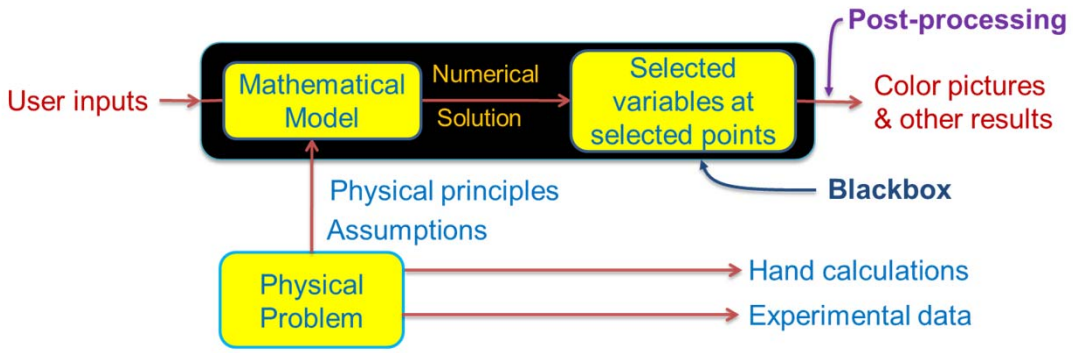
What's Inside the Blackbox?

Cornell Engineering



Pre-Analysis Section

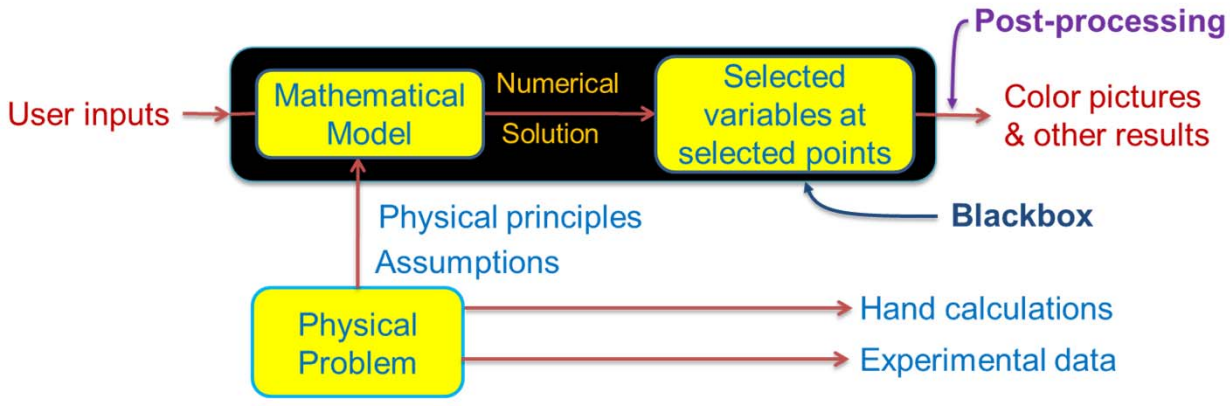
Cornell Engineering



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

Verification & Validation Section

Cornell Engineering



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

Student Comments

Cornell Engineering

- “A very clear and insightful exposition about the verification and validation concepts, showing the differences between them”
- “[What’s inside the] Blackbox technique is by far the best technique I [have] ever come across while learning about simulations”

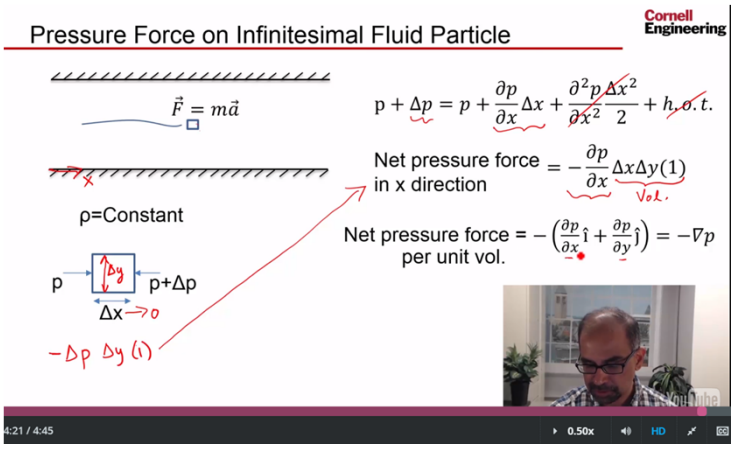
Student Comment

Cornell Engineering

- “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.”

Online Lectures

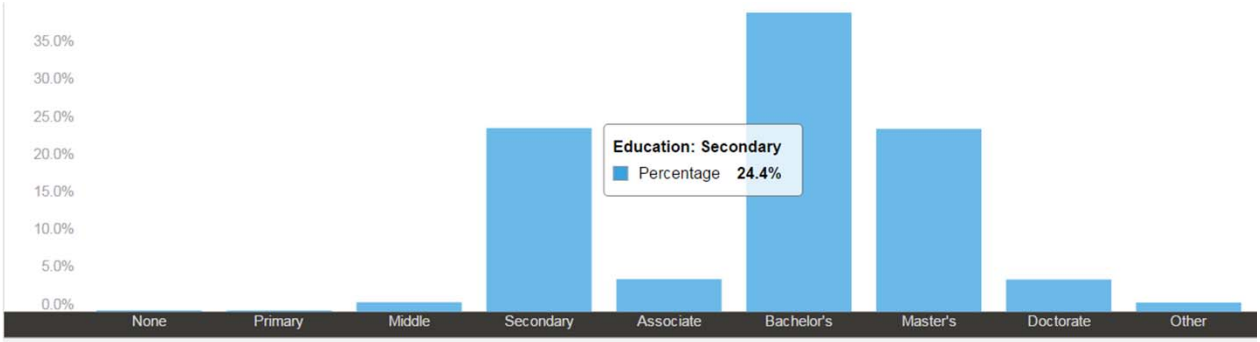
- Recorded in a self-service studio
- Can overlay chalkboard, Powerpoint, ANSYS
- Can bring in an industry expert
- Can chunk in a way that matches short-term memory



Enrollment Metrics

- 25,000+ from 165 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

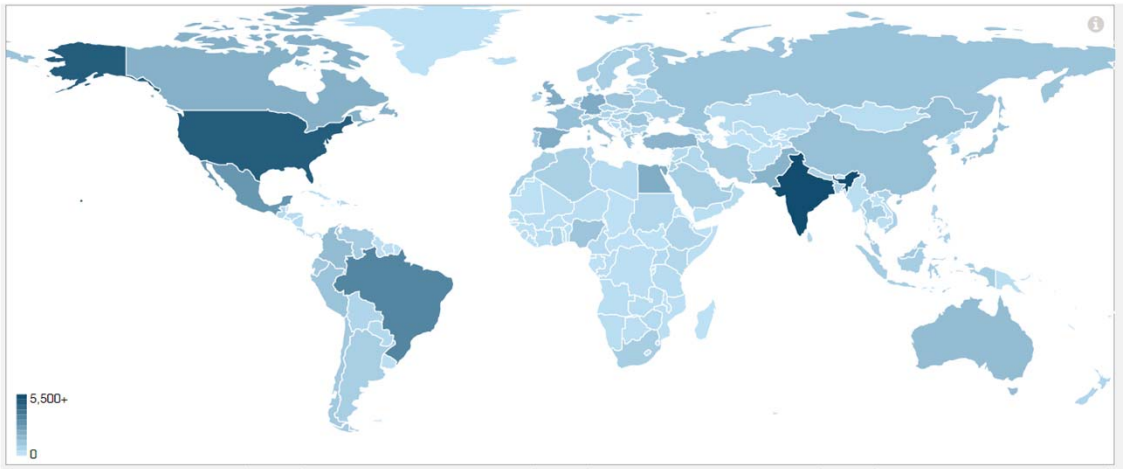
Education Level



Education Metrics

25.8%	44.1%	28.6%
High School Diploma or Less	College Degree	Advanced Degree

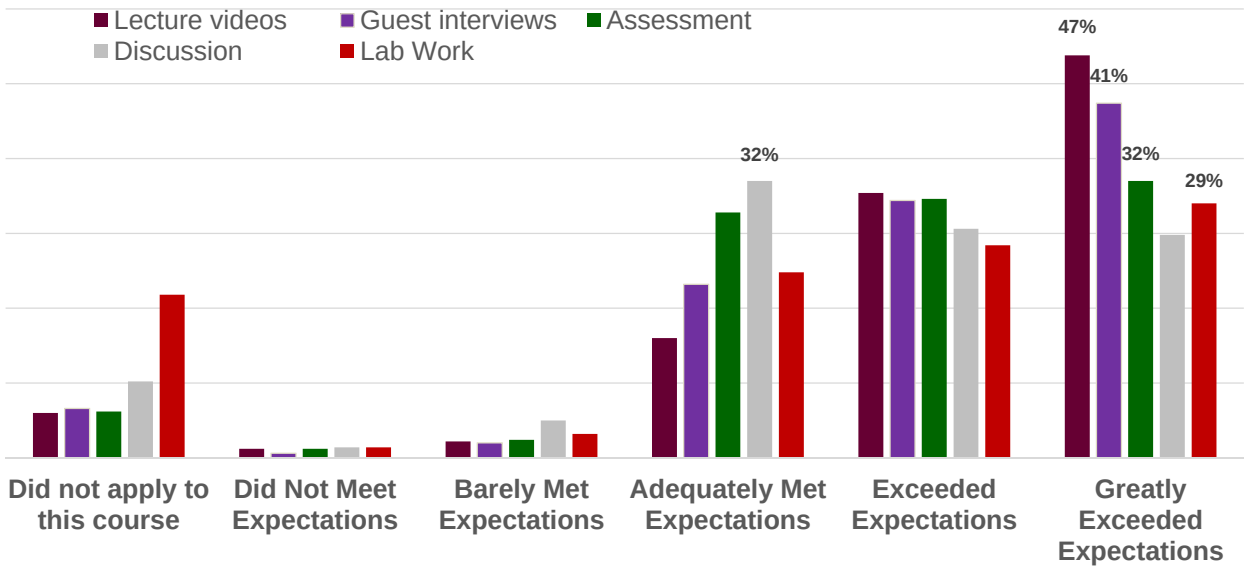
Geographic Distribution



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

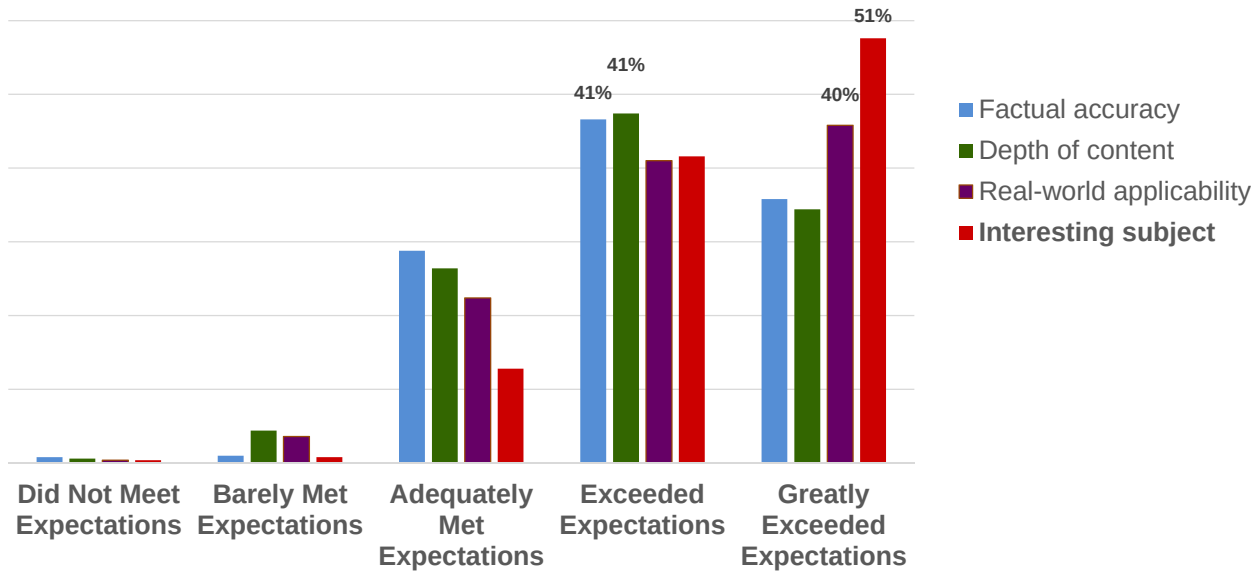
Please Rate Course **Materials**

Cornell Engineering



Please Rate the Course Content

Cornell Engineering



Open Comments Analysis (by Dr. Kim Nicholson)

Cornell Engineering

Top 3 Themes:

- ❖ *Great course/Amazing*
- ❖ *Positive experience/I <u>enjoyed</u> 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

Cornell Engineering

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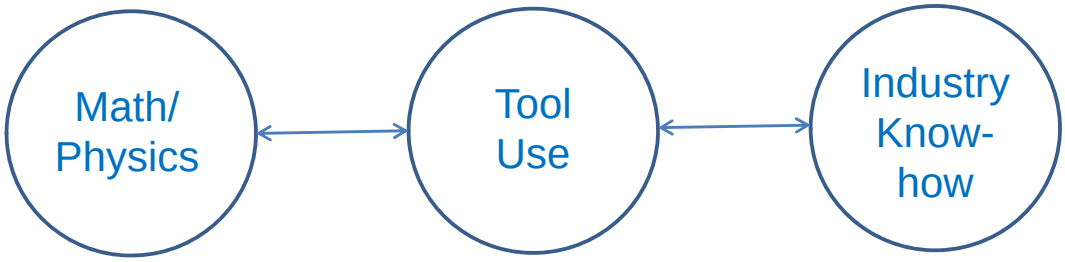
MOOC Demonstrates New Paradigm in Engr. Education

Cornell Engineering



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

How does this new paradigm disrupt status quo?

Cornell Engineering

1. Integrative
   - Cuts across traditional boundaries
2. Flips the curriculum
   - Students and non-experts solve complex math models
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: Lead the Democratization of Simulation

Cornell Engineering

- What is the limiting factor?
  - ~~Math models and numerical methods~~
  - ~~Hardware~~
  - ~~Software~~
  - People
- Plan:
  - Develop and disseminate a simulation-based engineering curriculum based on this new paradigm

Further Work

Cornell Engineering

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