The National Academies: The Board on Higher Education and Workforce Committee on Revitalizing Graduate STEM Education for the 21st

Committee on Revitalizing Graduate STEM Education for the 21st Century and The Next Generation Research Initiative

Bold Visions for the Future of Science

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The Boeing Company

NAE: Statement of Task

- How will disruptions to institutions of higher education and the workforce affect the system of graduate education, academic research (notably in the biomedical sciences), and research for industry? Are there particular nuances that may apply more readily to fields such as engineering and computer science than the other fields in STEM?
- How will the increasing rate of change in technology affect skills development and knowledge acquisition for STEM graduate students? For postdocs and early career faculty? What implications will it have on lifelong learning? If you were a member of these committees, what recommendations would you make and to whom would they be targeted?

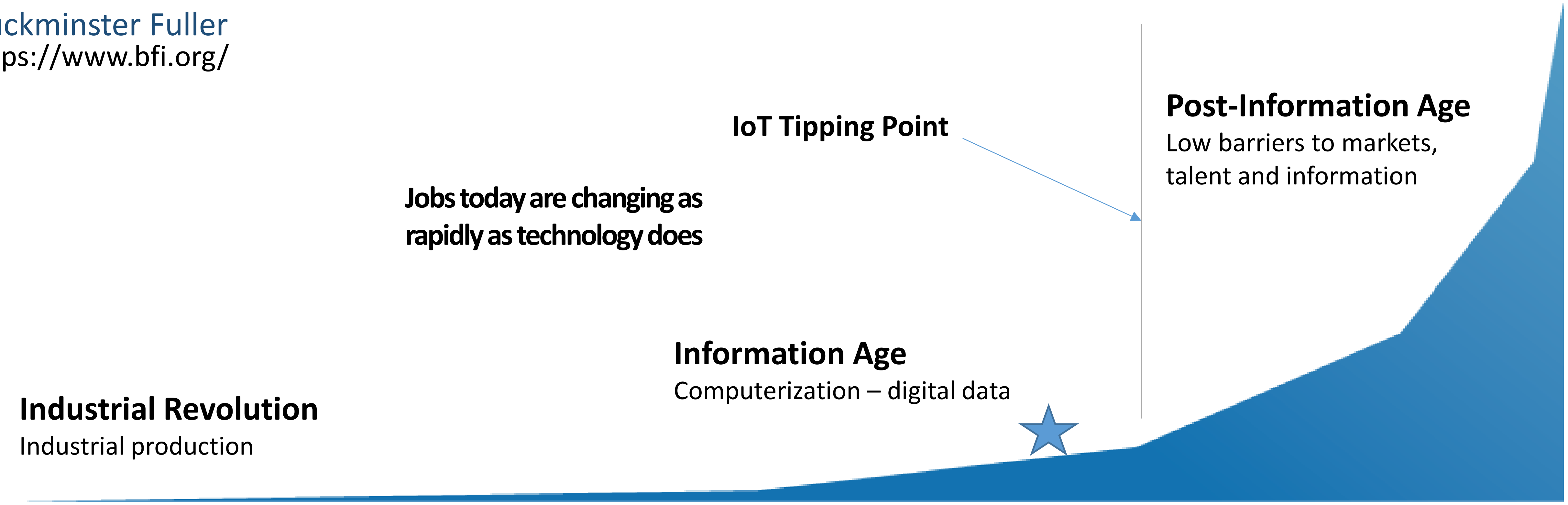
"Investigate the many new initiatives and models that are influencing graduate education, including MOOCs, other digital learning programs, increasing numbers of alternative providers of master's and Ph.D. degrees, and opportunities to secure credentials through multiple sources".

Layne Scherer, *Study Director, Committee on Revitalizing Graduate STEM Education for the 21st Century, Program Officer, Board on Higher Education and Workforce The National Academies of Sciences, Engineering, and Medicine*

Gutenberg to Zuckerberg: Exponential Information and Complexity

Information Doubling Curve

Buckminster Fuller
https://www.bfi.org/



1440 -1900
Knowledge doubled in 400 years →

1900-1950
Knowledge doubled in 50 years →

1950-1970
Knowledge doubled in 20 years →

1970-1980
Knowledge doubled in 10 years. →

1980-2000
Knowledge doubled in 8 years.

2017
Knowledge is doubling every 13 months. →

2020
IBM predicts the build out of the "internet of things" will lead to the **doubling of knowledge every 12 hours.**

"The Ages of our civilization evolve slowly and with incredible resistance, displacement ends as information adoption rates reach a tipping point. ."

NAE Grand Challenge: Advancing Personalized Learning

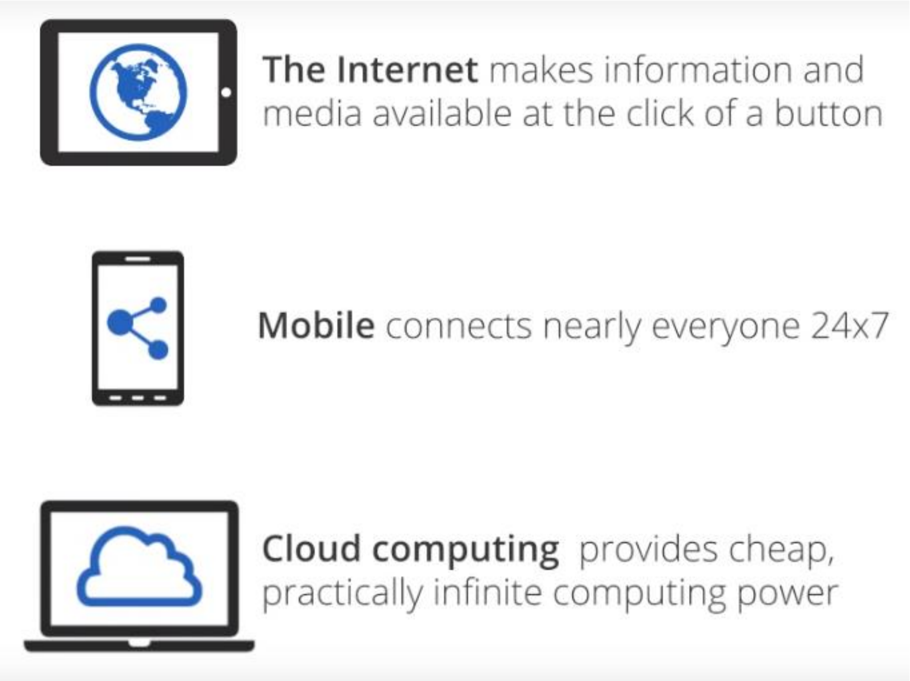
Source: http://www.engineeringchallenges.org/challenges/learning.aspx/

- Information is created at an **exponential rate** every day
- People require access to very **specialized information** at **particular instances** in time
- **Everybody** learns differently
- Requires neuroscientist, educators, statisticians, digital data designers, learning scientists, instructional designers, big data experts, etc.

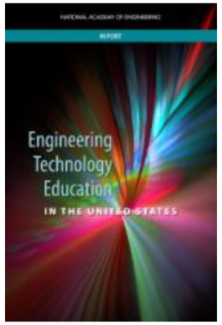
*"In recent years, a growing appreciation of individual preferences and aptitudes has led toward more "**personalized learning**," in which instruction is tailored to a student's individual needs".* NAE 2017

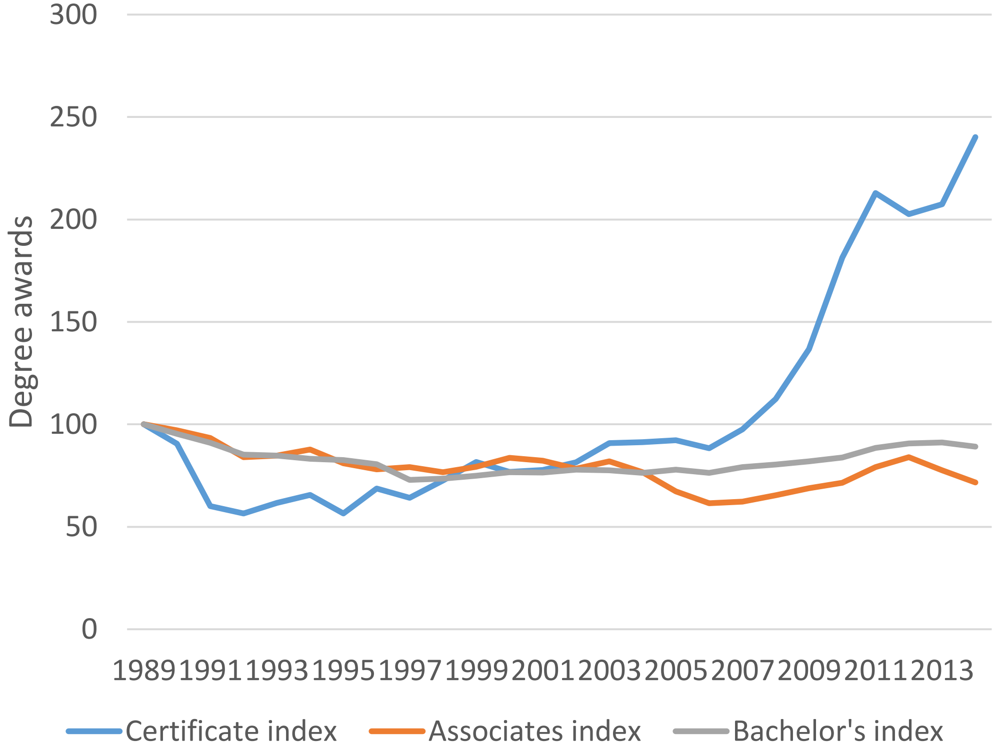
Engineering Education can play a critical role in advancing personalized learning as complex system integrators

The Rise of Micro certificates



2016: Engineering Technology Education and Workforce in the United States. Committee on Engineering Technology National Academy of Engineering





Source: Calculations from IPEDS data, NCES population of institutions.

Note: Hard economic times and advancements in job skills + learning technology can be an impetus for retraining which may explain some of the rapid growth in the five years spanning 2007-2014.

"the number of certificates awarded has skyrocketed more than 800 percent over the past 15 years."

By The Numbers: MOOCS-SPOCs in 2016

edX

MicroMasters™

58M Students

700+ Universities

6850 Courses

Top five MOOC providers by registered users:

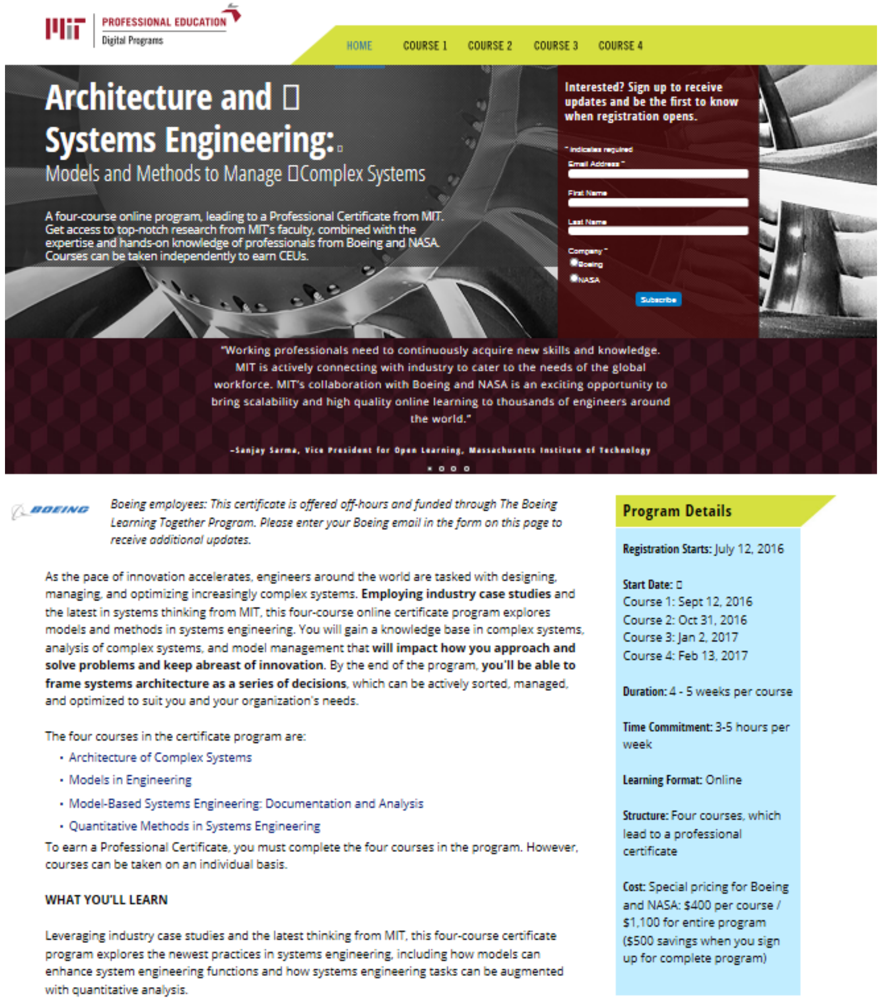
1. Coursera – 23 million
2. edX – 10 million
3. XuetangX – 6 million
4. FutureLearn – 5.3 million
5. Udacity – 4 million

edX Mission: Increase access to high quality education, enhance teaching and learning on campus and online, and research how online learners learn

https://www.class-central.com/report/mooc-stats-2016/

Case Study: EdX MIT – Boeing – NASA Partnership

Professional Education in Architecture and Systems Engineering: Models and Methods to Manage Complex Systems


MIT PROFESSIONAL EDUCATION
Digital Programs

HOME | COURSE 1 | COURSE 2 | COURSE 3 | COURSE 4

Architecture and Systems Engineering:
Models and Methods to Manage Complex Systems

A four-course online program, leading to a Professional Certificate from MIT. Get access to top-notch research from MIT's faculty, combined with the expertise and hands-on knowledge of professionals from Boeing and NASA. Courses can be taken independently to earn CEUs.

Interested? Sign up to receive updates and be the first to know when registration opens.

* indicates required
Email Address *
First Name
Last Name
Company *
Boeing
NASA
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"Working professionals need to continuously acquire new skills and knowledge. MIT is actively connecting with industry to cater to the needs of the global workforce. MIT's collaboration with Boeing and NASA is an exciting opportunity to bring scalability and high quality online learning to thousands of engineers around the world."

–Sanjay Sarma, Vice President for Open Learning, Massachusetts Institute of Technology

BOEING

Boeing employees: This certificate is offered off-hours and funded through The Boeing Learning Together Program. Please enter your Boeing email in the form on this page to receive additional updates.

As the pace of innovation accelerates, engineers around the world are tasked with designing, managing, and optimizing increasingly complex systems. **Employing industry case studies** and the latest in systems thinking from MIT, this four-course online certificate program explores models and methods in systems engineering. You will gain a knowledge base in complex systems, analysis of complex systems, and model management that **will impact how you approach and solve problems and keep abreast of innovation**. By the end of the program, **you'll be able to frame systems architecture as a series of decisions**, which can be actively sorted, managed, and optimized to suit you and your organization's needs.

The four courses in the certificate program are:

- Architecture of Complex Systems
- Models in Engineering
- Model-Based Systems Engineering: Documentation and Analysis
- Quantitative Methods in Systems Engineering

To earn a Professional Certificate, you must complete the four courses in the program. However, courses can be taken on an individual basis.

WHAT YOU'LL LEARN

Leveraging industry case studies and the latest thinking from MIT, this four-course certificate program explores the newest practices in systems engineering, including how models can enhance system engineering functions and how systems engineering tasks can be augmented with quantitative analysis.

Program Details

Registration Starts: July 12, 2016

Start Date:
Course 1: Sept 12, 2016
Course 2: Oct 31, 2016
Course 3: Jan 2, 2017
Course 4: Feb 13, 2017

Duration: 4 - 5 weeks per course

Time Commitment: 3-5 hours per week

Learning Format: Online

Structure: Four courses, which lead to a professional certificate

Cost: Special pricing for Boeing and NASA: $400 per course / $1,100 for entire program ($500 savings when you sign up for complete program)

Small Private Online Certificate SPOC

The purpose of the micro – certificate is to grow the system engineering and modeling competencies of Boeing - NASA engineers (including all design centers and partners).

- On-line format, Basic to Intermediate SE KSA development
- Addresses structural (academic – industry) KSA alignment (i.e., industry relevant)
- Scalable enterprise delivery structure (supports all design centers
- Responsive to space and brick and mortar instructor led constraints
- Cost effective
- Earns CEU's (LTP funded)
- Improves retention (skin in the game)
- Potential matriculation towards accredited degree (with prerequisite)
- Ability to serve non-traditional populations (public audit intro course for free)
- Changes role of SME and faculty, guide on side vs. lecture and drill model
- **Provides click stream data analytics, who – what – where -how**

This certificate represents a new form of micro credential that blend industry (practice) with traditional academic (theory) i.e., employee competency based credentials.

Certificate Design Principles

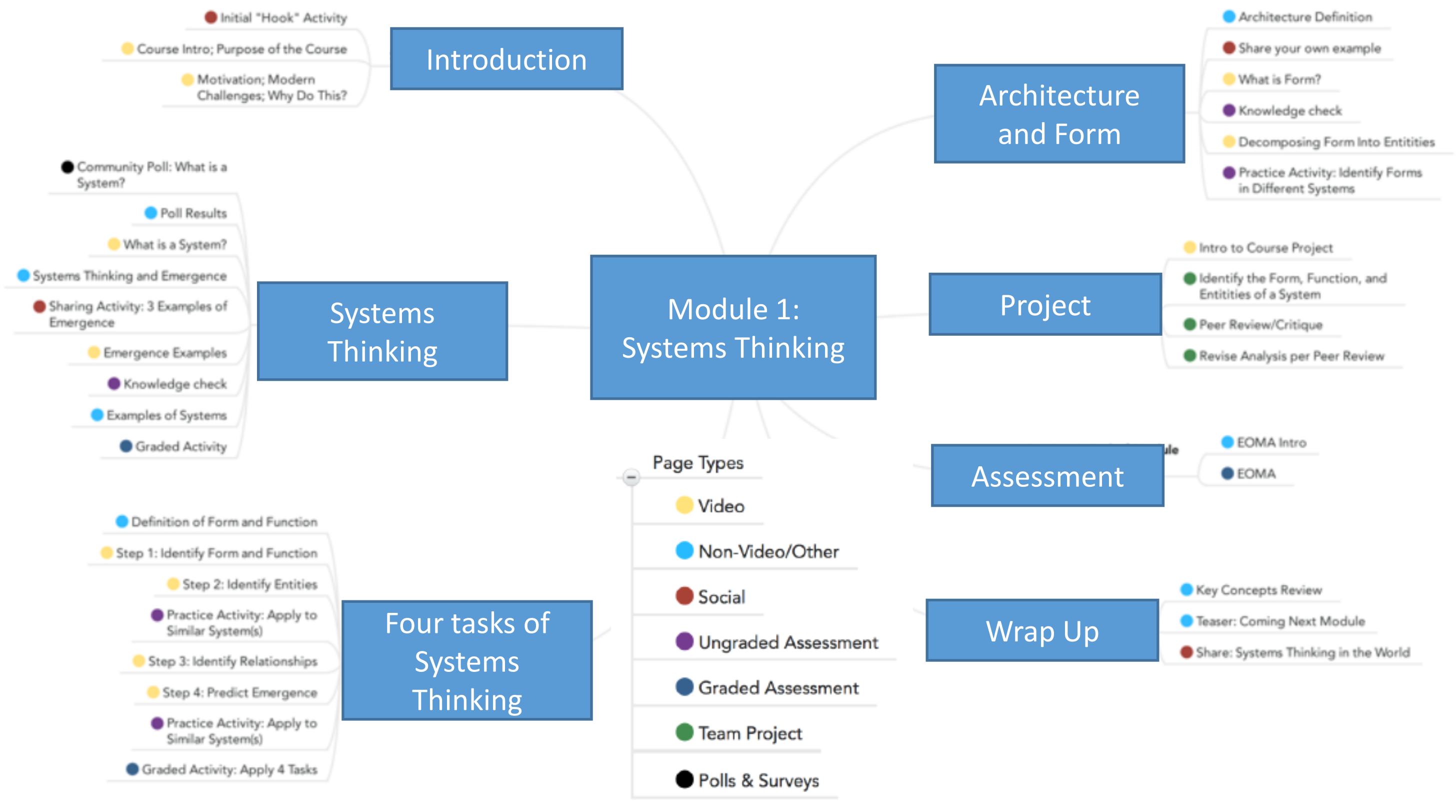
Professional Education in Architecture and Systems Engineering: Models and Methods to Manage Complex Systems

We are leveraging formative – summative (pre-post) assessments to probe student understanding to determine "what is in the Black Box" of the learner's mind (Black & Wiliam, 1998).

	LEARN	CONNECT	PRACTICE	ASSESS	APPLY	TOTAL (minimum time to get through week)
WEEK 1 Systems Thinking	50 min	20 min	50 min	30 min	1 30 hr min	4 hrs
WEEK 2 Function and Emergence	45 min	5 min	35 min	15 min	1 50 hr min	3 30 hr min
WEEK 3 System Architecture	30 min	15 min	5 min	15 min	1 30 hr min	2 35 hr min
WEEK 4 Modeling with DSMs and Modularization	60 min	20 min	1 20 hr min	0 min	1 50 hr min	4 30 hr min
WEEK 5 System Architect	50 min	15 min	25 min	30 min	1 30 hr min	3 30 hr min
	22% time spent learning	7% time spent connecting	18% time spent practicing	8% time spent assessing	45% time spent applying	

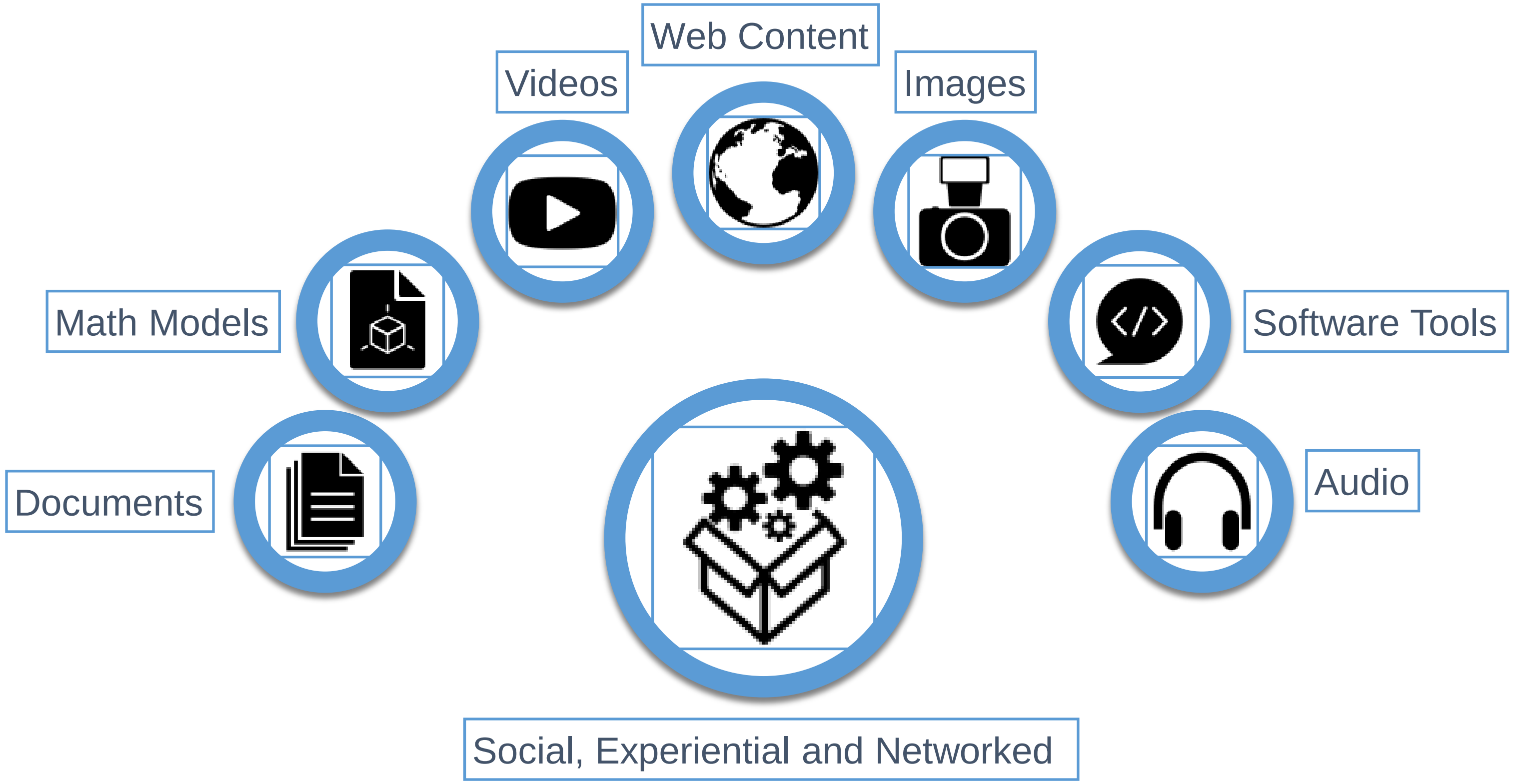
Course 1 Architecture: Module 1

NEW: Codified tacit expert knowledge embodied into formal learning structure



The relationships between learning technologies, learning science research, educational psychology, and theories of instructional design are complex, more like an interacting ecology of ideas and practices than a clear hierarchical structure-organization.

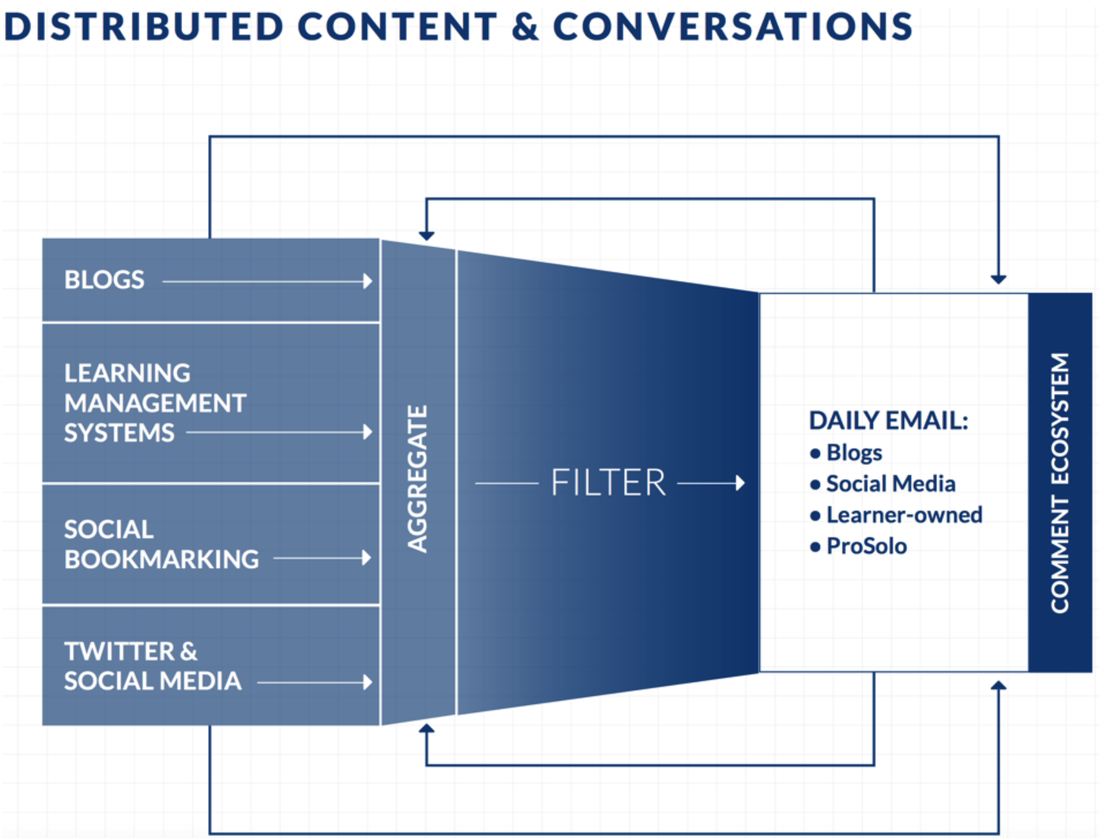
Personalizing learning experiences: Machine learning - Characterization



- The concept of coupling date between agents (learners) and the system structure (school or industry) with real world behavior enables us to see (**through the interaction patterns, agent sensing, acting and learning optimizing**)
- Individual mouse clicks of each student accessing an online simulation, amount of time spent viewing a screen of information, each answer to each multiple-choice question on a survey, and terms entered into search boxes.
- These data uncover the **distributive cognition of the social network**, uncovering "The ghost in the machine" where thoughts are embodied in the agent actions.

Learning - particularly using technology - is largely content centric

On-Line research and Learner CQI



Source: Dr. George Siemens, (2014)

Analytics

Adaptive learning develops a model of a learner's understanding of topics and concepts, allowing detailed feedback on progress and providing personalised pathways to reach learning outcomes.

Social network analysis provides tools to make online class and student networks more visible in order to help more effective learning, linkages and engagement.

Discourse analytics enables better assessment of the quality of contributions and connections that a student may make during their time on a course, including outside of formal class structures.

Semantic web technologies

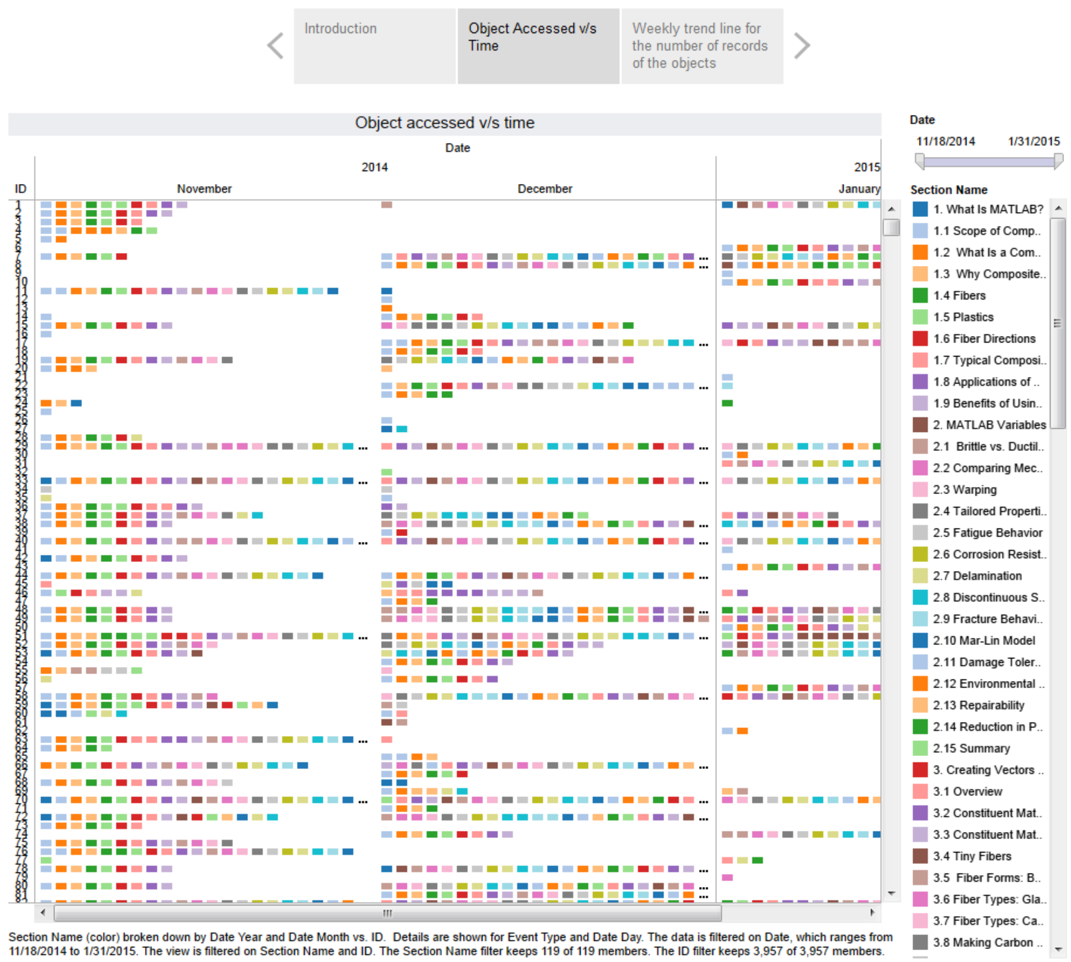
Automation of personalised support to construct knowledge by enabling technologies to make informed linkages across the web on the basis of labels and tags. Applied to education, this technique may enable programmes to identify resources of interest to students enrolled on a particular course in a more targeted and automated way, including, for example, location-specific learning opportunities. This augments the signposting role of the educator by enabling student to independently capitalize on the size and scope of the web.

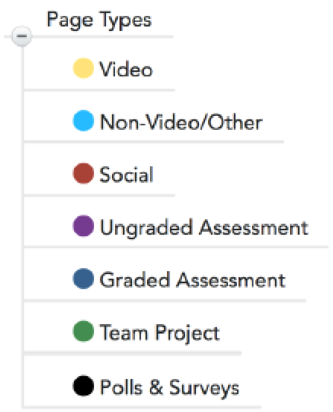
Virtual problem-based learning

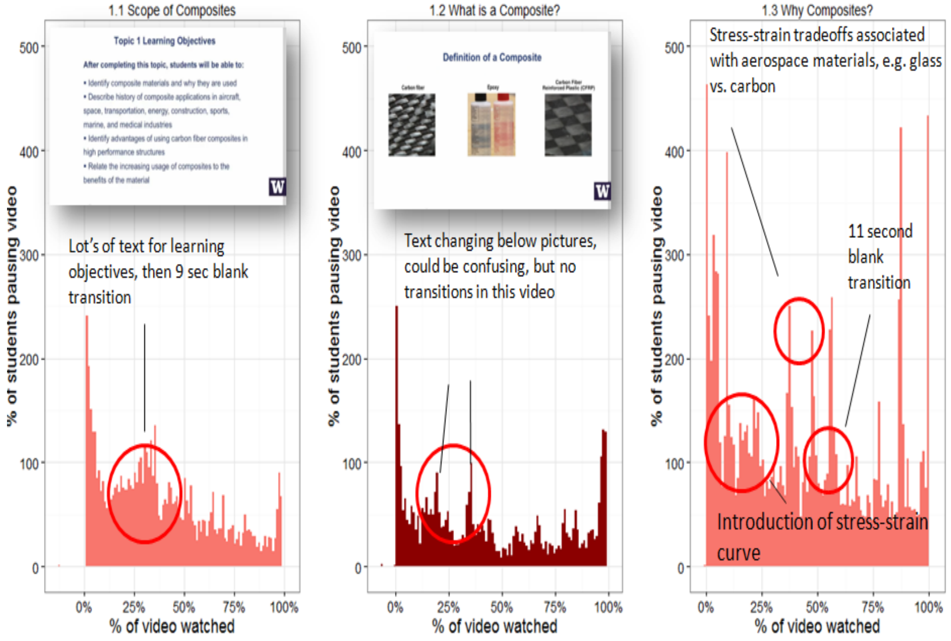
Development of procedural tools by using technologies to enhance problem-based learning approaches through immersive, experimental virtual learning environments. These models combine problem-based learning with techniques developed through computer games and other simulation programmes and can bring students and educators together from multiple locations. This can enable a variety of skills to be taught, ranging from basic foundation techniques through to more complex exercises.

Linking student performance and authenticity via on-line platforms, is achievable thru automated learning technologies.

Leverage Big Data and Learning Analytics to uncover the expert cognitive streams



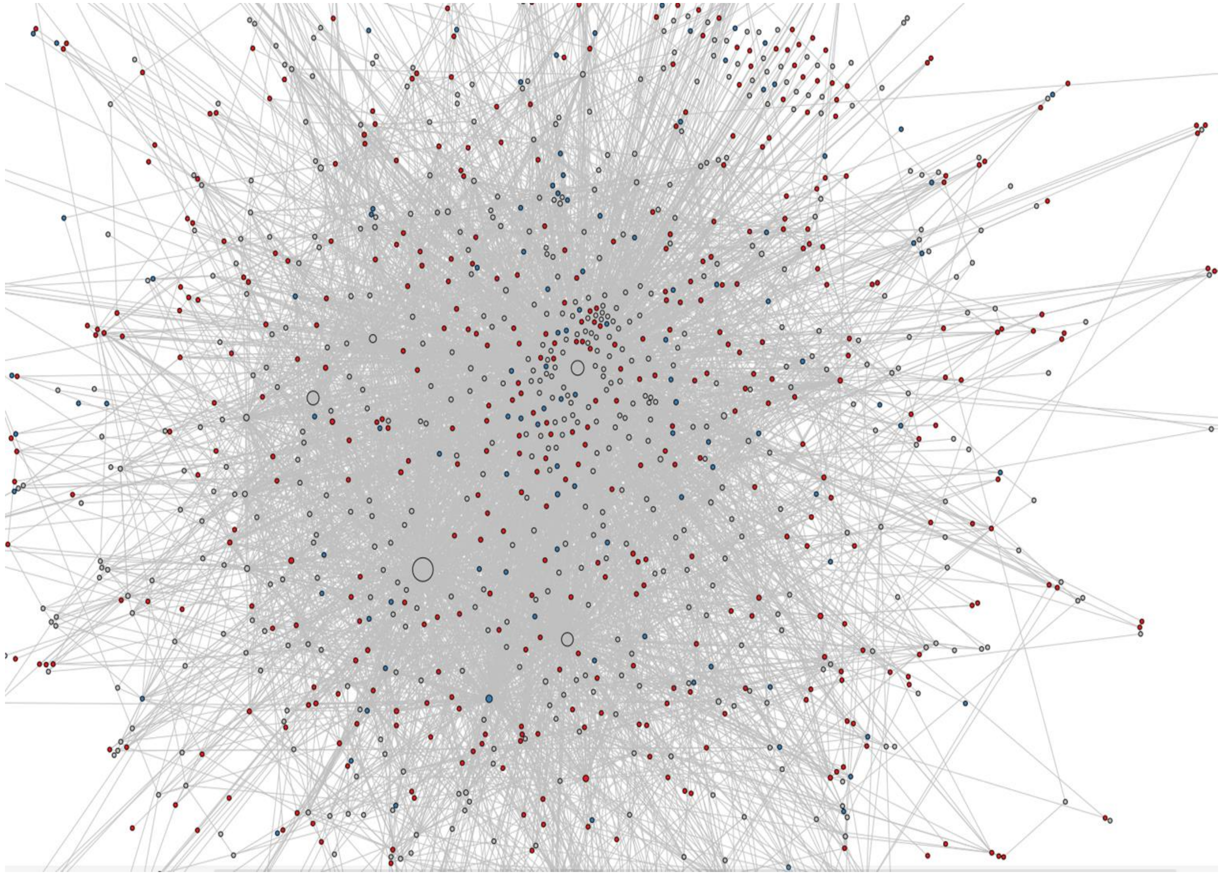




Example of UW Intro to Composites for Engineers MOOC
Video lecture analysis: What is making students pause?

"Learning analytics is the measurement, collection, analysis and reporting of data about learners and their context, for purposes of understanding and optimizing learning and the environments in which it occurs (SOLAR,2010)

Example of a Boeing Social Learning Network



Examples of Interaction networks:

- The Blogosphere
- Biochemical networks
- Gene-protein networks
- Food webs: who eats whom
- The World Wide Web
- Airline networks
- Call networks (AT&T)
- Expert – Novice networks

We are living in an age obsessed with intelligent systems. All walks of life are being transformed by innovations in machine learning, by software platforms that amplify human ability (from Mathematica to LinkedIn), ***improving online educational opportunities (MOOCs), and unprecedented access to the collective insights of globally dispersed communities of researchers and data sets*** *(Wikipedia, Stack Exchange). These facts are changing both science and business. SFI Action Business Network*

Recommendations: Broad Framing Questions

Advance Personalized Learning (NAE)

To our knowledge, there is no single architecture that explores learner interaction, data analytics, technical infrastructure and social network patterns

Objective 1: Build a network of transdisciplinary complexity though leaders to address the significance challenges inherent in adaptive networked learning including learning science, network theory and research to practice.

Objective 2: Explore the cognitive and sociocultural factors related to the new labor economy, evolving demographics and advancements in cyber-physical data rich complex learning ecosystems.

Objective 3: Explore concepts and methods of this evolution through a complexity lenses including the analytical, theoretical and methodology dimensions of data collection within a complex sociotechnical system.

Objective 4: Holistic – Transdisciplinary educational opportunities**:** Consider transdisciplinary teaming research models that expose students to collaborative research.

Objective 5: Consider funding for alternative credentialing models; for example: Low-cost, High quality and relevant to workforce certificates and Micro-Masters (Technical – Business - Soft skills)

Objective 6: Explore alternative future and life long learning (a 40 year relationship instead of a 4-6 year relationship**)** including the **c**reation of lifelong learning profiles, mapping of competencies, and building education – workforce models to anticipate future labor market knowledge needs

The relationships between educational systems, learning technologies, learning science research, educational psychology, and theories of instructional design are complex, more like an interacting ecology of ideas and practices than a clear hierarchical structure-organization.

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