ME 370:
The Mechanical Engineering Profession

Lecture 05: Innovation

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Purpose

Describe types of technology and business innovation that might be managed or exploited in economic competition.

Innovation is a huge subject and there are many ways to approach it

This lecture is just a quick overview

1. Basic and applied research as precursors
2. Example: Birth of the digital camera
3. Models of innovation: incremental, radical, disruptive
4. Diffusion of innovation: the social dimension
5. Disruptive innovation in commercialization of the digital camera
6. MOOCs: A potential disrupter to higher education?
7. “Failing fast”: an idea from software development
8. Recap

Manhattan Project: A watershed in science and technology policy

Manhattan project to develop the atomic bomb

- Physicists lead the effort
- Massive public that investment in goal-oriented science
- Many policy outcomes
  - Creation of National Laboratories and National Science Foundation

    Lawrence Berkeley, Los Alamos, Oak Ridge, Argonne, Ames
  - Funding of university research
  - Engineering education became more focused on science, as opposed to practice

US Science Policy and programs existed before the Manhattan project, but the Manhattan project profoundly influenced our approach to R&D, federal investment in research, and the structure and goals of industrial laboratories

http://www.osti.gov/accomplishments/manhattan_story.html

Linear model of innovation

Vannevar Bush (and others) took the success of the Manhattan project as a template for innovation. Inventions were believed to be the product of an orderly process

1. Basic research
2. Applied research
3. Development
4. Production
5. Diffusion

Time
(one-way)

see, e.g., Benoît Godin, *The linear model of innovation*

Alternative views of the linear model of innovation exist

Invention is just the beginning

Invention →	Innovation →	Diffusion
Creation of novel device, process or material	Application of invention to solving a problem or creating a new business	Adoption of the innovation by populations of individuals and organizations

http://en.wikipedia.org/wiki/Linear_model_of_innovation

Birth of the Digital Camera:

A cautionary tale about innovation.

Invention of the digital camera provides a case study in innovation

It took "a year of piecing together a bunch of technology in a back lab" – Steven Sasson, Kodak engineer credited with inventing the digital camera

http://pluggedin.kodak.com/pluggedin/post/?id=687843
http://bits.blogs.nytimes.com/2010/08/26/bits-pics-kodaks-1975-model-digital-camera/

Inventors also had to create a device to show the images

"It took 23 seconds to record the digitized image to the cassette. The image was viewed by removing the cassette from the camera and placing it in a custom playback device" – Steven Sasson

http://pluggedin.kodak.com/pluggedin/post/?id=687843

The first digital camera was ready for demonstration in December 1975

At the in-house demonstration, other Kodak employees asked

- Why would anyone want to view his or her pictures on a TV?
- How would you store these images?
- What does an electronic photo album look like?
- When would this type of approach be available to the consumer?

http://pluggedin.kodak.com/pluggedin/post/?id=687843
http://bits.blogs.nytimes.com/2010/08/26/bits-pics-kodaks-1975-model-digital-camera/

What was the state of technology in 1975?

The January 1975 issue of Popular Science introduced the Altair 88000 kit.

What was the state of technology in 1975?

The Internet, then known as ARPANET, was still relatively young

- The first message was transmitted over ARPANET on 29 October 1969, when the network had four nodes
- First email message was transmitted in 1971
- In July 1975, there were 57 Interface Message Processors (like modern routers) on the network

What can the story of the digital camera teach us?

- Ideas can be ahead of their time (obviously)
- Just having an idea and showing that it can work does not immediately lead to success
- Other enabling technologies were needed
  - Today's low cost, high volume, high density electronics did not exist in 1975
  - TV was the only widely available display technology
  - Economical digital storage did not exist
  - No ubiquitous computing – digital photos are just one use of today's computers
  - Communication networks for transmitting images were not available to the public

What can the story of the digital camera teach us?

- The proof of concept was complete
  - In one year, the team created the technology to capture and display images
  - The engineers created a working demonstration for their peers
- The creator of the innovation does not necessarily capitalize on the invention
- Innovation is not just about the creation of technology
- Advantages of the technology were not apparent to potential users

Types of Innovation

A view of innovation from the perspective of businesses trying to use innovation to their advantage

Warning: Jargon ahead

Innovation terminology can seem arbitrary and confusing

- Experts disagree
- Even the *definition* of innovation is dependent on context and who is talking

Innovation jargon can be descriptive or prescriptive

- Describe what is happening in an economy or industry
- Use terminology to organize and manage business

For some definitions, see
http://www.realinnovation.com/content/what_is_innovation.asp

Three types of innovation according to Davila et al.

Three basic kinds of innovation

- Incremental, a.k.a sustaining innovation
- Semi-radical
- Radical, a.k.a. discontinuous innovation

Tony Davila, Marc J. Epstein and Robert Shelton, *Making Innovation Work*, 2006, Pearson Education, Chapter 2

Incremental innovation is the dominant mode. It is essential for business success.

Qualitative features of Incremental Innovation

- Small improvements in products or business processes
- Continuous improvement in manufacturing processes to reduce cost, improve reliability, improve quality
- Update IT infrastructure to improve efficiency

Examples

- Upgrading Windows computers
- New model years of automobiles
- Replacing a fully machined part with a die cast part to reduce material waste and manufacturing operations

Radical innovation is significant change to both technology and business model

Qualitative features

- Changes the competitive environment
- Makes earlier technology or business obsolete or severely disadvantaged

Examples

- Disposable diapers
- Cell phones
- Transition from ice to vapor-compression refrigeration
- On-line sales of books

Incremental versus Radical Innovation: Impact on participating organization

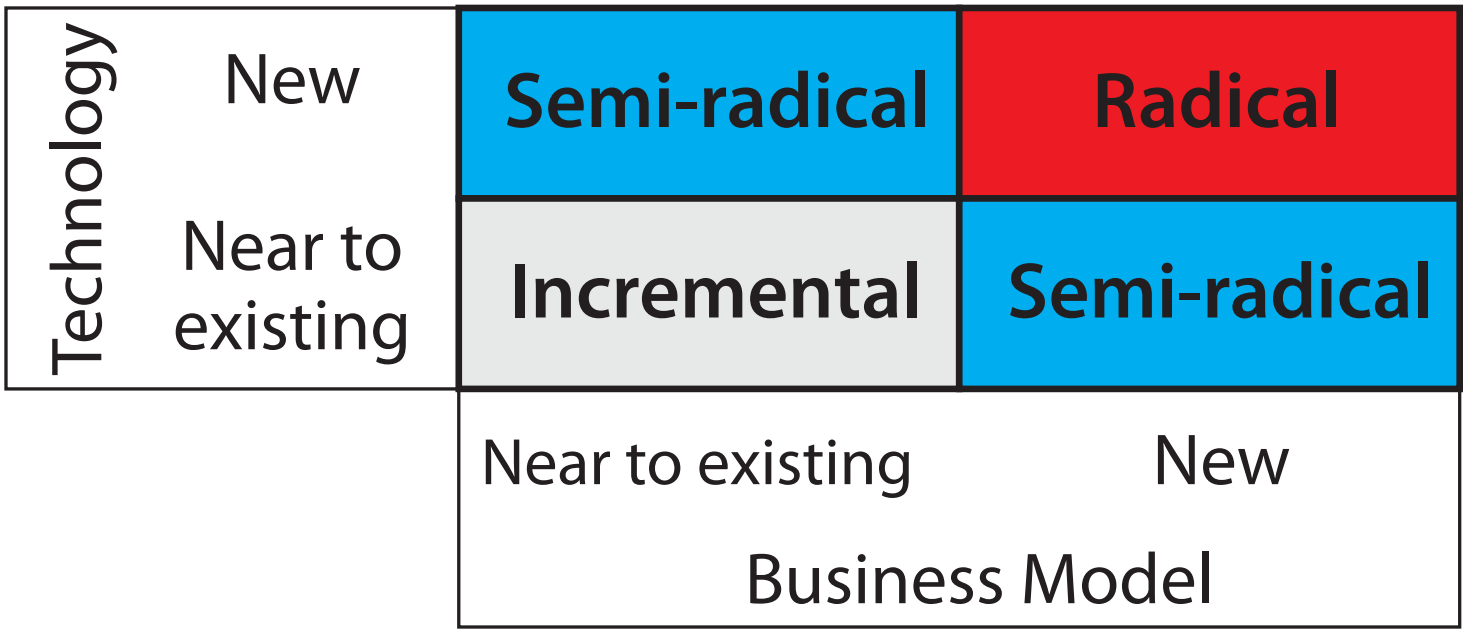
Incremental Innovation

- Builds on strengths: *competency enhancing*
- Is more easily integrated into existing business processes and organizational structures

Radical Innovation

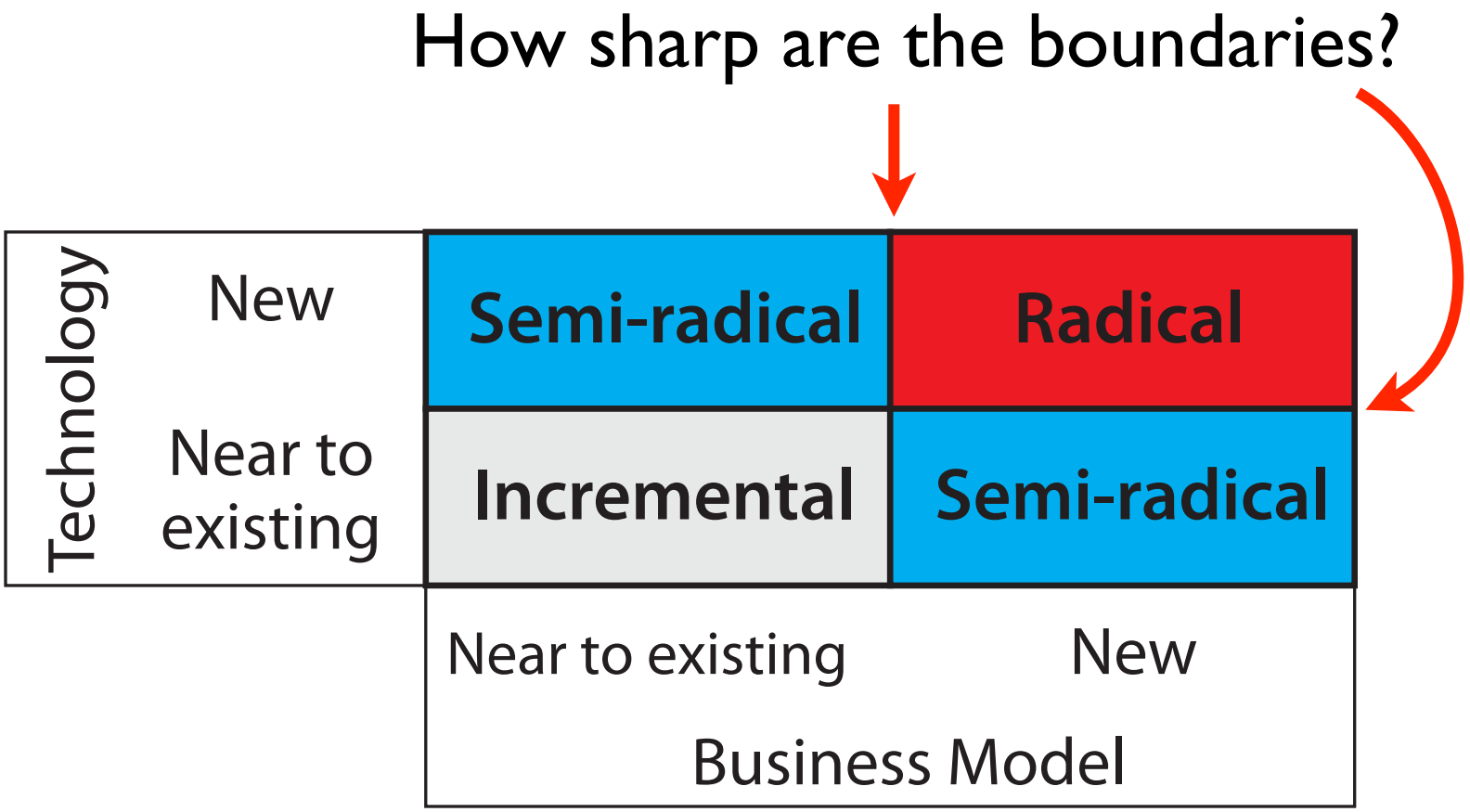
- Requires new strengths and may threaten existing products: *competency destroying*
- May be resisted by people and existing organizational structures

Davila et al. use an Innovation Matrix to distinguish three types of Innovation



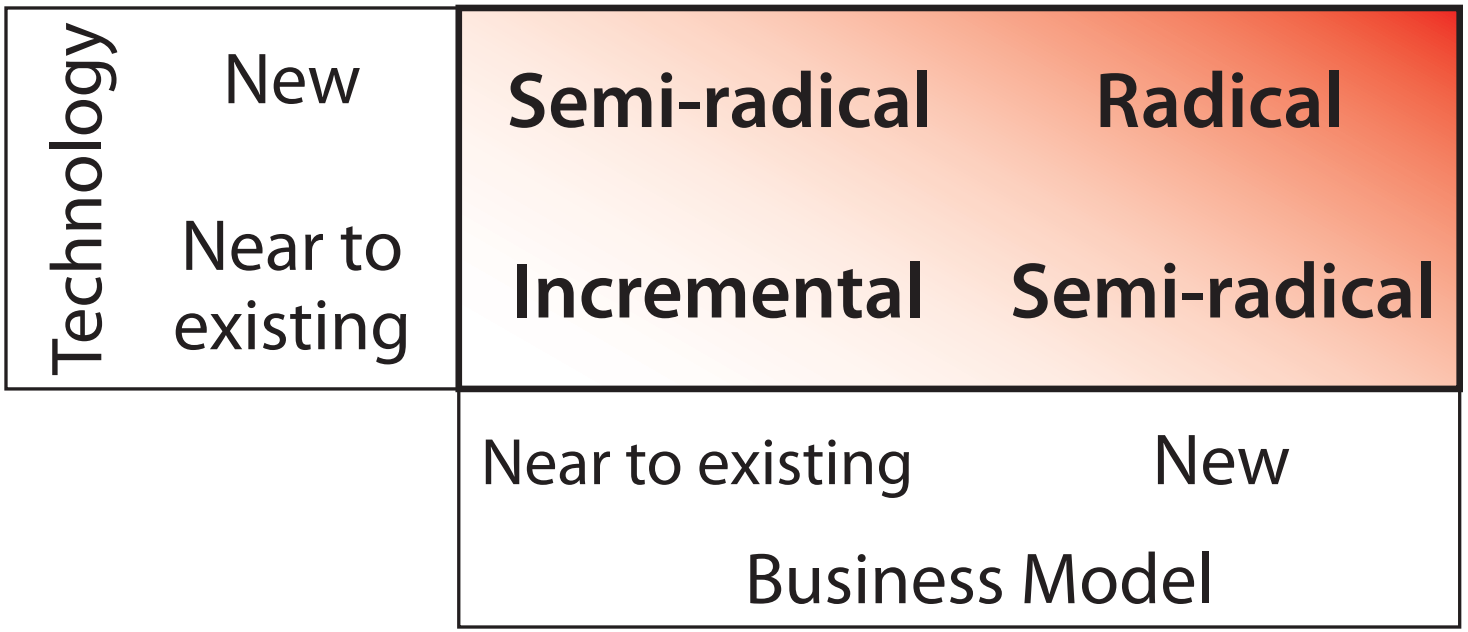
Tony Davila, Marc J. Epstein and Robert Shelton, *Making Innovation Work*, 2006, Pearson Education, Chapter 2

Distinctions between types of innovation do not seem to be precise



Tony Davila, Marc J. Epstein and Robert Shelton, *Making Innovation Work*, 2006, Pearson Education, Chapter 2

The difference between innovation types may be a matter of degree



Tony Davila, Marc J. Epstein and Robert Shelton, *Making Innovation Work*, 2006, Pearson Education, Chapter 2

The Diffusion of Innovation

A model to account for social factors that affect the speed at which innovations are adopted.

Diffusion of innovation depends on how fast people try out and use new ideas

Diffusion theory

1. A model to account for social factors that affect the speed at which innovations are adopted.
2. Developed by anthropologists and sociologists, especially in early 20th century who studied adoption of new farming practices

http://en.wikipedia.org/wiki/Diffusion_of_innovations

Everett Rogers developed a model of how people adopt an innovation

Roger's theory identifies five elements that contribute to the spread of an innovation

1. The innovation
2. Adopters: people or organizations that use the innovation
3. Communication channels between members of a social system
4. Time scale over which the innovation diffusion occurs
5. Social system in which the diffusion occurs: mass media, government rules

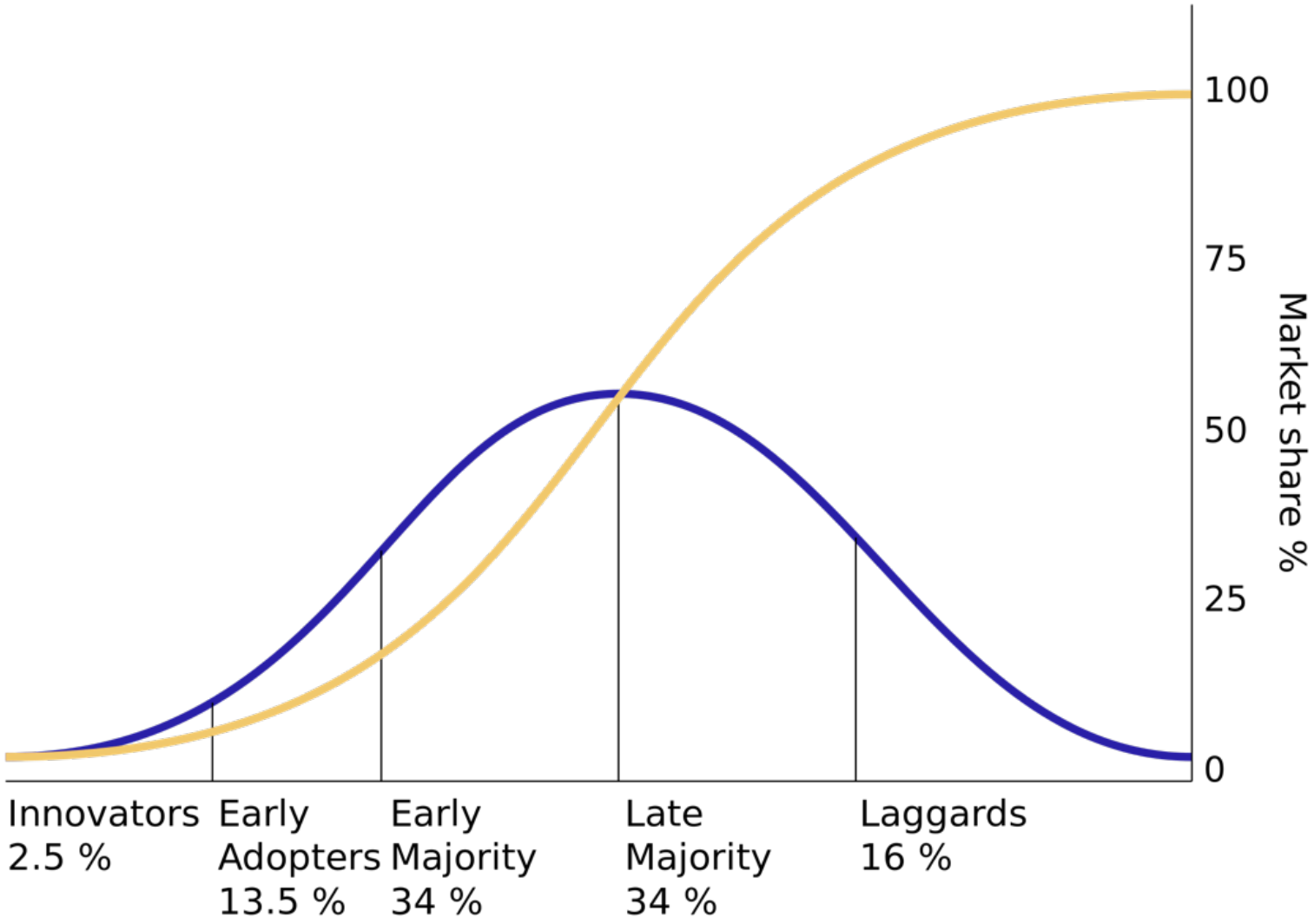
http://en.wikipedia.org/wiki/Diffusion_of_innovations

Members of a social group follow a five-step process in adopting an innovation

1. Knowledge acquisition
   Become aware of the innovation
2. Persuasion
   Develop a favorable view of the innovation
3. Decision
   Choose to adopt or reject the innovation
4. Implementation
   Use the innovation
5. Confirmation
   Evaluate the adoption and implementation

http://en.wikipedia.org/wiki/Diffusion_of_innovations

Adopters of the innovation can be grouped by how early they become users



http://en.wikipedia.org/wiki/File:Diffusion_of_ideas.svg

Diffusion theory suggests that marketing is a key component to innovation

Market research

- What are needs of the market?
  - products that will sell
  - problems that need to be solved
- Who are early adopters?

Marketing to promote

- Get information/products to early adopters
- Use appropriate communication channels
- Use policies and be sensitive to social norms and opinions of community leaders

Disruptive Innovation:

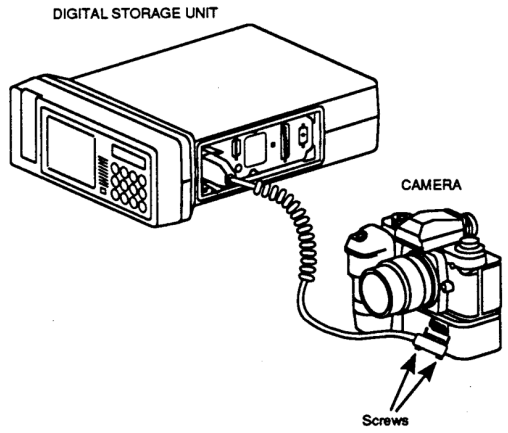
The case of the digital camera

A model of innovation that accounts
for substantial realignment of
dominant institutions

Kodak took a logical but unfortunate route in trying to capitalize on their invention

The first Kodak digital camera, the DCS 100, was released in 1991

- 1.3 megapixel
- 200 Megabyte Digital Storage Unit



DCS 100 photo from http://www.nikonweb.com/dcs100
Image of storage unit for DCS 100 User's Manual

Kodak listened to high end customers, which were only part of the total market

- Kodak's customers for their digital cameras were professional photographers
- Kodak worked with Nikon, the maker of the high performance cameras
- Kodak saw it's role as capturing and storing the image, not in creating the entire camera
- Kodak's core business was in wet photography
  - Kodachrome was the best available slide film
  - Kodak was competing with Fuji (Fujichrome and Fujifilm)
- Kodak's first point-and-shoot digital camera, the DC40, was released in 1995

Where is Kodak today?

According to wikipedia (accessed 15 September 2015)

- January 2012: Kodak filed for Chapter 11 bankruptcy protection. Kodak was delisted from the NYSE and moved to OTC trading, closing at $0.36/share.
- February 2012: after selling its Image Sensor Solutions division, Kodak announced that it would phase out production of digital cameras.
- December 2012: Kodak sells its digital imaging patents for $525 million.
- September 2013: Kodak emerges from Chapter 11 Bankruptcy protection, and says it will focus on commercial customers.

http://en.wikipedia.org/wiki/Eastman_Kodak

Kodak's story seems to fit a pattern, but it is not necessarily typical

Apparent theme:

- Dominant company continues to improve its product to satisfy needs of its existing customers
- Competition enters market with inferior product that appeals to a new group of customers
- Dominant company is surpassed by rivals who rapidly improve their technology (or service)

Examples:

- JC Penny and other retailers overtaken by Walmart
- Land line phone networks overtaken by cell phones
- Major steel mills overtaken by speciality steel mills

Kodak's story seems to fit a pattern, but it is not necessarily typical

Counter examples:

- IBM reinventing itself as a service company
- Apple's many near-death experiences
- Gillette is still in the business of selling razors
- Car companies make slight improvements to function and performance of cars every year

The Kodak story is a classic case of Disruptive Technology

Sustained innovation improves performance

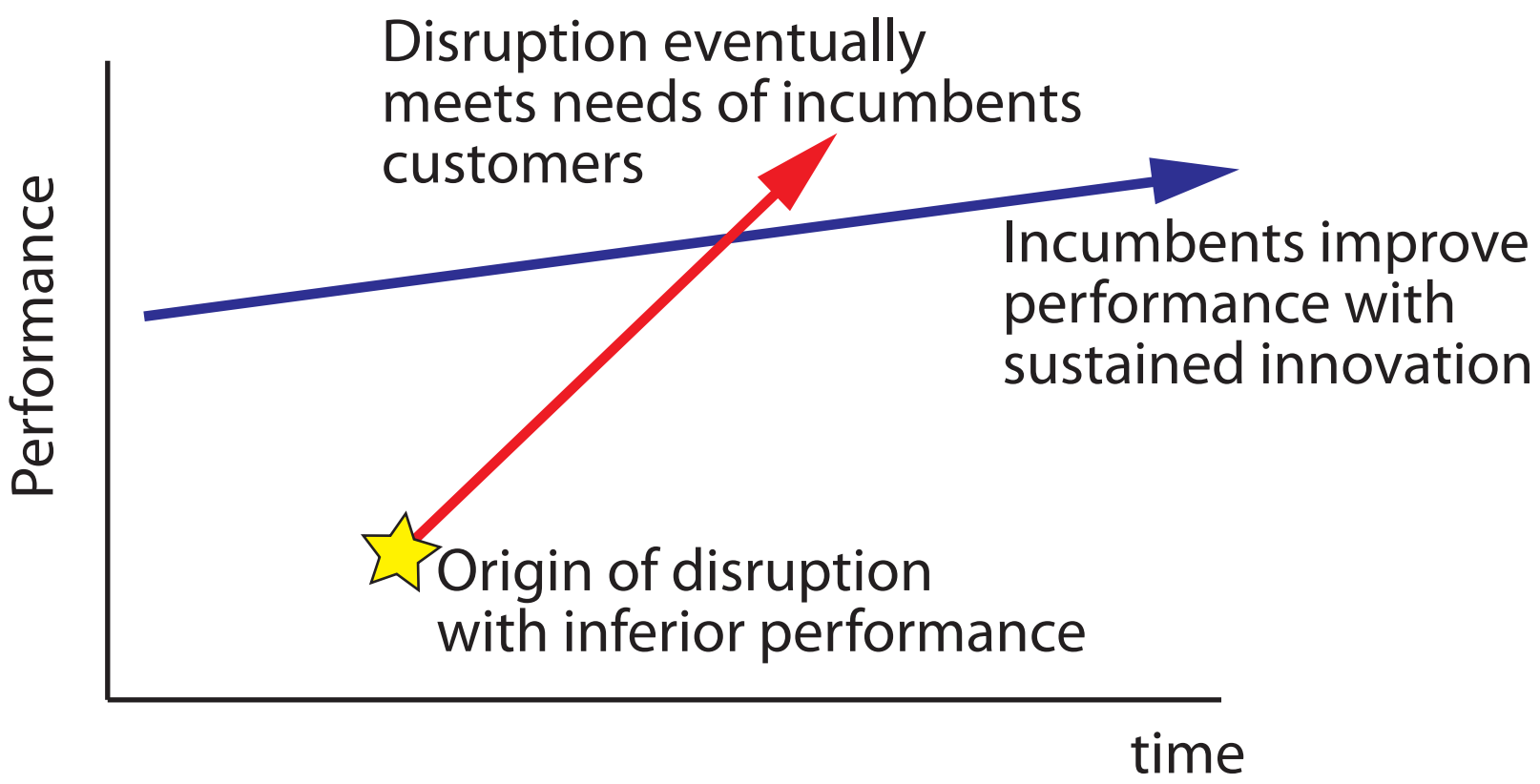
- Some customers demand better performance, others are temporarily satisfied.
- As companies improve their products, they outstrip their customer's ability to use that product.

A competitor with an initially inferior product enters the market

- The new competitor is focused on a different group of customers than the incumbent.
- Technology innovation allows the manufacturer of the "inferior" technology to leap-frog the incumbent technology leader (low-end disruption).

See, books by Clayton Christensen, e.g. The Innovator's Dilemma

Christensen's graphical representation of disruptive innovation



http://www.claytonchristensen.com/key-concepts/

Disruptive Innovation: Hype vs Reality

Disruptive Innovation is a popular meme

- An overused buzzword applied without precision

Disruption Innovation as a theory is criticized

- King and Tucci (2002) showed that Christensen's original case study – innovation in the hard drive industry – does not support his theory.
- Lepore (2014): "Disruptive innovation is a theory of how businesses fail. ... It doesn't explain change."
- King and Baatartogtokh (2015): 9% of 77 case studies used by Christensen exhibit 4 main characteristics of disruptive innovation

A. King and C. Tucci, Management Science, 48:2, pp. 171-186, Feb 2002
J. Lepore, The New Yorker, June 23, 2014.
King and Baatartogtokh, MIT Sloan Management Review, Sept 15, 2015

Disruptive Innovation in Education?

Could a new technology or business model disrupt the current model of higher education?

Massively Open On-line Courses: MOOCs

The term MOOC originated in about 2008. George Siemens and Stephen Downes at the University of Manitoba created an open on-line course with 25 registered students and 2300 non-paying students from the general public

In the Fall of 2011, Stanford created three courses that were free and open to the public. Enrollment in each course was about 100,000.

Since the Stanford experiment, a small number of companies and university consortia have launched MOOC courses.

http://mobimooc.wikispaces.com/History+of+MOOC+the+pioneers
NY Times overview video: http://youtu.be/KqQNvmQH_YM

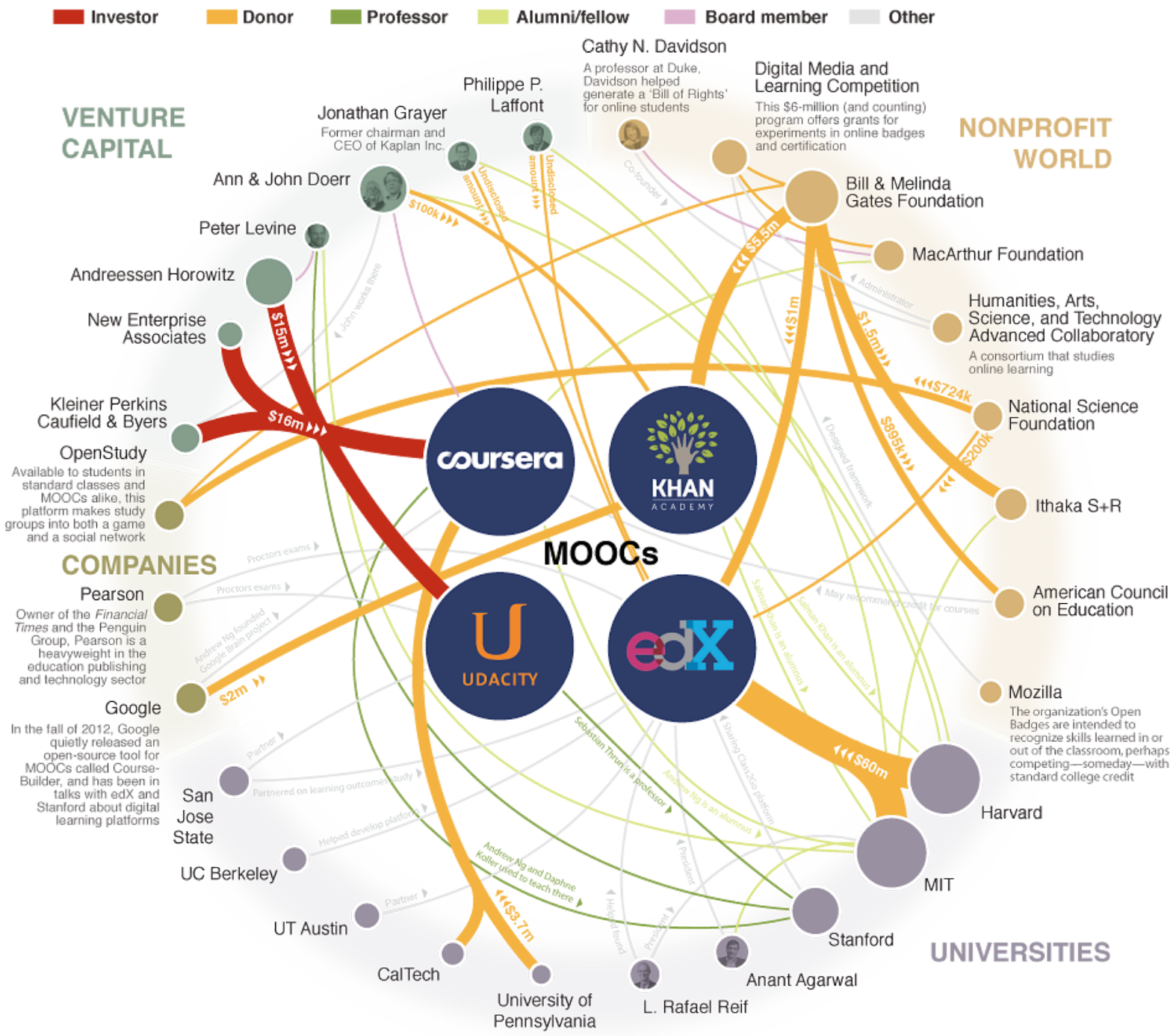
Massively Open On-line Courses: MOOCs

Early creators of MOOCs view them as experiments in participatory education based on the Connectivist model of learning.

Since 2011, the emphasis in MOOCs has been on the displacement of traditional models of higher education.

In March 2013, legislators in the California State Senate introduced SB 520, which would require faculty in the UC, CSU and California Community College system to accept MOOCs as substitutes for over-subscribed lower division courses. The bill did not emerge from the legislature.

http://www.connectivistmoocs.org/what-is-a-connectivist-mooc/
http://www.insidehighered.com/news/2013/08/01/controversial-california-bill-outsource-student-learning-dead-until-2014-or-later



http://chronicle.com/article/Major-Players-in-the-MOOC/138817/

Are MOOCs disruptive? Maybe not.

In late 2013, Udacity decides to focus on corporate training market. (The "pivot" by Sebastian Thrun.)

- Passive instruction for large numbers of students doesn't work if those students are not prepared
- Thrun admits poor quality of some Udacity courses
- Udacity to focus on more lucrative Corporate training

In 2014, excitement about (and fear of) MOOCs has subsided on many campuses.

It is possible that the disruption caused by MOOCs is yet to be felt. Recall the delay in the effect of the internet on newspapers.

http://www.fastcompany.com/3021473/udacity-sebastian-thrun-uphill-climb
http://www.insidehighered.com/quicktakes/2014/01/23/udacity-redesign-embraces-founders-pivot

MOOCs may morph into recruiting, branding and job placement tools

Applicants to competitive universities may take MOOCs in high school to increase their odds of admission (push)

Universities may recruit high performing students in their MOOCs (pull)

MIT is rethinking undergraduate education

- Focus on demonstrating knowledge of all content, not just passing a class
- Use MOOC-like classes to allow flexibility in scheduling and opportunities for extracurricular learning such as internships and research projects.

http://www.changinghighereducation.com/2014/01/mitx-and-the-transformation-of-residential-education.html
http://web.mit.edu/future-report/TaskForceOnFutureOfMITEducation_PrelimReport.pdf
http://www.newscientist.com/article/mg22129590.200-online-university-courses-cant-change-the-world-alone.html

Problems remain with MOOCs

How can MOOCs be financially sustainable?

- Spend $100k to develop the course
- Pay instructors and assistants to offer the course
- Give away the course for free
- Profit?

Low completion rates

- Is a 20% completion rate bad if 20,000 students complete the course?
- Measurements show that the early MOOCs attracted experienced professionals (including those with PhDs), not underserved students who could not afford college

Problems remain with MOOCs

Success in a MOOC requires resources and discipline

- Self-directed learners
- Access to high speed internet

Certification and Fraud

- How to award credit?
- How to you guarantee that the student receiving the credit was the one who did the work?

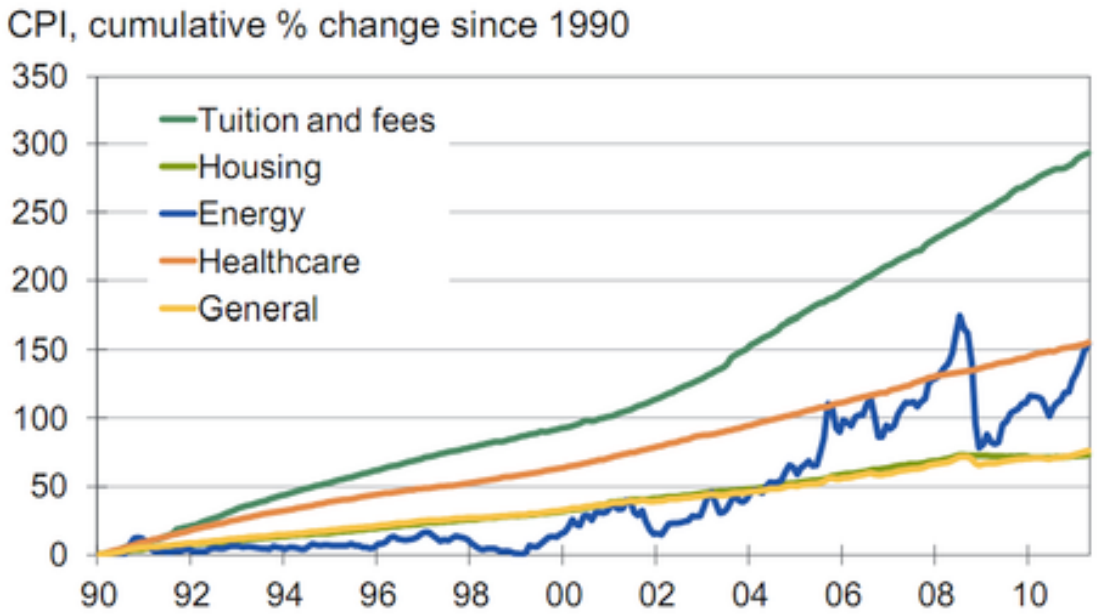
What's next for higher ed? More of the same

Financial pressure continues (chart from Moody's, 2011)

Global competition

Technological innovation

Resistance to change



http://image.exct.net/lib/fefb127575640d/m/2/Student+Lendings+Failing+Grade.pdf

MOOCs and technology-based instructional techniques are changing and challenging higher ed institutions.

On-line delivery

- MOOCs
- SPOC – small private on-line classes
  - Not open to the public
  - Use MOOC tools

Credit for Prior Learning

- Certify prior experience as equivalent to class work
- Need to relate practical experience to theoretical models

Flipped classrooms

- Watch video (pre-recorded) lecture at home
- Come to class for examples, discussion, group work

Putting Innovation into Practice

How do we think about innovation at the scale of an enterprise?

Broad theories and buzzwords are not a management plan

- We really need *technology management*
  - See MCECS Department of Engineering and Technology Management

    http://www.pdx.edu/engineering-technology-management/
- Engineers and managers need guidance at the project level
- Strategies vary with products and company culture

Whether or not your organization uses a buzzword-compliant strategy for managing innovation, you should at least have some plan for creating innovation and choosing *whether* to adopt innovations.

Engineering education model encourages seeking the "right" answer and avoiding failure

Robert Sutton, Professor of Management Science and Engineering, Stanford University

> "*the most creative people – and companies – don't have lower failure rates, they fail faster and cheaper, and perhaps learn more from their setbacks, than their competitors*."

How can we incorporate failure into a strategy for innovation?

http://bobsutton.typepad.com/my_weblog/2007/10/why-rewarding-p.html

Provocative advice

Jim Adams, Emeritus Professor of Electrical Engineering, Stanford University

"*Good companies reward success,*
punish failure,
and ignore inaction

Great companies reward success and failure
and punish inaction"

How can we incorporate failure into a strategy for innovation?

http://www.businessweek.com/innovate/content/feb2010/id2010028_823268.htm

Innovation in software and consumer electronics is often held up as a model

Minimum viable product

- MVP is a "learning vehicle"
- Not the "minimal" product
- Use minimum set of features to get feedback from early adopters
  - No formula for the minimum set of features

    "Probably much more minimum than you think!" (see slideshare, slide 4)
  - Goal is to iterate rapidly while getting useful feedback
  - Early adopters can put up with some deficiencies

Note: MVP is a popular buzzword and may not work in all situations. Whether using MVP or not, extract good (not necessarily maximal) information from each iteration.

http://www.startuplessonslearned.com/2009/08/minimum-viable-product-guide.html
http://www.slideshare.net/startuplessonslearned/minimum-viable-product

Innovation in software and consumer electronics is often held up as a model

"fail fast":

- Emphasis on the "fast" part of "fail fast"
  - Failure, by itself, is not the goal.
  - Goal is to identify areas/functions that need the most improvement
- Use "consumer" feedback and rapid iteration: MVP is the vehicle
  - Consumers may be internal or external to your organization.
  - Don't wait until product is finished before getting feedback.
  - Use quantitative measurements in addition to opinion.
  - Easier and cheaper to do with software than hardware.
- Strategy used by start-up companies without existing product, or established companies trying to create a new product.

Summary and Warning

Ideas presented here are meant to stimulate interest.

Management experience helps

- Engage leadership at your organization
- Find a mentor

Current thinking about innovation and technology management is dynamic.

- Expect the advice and buzzwords to change.
- Expect the pressure to innovate to remain

Summary

Innovation provides advantage in a competitive market

- Innovation occurs in *both* technology and business processes
- Sustaining innovation:
  - necessary continuous improvement
  - tends to maintain existing order
- Radical innovation:
  - shakes up status quo
  - large changes in technology and/or business processes
- Disruptive innovation
  - May explain the drastic impact of some innovations
  - Competitor with initially inferior product overtakes established leader
  - Theory is not consistent with all situations it is purported to explain
  - Is an overused term

Summary (2)

Diffusion theory attempts to explain the spread of innovation

- Social factors affect adoption
  - Speed varies from early adopters to laggards
  - Having good technology is not sufficient
- Use marketing to understand your customers
- Use marketing to spread your ideas

Rapid iteration is an innovation strategy

- Use Minimum viable product to test ideas
- Avoid costly commitments to a “final” product that may have weaknesses that can be addressed before production.
- Failing fast to learn: expose weaknesses early.

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