# Project-Based Learning for 3D Printing

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Wentworth Institute of Technology

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# Who is Stratasys?

## Systems


Fused Deposition Modeling (FDM)
PolyJet

## Parts Services

stratasys®
DIRECT MANUFACTURING

Fused Deposition Modeling (FDM)
PolyJet
Stereolithography (SLA)
Selective Laser Sintering (SLS)
Direct Metal Laser Sintering (DMLS)
Binder Jetting

Unmatched ability to meet customer's diverse additive manufacturing needs.

# Stratasys Locations


**26**
Global Offices

**4**
Manufacturing Locations

**+3,000**
Employees

**+260**
Resellers

# Stratasys Curriculum Materials

- Introduced in December 2014
- Promotes active student participation using project-based learning
- Supplements existing curriculum or can be used offer a completely new course
- Designed to prepare college students for careers being reshaped by 3D printing

# Stratasys Curriculum Materials

These schools put the curriculum to the test:

- Temasek Polytechnic in Singapore
- Wentworth Institute of Technology in Boston, Massachusetts

# Introduction and Background


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**AGENDA**

01 – Introduction and Background
02 – Ease of Use
03 – Layout of Course Units
04 – Flexibility
05 – Student Feedback
06 – Faculty Impression
07 – Assessment Data
08 – Lessons Learned
09 – Summary

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# Introduction and Background

## FALL 2011

Wentworth Institute of Technology (WIT) completes $3M renovation of Manufacturing Center including a dedicated 3D printing lab with Objet24™ and uPrint SE™ 3D printers. Use of 3D printing lab is limited due to lack of knowledge, training and manpower.

## SPRING 2014

Stratasys contacts WIT to discuss possibility of a pilot course using Stratasys Education's 3D printing curriculum.

## SUMMER 2014

WIT administration approves course offering as a "Special Topics" class.

## FALL 2014

Course is underway with 16 students. Course is very successful. Word gets around and interest increases dramatically. Quality of 3D Printed parts improves.

## SPRING 2015

3D Print Lab is a very, very, very busy place. Now requires a lab manager/facilitator, online ordering, staffed by work-study students each semester.

SECTION TWO

# Ease of Use

# Ease of Use


- 3D printing curriculum guide
  - Step-by-step guide broken into 14 weekly units
  - Sufficient content to fill two hours of lecture and four hours of lab per week
  - At Wentworth, this would be the equivalent of a four-credit course
- Sample STL files for units 01, 05 and 07
- Student project suggestions
  - Case study
  - Final project – “Something that Moves Something”
- Exam question bank
  - Relevant quiz/exam questions for each unit or you can write your own
- Assessment Tools
  - Suggested course grading scheme
  - Project assessment – includes rubric

SECTION THREE

# Layout of Course Units

# Layout of Course Units

Most units have a professionally created PowerPoint presentation with links to pertinent online videos and additional content including:


- Historical overview of manufacturing
- An agnostic overview of 3D printing technologies
- Going from 3D CAD to STL/OBJ printer files
- Getting familiar with Stratasys 3D Printer software
- Two-part series on gear systems
- Dynamic surfaces (modular mechanisms that change shape)
- What does the future of 3D printing look like?
- Midterm exam
- 4D printing (3D prints that change over time)
- Basics of ‘parametric design’
- Getting to the ‘nitty gritty’ of printing final projects
- Final presentations

SECTION FOUR

# Flexibility

# Flexibility

- Although the course can be taught as-is, there is sufficient room available to expand on existing topics or to introduce NEW topics.

- However, it is recommended that the first four units be taught at the beginning of the course in order to provide sufficient foundation in the terms and technologies used in 3D printing.

SECTION FIVE

# Student Feedback

# Student Feedback

**What did you like the most about the course?**

"3D printing was fun and easy to learn, understand."

"The opportunity to be creative with our prints beyond limitation. It expanded the way I thought about what could be 3D printed."

"Freedom of design is what I liked most about this course. Learning is far less painful when the subject of study can be directly related to one's hobbies or interests."

"The freedom to design with few guidelines and restrictions."

"What I liked the most was the challenge of the final project. Although difficult at times, I learned a great amount."

"Being able to learn about the different applications of 3D printing."

# Student Feedback

**What did you like the least about the course?**

“Being under pressure to design something I was not sure I could build.”

“Due to the size of the class and the cost of the materials, I was only able to print a few parts.”

“I didn’t feel that there was enough opportunity to use the printer software.”

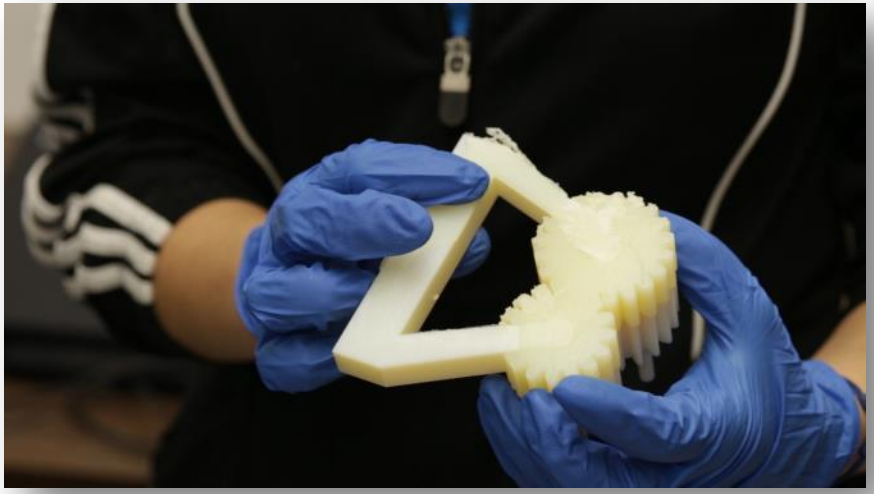
“So many choices/variations on what to make and print. Keep it simple and don’t let ‘great’ get in the way of ‘good enough’. I often had to repeat that in my head in order to not be too ambitious.”

“The amount of money wasted during 3D printing.”

# Student Feedback

**Would you recommend this course to a fellow classmate?**

All 16 students gave a unanimous thumbs-up to the course and would/did recommend it to other students – regardless of their major!



SECTION SIX

# Faculty Impression

# Faculty Impression

- Most faculty are aware of 3D printing and its importance.
- They have seen numerous ‘static’ parts 3D printed and have become accustomed to that.
- Once they saw functioning assemblies printed in one session with no assembly required they became more interested.
- Currently working with one of our faculty who teaches a kinematics course to introduce 3D printing into his curriculum. The students can design a mechanism, predict its motion, 3D print it and compare results to predictions.

SECTION SEVEN

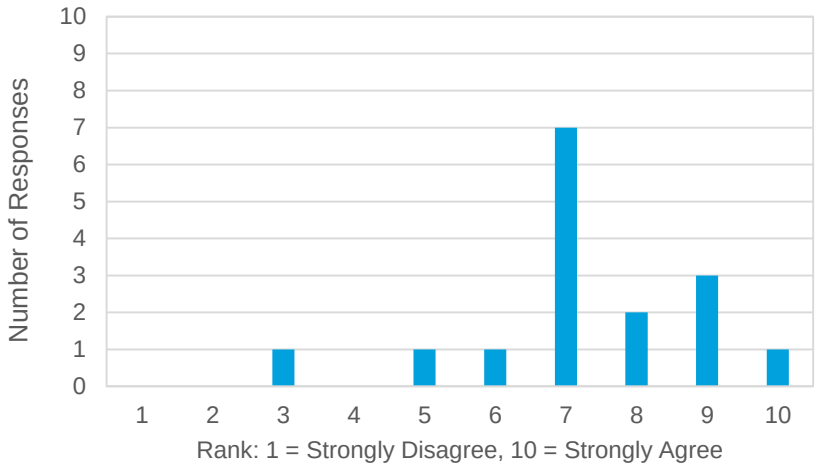
# Assessment Data

# Assessment Data

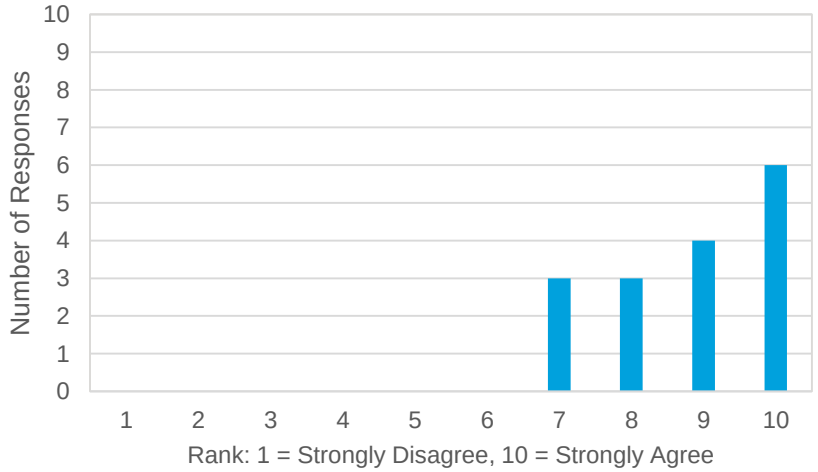
- Our end-of-semester survey contained seven statements based on the course objectives published on the Stratasys website.
- Each student was asked to rank their level of agreement with each statement on a scale of 1 (Strongly Disagree) to 10 (Strongly Agree).
- There were 16 students in the class.

# Results

*Objective 1: The course provided you with knowledge of key historical factors that have shaped manufacturing over the centuries.*

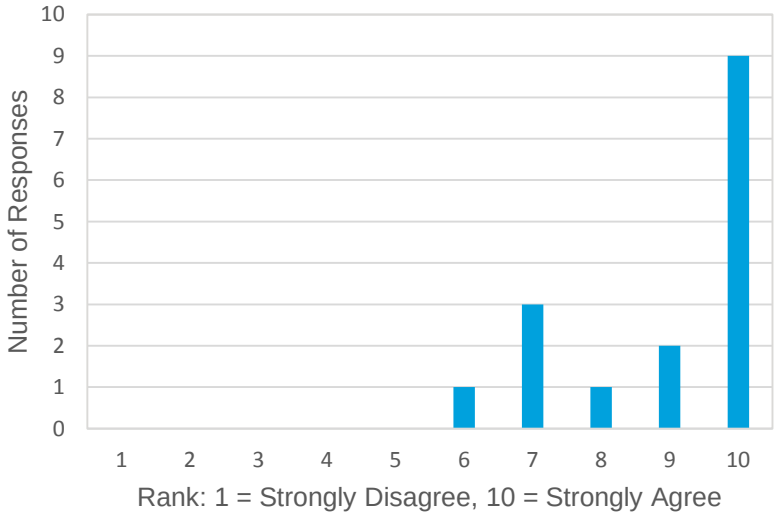



*Objective 2: The course explained current and emerging 3D printing applications in a variety of industries.*

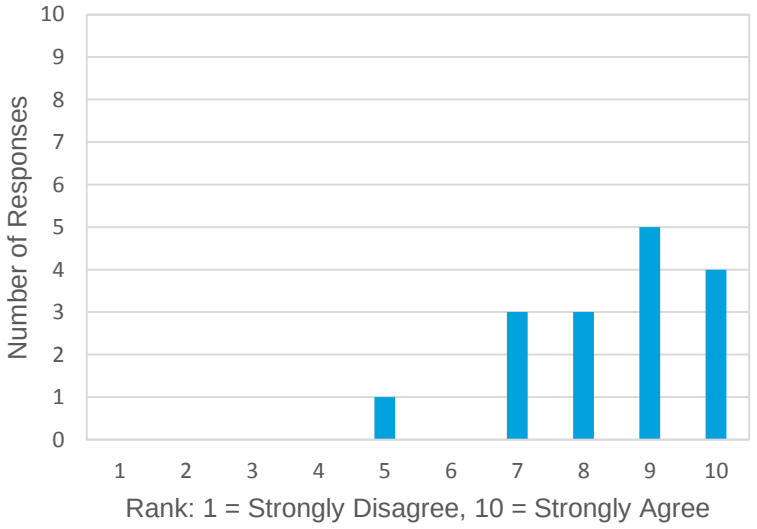


# Results

*Objective 3:The course provided a description of the advantages and limitations of the main 3D printing technologies.*

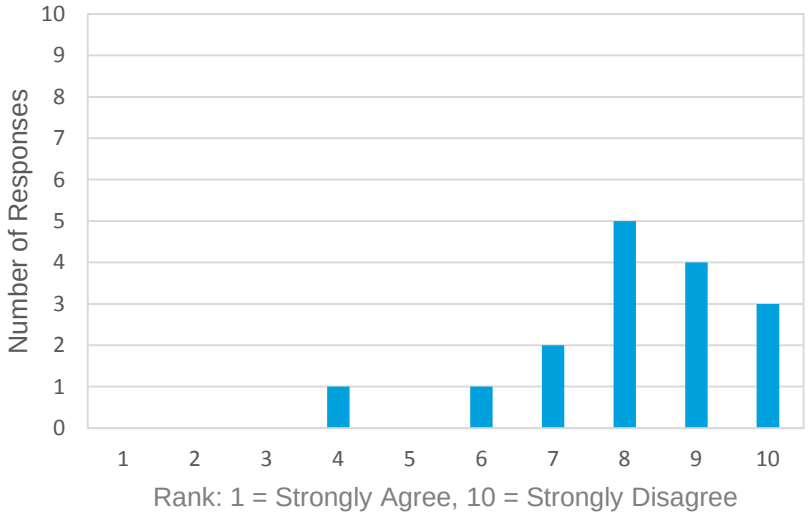



*Objective 4: The course provided you with the ability to evaluate real-life scenarios, and recommend the appropriate use of 3D printing technology.*

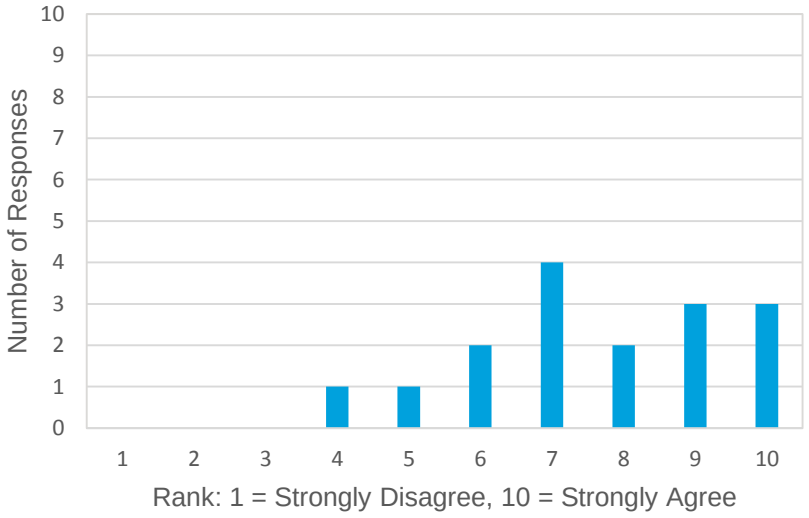


# Results

*Objective 5: The course provided you with the background to be able to identify opportunities to which 3D printing technology can be applied in order to reduce the time and cost of prototyping or small lot manufacturing.*

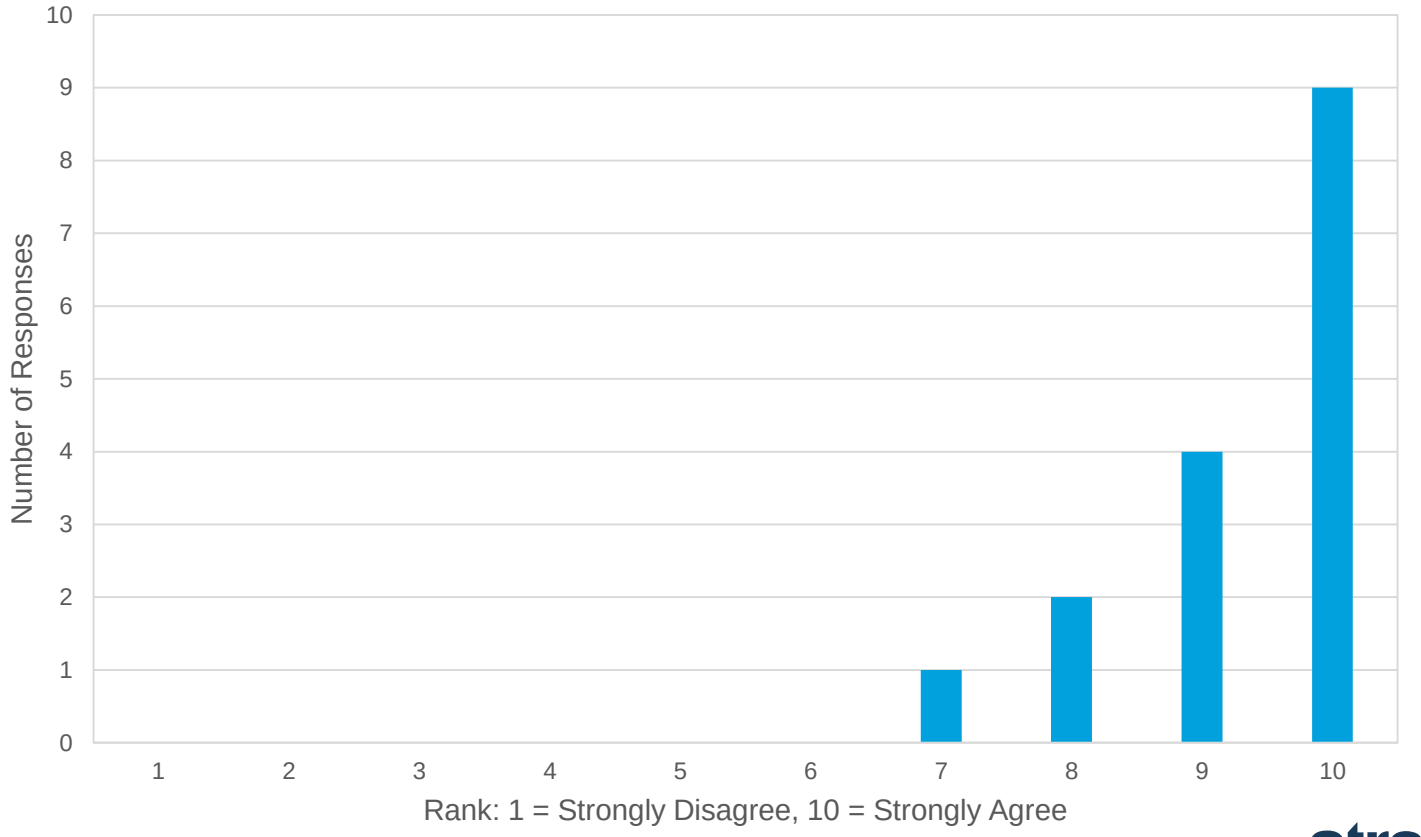



*Objective 6: The course provided you with an understanding of the economic implications of 3D printing, including its impact on startup businesses and supply chains.*



# Results

*Objective 7: The course provided you with the information necessary to design and print objects containing moving parts without assembly.*



# Important Lessons Learned

- Be sure that there is sufficient clearance between parts of the assembly to allow for the support material.
- Provide sufficient access for the removal of support material.
- Corrupt STL files (non-manifold, inverted surface normals).
- Students lost sense of scale and made parts too thin and delicate.
- Don’t let the students bite off more than they can chew.

# Summary

Stratasys has created an effective and engaging 3D printing curriculum that is:

- Turnkey
- Project-based
- Technology agnostic

There is sufficient content for a 14-week high school or college-level course.

Recommended pre-requisite: Instructor and students should have previous experience in 3D modeling software.

# More Information and Resources

**www.stratasys.com/webinar-curriculum**

- Download webinar slides
- View webinar on-demand
- Download curriculum guide
- Access curriculum materials

**Stratasys recently and permanently discounted materials for education by 50%***

**Offer is applicable to educational institutions in North America only and is for model and support materials only. Does not include material for use with the Objet1000, Objet1000 Plus, FDM soluble support, dental and hearing aid materials.*

# Questions?

www.stratasys.com/webinar-curriculum