The Class of 1960 Faculty Fellows, Professor Daniel Hastings and Professor Hal Abelson decided to use the generous funding from the Class of 1960 to support a set of educational innovation experiments. The experiments were sponsored by the MIT Council on Educational Technology (MITCET) to explore the key idea of using increased modularity in the MIT curriculum using online education resources. As a wrap up to these experiments, a large education symposium was held. Funding for each of these efforts has been provided by the generous support of the Class of ’60. ¹

This report presents a summary of these MITCET Modularity Experiments including preliminary assessments into the impact of online education and modularity, as well as the key themes that emerged from the MITCET Online Education Symposium, which brought together more than 100 MIT faculty and academic staff to identify and discuss important considerations around the adaptation and diffusion of online content.

I. MITCET Modularity Experiments

In Spring 2012, the MIT Council on Educational Technology (co-chairs are the Class of 1960 Fellows, Prof Daniel Hastings and Prof Hal Abelson) sponsored a set of experiments that used various approaches and technologies to deliver MIT undergraduate courses! Each experiment was carefully reviewed by the Council, following submission of a detailed proposal by the department, and selected based on its merit in advancing innovative practices for teaching and learning at the Institute.

Particular emphasis was placed on increasing the level of modularity in course delivery in a manner that:

- Increases flexibility in delivering the course, so that it need not be organized into one-semester blocks.
- Promotes the ability for students to follow the course remotely.
- Enhances the learning process for students

¹ A previous report was presented to the Class of ’60 in July 2011, prior to the start of the modularity experiments.
Accordingly, for each experiment, unique starting hypotheses were articulated by the participating faculty in coordination with MITCET and the Teaching and Learning Lab (TLL).

This report presents preliminary conclusions based on the recent completion of courses in which experiments were performed. The results of more detailed assessments conducted by the TLL will follow in a later report. In any cases where the online innovations presented in these experiments are adopted by a department, MITCET plans to conduct longitudinal assessments in order to better understand their impacts in advancing MIT’s strategic goals for online education, and present those findings.

1. **Chemistry Bridge: Modules for self-paced learning and review of complex and recurring core concepts**

   **Goal:** Bridge challenging concepts between courses with similar concepts

   **Hypothesis:** Student learning will be enhanced in a scalable way through networked modularity

   **The opportunity:** Across the sciences, certain key concepts have traditionally proven challenging for students at all levels. These concepts are typically taught in introductory classes, but faculty must review them repeatedly in advanced classes across the curriculum. The Chemistry Bridge project is developing self-paced modules to assist mastery of these key concepts outside the classroom setting. The modules can be used independently by students, or as a faculty tool to supplement instruction.

   **The experiment:** Students visit the Chemistry Bridge web site (currently under development) and take a “pre-test” to assess their understanding of the subtopics that constitute a core concept. Upon submitting their responses, students are presented with a “learning pathway”—a curated set of web sites, videos and simulations that have been selected to address that student’s learning goals. After completing the steps in the pathway, the student takes a “post-test” to assess how well they understood the concept.

   **Areas of innovation:** These modules are expected to advance teaching and learning at several levels:

   - They provide a model and potential platform for creating self-paced, customized learning pathways that allow novice and advanced students to better understand and master key concepts.
   - They will improve efficiency by reducing the repetition of core concepts in advanced classes.
   - They promote community curation of a set of existing web-based teaching materials that best explain the concepts.

   **Details:** The project is developing modules in the areas of:

   - Buffers
   - Electrochemistry and Redox
   - Quantum Mechanics
The key concepts are drawn from:

- 5.111 – Principles of Chemical Science
- 5.12 – Organic Chemistry I
- 5.60 – Thermodynamics and Kinetics

**Sustainability considerations:** The selection and creation of each new module initially requires a collaborative effort among faculty and domain experts to identify key concepts and their constituent subtopics.

Populating each new module requires a set of informed content aggregators (the project is working with advanced MIT undergraduates) who curate the best online teaching materials.

The tool that delivers the learning experience will require technical support and feature improvements to support evolving community needs.

**Future directions:** Although the tool is still under development, targeted for a Fall 2012 launch, the following future efforts have been identified:

- Feature refinements following usability testing with students.
- Expanding the number of modules to include other key concepts.
- Forming partnerships to implement the modules across Chemistry, and adapting the tool for use in other departments.

2. **Aeronautics and Astronautics: 16.20 & 16.90: Moving from lectures to interactive class sessions while enabling remote student participation**

**Goal:** Transform 16.20 & 16.90 to modular, active learning experiences, and enable self-paced completion of the courses

**Hypothesis:** It is possible to create a modularized semester where student learning is equal or better than the traditional approach and in-depth experiences are made easier.

**The opportunity:** Two trends drive a growing interest for creating more flexibility in the Aero/Astro curriculum. First, undergraduate degree students can participate in an increasing number of valuable academic opportunities beyond the campus, but most required courses are for residential students only. Second, Aero/Astro faculty increasingly consider the use of “active learning” methods in class to be an effective pedagogical technique.

In recognition of these trends, Aero/Astro faculty hypothesized that “a learning model, emphasizing active student-instructor engagement, coupled with student preparation, can be effective for achieving subject learning objectives for students both on-campus and of-campus.”

**The experiment:** In Spring 2012, two Aero/Astro courses (16.20: Structural Mechanics, and 16.90: Computational Methods for Aerospace Engineering) implemented several significant changes to the typical lecture-homework model. The experiment has just concluded and evaluation by the Teaching and Learning Laboratory is on-going.
Faculty oriented class activities around mini-lectures, focusing on topics that proved to be challenging to students, and collaborative sessions, in which students worked on problems or programming assignments together. Students were expected to review course notes before attending class. Students were also given the option of attending class remotely.

**Areas of innovation:** Participating faculty from both courses felt that the experiments exceeded their expectations.

Participants agreed that increased interactivity made the class sessions more valuable learning experiences. Typical student comments noted that: "Every class is like office hours with the professor" and "The class knocked down barriers. If I don’t get it, I can ask".

The use of embedded quizzes within the online pre-class material in 16.90 provided a dual benefit:

- Faculty could tailor class interactions around the material where students’ results showed an inconsistent or incomplete understanding of key concepts.
- Students appreciated immediate feedback on their grasp of the material, and came to class better prepared.

Class discussions were shared live via web-based videoconferencing enabling local and remote students to share the same class experience. Student remote participation was voluntary and typically 10% per class, with a different set of students choosing to remotely participate for each class.

**Sustainability considerations:** These experiments were notable for their use of relatively simple and low cost technologies:

Course 16.90 used a tool developed in the project for embedding questions into online course material, then scoring and sharing the results.

Remote participation used web videoconferencing technology (MIT-supported WebEx or Adobe Connect) and a tablet PC or electronic whiteboard (Mimio) for note-sharing.

**Future directions:** Given the success of this experiment, Aero/Astro is considering the following future options:

Expanding this model to more “professional area subjects” (junior and senior elective courses) in order to support off-campus opportunities.

Developing more embedded quizzes within pre-class material.

Exploring the MITx platform to provide a long-term supported infrastructure.

3. **Mechanical Engineering 2.002:** *Teaching a core required class to students at any distance*

**Goal:** Modularize mechanics and materials into discrete learning experiences

**The hypothesis:** It is possible to create a modularized course (for 2A) for teaching remote student where student learning is equal or better than the traditional ap-
The opportunity: The Mechanical Engineering undergraduate student is presented with an increasing number of valuable academic opportunities beyond the campus. While the department supports such activities, most required courses are only available on campus.

In parallel, the flexible 2A curriculum, which allows students to pursue specific “tracks” of knowledge and create a customized degree, envisions increased modularization of the mechanical engineering curriculum.

The combined goals of remote student participation and modularized course components sponsored an experiment in delivering a core mechanical engineering class to both residential and off-campus students.

The experiment: In Spring 2012, 2.002 was offered concurrently to both remote and residential MIT students. Ten percent of the class participated remotely—from Spain, Puerto Rico and California—and these students were held to the same academic standards as residential students. The experiment has just concluded and evaluation by the Teaching and Learning Laboratory is ongoing.

To support the remote students, all lectures, recitations, labs and review sessions were recorded and posted for viewing on the same or next day. Each remote student was provided a scanner for sending in assignments and exams, and an online discussion forum provided a channel for student interaction.

Areas of innovation: Participating faculty agree that a core mechanical engineering course can indeed be taught successfully online. With the proper support, tools and materials, Mechanical Engineering can offer an entirely online course without any reduction in quality or standards.

Course materials were modularized into an introductory core and four major components (plasticity, viscoelasticity, fracture & fatigue, and rubber). After completing the core module, students should be able to study the remaining components in any order.

Online content played a key role. The accelerated availability of lecture and lab videos, indexed by topic, enabled remote students to share a similar learning experience to residential students.

Online discussion supported significant levels of class interaction (130 questions solicited 450 responses). It linked residential and remote students in one community, and served as the primary channel for remote students’ questions.

Sustainability considerations: Two new roles—beyond the traditional course staff—proved essential to the successful delivery of a concurrent residential/remote course:

- An Online Instructor, who supports and interacts with remote students, providing online office hours and serving as their point of contact.
- An Educational Technology Coordinator, who manages the delivery of technical services—tools, platforms, and content.
Two key platforms were essential to providing an integrated learning experience: Piazza (an online discussion platform) and MIT TechTV (for video delivery).

**Future directions:** The faculty currently provide course materials through blackboard-based lectures. Interactivity and remote participation could be improved with more digital course material and restructured class sessions.

The faculty would like to experiment with course modularity, using the core and interchangeable modules.

The Online Instructor role could transition to existing roles within the department and a core MIT service could provide the Educational Technology Coordinator role.

4. **Anthropology Module (To be launched):** *Using online modules to teach ethnographic research methods*

   **Goal:** create an experimental module to teach anthropological fieldwork skills online to be available as a general MIT online resource across the MIT curriculum for students.

   **Hypothesis:** Online media can be used to teach rigorous ethnographic research methods without requiring extensive field-based practice.

   **Proposal:** The MIT Anthropology department will create an experimental module to teach anthropological fieldwork skills online. The goal is to institutionalize it as a central pedagogical tool and support the broad range of anthropological training required across the MIT curriculum and various departments. The development of this module is seen as being part of the overall evolution of the MIT Anthropology program, where modern research methods and multimedia resources are incorporated with rigorous qualitative ethnographic research to produce reliable and theoretically informed cultural analyses.

   The aims of this online workshop will be to teach students how to perform fundamental ethnographic and qualitative research techniques, such as:

   - Conducting interviews
   - Engaging in participant observation
   - Taking notes and gathering other forms of data, such as images and video, in the field
   - Analyzing data and developing hypothesis about social interaction
   - Communicating the results of research in both traditional written form, and via video and new multi-media sources

   **The experiment:** *(Note: This experiment has not yet begun)* This experiment will focus on developing an online module dedicated to interviewing skills. It will be built with several key elements that include:

   - Tutorial videos, licensed for near universal access through Creative Commons. Additional videos will be focused on conducting interviews, doing participant observation, and so on.
   - Texts, instructional materials, examples for commentary and critique.
• Additional web-based lessons, quizzes, and other materials.
• Internet-based communication tools such as Skype to develop an online interviewing system that will allow students from across the globe to practice conducting interviews with one another, and share transcripts as well as video segments of those interviews with other students in the module.
• An interactive online space built around students’ own work, where materials and questions can be shared and discussed among students and faculty alike.
II. MITCET Online Education Symposium

MITCET sponsored a workshop, supported by the Class of 1960 funds, on May 24th, 2012 to have the MIT faculty learn about the above experiments, as well as other online initiatives that are underway and to discuss their impact and implications for MIT education. Over a 100 faculty along with some academic staff and students participated in the workshop. Presentations and discussions focused on identifying the major considerations for adaptation and diffusion of the innovations that were presented. A number of key themes emerged:

1. Faculty and student engagement is a prime consideration when deciding how to use educational technology to enhance teaching and learning:
   - Lower-level classes will often involve a greater degree of passive information transfer, so faculty engagement is largely focused on clarifying key points.
   - Higher-level courses are more focused on faculty modeling critical-thinking or problem-solving skills, which requires deeper levels of interaction.
   - As we consider different technology-enabled teaching methods, we should remain aware of different student learning styles that can be impacted by these innovations.

2. Assessments present a rich area for further exploration:
   - Modular, embedded self-assessments in pre-class materials open up opportunities for shifting class time from passive lectures to targeted classroom instruction that addresses student gaps in understanding.
   - Dynamic assessments offer the possibility of creating customized learning pathways that recommend select content for addressing student gaps in understanding.
   - Assessments should better address the fact that students often learn from mistakes; feedback should be available when you're wrong.

3. The MIT community should begin establishing guidelines and principles around what types of teaching works best online:
   - Remote participation is broadly viewed as a positive innovation. We should further explore possibilities of remote guest lecturing and remote “field trips”
   - Online forums are positively viewed, with certain qualifications: Moderation, control and direction of discussion is important; Finding means to better ensure that content can be reused later by others; Considering means to rate how qualified certain participants are to answer questions.
   - Online lectures are positively viewed, with certain qualifications: It allows more flexible time management, but requires self-discipline to keep up with the course.
   - Online office hours and web videoconferencing is worth exploring further.
   - Online problem sets and the increased automation of graded exercises are viewed positively.

4. Faculty expressed interest in using students to better scale the extra work required for online teaching.
- Student peer grading, and student peer review of material prior to grading can increase the efficiency of the grading process.
- Students can help students through online forums. We must consider the motivations of students to answer question, and the desirability of a reward system to promote engagement.

5. Deciding which content to put online is an important consideration:
- Looking closely at modules that can be useful across multiple classes, and responsive to self-learning, will help build a curriculum level solution, rather than local course solutions.
- The access to primary texts remains difficult in many HASS courses.

6. Participants noted the following considerations for future development:
- There is strong interest in building innovative tools and models, but how do we incentivize the broader usage of these innovations into “steady state.”
- A shared infrastructure and more financial support would help expand the existing portfolio of experiments, beyond local pilots.
- We should pay careful attention to measuring the success of these experiments, looking at different modalities, and judging not merely on popularity but also effectiveness of learning.

7. Participants suggested the following services and infrastructure would help the community advance online learning:
- Reliable and inexpensive video capture services.
- A central resource summarizing best practices around online teaching, and the existing courses/communities that are currently experimenting with online teaching on campus.
- A recipe book for experimenting with online teaching models, along with services for teaching TAs how to help faculty with technology.
III. Budget Summary

1. Chemistry Bridge:
Recipient: Professor John Essigmann, Department of Chemistry
Amount: $84,000

2. Aeronautics and Astronautics: 16.20 & 16.90:
Recipient: Professor Karen Willcox, Department of Aero/Astro
Amount: $85,000

3. Mechanical Engineering 2.002:
Recipient: Professor Gareth McKinley, Department of Mechanical Engineering
Amount: $80,000

4. Anthropology Modules
Recipient: Professor Susan Silbey, Anthropology section
Amount: $70,000

6. MITCET Online Education Symposium
Amount: $8,000

Professor Daniel Hastings, Chair, MITCET
Professor Hal Abelson, Co-Chair, MITCET
Dr. M. S. Vijay Kumar, Executive Officer, MITCET