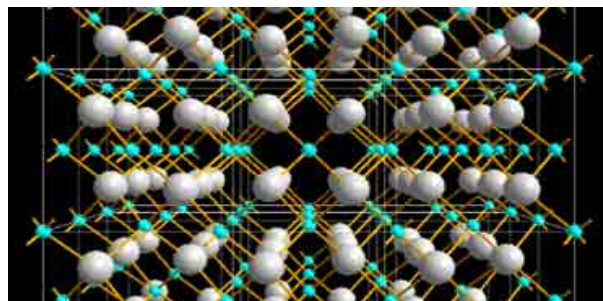


3.091x Introduction to Solid State Chemistry

MITx on edX – 2012 Fall



“3.091x explains chemical principles by examination of the properties of materials.” – edx.org

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Introduction. 3.091x is a first-year course where chemical principles are explained by examination of the properties of materials. The electronic structure and chemical bonding of materials is related to applications and engineering systems throughout the course. The on-campus version of the course has been taught for over 35 years and is one of the largest classes at MIT. The class covers the relationship between electronic structure, chemical bonding, and atomic order, and characterization of atomic arrangements in crystalline and amorphous solids: metals, ceramics, semiconductors, and polymers (including proteins). There is topical coverage of organic chemistry, solution chemistry, acid-base equilibria, electrochemistry, biochemistry, chemical kinetics, diffusion, and phase diagrams. Examples are drawn from industrial practice (including the environmental impact of chemical processes), from energy generation and storage (e.g. batteries and fuel cells), and from emerging technologies (e.g. photonic and biomedical devices).

3.091x was offered as a MITx on edX course in the Fall of 2012, by Professor Michael Cima.

Many participants in MITx on edX courses come with different intentions and levels of interest and many resemble shoppers and auditors in their course activity. This report identifies four subpopulations of participants (numbers below): those who registered, viewed some course content, explored the course, and were certified¹.

Important Dates		Participants	
July 24, 2012	Registration Open	Registered	24,493
October 9, 2012	Course Launch	Viewed	13,657
January 15, 2013	Course Close	Explored	2,803
September 8, 2013	Date of Report Data Collection	Certified	2,052

¹ See page 4 for definitions

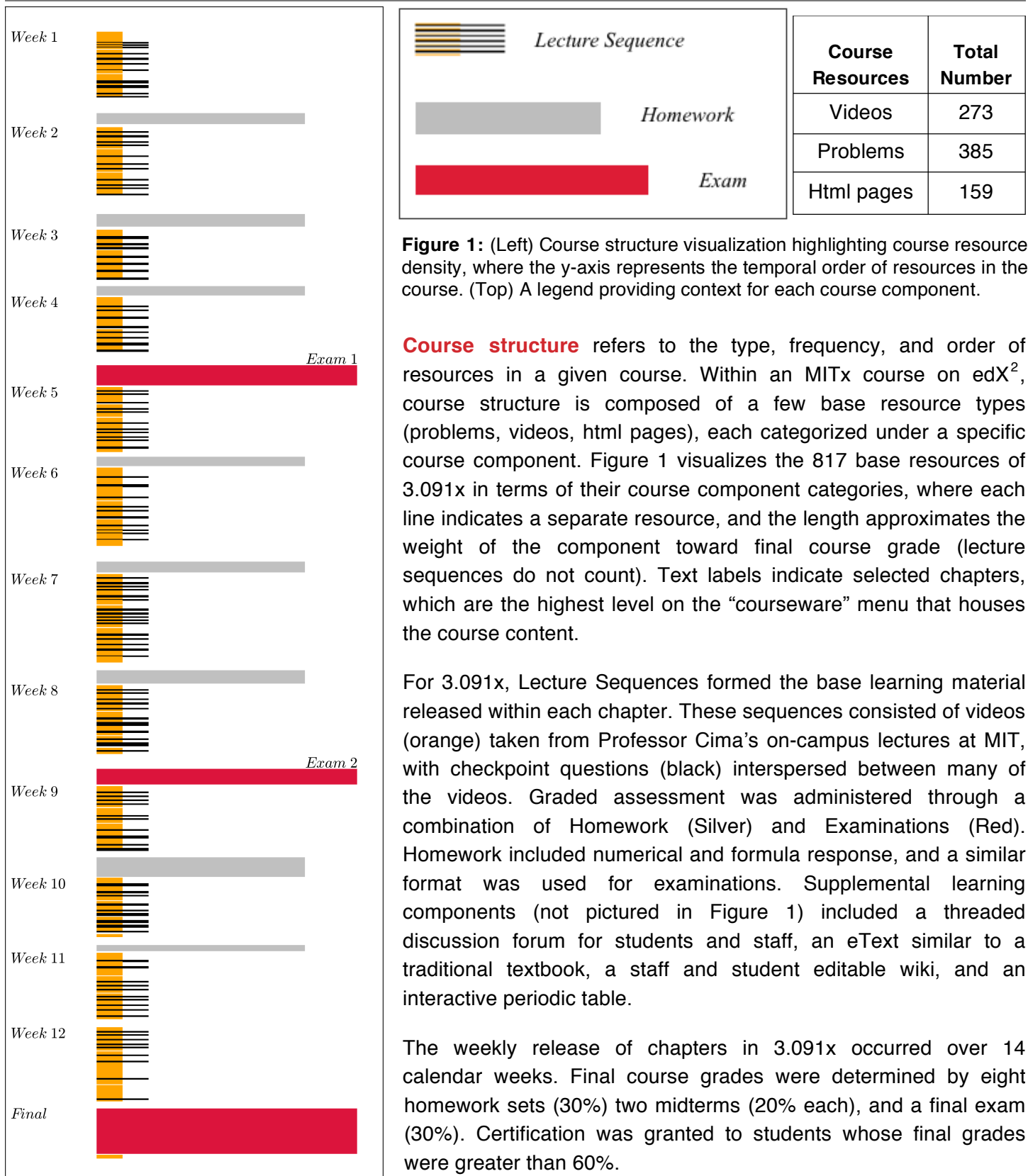


Figure 1: (Left) Course structure visualization highlighting course resource density, where the y-axis represents the temporal order of resources in the course. (Top) A legend providing context for each course component.

Course structure refers to the type, frequency, and order of resources in a given course. Within an MITx course on edX², course structure is composed of a few base resource types (problems, videos, html pages), each categorized under a specific course component. Figure 1 visualizes the 817 base resources of 3.091x in terms of their course component categories, where each line indicates a separate resource, and the length approximates the weight of the component toward final course grade (lecture sequences do not count). Text labels indicate selected chapters, which are the highest level on the “courseware” menu that houses the course content.

For 3.091x, Lecture Sequences formed the base learning material released within each chapter. These sequences consisted of videos (orange) taken from Professor Cima’s on-campus lectures at MIT, with checkpoint questions (black) interspersed between many of the videos. Graded assessment was administered through a combination of Homework (Silver) and Examinations (Red). Homework included numerical and formula response, and a similar format was used for examinations. Supplemental learning components (not pictured in Figure 1) included a threaded discussion forum for students and staff, an eText similar to a traditional textbook, a staff and student editable wiki, and an interactive periodic table.

The weekly release of chapters in 3.091x occurred over 14 calendar weeks. Final course grades were determined by eight homework sets (30%) two midterms (20% each), and a final exam (30%). Certification was granted to students whose final grades were greater than 60%.

² Often colloquially referred to as a Massive Open Online Course (MOOC)

To date, MITx courses on edX have had similar schedules of regularly released resources and periodic due dates. Like 3.091x, courses have used quantitative assessment supported by lecture sequences and textual material, as well as a few special learning components (see end of this report). In the figures that follow, we compare 3.091x data with those from other MITx courses on edX, from the Fall of 2012 to the Summer of 2013.

Demographics. For 3.091x, we have records of 24,493 students who registered for the course by the cutoff date of this report, September 8, 2013. According to self-reported demographics, registrants were 70.2% men, and as a group, highly educated: 34.8% have earned bachelor’s degrees, 19.2% have masters or professional degrees, and 5.2% of registrants had earned a doctorate (for certified students, percentages are 30.3%, 25.4%, and 6.7%, respectively). Distributions of level of education and gender are plotted below in the top half of Figure 2, along with the average distributions for all MITx courses³. Note, roughly 5% of 3.091x registrants did not self-report one or more of the demographic categories.

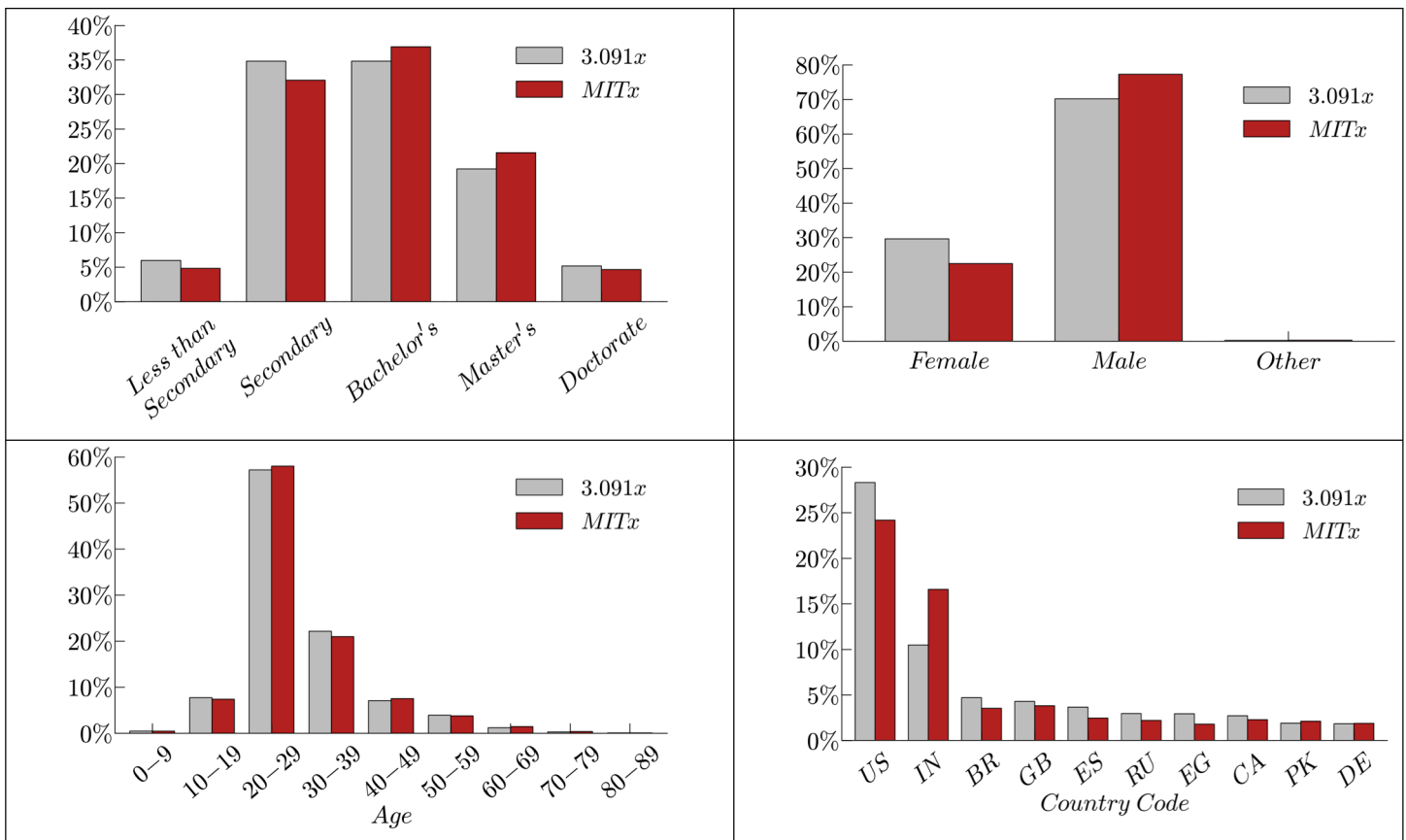


Figure 2: Distributions of demographic variables collected at registration for all registrants reporting data, with MITx-wide comparisons for reference: (top left) education attainment, (top-right) gender, (bottom left) age, and (bottom right) geolocation via IP look-up.

³ See also Ho, A. D., Reich, J., Nesterko, S., Seaton, D. T., Mullaney, T., Waldo, J., & Chuang, I. (2014). *HarvardX and MITx: The first year of open online courses*. (HarvardX and MITx Working Paper No. 1).

As with other MITx courses on edX, 3.091x students came from all over the world. Based on geolocation of student IP addresses, 28.3% of registrants came from the United States, but many students also came from over 150 other countries around the world. Consistent with other MITx courses on edX, the median age of registrants and certified students were higher than typical MIT undergraduates; namely, 26 and 26 years. Distributions of geolocated country and age are plotted in Figure 2 for 3.091x, along side the average distributions for all MITx courses.

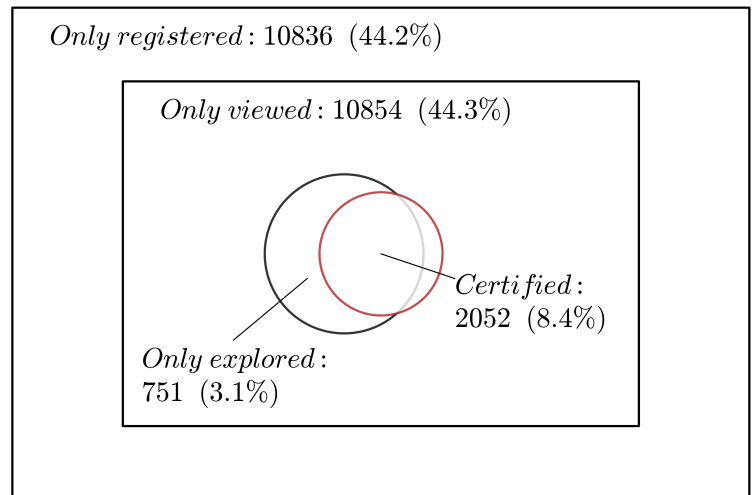


Figure 3: Participants separated into four mutually exclusive and exhaustive categories (not to scale).

Participants in 3.091x. Who are the students taking this course, and how much did they participate? The degree and kind of participation in the course varied considerably among those who signed up for 3.091x. Furthermore, like many MOOCs, this course remained open to new registrants, so that enrollment continued to rise through the semester. This asynchronicity is a key feature of open online courses. One feature of low barriers to registration, for example, is a large number of students who registered but never actually viewed any course material.

To illustrate the considerable variability in participants by their actions, we identify four subpopulations of interest within this course: those who (1) only registered, and never accessed the courseware, (2) only viewed, i.e. non-certified registrants who accessed at least one chapter but less than half of chapters, (3) only explored, i.e. non-certified registrants who accessed half or more of the chapters, and those who were (4) certified, by earning a final grade at or higher than the cutoff.

Certificate earners are the most conventional subpopulation, defined by crossing a certain threshold of achievement on quantitative assessments (well defined for 3.091x). The “only explored” subpopulation seeks to represent students having interacted with a considerable amount of course material, while the “only viewed” subpopulation highlights participants having only sampled the course. Both the “only explored” and “only viewed” subpopulations contain participants with highly varying levels of activity (as highlighted in the following two sections on persistence and activity). The fourth sub-population of “only registered” contains users that registered, but never accessed the courseware. This is a substantial number in 3.091x and many of the MITx courses on edX.

For 3.091x, the numbers of students who only registered, only viewed, only explored, or were certified, are shown in Fig. 3. The categories are defined as disjoint sets by using the “only” terminology, but the figure highlights the nested nature of registration, viewing, exploring, and certification. Students who were certified certainly viewed the course, but not all viewers were certified. Similarly, “explored” and “certified” are both subsets of viewed.

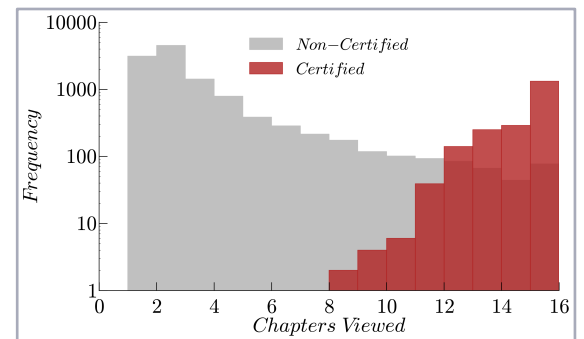
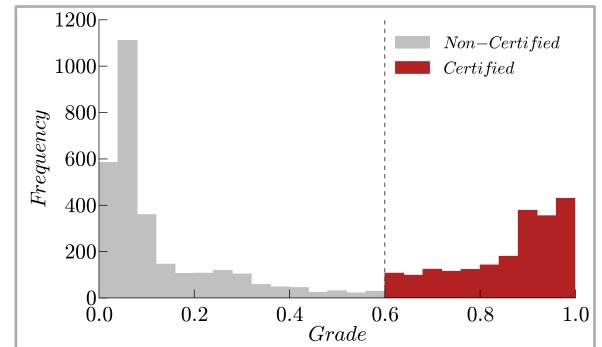
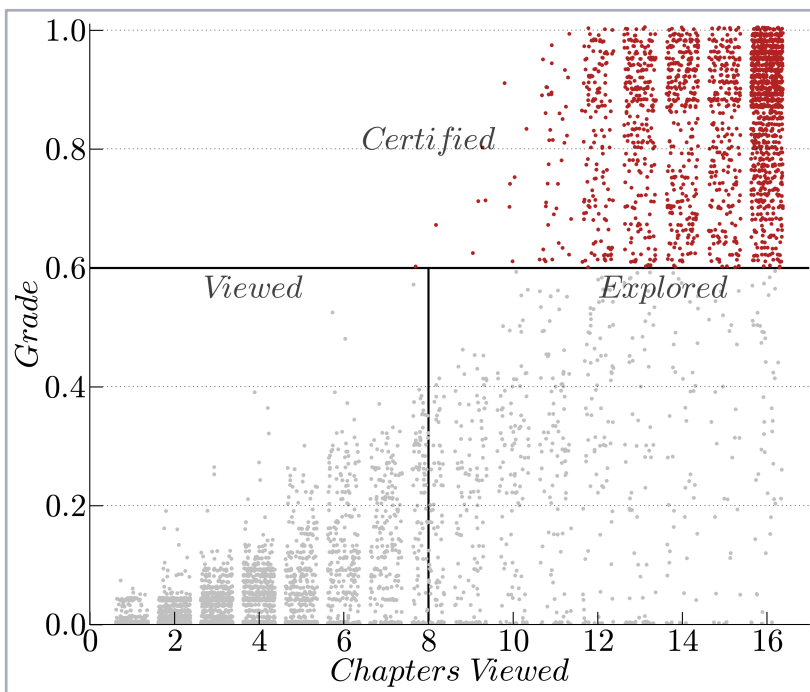


Figure 4: Scatter plot of grade versus chapters viewed (left), highlighting student sub-populations; certified students are red points and all points are jittered. Histograms of grades and number of chapters viewed (right) distinguished by student certification status.

Activity in 3.091x. The activity of students in MITx courses on edX is logged; activity level can provide perspective into which courseware components are of interest to students, and which specific activities students are undertaking in a course, e.g. to earn certification.

How diverse is the activity of students in the course? Consider the grade earned by students, which is determined in 3.091x by quantitative assessment with regular due dates and periodic exams. A scatter plot (Fig. 4) depicting earned grade versus the number of chapters visited, for each registered student, illustrates the distinctions between the sub-populations of students who only viewed, only explored, or became certified in the course. This plot also illuminates some possible registrant types: “completionists” (perfect grade, viewed all chapters), “optimizers” (occasional registrants that view minimal chapters but earn a certificate), and “listeners” (viewed all chapters, zero grade – submitted no work for credit).

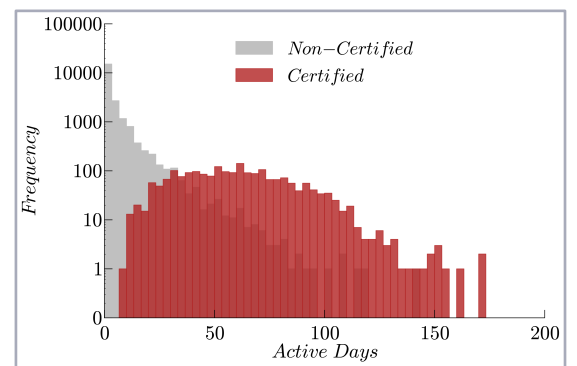
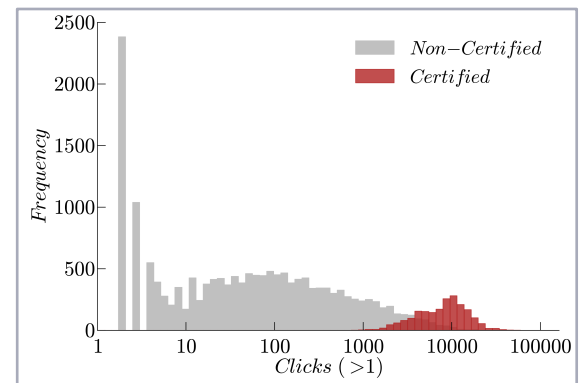


Figure 5: Distribution of clicks (total course interactions) and active days, distinguished by certificate status.

For 3.091x, edX recorded 25,766,443 events in its tracking logs, relating to students interacting with the course contents, through the cutoff date of this report. These events included interactions indicating when students played videos, attempted problems, browsed through text pages, read or posted entries in the forum, and other activities. Fig. 5 gives a glimpse into these data, presenting a histogram of the total number of events (“clicks”) recorded for all registrants with at least one event, and highlighting the population of students who earned a certificate in comparison with all other students. The figure also presents a histogram of the number of active days, where “active days” represents any day where a course interaction was logged. The distribution of active days for certificate earners is broad, further reflecting the variety of approaches by which a participant can earn a certificate.

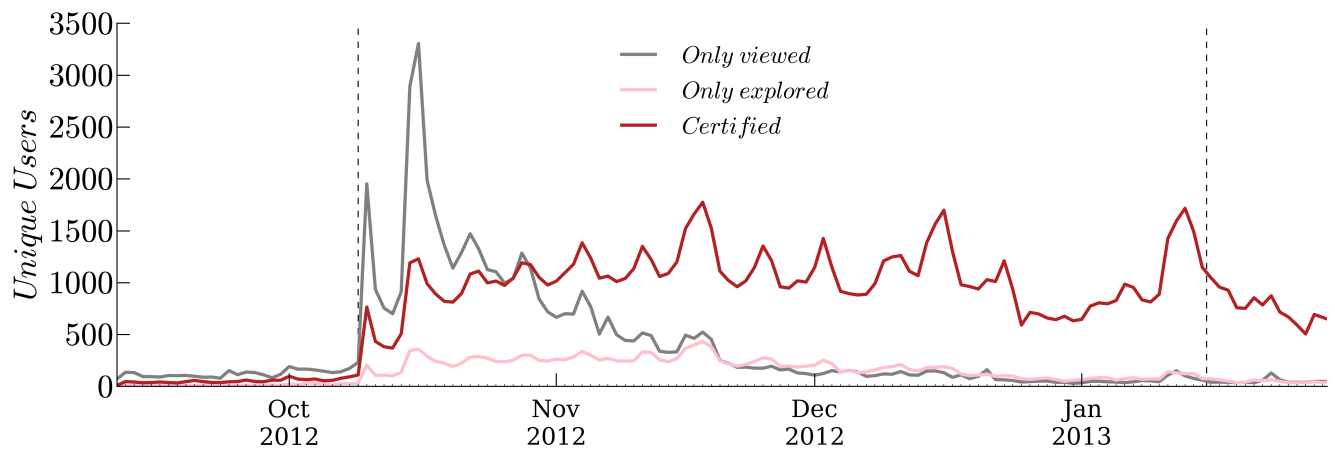


Figure 6: Daily number of unique participants accessing courseware or course-site (pre-launch) via our described participant categories. Vertical dashed lines indicate the start and end of the course.

Persistence in 3.091x. How does the activity of students change as the course progresses, particularly with students who persist to earn certification? Figure 6 highlights courseware and course-site (pre-launch) interactions for three of the disjoint participant types: only viewed, only explored, and certified. In 3.091x, there is a noticeable periodicity in each curve that is highly correlated with content release and due dates. Certified students show a relatively stable weekly periodicity, while the periodicity of the viewed and explored curves disappears after about one-third and two-thirds of the course, respectively. It is important to note that these curves do not account for registration date or for large times between user interactions. However, they do provide insight into the collective behavior of our defined populations. It is particularly interesting to formulate hypotheses about behavior early in the course, e.g., attempting to target struggling students that may benefit from intervention.

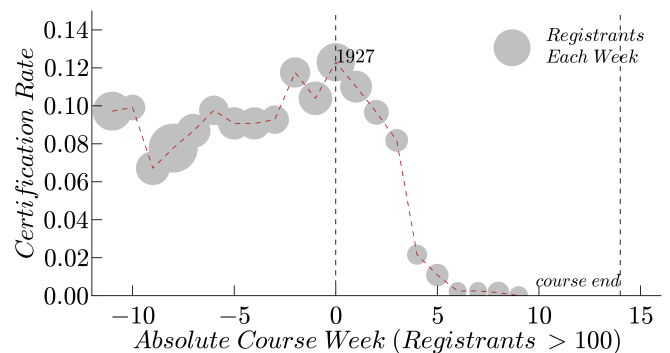


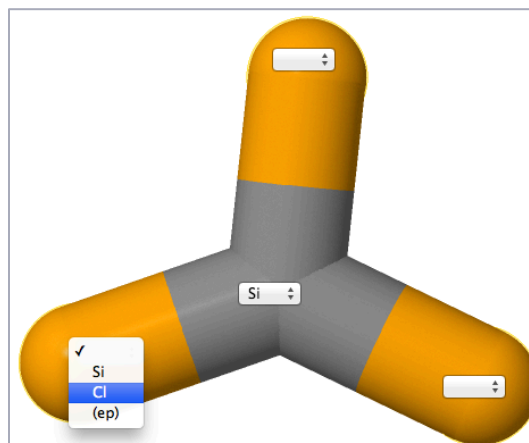
Figure 7: Certification fraction versus registration week relative to course launch. Bubble size represents the number of unique users registering each week

Do students who register early have a higher likelihood of earning a certificate than students who register late? Figure 7 depicts the certification fraction versus registration week relative to course launch (bubbles indicate total enrollment each week). Across MITx courses, certification rates do not depend greatly on registration dates prior to launch, although some courses have higher registration rates very early as well as just prior to launch. For 3.091x, about 10% of the users registering prior to launch earn a certificate regardless of enrollment week. After launch, the rate drops dramatically. Because of the highly structured due dates in 3.091x, it is reasonable to attribute most of the post-launch drop in certification rates to registrants who have missed due dates and find it difficult or impossible to catch up.

Special Features

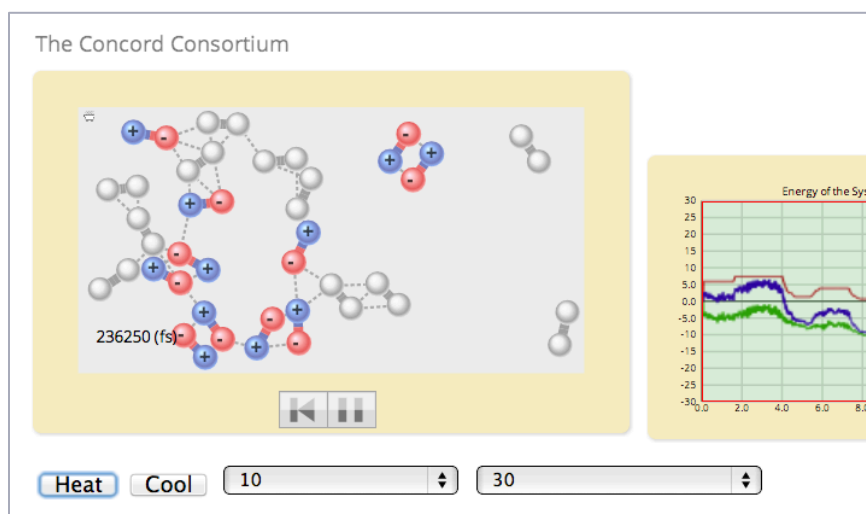
Each MITx on edX course includes special features unique to that course. 3.091x had several features:

- **Randomized selection of randomized problems.** The MIT 3.091 course has been taught on-campus for over 40 years, generating a “treasure chest” of assessment problems. This enabled 3.091x to construct 412 assessment problems, many of which had randomized parameters and numerical answers. Each student was then given randomly selected problems from this trove of problems, for each course topic.



- **Interactive chemical structure problems.** Students were asked to enter molecular structures in assessment questions, and additionally, were provided with a graphical interface for selecting the structure and labeling the atoms.

- **Chemistry simulations.** Interactive chemistry simulations, from the Concord Consortium, were embedded within the browser for students to do simple experiments, e.g. to understand melting points of materials.



- **Chemical formula problems.** These problems allowed students to enter the reactants and products for a reaction, with immediate feedback on the validity of the typed formula, and subsequent feedback on correctness.