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Over two decades of blended and online physics courses at Michigan State University

Gerd Kortemeyer
korte@lite.msu.edu

Michigan State University

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Abstract

In Fall 1992, our first physics course offered online homework. Over two decades later, we have seven physics courses online, spanning the whole range of introductory course offerings, with a total of over 1600 students in 2014. We found that several of the the purely online courses had better learning success than traditional lecture courses, as measured by exam scores. Particularly successful were online materials with embedded assessment. This result can be interpreted in different ways, but may serve as an indicator that during in-class lectures, we are oftentimes not taking advantage of the fact that we have the students on-site.

Keywords: e-learning; blended learning; virtual learning environments; web 2.0

Introduction

The paper describes the history and development of blended and online physics courses at Michigan State University of the last 22 years. We begin by a review of the history of these courses from introducing online homework in otherwise traditional lectures to the blended and virtual courses of today. We then discuss the logistics of these courses with a particular focus on the role of the instructor and the difficulties of giving online exams. The paper concludes with some “lessons learned” and an outlook for the coming years.

History

A blended beginning

Higher education in the United States is expensive; the average cost of a bachelor’s degree is around $80,000. Yet, in spite of the cost, particularly large enrollment “service” courses, i.e., courses in a particular subject area that are taken by non-majors, do not have the budget for sufficient staff to grade all incoming homework assignments. On the other hand, especially in the STEM (“Science, Technology, Engineering, and Mathematics”) disciplines, the formative feedback afforded by homework is essential. Thus, the earliest beginnings of large scale use of online components in teaching physics at Michigan State University were in the provision of electronically graded homework.

In 1992, our CAPA system came online solely as a homework tool, and it eventually also provided exam functionality. In 1992, “online” meant Telnet for students and X-Windows for instructors. Due the heavy reliance on mathematical notation, homework assignments were given out in printed form, using LATEX as intermediate format; Fig. 1 shows a problem rendered by this system. Students would then enter their answers in a Telnet session.

From day one, CAPA was built around the idea of immediate feedback and mastery-based formative assessment. It allowed for a wide range of problem randomization, such that students could not simply copy each other’s answers. Randomization includes different numerical values for quantities, different figures and graphs, different formulas, different options in multiple choice and ranking problems, even varied physical scenarios. Authoring these problems requires some care: constraints need to be put on the randomization space so that physical quantities and results remain in the physical, realistic realm — no student should need to deal with the proverbial “negative coefficient of friction.” The system was initially used as an online component of otherwise traditional physics courses, but eventually, online homework replaced traditional recitations in our department; surprisingly, exam performance increased as a result [1].

Around the same time, a group of faculty started developing a “hyper-textbook” for introductory physics [2], which replaced traditional textbooks and was distributed on a CD-ROM using a system called SuperCard (a commercial MacOS clone of the original HyperCard system [3]; a translation of this CD-ROM into German and into HTML later became available in Germany as “cliXX Physik” [4]). Fig. 2 shows a poster from a project presentation at the US Congress in 1997. Also in 1997, the content was transferred to the web, combined with a rudimentary homework system called LectureOnline (see Figs. 3 and 4) [5]. Homework could be embedded into the content to provide online “course packs.” These online resources were used in connection with traditional lectures in what today would be called “blended” scenarios [6], but this was also the start of our first completely online courses: algebra-based physics first and second semester became our first “virtual university” courses.

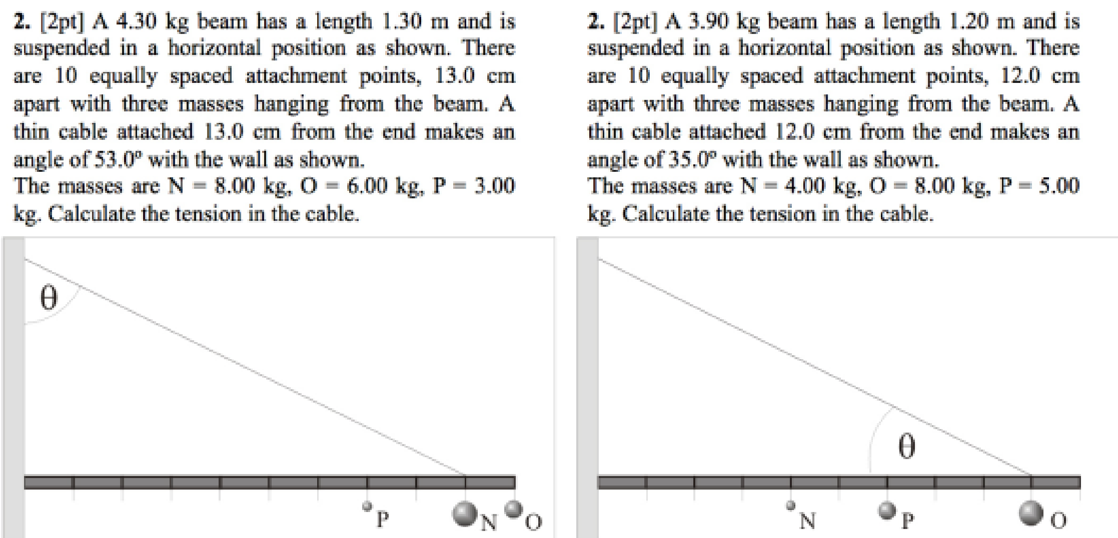

Figure 1: Printout from the original CAPA system, showing two randomized versions of the same problem (year 2000).

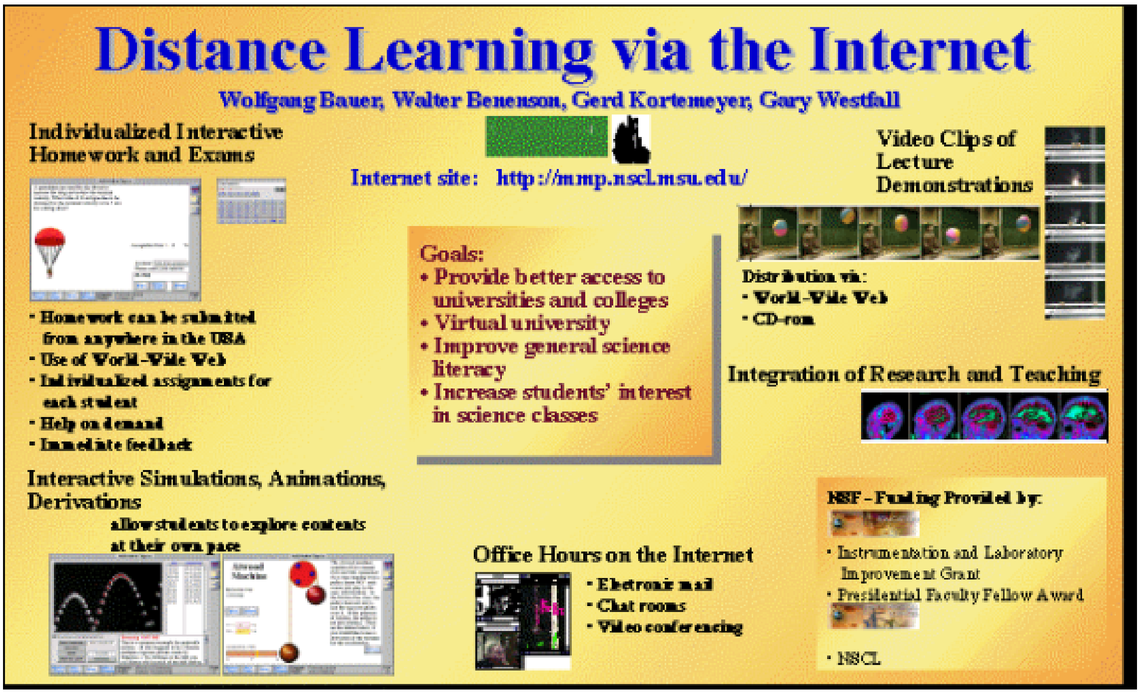

Figure 2: Poster of presentation at US Congress, 1997 (higher resolution not available).

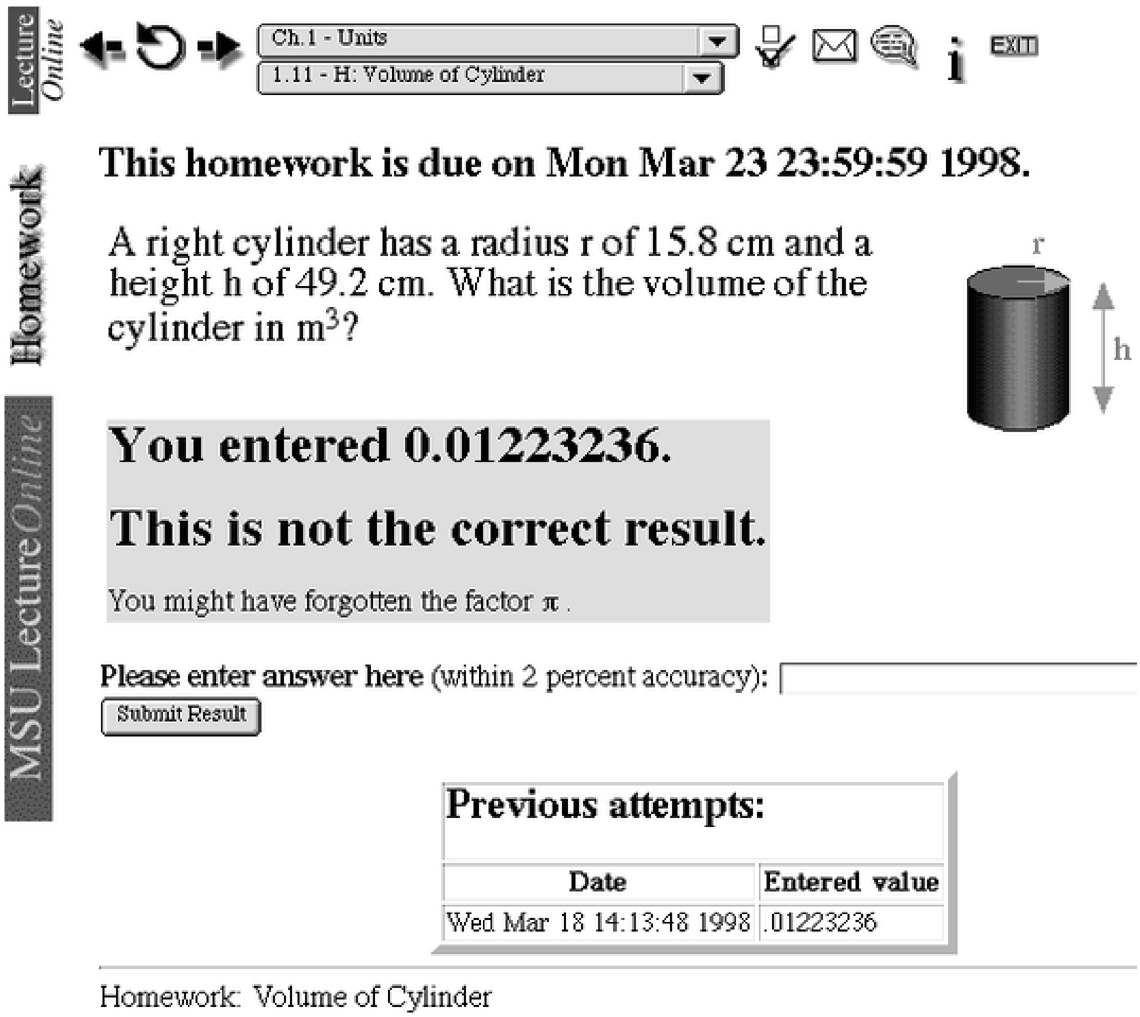

Figure 3: Screenshot of the LectureOnline system used in 1998 to deliver our first fully online courses.

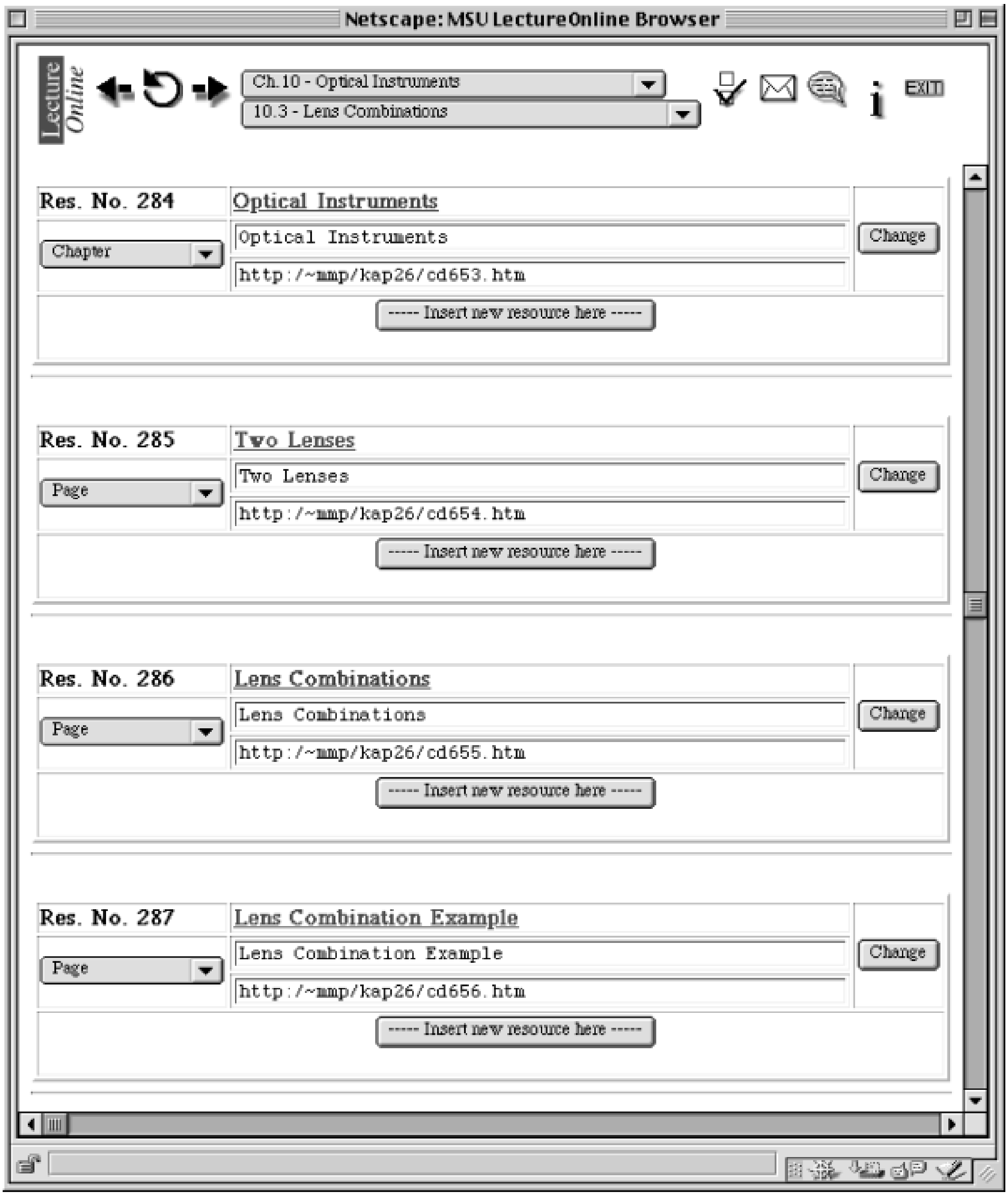

Figure 4: Screenshot of the LectureOnline system used in 1998 to deliver our first fully online courses.

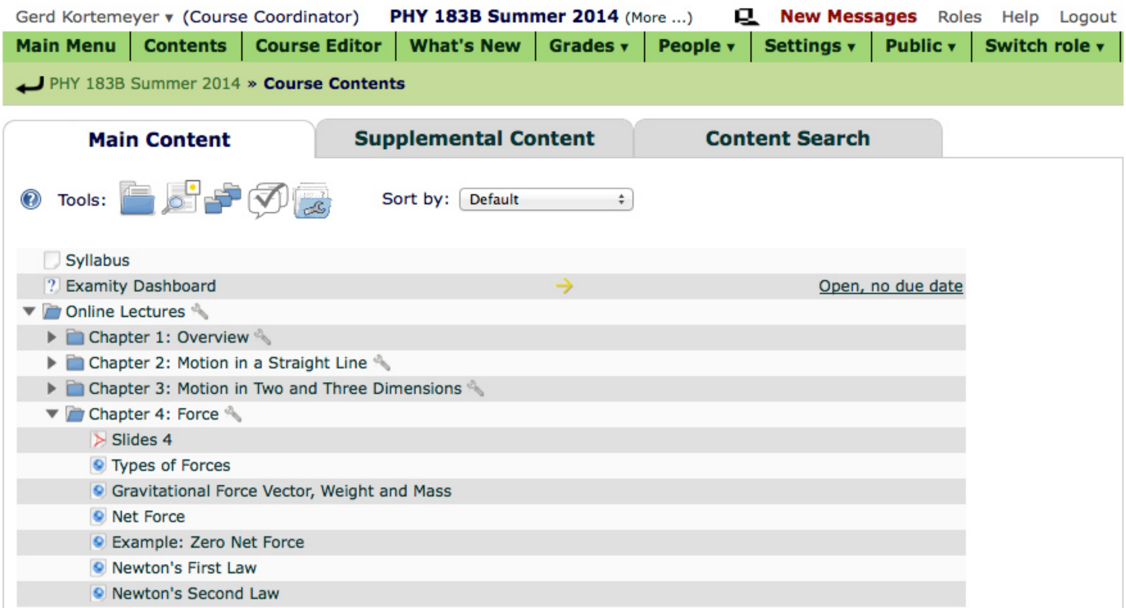

Figure 5: Excerpt of the table of contents of a recent "virtual university" course in LON-CAPA.

Virtual University

In 1999, CAPA and the virtual university efforts merged to start LON-CAPA, which has been serving our blended and online courses since [7] (Figs. 5 and 6 show screenshots from a recent course in LON-CAPA). This was during the first online education bubble, when universities in the United States scrambled to establish an online presence in order to market their courses worldwide (e.g.[8] [9], which provide an overview of a number of initiatives and possible business models at the time). Around this time, administration of our online courses was temporarily taken over by a central virtual university group [10]. In retrospect, it is clear why so many standalone virtual university efforts were doomed (e.g. [11]), but this is oftentimes hard to see when the hype waves washes over university administrations that are both in urgent need of finding new revenue sources and concerned about falling behind the competition. As it turned out, at least initially, most of the students in our online courses were already students of Michigan State University — they just chose the online venue because it was more convenient, fit better into their schedule, or because they had to repeat the course and did not want to again sit through the lectures. Our handful of international students were mostly military personnel on assignments abroad. Eventually, the central virtual university folded, and course administration reverted to the department.

MOOCs

The second bubble of online education were MOOCs, Massive Open Online Courses. As a department, we decided to not get involved in this effort and keep our courses in the for-credit realm. Considerations included mostly sustainability concerns, but also market considerations: introductory physics neither has the "cutting edge" appeal of artificial intelligence or machine learning courses, nor is there any particular glitz to our virtual courses compared to on-campus courses around the nation; such courses are also offered as advanced placement high school classes or at any community college. Our “edge” is offering solid and tested convenient online courses for transferable credit; after all, the majority of students are taking physics for credit, not necessarily for fun. In retrospect, it was a good decision, as the MOOC hype wave has died out [12], just like the virtual university hype wave had died out and eventually became commoditized a decade earlier. MOOCs need to do their homework to address issues of attrition [13], learning theory [14], sustainability [15] , faculty load [16], and accreditation [17].

Steady as she goes

All the while, our department kept offering for-credit blended and online physics courses. The very same assets are used for online as well as on-campus blended instruction, where they form the online component of otherwise mostly standard courses, at a minimum online homework. In addition, a residential college on our campus offers its own version of the calculus-based sequence, and implemented a flipped design, where students use these online materials with embedded online assessment (“reading questions”) prior to the in-class sessions on the topics.

Fig. 7 shows the student course enrollment in purely online university courses over the years, while enrollment in on- campus blended introductory courses essentially remained unchanged at about 4800 annual student course enrollments (i.e., we currently have more than double the number of students in blended than in online courses). Online enrollment is steadily increasing, now mostly due to students from other US-american universities. Once again, convenience is the largest factor. For example, students can complete the first and second semester algebra-based physics sequence in just one summer using our accelerated online offerings. Credit from Michigan State University is transferable, and thus allows students from other universities to accelerate their studies or make up for failed courses.

The slow steady rise also has its disadvantages: since there was never any dramatic jump in enrollments, personnel and organizational infrastructure for these courses are only now adjusted to the new realities — a typical “boiling frog” scenario. In principle, our course offerings are highly scalable, and an order of magnitude more online students is not out of the question as long as personnel is adjusted accordingly (one should not have more than 400 students per instructor); online student population would then have overtaken on-campus enrollment. That, in turn, is possible, as after the demise of the centralized virtual university effort, a higher percentage of online-generated tuition dollars flows directly to departments to support local logistics.

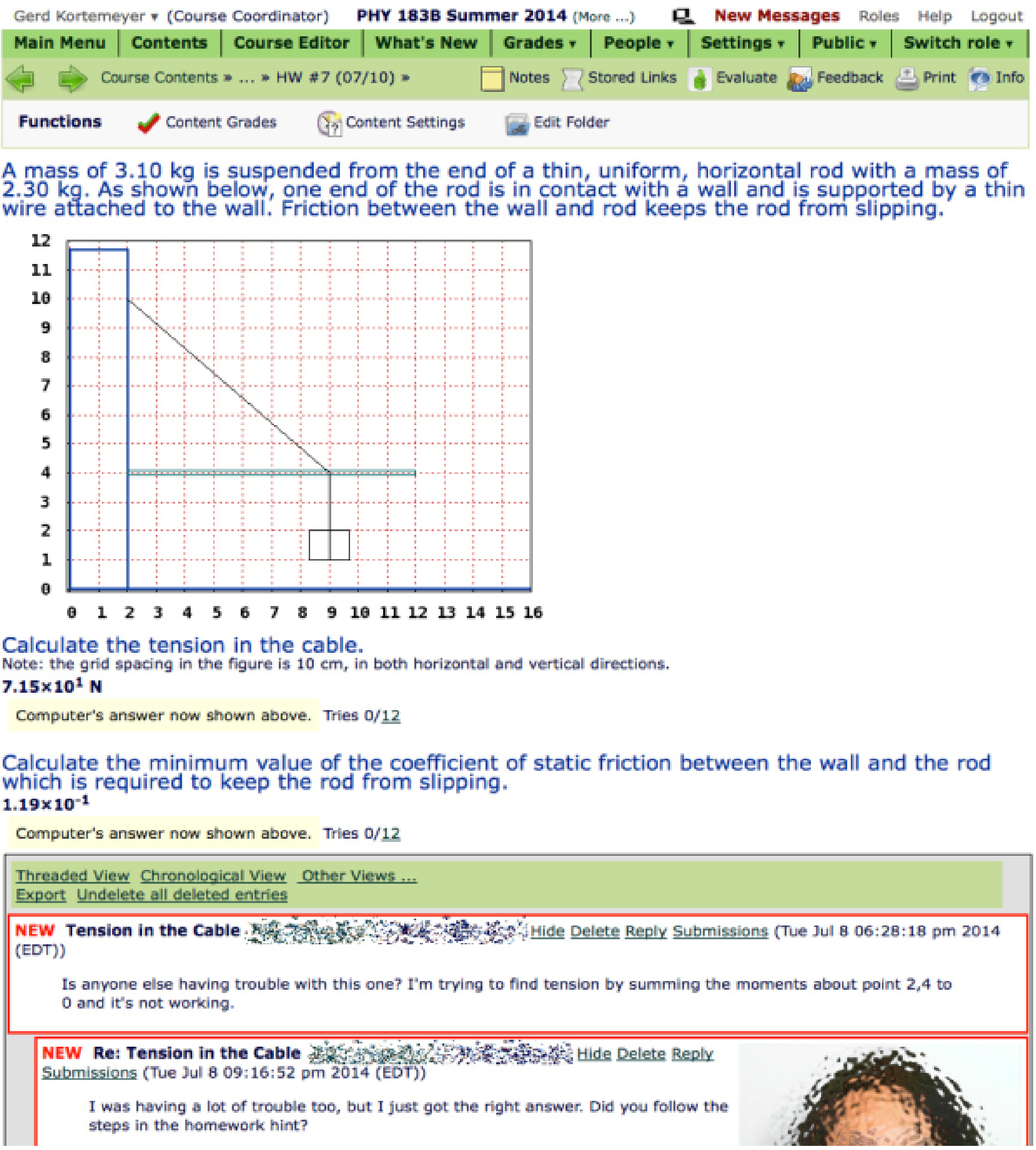

Figure 6: Screenshot of a problem in LON-CAPA in a recent course, similar to the problem in Fig. 1 from 15 years earlier.

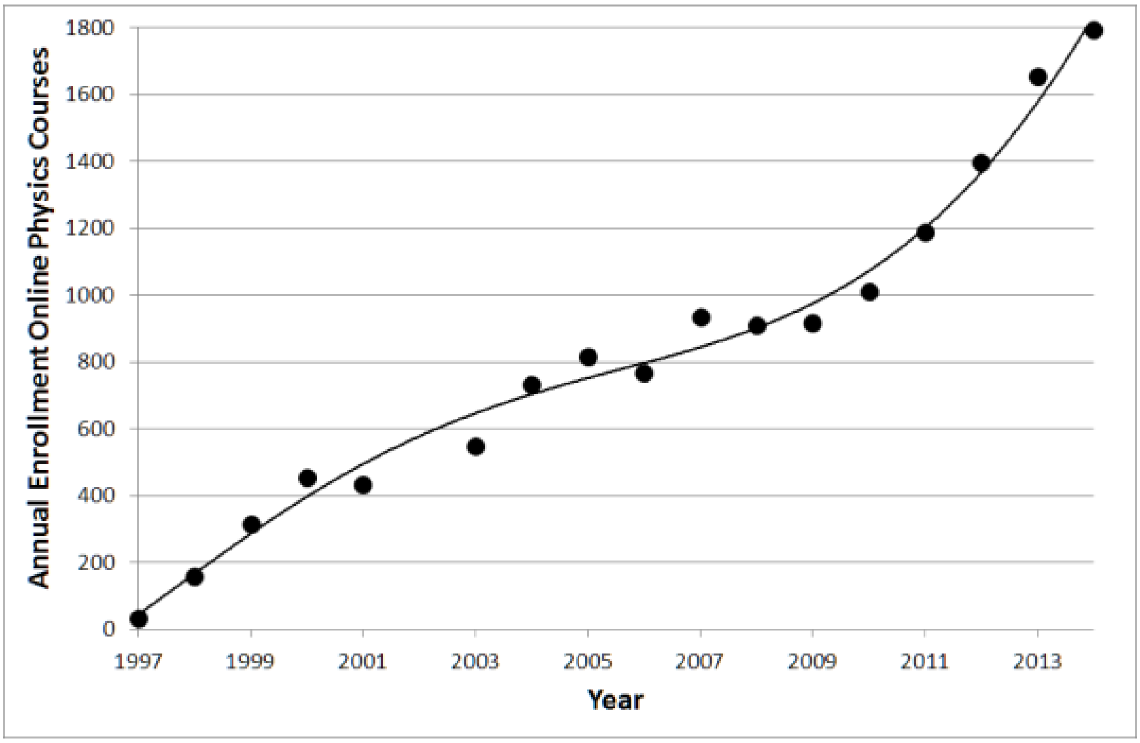

Figure 7: Annual enrollment in online physics courses at Michigan State University. Data from one the years where the courses resided in the central virtual university effort is unfortunately missing.

Logistics

Content and content maintenance

We clearly had a head start into launching our first online course, as we could port existing materials from CAPA and SuperCard: we already had all the homework we needed and all the textual material. Before we launched, we added some Java applets with simulations and several movies with lecture demonstrations, which, like the original materials, were produced by physics faculty mostly for the creative enjoyment and the satisfaction of being at the forefront of multimedia (at the time).

Over the years, the material underwent several iterations, and it was forked for different courses (most notably algebra- and calculus-based courses, but also “physics for poets” and life-science majors [18]) and instructors (different instructors have different “tastes”) — the ability to not only reuse but also remix is essential in learning content management.

Online content has a short shelf-life; even though the physics does not change, multimedia needs maintenance: Java is prone to fail and needs to be replaced by HTML5/Javascript, video codecs become obsolete (and old 320x240 pixel videos look substandard in the days of YouTube HD), new technologies and toolsets become available (Camtasia [19] currently being one of our favorites), new devices need to be supported (particularly touchscreen devices, and more and more students do their homework on their phones or tablets), and an absolute “must” today is accessibility (for example for screen readers). The continual renewal and expansion is supported by fine-granular asset management, which allows for modular replacement of course assets. Today, LON-CAPA hosts about 110,000 online assets for physics courses [20].

While LON-CAPA is open-source freeware, the assets in the LON-CAPA content pool are not open educational resources in the traditional sense: they are shared among instructors, but not openly available on the web. The reason is that many of these assets are homework and exam problems, and as part of our mission, we have a stewardship responsibility toward instructors to preserve the integrity of these items [21]. [a]

The role of the instructor

We run most of our online courses as separate sections of the same physics courses, so we technically or de-facto have one course in a given semester, of which some sections are on-campus and some online. Online courses are not on autopilot. The role of their faculty instructor is not so different from traditional courses, apart from not getting to be the sage-on-the-stage. Instructors still need to answer student questions, which in both online and on-campus courses mostly takes place in the online forums. The major difference is that interaction is expected at odd hours of the day and often more rapidly than in on-campus sections; the online media seems to instill a sense of immediacy that is not present with sections that meet regularly in physical spaces.

The other major difference are exams: faculty members still need to write the exams (which can be a lot of work), but they also need to deal with the exam logistics. Arguably, exams are the single-most work intensive component of the instructor role in our online courses.

Exams

Exams in the online sections are challenging in many respects, mostly because faculty need to guarantee the integrity of the grading. Regarding the logistics, we are taking a hybrid approach. Students who live within 30 miles of campus need to take the exam on-site in a standard setting, while students who live further away can take the exams in a proctored setting. For the longest time, this always meant that the students had to identify a proctor (typically faculty at another college or university, librarians, or commanding military officers) or go to a testing center. In any case, our faculty has to deal with the logistics of approving the testing venues and getting the exam materials back and forth. This mechanism does not scale well in light of the growth of our online offerings, and thus recently, we switched to online exams with a commercial online proctoring service, Examity [22].

Online proctoring requires locking down the exam content in LON-CAPA, so that proctor input is needed to open it up. The proctors provided by the company are mostly located in India, and they are using a standard video conference solution to monitor both the screen and the webcam of the student. At the beginning of the session, proctors verify the identity of the student (using photo IDs and the webcam) and then have a “look” around the room. Once the exam is running, proctors monitor compliance with the exam guidelines provided by the faculty and flag any possible violations in the video recording of the session. It is then up to the faculty to view flagged content and make final judgments.

The cost of approximately $15 per exam session is currently paid by the department, but that may have to change in the future. Acceptance of this mechanism has been surprisingly high among the students, which may underline the students’ own desire for exam integrity — nobody likes cheaters. Technical problems certainly exist, and some student hardware or connectivity is not up to the requirements. However, those problems are sorted out by the time of the second midterm exam. Scheduling is probably the biggest issue, as the company can only offer a limited number of proctors per time slot, and students tend to play games with the online scheduling system in order to gain a desirable time slot. The problem is aggravated by the fact that the company offers global around-the-clock services, but our learners are predominantly located in the American timezones, leading to “crunch times.”

Lessons learned

Using the same exams for the traditional and the online courses some years ago, we actually found that the students in the online course had significantly better scores [23]. While the online students were self-selected and possibly a slightly different population, we still learned an important lesson: our traditional lectures were not as effective as we thought, maybe even counter-productive for some learners. Whether or not students sit in a lecture hall and attend a traditional lecture made no positive difference in their learning, as measured by standard exams. It also did not matter who lectured; as the faculty assignment of these classes rotates, but outcomes remained unchanged, it became apparent that different instructors may have different entertainment, but not very different educational value.

The result underlined the need to reform our traditional courses, e.g., incorporation of problem-solving and peer-instruction, and in some cases the elimination of traditional content coverage. It has long been understood that in online courses, one has to take advantage of the medium, but the same should be true for on-site classes: if “on-site” means nothing more than sitting through a traditional transmission-style lecture, online is superior. We found that increasing the rate of in-class assessment and feedback increased use of the online resources [24] and led to better course performance [25]. This corresponds with earlier findings in an analysis of preferred learning paths of students in our online courses. Based on access log analysis, we found that almost invariably, students first gravitated to the online assessment and only if they could not solve the problems actually read the materials [26]. We also found that particularly among female students, formative assessment was used as an opportunity for peer-teaching [27]. We thus now do not have a single introductory physics class on campus anymore that does not use clickers, peer-teaching, and in-class active problem solving.

In both online and on-campus scenarios, assessment that is directly embedded into the online reading materials (not in a separate compartment of the learning management system) is particularly effective. Somewhat disappointingly, we also found that students do not use simulations or movies unless they are coupled with assessment. Access logs show that the vast majority of students do not bother even considering these multimedia components — students are on a time budget and do not want to “waste their time” unless the toys are coupled with graded assessment problems. We have thus moved to making the simulations and other free-form answers themselves graded assessments, which based on HTML5/JavaScript can be integrated into LON-CAPA (e.g., [28]).

Where do we go from here?

In the foreseeable future, there are no plans to stop offering lectures; instead, we aim to continue moving them toward more reformed curricula and methods of teaching. If the students are spending face-to-face time with us, we need to make sure this time is better spent than lecturing to them, since we have proven that that is indeed a complete waste of time. Technological innovation in online and on-campus classes are moving in parallel, since these are essentially sections of the same course run by the same department with the same standards.

At the same time, we plan to expand our online offerings, both in terms of number of courses and frequency of offering them. Particularly students from other universities and colleges bring additional revenue on campus, which by now makes up a sizable component of the department budget. In terms of platform, we are working on replacing the aging LON-CAPA platform by a more modern and modular system. We will hopefully be able to transition to this new system three years from now.

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[a] Demo access is available upon request from the author for academic faculty and staff.