Massively Empowered Classroom: Enhancing Technical Education in India

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ABSTRACT

Students in the developing world are frequently cited as being among the most important beneficiaries of online education initiatives such as massive open online courses (MOOCs). However, very little research has actually been done on the effects of online education in developing contexts. We describe a case study of our experience building and deploying Massively Empowered Classroom (MEC), an experimental project designed to explore how online educational content and techniques in blended learning can be used for undergraduate education in India. Our pilot study of a single course in algorithms extended over two semesters to more than 120 colleges in three state technical universities in India, and reached more than 4000 students. We identified a number of issues that we believe are unique to the Indian educational context. Specifically, we identify four key domains that MOOCs and similar educational initiatives must manage: *Content, Incentives, Awareness,* and *Bandwidth*. We believe that similar issues will extend to other developing countries with significant resource constraints.

Author Keywords

Massive open online course; MOOC; India; Blended learning; Online education

INTRODUCTION

Recent advances in online education and massive (open) online courses (MOOCs) have led many people to suggest that a revolution in learning is imminent. In particular, a common claim is that these technologies will enable a democratization of education, allowing everyone to receive the same high-quality education whether they live in India, China, Sub-Saharan Africa or San Francisco [9, 12]. The notion is that services such as edX, Coursera, Udacity, and Khan Academy will be able to overcome many of the serious constraints in the developing world and grant smart, motivated students access to teaching that they would never have been able to receive before. And while most MOOCs are still almost exclusively in English, Khan Academy is working to translate much of its content to Spanish [7], and recently both Coursera and edX have announced partnerships to extend the MOOCs to Chinese [5, 21].

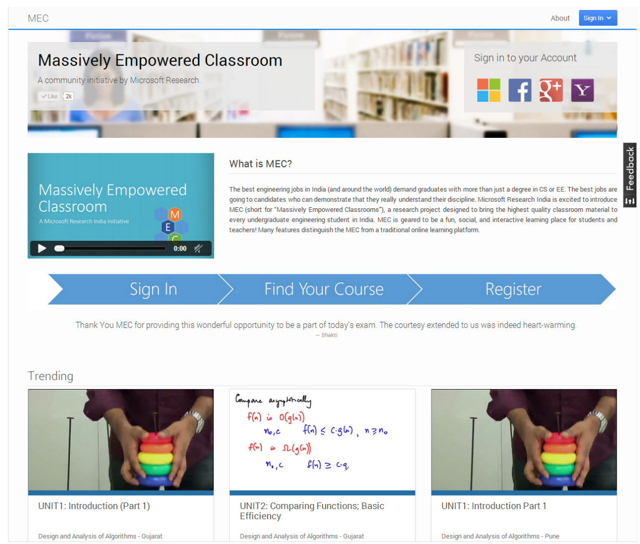

Figure 1. A screenshot of the front page of Massively Empowered Classroom.

Despite the hype, little research has actually explored what the impact of online education in the developing world is. We set out to understand how online education might benefit undergraduate technical education in India. To do this, we built our own system and deployed it to students in two pilots in partnership with three university systems (each containing hundreds of affiliate colleges) in India. In this paper, we present a case study of our experience building and deploying Massively Empowered Classroom (MEC, see Fig. 1 for a screenshot), an experimental project designed to explore how online educational content and techniques in blended learning might be used for undergraduate education in India. Over the course of two semesters, we partnered with a number of colleges affiliated with state technical universities to assist in teaching courses in the Design and Analysis of Algorithms. To date, more than 4000 students in more than 120 colleges across India have viewed content in MEC. We describe some of the main lessons learned to date in our pilot deployments. We believe these lessons are relevant for anyone wishing to reach students in India and other developing countries with significant constraints in infrastructure and other resources, as well as very different educational milieus from those common in the Global North.

ONLINE EDUCATION IN INDIA

MOOCs and other initiatives in online education have taken center stage in much of the public and academic discourse surrounding pedagogy in the US, Canada and Europe. However, in India these efforts are still virtually unknown outside of an elite population. While supporters cite the thousands of students from India that enroll in MOOCs, as a proportion of the student population of India (3.5 million in engineering alone) the numbers are still very small. Our research suggests that currently these resources are mostly used by adults for continuing education and a very small fraction of students (perhaps the top 0.1%) who are driven to learn. Indeed, while students in elite institutions such as IITs are likely to be aware of these kinds of online resources, it seems that those who could benefit most from better quality teaching are the least aware of MOOCs.

Between October of 2012 and July of 2013, we held four regional workshops in three different states of India (Karnataka, Maharashtra, and Gujarat) to discuss how online education might be used to improve education in India. More than 200 teachers and administrators from approximately 140 regional technical colleges from ten different states attended. We introduced the concept of MOOCs, LMSs, and various forms of blended learning in the classroom (including our pilot system), and engaged in discussions about how these might be adapted to the Indian context. In addition, we made in-person visits to a large number of technical colleges to speak with students, teachers, and administrators on site.

On the whole, very few of the students or faculty we spoke with had ever heard of MOOCs (edX, Coursera, Khan Academy, Udacity, etc.), and still fewer had actually participated in a course—and these were only top students at the better-resourced colleges. Many teachers were aware of NPTEL (the National Programme on Technology Enhanced Learning, a government-sponsored archive of online lectures) [16], though again, very few students or teachers regularly used this as a learning resource.

From these discussions we distilled four main reasons that we believe MOOCs and other online resources have had limited success in India so far:

1) The syllabi of online courses differ from university courses, and the level/speed of teaching is often too fast for students at regional colleges. In addition, the accent of teachers (often American) can make it difficult for students to follow. A corollary of differing syllabi is that online materials are not directly relevant for exams. Students optimize virtually all their effort around cracking exams (see below). Even if online material relates directly to concepts taught in class, if it won't directly improve exam scores then students aren't interested.
2) Students do not perceive any utility of online courses for getting jobs. At the end of the day, it all comes down to employment. Currently students do not feel that online content will improve their prospects.
3) There is a pervasive lack of awareness of online materials among faculty and students. This should change over time, but as noted above, most students and faculty that we spoke to did not know what a MOOC is, much less how they might benefit from online courseware.
4) There remain serious network bandwidth constraints for most colleges and students. We initially underestimated the importance of bandwidth (see below), but this became obvious over time. In every college we visited, video streaming was very difficult, and in many cases impossible. Outside of colleges, students see huge variability in bandwidth availability and cost. However, most online courses assume the constant availability of high-bandwidth connectivity to support video streaming and other interactive content.

We concluded that to be successful in India, any online education initiative must address four key issues: *Content, Incentives, Awareness,* and *Bandwidth*. We designed MEC to help us understand how these concerns might be met.

TECHNICAL EDUCATION IN INDIA

Before we describe our pilot project, it may be useful to understand the context of technical education in India. Engineering education in India is a huge enterprise and is very heterogeneous. In 2012, there were more than 5600 engineering institutes in India, teaching more than 3.5 million students [1]. Outside of India, many people are familiar with elite institutes such as the Indian Institutes of Technology (IIT), National Institutes of Technology (NIT), Birla Institutes of Technology and Science (BITS), and others. However, these teach only a small fraction of all the engineering students in India (e.g., the total number of new seats for all 16 IITs in 2014 is expected to be ~10,000 [13]). The vast majority of engineering students enroll in a variety of other institutes across the country. Some of these are autonomous "deemed" or private universities, and a large proportion are colleges affiliated with state universities.

State Universities

For our pilot project, we decided to focus on technical colleges affiliated with state universities. State universities are run by the state governments of each of the states and territories of India and can be very large. For example, Visvesvaraya Technological University (VTU) in the state of Karnataka comprises 201 affiliated colleges, teaching more than 67,000 undergraduate students [19]; Anna University in the state of Tamil Nadu comprises 520 affiliated colleges, with more than 120,000 engineering students [2, 11]; and the four Jawaharlal Nehru Technological Universities in Andhra Pradesh comprise more than 800 engineering colleges [14, 15]. These state technical universities share several properties that have interesting implications for online educational initiatives.

First, all affiliated colleges in a university share a single, synched curriculum for every course. Textbooks, syllabus, and order of presentation of material are all prescribed by a central university authority. In addition, for each course there is a single shared final examination that is given to every student in the university and students' grades are largely dependent on this exam (typically about 70% of the final grade). Affiliate colleges (and teachers) have very little autonomy in what they can cover and how they evaluate a student's progress.

Second, in most universities there are a few high-performing institutions and a long tail of colleges with much lower quality and fewer resources. Thus, there are almost always a few very good teachers at these "apex colleges" with extensive experience and language skills[1] for teaching students from that state. Many of these teachers act as mentors or help with continuing education for teachers in the "tail."

These properties are particularly interesting for online education. The fact that the curriculum is unified and synched across affiliate colleges makes it easier to provide relevant content for a single course across hundreds of classrooms. And the presence of experienced teachers in each university should make it easier to scale the production of quality content across the various courses and curricula that a university offers.

A web of difficulties

These so-called "second-tier institutes" face a number of serious challenges. First, there is a critical shortage of qualified teachers. Every year, the number of students in engineering increases and there are not enough instructors to meet the demand. Most students who do well in their studies take high-paying jobs in industry upon graduation. Some first-time teachers told us that they began teaching because they could not find a job in industry. This leads to enormous inequality between institutions, with a few high-performing schools and a long tail of rural institutions with under-qualified staff. Because of high turnover and limited experience, teachers are given very little autonomy and must follow a rigid curriculum. In addition, they are given very little latitude in grading, with the majority of a student's grade coming from standard final exams set by the university. In turn, universities are often evaluated by their graduation rate, and thus have an incentive to evaluate students favorably. This causes exams to be dumbed-down, testing rote knowledge instead of deeper understanding. High marks are given to underqualified students, and the best students have little opportunity to distinguish themselves.

A high demand for engineers by industry coupled with a lack of well-trained teachers and the near-irrelevance of classroom performance leads to uninspired students with little interest in subject mastery. In many instances, students spend their time optimizing for short term goals (e.g., memorizing questions from test banks) rather than learning the material. Naturally, this creates a feedback loop in which many teachers have little incentive to improve their skills or enhance the classroom experience for uninterested students who have no reason to pay attention.

As a result of these problems, industry has largely given up on universities' ability to deliver quality education. Large companies such as Infosys and TCS hire students mostly on "raw intelligence" and then train them in custom computer science curriculum for up to 6 months before putting the new hires to work [18]. In our view, this represents an enormous waste of time and energy and leads to the question: Can this situation be improved through innovations in pedagogy such as blended learning and online education?

MASSIVELY EMPOWERED CLASSROOM

Based on the workshops, site visits, and our understanding of the Indian education system (particularly in state universities), we decided to build and deploy a pilot program to address some of these issues. We built Massively Empowered Classroom (MEC) to explore how online educational content and techniques in blended learning might be used for teaching computer science at state technical universities in India. Because online education is virtually unknown in these colleges, our research goals for MEC were quite broad and exploratory. However, in addition to the research we had two primary outcomes we wanted to achieve.

First we wanted to provide students access to high-quality teaching for the curriculum that they were already enrolled in. At the end of the day, what really matters is student mastery of the material. We wanted to provide an environment in which students could learn everything they need to know for the subject they were studying.

The other goal of MEC was to provide some instructional modeling for inexperienced teachers. We thought that, irrespective of whether students viewed the material, teachers could benefit from getting ideas for how to teach many of the concepts in the syllabus. Because students would still have to attend class[2], if we could improve the quality of in-class teaching, we would consider MEC a success.

[1] While English is the official medium of instruction for undergraduate technical education in India, in practice many students from less affluent areas have only limited competency in English. As a result, teachers frequently supplement instruction with explanations in the local language.

[2] Unlike many colleges in the US, most colleges in India have strict classroom attendance requirements.

As noted above, we felt that to be successful, MEC had to address four key issues: *Content, Incentives, Awareness,* and *Bandwidth*. Each of these could support a research program of its own and they all interact with each other. To facilitate our exploration, we built our own platform. While at the time of this writing (late 2013), there are a few potential platforms that we might be able to use (e.g., [8]), when we began this investigation these options were not available. Building our own platform also gave us a great deal of flexibility to explore features and to experiment with different ideas, as well as access to data and statistics about usage. MEC was designed to incorporate several features of MOOCs that we thought would be useful for this context, as well as a number of features that are not as common for MOOCs.

The main features common between MEC and MOOCs were:

- MEC instruction comprised a collection of short (< 15 minute) videos of high-quality teachers, each focused on one or two concepts.
- Instruction spanned the entire course curriculum (i.e., a full course)
- We scheduled periodic online quizzes to check understanding. Some of these were given explicit deadlines (for credit) to encourage students to stay up-to-date.
- MEC included an online forum to facilitate peer learning and communication with instructors and teaching assistants.
- We provided periodic supplementary challenges and problems to keep up student engagement.
- We offered a proctored exam at the end of the course for all students who had viewed most of the videos and scored 70% correct on the online quizzes. This exam was independent of the final exam given by the university.

In addition, some of the features that were not common to MOOCs:

- All instructional content (videos, quizzes, etc.) in MEC was explicitly tied to, and synched with, the curriculum of the university (shared among all affiliate colleges).
- MEC was designed and marketed as a classroom supplement. This is in contrast to the traditional idea of MOOCs as stand-alone courses (though Khan Academy does embrace this model [20, 6]). We often use the phrase “21st century textbook” when talking about MEC.
- MEC includes the concept of a “course universe.” What this means is that there is a base “universe”(-ity) of a given course (effectively a master set of instructional videos, quizzes, problem sets, etc.) that is common to all affiliate colleges of a university. However, each college or teacher is able to supplement and personalize this material with content for their students. When students sign up for MEC, they identify which college they attend; this association allows each college to personalize content for their class, and enables competitions within classes and between colleges.
- Student performance analytics are available to teachers of each college. Teachers can easily explore how students are progressing in MEC including what videos they have viewed, their performance on quizzes, etc. This may be particularly useful for blended learning techniques such as “flipped classrooms” (again, see Khan Academy).
- Instructional videos are available to be downloaded for offline viewing and sharing. Because broadband internet is not uniformly available, we needed to provide the capability for teachers and students to download videos for sharing and viewing at their leisure.
- We have explored several ideas for incentivizing students, teachers and administrators, ranging from completion certificates (personalized pdfs mailed to students), various kinds of participation recognition for colleges (important for administrators looking to market their program), extensive integration of social media, local workshops, and even offering internships at our organization for the top-performing students.

MEC pilot course

For our pilot exploration, we focused on a single course because we felt that this would give us a good foundation. We chose to start with a course for the Design and Analysis of Algorithms (DAA). We picked DAA because we felt that a knowledge of algorithms is fundamental for computer science curricula (as one of our instructors put it, understanding algorithms is the first step to “computational thinking”). Second, DAA is a fairly hard course, and students often report difficulty in grasping the concepts. Finally, questions related to algorithms are frequently featured by industry recruiters, so actually understanding the material (vs. just cramming for exams) was thought to be more important for students in this course than many others.

We scheduled the first pilot for the spring semester of 2013 with a number of colleges affiliated with Visvesvaraya Technological University (VTU) in Karnataka. We chose VTU because they were relatively local (our lab is based in Karnataka), and because the course on the Design and Analysis of Algorithms was scheduled for that semester. Following this, we expanded to two other universities that were scheduled to teach Design and Analysis of Algorithms in the fall term of 2013 and recruited a number of colleges in each. The first was Gujarat Technical University (GTU) and the second was University of Pune (located in the state of Maharashtra). The second term is still in session at the time of this writing.

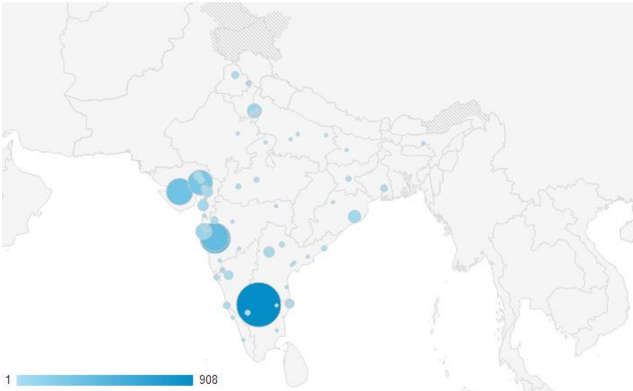

Figure 2. Geographic distribution of students for the two terms of the MEC pilot (to date).

We chose these three university systems for several reasons. First, we sought collaborations with university systems who were willing to partner with us and explore how MEC could enrich learning given the challenges highlighted above. College staff and students were very supportive of our experiments. Second, we chose university systems that had sufficient scale to reach out to a large student population—many features of MEC (such as forums) are enhanced by having large numbers of participants. Third, we wanted to cover a broad of diversity of students, teachers and infrastructural constraints. We chose university systems from geographically different regions, each comprising colleges from urban and rural areas and a range of resources. In addition, Karnataka and Maharashtra both have existent IT industries and therefore receive more attention from companies seeking CS students than Gujarat. Finally, the curriculum for DAA is different: in both GTU and VTU, DAA is taught relatively early in the CS curriculum (3rd and 4th term, respectively). In contrast, in University of Pune, DAA is taught near the end in the first half of the fourth year (7th term). As a result, the syllabus for University of Pune is a bit more advanced than VTU or GTU—it is accelerated and includes more content. Together, we felt that these differences would tell us how systems like MEC would be used in a range of contexts.

Note that while we worked closely with these three universities, anyone could sign in and take the course for free. Figure 2 illustrates the geographic distribution of students who accessed MEC. While large clusters can be seen centered in Karnataka, Maharashtra and Gujarat, students logged in from all across India.

Content was created by a team of three to four teachers drawn from local research institutes and colleges. These teachers worked together to ensure that the material was of good quality and matched the syllabus of each university course. In addition, they made sure that the content was pitched to the level of our students and delivered in clear English (with an Indian accent).

The DAA course provided to VTU on MEC had over 45 videos covering 8 units from the course syllabus (52 hours of classroom teaching), with 10 quizzes interspersed roughly every week. Students were offered certificates at various levels to encourage participation: a “participation” certificate for watching 40 videos and taking 5 KCs, a “completion” certificate for watching all videos and taking all KCs, and a “distinction” certificate for watching all videos, scoring above a 62% average across the KCs, and scoring above a 70% on the in-person exam we administered after the semester ended. Details for GTU and University of Pune are similar, though as noted above the University of Pune contained a bit more content.

FINDINGS

For our first pilot, we wanted to start relatively small to see how well the model would work. We began with a modest goal of recruiting 1000 students at about ten colleges at VTU. By the end of the semester, over 2000 students had signed up for MEC. Of those, ~600 completed the first quiz, and about 400 completed 75% of the course. In the end, around 140 students stuck through to the end of the course and were invited to take a proctored final exam to qualify for a certificate of distinction. This was somewhat disappointing, but matched the common experience of MOOCs, where a massive attrition between sign-up and completion is often seen [3, 4]. If one looks only at the attrition between completing the first quiz and finishing the course, the rate is ~20%. This is better than many MOOCs, but still not great. However, we should note that unlike a MOOC, these students cannot really drop the course (this is not allowed in Indian universities). Thus, the problem of attrition for MEC is probably easier to overcome.

Our experience provided us with a number of insights that we believe are relevant for anyone attempting to deploy online educational initiatives for students in similar contexts. Our findings tend to reinforce our view that *Content, Incentives, Awareness,* and *Bandwidth* are critical for success.

Empowering the classroom through teachers?

One major goal of MEC was to explore how online content could be used to supplement teaching. We explicitly designed MEC with teachers in mind: e.g., providing student analytics, the ability to customize content, and with the indirect desire that they might view the material to improve their own understanding and effectiveness. In addition, we spoke to teachers about how they might use the content with their classes using different blended learning techniques. However, in the first term we struggled to actively engage teachers. Indeed, only a handful of teachers ever signed into the site, and fewer still viewed a video or reviewed student analytics. It became clear that teachers saw no real incentives for experimenting with MEC.

Based on these observations, we had in-depth discussions with teachers about what might motivate them to participate on the platform. Two interesting incentive models emerged: recognition in the form of, industry certification or tangible outcomes for their resume, or clear directives from their administration. Hesitation to use the platform was exacerbated by the fact that many teachers are less technically-savvy than their students. For example, some struggled to with the notion of signing in with the login ID and password for the online account that they generated to log into our system (e.g., Microsoft, Gmail, or Facebook accounts). Further, we learned that many teachers were unable to easily view the content or understand how their roles on the platform were different from students. In sum, we found that in our first term MEC was not embraced by teachers either for personal enrichment or for use as direct supplement for their classes.

However, in those cases where teachers *did* familiarize themselves with MEC, they would evangelize use to their students and we saw much greater uptake. These teachers would note the quiz deadlines during class and encourage students to view specific videos related to topics raised in class.

Therefore, teacher engagement became an important focus for us for the second term. In particular, we wanted to understand how we might encourage experiments in blended learning, project-based instruction, or other uses of MEC content with their classes. Is it possible to use a system like MEC to encourage teachers to explore pedagogical methodologies beyond "chalk and talk"? To encourage this, we took a two-prong approach of education and incentives. First, we architected a mechanism to make it very easy to author course supplementation for their classes. This could be as simple as uploading pdfs or slides, composing online quizzes using a shared question bank, or even recording and posting their own videos. The idea was to make the technical barriers to entry as low as possible.

In addition, we also created a number of venues and mechanisms for explicitly engaging with teachers to encourage new teaching methods, including workshops and periodic newsletters. We began the fall semester with a workshop in which we invited faculty (DAA teachers) from a number of colleges to come and talk about teaching using systems like MEC. In the workshops, we demonstrated MEC and talked about various models for using online materials in the classroom (e.g., flipped classrooms [6], screening videos in class for discussion, and project-based learning). Newsletters to all faculty reinforced these ideas and introduced new methods and encouragement.

In contrast to some Western contexts, the Indian educational system is very hierarchical. Teachers have little autonomy in what and how they can teach, and as a result are very conservative. If they are going to move beyond the mandated minimum curriculum, teachers need to believe that they will be rewarded somehow: with career advancement, monetary remuneration, or fame. But, beyond this, they also need to believe that whatever they are doing is endorsed by their superiors. A mandate by a high-ranking official can overcome a great deal of inertia on the part of teachers. One example of this was that the chancellor offices of two of our partner universities (VTU and GTU), sent a circular encouraging all colleges to use MEC and we saw a significant bump in enrollment for each.

Career advancement and monetary rewards may be beyond our scope, but we can help to provide publicity and the regard of peers. We may also be able to provide some top-down encouragement through administrators.

The primary motivation of most institutional administrators is enrollment, and competition between similar colleges for students is high. Anything that seems likely to increase enrollment will be met with enthusiasm, particularly if it comes with little cost. High exam scores and student placements at prestigious companies are important goals because this is what attracts parents to their institutes. Similarly, any kind of evidence for excellence that they can use to "stand out" is eagerly sought. Awards (trophies, plaques, etc.), endorsements or affiliations with high-profile companies, and media exposure may be very useful in getting the support of administrators.

To address these motivations, we introduced some incentive programs particularly with administrators and teachers in mind:

- To encourage teachers and their departments to advertise MEC to their students, we offered partner institutes the opportunity to be recognized as a "MEC Community Partner" if 70% of their students signed up. This would include an inscribed plaque that the institute could display.
- We also offered faculty the opportunity to be recognized as "MEC Champion" teachers. To qualify, they had to: 1) participate in a programming contest with their students (essentially a means to encourage structured project-based learning); 2) screen a MEC video in class with an in-class discussion of the material; and 3) create an online quiz for their students.

At the time of this writing we do not know how effective these different initiatives are, but early signs are encouraging.

Student engagement and evangelism

Of course, we can't solely depend on teachers to recruit and motivate students. Surveys and extensive interviews revealed that the best way to communicate with them was through social networking. First, it was clear that virtually every student we interacted with was on Facebook and used it extensively. During the first term, we discovered a "VTU Alerts" Facebook Group and used it to great effect for evangelism. Therefore, for the second pilot most of our student communication was mediated by Facebook. This appears to be much more effective than email for our students.

Second, students seemed to respond very well to short-term contests and awards so we began launching weekly challenges via our Facebook page with competitions to solve problems based on lessons taught in MEC. So far, the response to these efforts has been overwhelmingly positive, and we are interested in exploring other ways to use Facebook to reward students and evangelize MEC at scale (e.g., posting successful completion of quizzes to students' walls, publicly recognizing contest winners, etc.). In addition, we are interested in exploring different kinds of gamification (e.g., leaderboards and badges) to see if other kinds of incentives would keep up interest. The programming contest described above will be launching shortly and we expect a strong response to it.

Finally, we are trying to increase peer learning among students by encouraging the use of forums and creating other ways for students to interact with each other. The programming contest and weekly competitions are examples of these initiatives.

Forum use and peer learning

As is common in many MOOCs, we provided a forum for students to ask questions, help each other out, and talk about the material. In the first term, we were somewhat disappointed to see that while a number of students posted questions to the forum, students rarely responded to other's queries. In subsequent interviews with students it became clear that many students misunderstood the purpose of the forum. The students we spoke with had very little experience of peer learning inside a classroom environment. They assumed that the forum should mirror their common classroom experience: students ask questions and only teachers respond. When we suggested that the point of the forum was for them to answer each other's questions, many seemed surprised at the idea. This indicates to us that some explicit training in the expected use of forums is required for students in our target group. For example, in the second term, we have explicitly tied several activities to the forums. Other ideas for improving use might include an orientation video, as well as some "priming" of the forum by teaching assistants and enthusiastic students who are recruited to answer questions in the forum.

While the forum was not really used as intended, other forms of peer learning were more common. For instance, some students would view MEC videos together in study groups. In addition they often discussed the quizzes among themselves, though this form of "peer learning" may be less desirable (see below).

Plagiarism and cheating

By the end of the first term, we were convinced that plagiarism and cheating will be an important consideration for any educational initiative such as MEC. This was somewhat surprising to us because it wasn't obvious why students would feel the need to cheat on quizzes. In the first place, students' performance in MEC had no direct influence on their grades in the class (aside from potential improvement due to mastery of material). And, while students could earn special certificates (awarded by us), these were independent of quiz performance: students could earn a "completion certificate" simply by completing most of the material, and a "mastery certificate" by passing the proctored exam we held at the end of the course. About halfway through the semester, we became concerned that many students were cheating by sharing answers or creating multiple logins to get the correct answer, because performance on the quizzes was extremely high. To test this, we created a particularly difficult question in one of the quizzes. Virtually everyone got the right answer.

This might not be that problematic if we believed that students were still learning the material. That is, even if they are gaming the system to get the right answers on quizzes, if they manage to retain the content and understand *why* the answers are correct, then MEC is still doing its job. Unfortunately, this did not seem to be the case. In our final exam, we asked a nearly identical question to the "poison pill" that we posed in the quiz (we just changed the wording a bit). Less than 5% of those taking the exam could answer this question correctly.

Unfortunately, this is a common problem for MOOCs [10, 22, 23]. Our findings suggest this isn't unique to MOOCs and is likely a pervasive issue with online learning initiatives. We believe that this is an important area of future research. Solutions may include randomized question assignment from large question banks, automated problem generation [17], or other approaches.

Internet bandwidth

When we first began the MEC project, infrastructural concerns were top of mind. Anyone who has spent time in India knows that one cannot take for granted things like constant power or internet bandwidth when deploying IT projects. However, as we spoke to administrators, teachers and government officials, we were assured that these concerns could be laid to rest for technical colleges; all accredited technical colleges in India are guaranteed broadband connectivity, and every college we spoke to confirmed this.

Unfortunately, our experience has been that while technical colleges do have internet connectivity, there are significant problems with bandwidth. Low-bandwidth activities such as email or light web browsing are feasible, but we could not consistently stream video in any college we visited and frequently resorted to using a 3G USB dongle (from a telecom provider such as Airtel, Vodaphone or Tata) to give demonstrations of MEC. In one memorable case, after struggling for over an hour to demonstrate our system, we were invited down to the basement of the college where a technician physically patched our laptop into the college's main network feed. Once hooked into the mainline, everything looked great! But needless to say, one can't expect the average student (or teacher) to be able to hack into the main trunk just to watch a video on Huffman coding.

In surveys and interviews following our pilot, MEC students identified offline video as their number one feature request. In some colleges, students claimed that they had "free wifi broadband" in their dormitories, but when questioned further, it was clear that the bandwidth was quite low. While video downloads were very popular, the practice was to download content and share it locally; bandwidth was insufficient for streaming content from YouTube or other sources.

[We are in the process of measuring the actual internet speeds for many of our users.]

The lack of bandwidth for streaming video is critical for educational initiatives (such as MEC) that assume broadband connectivity. We are certain that much of the attrition we saw in the first semester was simply because of the terrible experience of viewing content over a low bandwidth connection. Indeed, for the second semester, we went to great effort to improve the experience for low-bandwidth users. We made some progress on this front and it continues to be a core area of research. While we were not (yet) able to architect a completely effective solution for bandwidth constraint, for this pilot we provide two capabilities: 1) for every video, there is an option to download the video for offline viewing; and 2) we compiled an offline version of the whole course that can be launched from a USB flash drive. This provides all the video content for a given university curriculum. However, it does not include quizzes or other interactive content that requires connectivity. One area of current research is how to sync this content with online activity, gather some asynchronous measures of activity and maintain updates to course content.

Bandwidth constraints are an important consideration for any online educational program that aims to serve the developing world. The promise of reaching the billions of underserved people in countries in the global south is seriously undermined if they cannot view the content! This is an easy point to forget for content developers who can take for granted fast, reliable broadband. One important area of research is how to provide offline and low-bandwidth content consumption while preserving capabilities such as tracking student performance, slip-streaming new content, updating errors in old content, preserving interactive experiences, and preventing cheating.

CONCLUSION

At the time of this writing, it has been almost one year since we began the MEC project. The sudden explosive rise of MOOCs and related services inspired us to understand whether these technologies could be used to address some of the serious problems facing Indian education. Our research indicates that so far MOOCs are not being widely used in India. We designed MEC to fit into the Indian education system, particularly state technical universities, to see whether we could catalyze the use of online education resources for students in India and understand what factors are important for a successful system.

Over the course of a pilot deployment over two semesters with three different universities, we uncovered a number of issues that we feel are important for anyone wishing to provide online education in India. We summarize these as follows:

- **Content.** The content on existing MOOC platforms has limited bearing on students' ability to pass local exams. To address this issue, we developed content that directly mirrored the curriculum of state universities, enabling it to naturally supplement the in-class learning experience rather than compete with it. Also, while we did not discuss this in detail, the production of high quality video content remains extremely time-consuming and expensive. In MEC, we worked with local teachers to produce almost all of the content for our partner universities. This is a difficult process that takes considerable time and resources. However, to truly scale, universities would need to produce their own quality content for any course that they want to offer. Easy mechanisms for authoring content remain an important area of research.
- **Incentives.** Understanding effective incentives for students, teachers and administrators will be critical for maintaining the effort and effectiveness of the whole educational ecosystem. While some students are eager to master material both inside and outside their curriculum, most are primarily interested in anything that will improve their employability (certificates, access to interviews, interaction with employers, etc.) Similarly, teachers are strongly motivated by career advancement (recognition) as well as access to materials to help them teach their courses. We believe that gamification and social networking tools may provide excellent avenues for future work, and we are very interested in exploring new ways of encouraging peer learning and other effective pedagogical techniques. In addition, we are actively collaborating with employers of CS students to see if it is possible to connect performance on MEC with job opportunities. Unfortunately, plagiarism and cheating remain major problems for systems like MEC. However, we are optimistic that future research may help to provide a technical solution to this pernicious problem.
- **Awareness.** While global MOOC platforms celebrate participation by students from India, when we surveyed large numbers of Indian engineering colleges we found almost no awareness of MOOCs by students, teachers, or administrators. We found that part of the challenge is that teachers are often less tech-savvy than their students, lacking the skills to login and explore MOOCs in advance of championing them to their constituents. In order to increase awareness, we

aggressively used Facebook to connect with students and employed a series of workshops, publicity, and events to reach out to engineering colleges in India.

- **Bandwidth.** Dealing with the major constraints in bandwidth that are experienced in developing countries such as India remains a critical area of future research. To reach more than a small fraction of the population of these areas, an online education system *must* deal with this issue. A good low-bandwidth solution could have enormous impact for students in the developing world.

These issues are significantly different from those seen in Western contexts. Any successful deployment of online education must deal with each of these to varying extents, depending on the focus. For traditional MOOCs, these issues may be somewhat different from the concerns of initiatives seeking to directly supplement existing educational enterprises (such as MEC). Nevertheless, we believe that to be successful any system must grapple with them on their own terms, and important research remains for each.

In the near future we intend to use the MEC platform to investigate each of these areas. We believe that computing and Web technologies have the potential to dramatically improve education in India and other developing regions. Clearly, major hurdles remain in many areas that technology cannot remedy, but used wisely and in conjunction with other reforms, it can be an important part of the solution.

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REFERENCES

1. All India Counsel for Technical Education “AICTE.” http://www.aicte-india.org/sallinstitiutesstatewisehtm.html.
2. ANNA University. http://www.annauniv.edu/cai13b/Options.html
3. Breslow, L. B., Pritchard, D. E., DeBoer, J., Stump, G. S., Ho, A. D., and Seaton, D. T. Studying learning in the worldwide classroom: Research into edX's first MOOC. *Research & Practice in Assessment,* **8**, (2013) 13-25.
4. Clow, D. MOOCs and the funnel of participation. In *Proc. of the Third International Conference on Learning Analytics and Knowledge*, ACM Press (2013), 185-189
5. Coursera Zone. http://blog.coursera.org/post/63406806112/a-new-partnership-to-bring-coursera-to-the-hundreds-of.
6. Davies, R. S., Dean, D. L., and Ball, N. Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course. *Educational Technology Research and Development*, (2013), 1-18.
7. Donlan, K.A. Carlos Slim’s foundation puts its weight behind Khan Academy. http://www.forbes.com/sites/kerryadolan/2013/01/14/carlos-slims-foundation-puts-its-weight-behind-khan-academy/ *Forbes* (Jan 14, 2013).
8. edX Code. http://code.edx.org/
9. Friedman, T. Come the revolution. *New York Times* (May 15, 2012).
10. Gibbs, L. Coursera fantasy: Blogging my way through a MOOC. http://courserafantasy.blogspot.kr/2012/08/yes-plagiarism-how-sad-is-that.html (Aug 12, 2012).
11. Henry, N. Engineering colleges in Andhra Pradesh facing bleak future. *Times of India* (Aug 31, 2013).
12. Hyman, P. In the year of disruptive education. *Communications of the ACM*, **55**(12) (2012), 20-22.
13. JEE Brochure. http://www.jee.iitb.ac.in/#
14. JNTU Hyderabad. http://jntuhaac.com/allcolleges.php
15. JNTU Kakinada. http://jntuk.edu.in/atozindex/atozinstitutions/
16. NPTEL. http://nptel.iitm.ac.in/
17. Singh, R., Gulwani, S., & Rajamani, S.K. Automatically Generating Algebra Problems. In *AAAI* (2012).
18. TCS Brochure for new hires. http://www.tcs.com/SiteCollectionDocuments/Brochures/TCS_Software_Engineer_Profile.pdf
19. Visvesvaraya Technological University. http://vtu.ac.in/index.php/about-us/about-vtu.html
20. Welcome to the teachers’ toolkit. http://www.khanacademy.org/coach-res (Aug 21, 2012).
21. XuetangX. http://www.prnewswire.com/news-releases/edx-open-source-platform-chosen-to-power-chinas-new-online-education-portal-227183811.html.
22. Young, J.R. Inside the Coursera contract: How an upstart company might profit from free courses. *Chronicle of Higher Education* (July 19, 2012).
23. Zhang, Y. Befitting from MOOC. In *World Conference on Educational Multimedia, Hypermedia and Telecommunications*. 1 (2013), 1372-137