

White Paper

Online Learning in Computing

ACM Education Board / Council

Frequently asked question:

What is ACM's position on MOOCs?

Response from John White, ACM's Executive Director and Chief Executive Officer:

ACM does not have an opinion on MOOCs. Rather ACM provides a platform to encourage discussion and debate about the issues, so allowing members to form their own opinion on the matter.

1. Context

Online learning has existed for many years (even decades) in different forms. However, recent developments such as the much-publicized Massive Open Online Courses (MOOCs) have taken existing learning models to new platforms with much broader scope. The wider distribution of online learning opportunities has caused many to question what role online education will now play in educating people around the world. In particular, what do the delivery mechanisms look like (both technology and business models) and what are the implications for existing educational systems? Further, many institutions (academic, private, government) are questioning the value of continued traditional education and its rewards relative to career pathways.

Given these trends and given ACM's leadership as a non-partisan steward of computing and education, the ACM Education Board and the ACM Education Council decided to articulate a white paper concerning online education with the goal of serving the interests of ACM's many activities as well as the interests of the wider educational community. This paper aims to provide a background on trends and issues in online education and to mention some principles that educators in computing (and perhaps other fields) should consider when thinking about the role of online education in different contexts such as pre-university education, higher education, and international education.

1.1 ACM's Education Council

By way of background, ACM's Education Council is internal to ACM and represents computing education interests within ACM. It contains representatives from a variety of ACM's special interest groups (e.g., SIGCAS, SIGCHI, SIGCSE, SIGITE, SIGGRAPH, SIGPLAN), the Computer Science Teachers Association (CSTA), the Computing Education Policy Committee, the editors of computing education publications, CSAB/ABET, industry, international, and members of ACM's Education Board. Council membership totals about 30 people.

Meetings of the ACM Education Council occur approximately every eight months. Typically, these meetings aim to address current issues in computing education. The prelude to this paper was a panel session on online education, which had taken place at its most recent meeting in San Francisco, 18-19 June 2012. Mehran Sahami (Stanford University) organized the session, which included panelists Woodie Flowers (MIT), John Mitchell (Stanford), Peter Norvig (Google), Dave Patterson (Berkeley), and Candice Thille (CMU). For more details on the topic, see [1].

1.2 Current Priorities of the ACM Education Board / Council

An extract from the scope of the ACM Education Board's activities reads:

The general scope of the Education Board is to promote computer science education at all levels and in all ways possible. The Board will be an executive-like committee overseeing the Education Council and will initiate, direct, and manage key ACM educational projects. This includes activities such as the promotion of curriculum recommendations, the coordination of educational activities, and efforts to provide educational and information services to the ACM membership.

At a meeting of the Education Board in Seattle in December of 2010, the Board agreed on a focus for its activity. The following priority areas were identified:

- The Advanced Placement initiative and the related CS 10K teachers issue
- CS 2013, the next major set of guidelines for computer science curricula
- An educational initiative involving ACM India
- Statistics gathering for all institutions that offer computing degrees

It was natural that the online discussion should focus on the first three of these priority areas. (The fourth had already given rise to the ACM Non-Doctoral Granting Departments in Computing (ACM-NDC) project, formerly known as the TauRus project). However, the Board recognized that it should take the opportunity to draw these developments to the attention of the membership of ACM, to its various special interest groups, and to other potentially interested parties.

2. What is New?

While online learning has existed in various forms for several decades, initiatives in the past eighteen months have created new opportunities and dynamics in this arena. Notably, the availability of free online courses offered by institutions such as Stanford, MIT, Harvard, UC Berkeley, Google, and others has created heightened awareness of and broader opportunities for participation in online education. These MOOC courses have already enrolled hundreds of thousands of students and they have spawned a variety of delivery platforms. Relevant reference sites are:

Coursera (<https://www.coursera.org/>)
EDx (<http://www.edxonline.org/>, which originated as MITx)
Google's material at www.canvas.net/
Khan Academy (www.khanacademy.org/)

Udacity (<http://www.udacity.com/>)

And there are many others (such as Code Academy <http://www.codecademy.com>) with the possibilities increasing by the day. The technical underpinnings of this new wave of online courses have been attributed to advances including an increase in bandwidth that allows advantages such as seamless video streaming, real time video-conferencing (as in hangouts), and interactive experiences through modern tools (e.g., HTML5). An important additional differentiator involves more social benefits than technical issues. Here, the ability to simulate through a variety of community-focused functionalities and the impression of a global cohort taking a class together help to improve the student experience and create the notion of a true (virtual) class rather than simply a set of available online educational materials. Moreover, the ability for hundreds of thousands of students to watch (essentially simultaneously) course videos, coupled with assignments with specified due dates, are aspects of an explicit decision to “temporally” align students in the course. This alignment keeps students near-synchronously paced in the course, which in turn causes interactions (e.g. online discussions) that focus on a current set of topics in a course at any given time. Such pacing of the online content is a sensitive matter that creates a certain momentum as well as expectations.

From a pedagogical perspective, the traditional (hour-long) lecture can be restructured around a set of videos organized into smaller chunks of more readable and digestible content. Mention should be made here of the influence of Sal Khan through the Khan Academy. He demonstrated considerable virtuosity in the selection of material, in his pacing of material and in learning exercises; he also employed the 5-10 minute video window of YouTube to provide free distribution of one-topic videos. These videos were typically interlaced with online exercises—and automatic assessment methods—to provide immediate feedback.

Interactive techniques such as the use of multiple-choice questions, short-answer assignments, certain kinds of programming assignments, and essay grading can be employed. To complement the above, forums are typically formed to create communities sharing a specific interest. The instructors of some MOOCs have even reported geographically co-located students forming local meet-ups and study groups.

Of course, those involved in the delivery of online courses fully recognize certain shortcomings, many of which pre-date the latest wave of MOOCs. Some of these issues include:

- Lack of authentication of students enrolled in the courses (e.g., who is really doing the work);
- Possibility of increased plagiarism in the context of providing solutions to assessments (including direct copying from others as well as the use of multiple accounts by a single student in order to employ some of those accounts simply to gather answers/feedback on questions in the course);
- High dropout rates, including 85% for one popular course and 95% for another, have occurred; these figures need to be tempered by the observation that many are known to have registered for courses without taking them seriously
- Lack of clarity about effective and sustainable business models

- Possible mismatches between maximizing accessibility to material and filtering out an elite subgroup

There have been some attempts to address these issues such as potentially requiring students wishing to get certification for an online course to be present physically for certain assessments (and doing so through partnering with existing testing centers). Certainly, this area requires a great deal of attention moving forward.

Still, despite such issues, the basic intention of such online offerings is to make learning more widely available and to encourage its uptake. Thus, opportunities may also exist for the employment of online educational resources outside of the traditional role of student certification.

Unfortunately there is a common notion that online courses are intended to replace existing teachers. ACM does *not* endorse this perception. A more productive view is that online courses provide teachers with better access to materials and tools, so enabling teachers to give more coaching/mentoring attention to their students.

3. Implications for Education Board / Council Activities

The ACM Education Board and Education Council have been considering the implications of these developments for its current priority areas. These areas straddle activities that are representative of the use of online learning materials.

3.1 The CS 10K Challenge

There is large body of educational research examining the efficacy of online learning in a wide array of academic disciplines and this research points to a need for caution when considering the potential use of online learning for elementary and secondary school students and for teacher professional development. In particular, the following drawbacks have been identified:

- The flexibility and individualized nature of online learning requires a high level of responsibility. Learners who are not well organized, self-motivated, and have good time management skills tend to perform very poorly in online learning experiences. Without the routine structures of a traditional class, students may get lost, confused, and discouraged. This is particularly true of pre-college students.
- Lack of access whether it be for economical or logistics reasons will exclude otherwise eligible learners. If the participants' time online is limited by the amount of Internet access they can afford, then instruction and participation in the online program will not be equitable for all learners in the course.
- Successful learning experiences for both teachers and students must include opportunities to incorporate work, life, and other educational experiences as part of the learning process. Online learning, precisely because it is designed for highly generalized and large audiences, is rarely grounded in the learner's cultural or professional experiences.
- Meaningful reflection and critical analysis of information are an essential part of the learning process but much online content, and hence assessment, focuses almost exclusively on the delivery and assessment of incremental

units of technical knowledge.

- Online learning eliminates the potential for culturally-relevant, learner-centered instruction which is shown to be an especially critical element of increasing the engagement of under-represented minorities.
- Online learning eliminates the potential for perception of the subtle, often non-verbal cues that alert in-person educators to learner confusion, difficulty, or disengage. While some of these drawbacks can be addressed through frequent assessment and automated error feedback, these methods are shown not to be as effective in promoting deep learning and ongoing engagement as face-to-face instruction.

Despite these drawbacks, there is considerable excitement within the computer science community with regard to the potential role of online learning in support of current efforts to improve pre-college computer science education. Within the United States, exciting developments in high school computing are taking place, namely the development of a new Advanced Placement *CS Principles* course. (See <http://www.csprinciples.org/>.) Pilot versions of this course have already occurred at five colleges/universities (Phase I of the pilot) and they are now going through an expanded second phase involving ten additional colleges/universities, each partnered with a nearby high school. Associated with this effort is the challenge of having some 10,000 teachers who are well prepared to teach computing at the high school level to help deliver this course broadly. Naturally, a discussion has arisen as to ways to prepare and accredit such teachers.

It has been posited that, having a number of well-targeted online modules is an obvious way to provide increased access to computer science learning for students and professional development for teachers planning to implement rigorous computer science courses in schools.

Such an online delivery would have the following benefits:

- MOOCs could offer learners flexibility in terms of when to study the modules and of creating a self-supporting community of interested groups.
- Modules covering topics that proved difficult to teach would be valued (potentially by students and by instructors)
- MOOCs could accommodate the huge variance in teachers starting out with *CS Principles* by defining material and filling knowledge gaps.
- Passing assessments on particular modules could be used as the basis for awarding credit for the course through separate (potentially offline) assessment schemes.
- The large population of students allows the system to recognize “I’ve seen a student like this before, so ...” and customize instruction.
- Thinking of a module as an “online book” allows students to study it before hands-on activities, which are very effective.
- One could apply a module that is not very tailored to a particular use with many teaching styles; it is very valuable to give teachers some degree of flexibility.
- Find ways in which students could learn this kind of material (learning curve analysis).

Potential cautionary items were also noted. These include:

- Online learning is not a miracle cure for everything.
- Development of a module is very time-consuming; tasks include finding knowledge components, sequencing them, designing processes to get students “unstuck,” and assessment.
- Avoid having a teacher think s/he is an add-on. It has happened and it could destroy a project.
- Handle programming language agnosticism by having versions covering the main language choices.

Given both the potential benefits and drawbacks it was suggested that one approach would be to build some module (topic) and do that well. A source of possible module topics was to identify material that instructors and/or students of the existing pilot courses had difficulty with. Approaches such as rapid prototyping have been employed successfully by the Khan Academy.

A critical element for building a successful online module was the *domain expertise* of the faculty member:

- Some take to it and like it, but that is not true of everyone.
- Learn from the past and learn from successful modules; recognise that new skills are involved such as techniques for capturing the imagination and attention of pupils.
- Harness these new skills and promote them with interested faculty members.
- Explore the possibility of using Pilot I faculty to support a “community of practice”.

Early estimates of the cost for the development of a top quality module were around \$500K, with follow-on modules being far less expensive because all the templates would be in place; recently such costs have fallen dramatically and indeed Google has produced tools for support of the creation of online learning courses – see <https://code.google.com/p/course-builder/>

3.2 New Curricular Developments – CS 2013

For over forty years, the major professional societies in computing—ACM and IEEE-Computer Society—have sponsored the creation of international curricular guidelines for undergraduate programs in computing. The next volume in the series, Computer Science Curriculum 2013 (CS2013), is currently in progress.

At a high-level, it is important to decouple curricular coverage, as outlined in guidelines such as CS2013, from the delivery mechanism for the content (i.e., online or offline courses). In that respect, the CS2013 *topical* guidelines presented in the body of knowledge that computer science undergraduates would be expected to know are (and will remain) independent of developments in online education.

From the standpoint of how curricular recommendations may be more easily adopted, the existence of online resources presents new opportunities. CS2013 currently plans to include a set of course exemplars, which are brief descriptions of and pointers to

existing courses (not necessarily online) that cover different knowledge areas in the curricular guidelines. These exemplars serve as working models for different ways one could cover this material in an undergraduate program.

In a similar vein, online course content aligned with the curricular recommendations (especially with regard to topics that are newly included in CS2013) can help to speed the adoption of such material in a program that might otherwise be slow to respond. Online courses that cover portions of the CS2013 Body of Knowledge can both help to provide direct coverage where a program might otherwise initially lack faculty expertise or help better prepare faculty to offer their own courses. Hybrid models, where faculty and students *simultaneously* take an online course, are also possible. Here, the faculty member provides additional assignments and guidance to the students in the course while also gaining greater insight into the material him/herself. For one example of such a hybrid model, see [2].

Also worth noting is that the adoption of any curricular guidelines is subject to an institution's constraints and resources. As noted above, faculty resources—both in terms of numbers and areas of expertise—is an area that can potentially be augmented by online education. A related constraint is the notion of how topics are organized for delivery to students. While the traditional package used at colleges/universities for providing material to students is a term-long course, such a packaging may not always be at the best level of granularity for covering a set of disparate curricular topics. As a result, online education may provide an impetus for faculty to consider organizing material at a finer level of granularity than a full-term course. Such reorganization can help have the following consequences:

- Encourage the dissemination of learning materials in a modular form tied less to complete courses, making them more adoptable in other settings.
- Foster the creation of mini-courses that are sufficient to cover areas that do not require a full term.
- Support new ways of composing modules into courses so they conform to institutional constraints, while still providing full coverage of topics recommended for inclusion in a curriculum.

Of course, such rethinking of curricular reorganization is not intrinsic to CS2013. Rather, the creation of new curricular guidelines at the same time as the development of new online educational models highlights the possible ways synergies might occur between the two activities.

Beyond just providing recommendations for topical coverage in a curriculum, CS2013 also outlines some of the characteristics that are important for computer science undergraduates to have at the completion of their program. Two among these that are particularly relevant in light of online education are a commitment to lifelong learning and the ability to work in a group. Clearly, education does not end with the completion of one's formal studies at a university. Especially in a field like computing, the constant ability to keep abreast of technical advances in the field is necessary for practitioners to keep their skills fresh. Open online education falls squarely in the realm of promoting lifelong learning, and therefore experience with this medium has the potential to help students use it as a means to continually enhance their skill set beyond formal schooling.

Interestingly, some of the ways in which students in online courses have self-organized, using technology to allow for remote collaboration, are some of the same skills that are of growing importance for computing practitioners who need to be effective as part of large and potentially geographically distributed development teams. Again, it is important to emphasize that the ability to collaborate remotely is not intrinsic to CS2013, but simply an additional way that online education interplays with the set of skills that are important for students in computing to have.

3.3 The ACM India Initiative

ACM India is keenly interested in promoting more opportunities in computing education in India. By way of background, we now provide an overview of the development of Indian technical higher education. This narrative provides some insights into the current problems highlighted by ACM India.

Some twenty years ago in India there were:

- Few engineering colleges
- 6 Indian Institutes of Technology (IITs)
- Approximately a dozen regional engineering colleges
- Approximately 100 engineering colleges

The 1990s experienced considerable growth in the number of colleges, brought about by the fact that government institutions were unable to meet the demand for education. Consequently, numerous private colleges came into existence. This growth was followed by a certain liberalization of the economy, resulting in growing demand from the IT industry. In effect, the country needed about 100,000 engineers each year.

The current position in Indian higher education is that there are:

- Approximately 630 degree-granting institutions
- 8 Indian Institutes of Technology, with eight more being started
- 11 Institutes of Information Technology, with another twenty National Institutes of Technology being started
- Approximately 3800 Engineering Colleges with around 700,000 new entrants each year
- Many of the colleges are privately run, but with government concessions and grants

Regarding standards and quality, there are widely varying selection standards. For instance:

- 455,571 candidates took the IIT entrance test, with 1:50 being selected (2010)
- Of the other institutions, good institutions take around 1:5
- Smaller engineering colleges take the rest, and then the quality is widely varying

The IITs offer world-class education. However, typical small engineering colleges are under-provisioned, under-resourced, and poor teaching exists. Nevertheless, they are used as a stepping-stone to jobs or entry to higher degrees.

At the ACM Education Council meeting, an animated discussion ensued on online higher education for India. Mathai Joseph from the ACM India Council had proposed using online education as a means of making available high quality teaching material in a context in which higher education institutions were proliferating, class sizes were increasing, and teachers were scarce. The scale of the problem was enormous: over 3800 institutions teaching computing to almost a million students.

The aim was not to train people for any particular industry or service, but to produce young graduates with a good understanding of computing and computer science with the ability to make use of it in any profession they might choose. Some key requirements for such an effort were identified:

- a. The system should contain a common platform with a common look and feel for the courses that should have associated rigorous assessment. They should be widely available to faculty, to students enrolled in universities, and to students not enrolled.
- b. The system should provide a running textual version (captioning) of any online video courses so that students could follow the material even if the language and accent were not fully comprehensible to them.
- c. Support should exist for learning through an effective problem generation and grading system that would challenge the student's understanding of the material taught. This should be independent of any proctored examination used for final assessment.
- d. Good social network support should exist to allow students to create their own sub-networks and to work together for solving problems.

A number of people at the discussion felt that none of these requirements was new and much was in fact available. However, it was pointed out that while there are demonstrators that show that many of the needs could be met technologically, there was no online learning framework that incorporated all of them (especially online problem generation and grading) in a pedagogically usable form.

A second set of comments centered on the possibility of using existing players in online education to extend their services to India. Various names were mentioned. However, on closer examination, the feeling by ACM India was that these would be unsuitable. For instance, some worked well in limited contexts where there was human tutorial support available; given the acute shortage of teachers, that kind of solution would be hard to implement on the scale necessary in India.

The session concluded with the thought that teachers and students in India could discuss the problem with people in the ACM educational community and they could all work together to start some initiatives on extending and improving online higher education in India. The ACM Education Council could have a role in helping to shape the requirements of courses. The discussion considered the possibility of initial pilot courses involving relatively small numbers of students (e.g., maximum 500).

4. Additional Observations

The developments in online learning would have considerable effect beyond the current priority areas of the ACM Education Board.

The Broader ACM Community

An important aim in producing this paper has been to draw these developments and discussions to the attention of the wider membership of ACM, for instance, to the various special interest groups (especially those with a significant educational focus) and groups such as the Practitioners Board. Fortunately, many of these groups have representatives within the Education Council itself.

Higher Education

Since these online materials are available to all, they can be used elsewhere in higher education. However the issues of the authentication of users and plagiarism place limits on their role for providing related credit. However, individual institutions could always provide additional assessments. Of course, students can engage with MOOCs in advance of a lecture and the lecture itself can then be used for other purposes such as discussion on certain related topics.

It is worth observing that the extent to which these online learning courses (if appropriately designed) demand a considerable level of engagement and concentration by students is a huge factor in their attractiveness. Many of the common alternatives, e.g., being present but disengaged in a huge lecture, are increasingly unacceptable. Of course, to achieve the effect of buy-in from students (with high levels of engagement and commitment), faculty need to design courses appropriately and for that a level of support is required, e.g., in the form of highlighting techniques to achieve appropriate levels of engagement and motivation.

Over time, it is likely that improvements will occur in the technology supporting education (e.g., improved ways of automatic assessment in computing and a wide range of other disciplines) and in the recognized issues of providing authentication and detecting/avoiding plagiarism.

It is important to note that online activity has now become a feature of many areas of employment. Activities such as acquiring skills in giving webinars, providing online demonstrations (possibly remotely), and preparing reports cooperatively are now a common requirement in many areas of employment. The online courses currently do not tend to address these areas.

There is a view that, for higher education, these developments are a serious threat to conventional education. That view is not shared by everyone, but it exists. Beyond reflecting on that view, a reasonable conclusion is that an aspect of online learning should be an essential and integral part of higher education and be seen in part as preparing students for employment. Its role in preparing students for the inevitable continuing professional development would seem to be fundamental.

Broadening Participation

In Greece the MOOC concept has been used to provide students with an inexpensive way of preparing students for public exams. This same idea points to the use of MOOCs in broadening participation in (college, professional development-related) education; for instance disadvantaged students have free access to a range of courses which they can undertake at times and in circumstances convenient to them.

Continuing Professional Development

The discussion about the ACM India initiative (as well as CS2013 to some extent) indicated that recent developments in online education could have an obvious benefit for those seeking to undertake continuous professional development.

5. Concluding Comments

The advances discussed here herald new developments in education and these have the potential of having huge implications. Having taken the initial steps with a panel discussion on the topic, many, including members of the ACM Education Board / Council, will need to reflect carefully on how to take forward these activities.

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