Online Addendum to the Final Report on the Workshop on Multidisciplinary Research for Online Education

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Overview of the Online Addendum

The online addendum to the Report on the CCC-CRA Workshop on Multidisciplinary Research for Online Education (http://www.cra.org/ccc/visioning/visioning-activities/online-education/286-multidisciplinary-research-for-online-education) is intended to (a) summarize the various plenary and breakout sessions of the workshop, as well as (b) elaborate on emerging results and trends at the intersection of the computing and learning sciences, with special attention to characteristics of scale and openness. Periodically, as new and revised content are made available, perhaps as much as every 3-6 months for a time, this online addendum will be updated and reposted.

Appendix A is a summary of all plenary sessions, to include keynote speakers and panels. In addition to these, there were 2-minute report outs of breakout sessions and the reformatted slides used in these breakout report outs are given in appendix A. These very abbreviated summaries were also printed in the final report (an online copy can be found at the workshop Web site, indicated above).

Appendix B contains extended summaries of breakout sessions, perhaps with updated material in the relevant areas. At any given point, appendix B will only contain extended writeups for selected sessions. As breakout leaders, scribes, or other participants create content for a breakout, it will be added to appendix B.

Appendix C includes additional (often the newest) references and discussion in the areas relevant to the workshop. For example, we believe that *simulation and modeling* will play an increasingly important role in online education at scale, perhaps with challenges to maintain substantial openness given the computational costs of many simulations. While we discussed gaming in the printed report, attention to more general issues of modeling and simulation could be better represented. We welcome community contributions to the online addendum, particularly to appendix C.

Online Appendix A: Detailed summary of plenary sessions

All of these presentations can be watched by going to the Workshop website noted above, and scrolling to the bottom to “Workshop Speaker Videos”. To some extent summaries below also include observations, anecdotes, and other facts and opinions brought in by the editor, but the intent is that they remain largely summaries.

A.1 Opening remarks by Dr. Farnam Jahanian, Assistant Director, CISE Directorate, National Science Foundation

Dr. Jahanian highlighted the importance of interdisciplinary research, with focus at the intersection of computing, and social, behavioral, and economic sciences. Increasingly, social networks are being used for solving complex problems. Through technology-mediated human computation *foldit* (http://fold.it/portal/), for example, the structure of an enzyme involved in HIV was mapped in 10 days, a problem that has challenged scientists for years. In a similar way, improving learning by bringing computing technology and analytics to bear on the research of learning and behavioral sciences—cyberlearning—is the key to supporting interactive learning, adaptive and personalized learning, and automated assessment. Dr. Jahanian mentioned that this would be a promising area for Presidential Innovation Fellows.

A.2 Presentation by Professor Beverly Woolf, University of Massachusetts, Amherst

In her plenary talk, Professor Woolf summarized the earlier CRA/CCC-sponsored report entitled “*A Roadmap for Education Technology*” (ARET) (http://www.cra.org/ccc/docs/groe/GROE%20Roadmap%20for%20Education%20Technology%20Final%20Report.pdf), giving a backdrop on the rich history of online education against which the current workshop could be framed. The earlier report identified and elaborated on important *educational* themes, such as personalizing education; assessing student learning; supporting social learning; diminishing boundaries between various categories of learning, such as formal and informal learning; and alternatives to “standard” teaching approaches (e.g., like those found in “flipped” classes). The report also identified important *enabling technologies f*or these educational desiderata, such as mobile systems, social networks, student modeling, and educational data mining.

In many respects, the 2013 February workshop was a revisiting of some of the findings of the earlier activities on computing in support of online education. Both the ARET report and another, entitled “*Enhancing Teaching and Learning Through Educational Data Mining and Learning Analytics*” (http://www.cra.org/ccc/docs/learning-analytics-ed.pdf) were provided as background prior to MROE workshop, and we will refer to these and other background material throughout this report. Professor Woolf elaborated 5 grand challenges identified by the earlier workshop, which remain grand challenges today.

Grand challenge 1, a teacher for every student, is concerned with personalizing education, shaping education to each student's traits (e.g., personality, learning style) and state (e.g., level of engagement, alertness). Traits are rather permanent characteristics of an individual, whereas states are transitory; traits are to states, as climate is to weather. Research issues for this area include the capture of student behaviors at multiple grain sizes, and representation and simulation of student models. Woolf indicated that there has been much work in this area, though much of it has not permeated actual education practice. Moreover, the examples of research addressing this challenge appear to focus on state identification, and NOT trait identification. It appears that modeling of student traits is much less explored than modeling of student states, and thus characterizing and modeling of student traits may be an important long-term research agenda.

Grand Challenge 2 is realizing lifetime and lifewide learning. Woolf highlighted the promise of mobile technology, in particular, for creating opportunities for seamless, ubiquitous learning across educational boundaries. Of special interest here are the ways in which lifetime learning is related to personalized learning. Just as much of personalized learning is concerned with tracking and responding to student states over relatively short time intervals and limited environmental influences, lifetime and lifewide learning will likely benefit from tracking student traits over a lifetime, and very broad environmental contexts.

Grand challenge 3 is making education at all levels universally accessible; through technology-enabled global classrooms; with easy, single-portal access, interoperability of learning platforms and applications, and APIs for multiple languages. MOOCs are a step in this direction, though with a long ways to go in terms of pedagogy and technology.

Grand challenge 4 is discovery about teaching and learning through acquisition and mining of student behavioral data. This will be a critical enabling technology for personalizing learning, in particularly the discovery of student models. Examples of data mining tasks include classifying people with similar learning difficulties, detecting student gaming of educational software and off-task behaviors by students, and predicting student states. Grand challenge 1 and 4 go hand in hand: *student models will inform guide educational interactions, and educational interactions will be the source of data to discover and refine student models.*

Finally, Woolf suggests that grand challenge 5 is to educate students for a global economy.

A.3 Presentation by Professor Roy Pea, Stanford University

Professor Roy Pea presented "*Learning Sciences Meets Learning Analytics: Time for a Marriage*", pointing out that there was limited inclusion of learning sciences in the design of high profile MOOC offerings, though clearly optimistic that the MOOCs of tomorrow can and should be informed by pedagogical theory. In addition, the marriage is further motivated in the other direction -- MOOCs and other online resources are being instrumented to collect student behavioral and other data at previously unheard of scales, and the learning sciences can benefit mightily from analysis of that data. This all motivates the great desirability of learning scientists and data scientists to work closely together.

Pea summarized main points from the "National Educational Technology Plan" (http://www.ed.gov/technology/netp-2010) and "*Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge*" (http://www.nsf.gov/pubs/2008/nsf08204/nsf08204.pdf), and focused on the grand challenge of realizing in depth personalized learning. To achieve this he pointed to six imperatives: (a) developing interconnected concept maps; (b) design for engaged social learning; (c) educate for broader competencies (beyond the cognitive); (d) use richer pedagogical models; (e) better understand learner goals; and (f) forge interdisciplinary teams.

(a) The imperative that he spent most of his talk on was the development of *interconnected* concept maps, which are used to guide students, often by a human or automated teacher, through learning of content. These maps (aka guidelines, …) are typically coupled with specific domains and even specific materials, and a limitation is that they are isolated from other content that students must learn. A challenge is to abstract over and interconnect maps from different domains and media, to facilitate cross-media and cross-domain recommendations for lifelong and lifewide learning (Shared Learning Collaborative: http://slcedu.org; https://www.inbloom.org/).

(b) Another affordance for personalized learning are platforms and pedagogies for engaged *social learning*, one that takes seriously the prospect of distributed expertise, in which all learners are (in some case) teachers and guides as well. Mutual support in a learning community will be facilitated by quality user profiles and reputation systems, computer supported collaborative learning tools such as shared whiteboards, models, intelligent search facilities (e.g., of crowded and changing discussion boards).

(c) Pea advocated *education for broader competencies*, beyond the “cognitive” (e.g., content knowledge), to intrapersonal (e.g., self-awareness, openness) and interpersonal such as communication abilities (National Academies report on “*Education for Life and Work*”; http://www.nap.edu/catalog.php?record_id=13398).

(d) *Rich pedagogical models*, which are often missing in today’s MOOCs, include project-based learning, problem based learning, learning by argumentation, learning in virtual worlds, cognitive apprenticeships, and immersive and embodied learning; most of which are missing in most of today’s MOOCs. Implicit in many of these pedagogical models is learning with others, as part of a cohort or otherwise. All of these models have important implications for technologies such as gible computing; collaboration scripts; virtual worlds; haptic interfaces; and geo-aware computing.

(e) *Understanding learner goals* may become a richer area given the instrumentation opportunities in online education. Dr. Pea underscored this point by summarizing a study intended to qualify and shed light on low MOOC completion rates (http://www.stanford.edu/~cpiech/bio/papers/deconstructingDisengagement.pdf; also referenced in http://m.technologyreview.com/news/515396/as-data-floods-in-massive-open-online-courses-evolve/). Auditors, samplers, and disengaged students had different motivations, differing non-cognitive characteristics like mindset and persistence, and differing life constraints. Thus, different affordances, such as alternative pacing, would variably help different groups.

(f) A final imperative is to forge interdisciplinary research teams for online learning, as noted earlier, to include members of the social sciences, computer sciences, domain scientists, learning sciences, and statistics, as CMU's Open Learning Initiative did (http://oli.cmu.edu/), promoting the creation of research and practice collaboratories for online learning.

A.4 Panel on Educational Data Mining and Learning Analytics

This panel was organized by Ryan Baker (who sent regrets due to weather) and moderated by Jack Mostow. The panelists were asked to describe their favorite use of Educational Data Mining (EDM) and Learning Analytics (LA) and the opportunities in those examples for benefiting online education. Jack Mostow, as substitute moderator, opened the panel by comparing definitions of EDM and LA:

> EDM: "developing methods for exploring unique types of data that come from educational settings, and using those methods to better understand students, and the settings which they learn in"
>
> LA: "the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs"

Both combines models and algorithms from data mining, psychometrics, visualization, user modeling and AI in education.

Ryan Baker slides were concerned with modeling the student by adding motivation and emotion, and even recently assessing present to predict future learning outcomes (and not future knowledge state per se), such as whether a student will drop out of high school or finish college. Ideally, "markers" can be found that predict negative outcomes and motivate intervention. For example, mining student data with association rule discovery suggest that students who missed a question on a midterm are at risk for poor performance on a particular final exam question.

Tiffany Barnes' theme was EDM for "Surprising us with Data". For example, Shih found that students who were asking for hints, were NOT gaming the system as had been assummed, but rather these students wanted worked examples to improve learning. Stamper and Barnes analyzed student data on problem solving for purposes of generating hints for new students. Barnes gave other examples of data mining.

James Lester discussed multi-Stream Learning Analytics -- doing advanced analytics with fully instrumented learning environments, currently with 800-1200 students ("small") in gaming environments, but in the future with large numbers and very different and culturally varied student populations (e.g., young/old, low/high learners). Lester elaborated on a topic of discovering student goals by looking at student behavioral trace data, assessing how accurately and with what latency goals are recognized through automated means; and identifying through analysis student and teacher misconceptions, studying affective transitions, and asking what affective states more effective.

Jack Mostow, in his role of regular panelist, addressed the teasing apart of effects of practice and help - "Does help help?" (Beck et al., ITS2008 Best Paper). Using using knowledge tracing (i.e., trace the probability that a student knows a skill from observations of their performance), subtle but measurable effects were found on later learning based on whether student received help in the form of hints, effects of spacing of hint, and effects of context of hints.

Gautam Biswas addressed supporting student learning in open ended learning environments, in particular by using sequence mining to find patterns of primary behaviors in high performing and low performing learners.

Norma Ming addressed assessment by analyzing usual class operations without a lot of new interventions, particularly by inferring conceptual knowledge from unstructured student writing through hierarchical topic modeling. For example, predicting final course grades from discussion posts showed that hierarchical topic modeling yielded high accurate predictions, with students earning Cs discussing issues at shallower topical levels; and with A and B students using deeper Z(more specific) topics. In addition higher performing students addressed different topics, showing greater breadth, as well as greater depth.

Q&A covered data for description as well as prescription, desirability of MOOCs not as interactive platforms in which EDM and LA used, enabling teachers to know what students are doing rather than think they are knowing, and finer grained content particles, and bottlenecks that would make scaling methods up difficult (e.g., a centralized expert).

A.5 Panel on Translating Collaborative Project-Based Learning to Online and Blended Environments

This panel was organized and chaired by Cindy Hmelo-Silver, with topics addressed by panelists to include problem and project based pedagogies (Cindy Hmelo-Silver and Mark Guzdial), inquiry learning (Beverly Woolf), computer-supported collaborative learning (Carolyn Rose and Sharon Derry). All rely on small group discussions and teacher involvement, so challenges of scaling these approaches up is of great interest.

A more complete summary may be provided later. The complete panel is captured on video at the workshop website noted above.

A.6 Breakout Session Slide Summaries

This section contains reformatted slide summaries from two-minute breakout group plenary reports. These summaries are also in the final report, but are listed to here as well. These brief summaries typically list general research areas and questions identified by the group. Some extended summaries are given in Appendix B, and more extended summaries will be added, as they become available.

A.6.1 Personalizing Education: Roles of Computing

Participants: James Lester (Lead), Dan Garcia (Scribe), Vincent Aleven, David Klahr, Norma Ming, Vitaly Shmatikov, Emily Dalton Smith, Loren Terveen, Beverly Woolf

- What is Personalization?
    - Everyone gets what they need (content, style [video, audio, text, ...] ...) when they need it (availability, PBL "pull", etc):
    - What happens when there are collaborations?
- META: Where is the pain in the classroom? Is personalization serving that? What is there demand for and what can we do?
- Big Research Questions
    - Non-STEM: What to do for ill-defined domains?
    - Data: How to connect it across systems, standards?
    - Doing it: What to adapt, how to adapt (using learning models)
    - Assessment: What if there's a wobbly start/finish?
- Concerns & Challenges
    - Who will build it (workforce), use it (not if we didn't build, policy), sustain it (if builder leaves), what happens to competition (what does it mean to be good), tracking (what if they stumble), privacy. Obv, start with low-hanging fruit.

A.6.2 Assessment of Student Learning

Participants (morning): Scott Klemmer (Lead), Dan Hickey (Scribe), Jeffrey Bigham, Knatokie Ford, Marcia C. Linn, Rob Miller, Jack Mostow, Beth Simon, Candace Thille, Mark Wilson
Participants (afternoon): Anoop Gupta (Lead), Derek Bruff (Scribe), Karen Brennan, Brian Butler, Sharon Derry, David Klahr, Chris Makler, Norma Ming, Dawn Rickey, Vitaly Shmatikov, Raluca Teodorescu

- Many flavors: How, when, for who? What's the landscape? ...and lamppost(s). What can we learn from and contribute to theory?
- How might we assess the experience? Free-range assessment, the value of process, and what are roles & opportunities for feedback?
- How might we combine people & algorithms? ...and leverage insights across classes?
- Less worried about cheating. Except... do we have to throw out all our great questions? ("keeping it fresh")

A.6.3 Supporting Social Learning

Participants: Carolyn P. Rosé (Lead), Cindy Hmelo-Silver (Scribe), Sharon Derry, Dan Hickey, Anita Jones, Jihie Kim, Beverly Woolf, Trey Lathe, Norma Ming, Glynda Hull, June Ahn, Ben Bederson, Karen Brennan, Derek Bruff, Amy Collier, Irene Greif, Beth Mynatt, Gerry Stahl, John Cherniavsky

(also see the online workshop addendum at reference [0] for more complete write-up)

Research Questions

- [Analysis version] How can we design a communication medium that can adjust to different scales so we can have the whole community, but there can also be small groups or subcommunities that thrive within that larger environment?

- What can we learn and leverage from research on crowdsourcing? How can we balance concerns about community endeavors (getting work done in community, e.g., answering questions) with supporting the kinds of interactions that are conducive to the rich interactions that promote learning?
- How do best practices in design from existing online communities transfer into massive online learning contexts? What is similar/different in this context that might require new questions to be answered?

Research Directions

- Develop infrastructure for socialization of “online learning survival skills”. Perhaps MOOC to prepare people for MOOC based education. As a specific example: Develop affordances for socializing civility.
- [Design version] Design a communication medium that can adjust to different scales so we can have the whole community, but there can also be small groups or subcommunities that emerge and thrive within that larger environment.
- Platform development: Create affordances for visualization, access, and navigation of community resources. Facilitate building large-scale, collaborative, educational applications. And make it easy to integrate them with existing online educational platforms.

A.6.4 Machine Learning and Data Mining

Participants (morning): Emma Brunskill (Lead), Deepak Kumar (Scribe), Dan Butin, Sharon Derry, Ed Dieterle, Sidney D'Mello, Scott Rixner, Mehran Sahami, Juan Vargas.
Participants (afternoon): Jack Mostow (Lead), Amy Collier (Scribe), Marianne Bakia, Gautam Biswas, Lee Giles, Edith Gummer, Jonathan Huang, Jihie Kim, Chris Makler, Mack Olson, Roy Pea, Carolyn Rosé, Loren Terveen, Mark Wilson

(also see the online workshop addendum at reference [0] for more complete write-up)

Filling sensory, representational, and meaning gaps:

- How can we discover educationally significant events and features (e.g. dis/engagement, learning, complex problem solving, skills, gaming, cheating, ...) in low-level multimodal data of diverse types?
- What kinds of knowledge (e.g. about content, context, students, learning, instruction, social networks, …) can machine learning exploit to make sense of such data, and how?
- Can ML be used to automatically create new representations of content areas, modularizing and organizing course material into objects, and making tailored object recommendations to students?

What makes online learning data fruitful to mine?

- How can online learning be designed or transformed to log such data?
- What automation can support this design or transformation process?

Human-machine division of labor:

- How can online learning platforms combine ML and human computation (e.g. crowdsourcing, peer input, referral) to scalably assess learning, annotate, evaluate instruction, or teach better?

A.6.5 Formal and Informal Learning

Participants: Marie Bienkowski (Lead), Brian Butler (Scribe), Gautam Biswas, Gerhard Fischer, Jonathan Huang, Dorothy Jones-Davis, Taylor Martin, Roy Pea, Jenny Preece

(also see the online workshop addendum at reference [0] for more complete write-up)

Research Areas

- Embedded Learner...with mediated experiences that flow among settings, and reveal what happens in informal settings
- Social/Collaborative Learner...with shifting roles from teacher to learner, from consumer to prosumer, etc. (Digital Learning Commons)
- Creative Learner...how does learning the facts differ from creating, designing, making, doing?
- Activated Learner...how does technology help with developing agency and self-regulated learning

Representative Research Questions

- What role do informal experiences have on interest in STEM?
- Can we develop models to predict when learners will benefit from specific pedagogies and content?
- What role do so-called noncognitive factors play in across settings and across timescales?
- What are effective techniques for blending qualitative and quantitative data and methods in a big data world?
- What are the evolving roles for teachers in the new digital learning world?
- What new roles can multiple sensors play in establishing the learners context?

A.6.6 Pedagogical Needs and Constraints of Various Domain Areas

Participants: Mark Guzdial (Lead), Chris Makler (Scribe), Lee Giles, Mitch Green, Beki Grinter, Glynda Hull, David Karger, Lauren Resnick, Margaret Soltan, Raluca Teodorescu, Gary White

Research Areas: We recommend more research in:

- Automated evaluation of text discussion. Other domains rely more on discussion. We need to be able to facilitate discussion at scale, and judge content.
- Peer-teaching and the identification of good peer-teaching. We need peers to act as

models, coaches, and evaluators. What makes for good peer-teaching, and how can we encourage the best to do more of it?
- Understanding mappings between different representations. Summarizing a diagram in text, or creating a network representation from text are skills we ask students to do in some domains. We should be able to create algorithmic assessment methods for these.

Research Questions:
- How do we support on-line learning for various ways of coming to know: Correct knowledge (STEM), humanities knowledge (different interpretations of same text), historical knowledge, and design knowledge?
- How we facilitate (guide and assess) productive, accountable talk for student learning?
- How do we automatically check problem-solving process?
- How do we recommend pace and face-to-face/blended/on-line learning?

A.6.7 Interacting with Objects

Participants: Mary Lou Maher (Lead), Fred Martin (Scribe), Tiffany Barnes, Winslow Burleson, Andrea Forte, Anoop Gupta, Rogers Hall, Dawn Rickey, Gerry Stahl, Tsuihsia Tseng, Janet Kolodner

Objects that are integral parts of learning:
- physical objects: Froebel's gifts, tangible devices, lego
- conceptual learning objects: chunks of content around a learning purpose
- virtual objects: virtual humans, simulated physical objects, online labs
- software objects: apps, MOOCs, games
- communities that form around objects of learning

We distinguished between objects made for learners to use, and objects made by learners.

Research Questions:
- Physical vs virtual: How can online learning include physical and virtual objects for recording, augmenting, or replacing physical interaction? What are the tradeoffs of using virtual versus physical on learning outcomes?
- Motivate learning: How can the different layers of objects (e.g. physical, model, simulation, interaction) be designed to ask the right questions and motivate deep learning?
- Social learning: What interaction design advances need to occur for people to collaborate on making, sharing and playing with (physical) objects online?
- Objects tell stories and can be watchful

A.6.8 Social Computing & Networking

Participants: Candace Thille (Lead), Jeffrey Bigham (Scribe), June Ahn, Emma Brunskill, Rogers Hall, Cindy Hmelo-Silver, Irene Greif, David Karger, Scott Klemmer, Mary Lou Maher, Jenny Preece

How do we design/instrument online education environments in order to create effective learning environments and simultaneously answer questions that will allow us to contribute back to theory?

Current

- Most of the current use of social media to support learning is
    - Not designed.
    - Not collecting meaningful/accessible data
- Need to review
    - what people are doing now with existing social technology (e.g. discussion boards, blogs, youtube, facebook, hangout, etc.)
    - work from fields beyond cognitive science, learning science, education science, computer science.

Research Questions

- What are the fundamental benefits of social learning and how do they scale up?
- What about social learning persists/changes when you switch to online? How / when to blend?
- How do you design social groups (size, diversity) for education and scaffold social experiences?
- What social computing environments encourage what kinds of learning? (competition/collaboration)
- How do you design for different populations

Motivating questions: Once online higher education is embedded in larger social contexts, how can computational systems support student collaboration and engagement? What is the process by which teams work in virtual, collaborative learning environments? Which tools will match learners with other learners and/or with mentors taking into account learner interests? How can software both support collaboration and coach students about content? How do we examine learning communities, and what is the scope and other characteristics of these communities? How do learning communities morph into global communities with orientations beyond education? How do learning communities sustain, build on and share knowledge? How do we address infrastructure (API, management) and application level (representation) issues? What integrations/mash-ups of devices/ platforms would more effectively support social learning distributed across time, space and media?

A.6.9 Long-term implications of online learning for cultural interactions

Participants: Taylor Martin (Lead), Doug Fisher (Scribe), Ed Dieterle, Gerhard Fischer, Mitch Green, Dorothy Jones-Davis, Margaret Soltan, Gerry Stahl, Sharon Derry, Glynda Hull

A Few Themes

- Broadening participation

- Cultural relevancy, culture-informed course design
- Technology encouraged cooperation, community, competition
- "respect" cultural differences versus change culture
- Education culture; Implications for diversity (and uniformity) of content

A Few Questions

- What online course formats and content lead to diversity in the active, participating student populations, and what conditions lead to uniformity?
- "To what extent, why, when, and how online models work or do not work for different student populations, especially historically disadvantaged students and underserved populations?"
- How will online formats change educational culture from 'sage on stage', not just because of 'flipped classroom' guide on side interactions, but as faculty (openly) become 'consumers' of online education and become members of learning communities with their students? (vice versa)
- How can MOOCs be customizable and personalizable in "real time"? (smart, not offend, create bonds)
- HCI to support massive global discourse; HCI for deep, compelling immersion (promote empathy?)

A.6.10 Implications for Computer Science Education

Participants: Beth Simon (Lead), Mark Guzdial (Scribe), Ivon Arroyo, Marie Bienkowski, Sidney D'Mello, Dan Garcia, Deepak Kumar, Fred Martin, Mehran Sahami, Tsuihsia Tseng, Juan Vargas

Research Questions

- Can we use games as a model for supporting development of a growth mindset in learning computing?
- We know that some face to face PP/PI (paired-programming / paired-instruction) works really well. How do we map these online?
- Why is it so often that undergrads in CS teach other undergrads? How do we create near-peer on-line tutors/mentors/guides?
- What is CS PCK (pedagogical content knowledge)?
- Existing MOOCs to date are incredibly not diverse. CS already has a massive lack of diversity. How can diversity be supported?
- What needs to change to increase retention and completion online. Is it the modularity? Should MOOCs be a week long? What about degree programs?

A.6.11 Human-Computer Interaction

Participants: Ben Bederson (Lead), Dan Butin (Scribe), Beki Grinter, Janet Kolodner, Beth Mynatt, Loren Terveen

HCI offers a perspective on many of the other topics:

- User experience design ⇒ learner experience design
- Motivation & participation
- Ethics & diversity
- Range of participants (learner, teacher, coach)

Motivating questions: How do we develop dynamic assessment within online and hybrid formats? How do we develop learning models that represent what learners know, along with when and how knowledge was learned? How can algorithms identify pedagogy that worked best for each individual? How do we address the communicative interaction between learner and software, and use multimedia to switch modalities as appropriate? How can intelligent ambient environments reason about student cognition? What interfaces best support collaborative learning, both collocated and at a distance, both synchronous and asynchronous?

A.6.12 Games & Gamification

Participants: Tiffany Barnes (Lead), James Lester, Vincent Aleven, Scott Rixner, Bev Woolf, Dan Hickey, Jihie Kim, Marcia Linn, Win Burleson

Research questions

- How do we integrate good assessment with games? In multiplayer?
- How can we create games that encourage connections between learning/life?
- How do we merge good pedagogy (e.g. reflection) with good games?
- How can we support teachers to use games? What is the role of the game and the teacher? How do we integrate games with learning/classes?
- How can we integrate automated feedback?
- What are the key features of game reward structures, or other ways that engage & motivate?
- How can we balance just in time with just in case learning?

Recommendations

- Help players and teachers see/understand game performance
- Design in/out of game experiences
- Design for alignment between game and the learning task(s)
- Look for ways to support collaboration in games

A.6.13 Crowdsourcing of assessment

Participants: Tiffany Barnes, Emma Brunskill, Dan Garcia, Jack Mostow, Jon Huang, Jeff Bigham, Chris Makler, Dan Butin, Mark Wilson, Loren Terveen, Lee Zia, Jeff Forbes, Armando Fox

- How can we promote learning by assessors? What resources do assessors need to learn the content better, and to be better assessors?
- What are effective incentive models for crowdsourcing of assessment? (required, paid, volunteer, etc)
- How do we best match assessors with assessees?
- How should crowdsourcing of assessment change based on its purpose? (e.g. for credentials, formative feedback) ?
- What are desirable relations among the assessment task, the knowledge and skills of the assessor, the knowledge and skills of the assessee, what they know about each other... and the purpose of the assessment?
- How do characteristics of people influence assessments? How can we make crowdsourced assessments personal (as opposed to impersonal)?
- How can you psychometrically evaluate crowdsourced assessment?
- How and when should we combine types of feedback: automated, expert, reputed, and general crowdsourced?
- How can we best combine effective models for crowdsourcing with effective models for assessment?
- How can we facilitate sharing of content and assessment across classes/domains? (e.g. one class uses assignments from another)

A.6.14 MOOCets (K-6) & MOOCoids (65+)

Participants: David Klahr, Doug Fisher

- Core idea1: MOOCs for populations outside the conventional "target audience age range"
    - Kids & Elders: in the tails of the distribution of:
        - technical access & competence
            - research needed for characterizing current and future state of digital divide for these populations
        - motivation and learning goals
        - attractive and enabling technologies (affordances) vary
            - educational games; (e.g. merge MOOC and MMOG concepts)
            - school based and out-of-school
- Core idea2: cross generational access to learning (GPs and GKs)
- Core idea3: Move "Commons" of material (Sesame Street) to MOOC for instruction & assessment (Teacher: how much do my students know?)
- comfort of a common anchor (Mr. Rogers, Sheriff John, ... Khan Academy) across curriculum
- synergies: interacting with objects, ad hoc technologies, culture,...

A.6.15 Blended/flipped classrooms

Participants: Beth Simon, Scott Klemmer, Lance Fortnow, Gautam Biswas, Lee Giles, Anoop

Gupta, Scott Rixner, Fred Martin, Vincent Aleven

Definition: Basic information is acquired outside of classroom; classroom used to achieve deep learning

- Before class: Video lecture with quizzes, MC questions
- In class: Small group discussion spurred e.g. by carefully crafted MC questions or small projects (active learning)
- Fit with MOOCs: Watch Coursera course at home, discuss in class

Big question: how to help people get started; not whether to have flipped classrooms

Research Questions

- How do we make the every day instructor awesome?
- What are the key ingredients for blended learning?
- Do blended courses lead to better learning (e.g., transfer, retention, preparation for future learning)?
- How do we do experiments when technologies and attitudes are changing every year?
- What is the unique value of physical presence? Can the flipped classroom experience be converted to an online experience.

A.6.16 Communities of Learners

Participants: Cindy Hmelo-Silver (Lead), Carolyn Rosé (Lead), Sharon Derry, Dan Hickey, Anita Jones, Jihie Kim, Beverly Woolf, Trey Lathe, Norma Ming, Glynda Hull

Research Questions

- **Conceptualization:** Is community even the right way of conceptualizing the social spaces we're talking about? What would an "online campus" mean? What needs would that campus community meet?
    - Are we deeply leveraging the Communities of Practice theory/ model?
    - Contextual issues: domain structure, time, scale, and age
- **Understanding:** How do we analyze emergent structure in communities? What novel computational techniques will be capable of this? What data do we need -- how many courses, over what time span? How long does it take community to form?
- **Function:**
    - What roles do we need to pay attention to and support? What are roles at the community level (outside of a single course), and what is their function? Whose job is it to foster community?
    - How can we turn dysfunction into learning opportunities? What does dysfunction look like? What about cultural differences in expected behavior?
    - What would motivate people to participate and contribute? Extending the literature on commitment and contribution to online communities? (Kraut and Resnick)

Research Agenda

- Build a theoretical framework with clear dimensions that facilitates understanding and

prompts effective development
    - Fostering/ Supporting
    - Assessing
    - Providing information for researchers/ teachers
- Build supportive technologies, e.g.,:
    - Develop new kinds of dashboards: what do we need to know about/report individual, group, and subcommunity norms and behavior?
    - Develop technology for expertise tracking: matching help needers with help providers, extending student modeling technology so that it models the ability of students to function in participant roles in addition to modeling their progress achieving course learning objectives

A.6.17 Alternatives to MOOCs

Participants: Mary Lou Maher (Lead), Irene Greif (Lead), … this was a very large group and other participants were not recorded

(also see the online workshop addendum at reference [0] for more complete write-up)

Research to understand MOOCs:

- Models: What are the many models for MOOCs (Coursera only being one): Open University, cMOOCs, xMOOCs, EDx, Kahn Academy, Udacity, Active Worlds
- Benefits: What do we want to preserve from MOOCs? curiosity-driven learning, massive, single course, learning on demand, self-directed learning, online community

Research towards new models:

- Scale: What do we want to scale? teachers, courses, diversity of learners. What are the economics of scale for developing and distributing online learning? comparing intelligent tutoring to professors to crowdsourcing peer learning
- Technology: Can we achieve massive beyond high bandwidth online to reach low tech students?
- Learning: Design models for education systems that break down educational elitism: break down conventional course/degree boundaries, break down expectations about completion/credentials
- Populations and Culture: What research is needed to reach those people not served by existing MOOCs? What are the characteristics of MOOC participants and who is not using MOOCs? How can we adapt online learning environments to specific situations of underserved learners, specific situations, different cultures, parent-child learning? Design models for learning environments so students can tell different stories to satisfy the different constituencies that are important to them.

Online Appendix B: Detailed Breakout Reports

Appendix B contains expanded summaries of individual breakout sessions, typically prepared by the breakout leader and/or scribe; these writeups may also go beyond the discussion in the breakout itself. Summaries given here also go well beyond the brief summaries that were printed in the final report (and found online at http://…). Importantly, expanded summaries can be added in the future, and "republished" here.

B.1 Personalizing Education: Roles of Computing (TBD)
B.2 Assessment of Student Learning (TBD)

B.3 Supporting Social Learning

Expanded summary prepared by Carolyn Rose with input from participants

Leader/Scribe Team: Carolyn P. Rosé and Cindy Hmelo-Silver

Other Participants: Sharon Derry, Dan Hickey, Anita Jones, Jihie Kim, Beverly Woolf, Trey Lathe, Norma Ming, Glynda Hull, June Ahn, Ben Bederson, Karen Brennan, Derek Bruff, Amy Collier, Irene Greif, Beth Mynatt, Gerry Stahl, John Cherniavsky

The Social Learning breakout sessions focused on the related issues of designing a social environment that is conducive to group learning as well as teaching social skills that are key for productive participation in online learning communities. Through the discussions, five theme areas were identified for work going forward, including Conceptualization, Participation, Design, Science and Methodology, and finally Technology and Development.

Conceptualization

While much focus has been given to MOOCs as being at the frontier of the world of online learning, and while it is not hard to imagine that we are on the cusp of transformation, the discussion in our breakout sessions was aimed at shaking us out of narrow focus on the MOOC as a paradigm for learning at scale. The first order of business at this time of transition is to build a theoretical framework to organize our research going forward. Taking a step back, the question was raised as to whether it is even valid to conceptualize the kinds of learning spaces we are envisioning as communities. As part of our conceptualization work, we should consider what an "online campus" could mean and what needs such spaces should aim to meet. If we accept community as a conceptualization, to what extent can the Communities of Practice theories and models challenge our current conceptions about massive scale online learning? Does that existing theoretical framework shed light on related conceptions of disciplinary norms, community persistence, and longevity of participation at a massive scale?

Beyond the foundation laid in our own disciplines of learning sciences, instructional technology, e-learning, and computer supported collaborative learning, we should not neglect to leverage related research from neighboring areas that might speak to the new issues and problems we are facing. For example, research from the field of Computer Supported Cooperative Work might be leveraged. In particular, we should consider how best practices in design from existing online communities transfer into massive online learning contexts as well as what questions are left unanswered because of differences between the kinds of environments that have more frequently been the focus of that research community's work. As a specific example, research in the area of Crowdsourcing might have valuable insights for our work. For example, how can we balance concerns about community endeavors (getting work done in community, e.g., answering questions) with supporting the kinds of rich interactions that are conducive to and promote learning? Ultimately, what we need to do is create a theoretical framework, framed by these concerns, and guided by clear dimensions that facilitates understanding and prompts effective development of a new generation of learning communities. These dimensions include Fostering and Supporting participation and learning, Assessing learning, and Providing data and insights for research on learning at scale.

Participation

At the heart of learning at massive scale is the key component of human participation. At a basic level, we must consider what participation in these learning environments of the future might look like. Part of the work under this scope includes identification of key roles within our target learning spaces. For each role, we must identify the responsibilities and behaviors associated with that role. For example, whose job is it to foster community? The instructor? Experienced students? Trained facilitators? Conversely, we must consider what is challenging about each role and what support needs might be associated with them. Furthermore, how are members socialized into roles? Do roles persist, or are members promoted from more junior roles to more senior roles? Are there gatekeepers? Work on roles has typically focused on roles within single environments. However, as well look to ecologies of related learning communities, for example multiple courses offered by the same organization, new questions are raised about contrasts between roles that are specific to single communities versus roles than exist across communities. Is there a need for thinking about cross-community roles? Whose job is it to create connections across courses? What would motivate people to participate and contribute? Extending the literature on commitment and contribution to online communities? (Kraut and Resnick, 2012)

As we consider important questions related to support needs, we must consider that communities are made up of individuals that bring with them both assets and dysfunction. We have already observed the harmful effects of anti-social behavior in existing massive scale online communities. Some issues might simply amount to differences in expectations and norms between cultural groups. Antisocial behavior degrades the quality of the environment for others. However, if we put a positive spin on it, we can take the existence of such behavior as a research challenge and seek to turn dysfunction into learning opportunities (or at least contain it so that it is not harmful to others). What does dysfunction look like (how can we operationalize it so it can be detected)?

Design

Building on an effective conceptualization and an understanding of what participation should and should not look like, the challenge of designing environments with appropriate affordances is the next order of business. In particular, the discussion about design focused on the challenge that instructor time is likely to be scarce. Thus, consideration of what alternatives might provide alternative facilitation was discussed. The issue of scale itself creates new challenges. How can we design a communication medium that can adjust to different scales of participation so can accommodate whole community wide discussion, but it can also provide the opportunity for small groups or subcommunities to form and thrive as smaller cohorts within that larger environment?

Science/Methodology

Some of the most exciting opportunities that come with learning at a massive scale include the research opportunities. Thinking about the example of the MOOCs, the unique developmental history of MOOCs creates challenges that require insight into the inner-workings of massive scale social interaction in order to meet. In particular, rather than evolving gradually as better understood forms of online communities, MOOCs spring up overnight and then expand in waves as new cohorts of students arrive from week to week to begin the course. As massive communities of strangers that lack shared practices that would enable them to form supportive bonds of interaction, these communities grow in an unruly manner. Early attempts to organize the community into smaller study groups may be thwarted by such periodic growth spurts paired with attrition, as groups that initially had an appropriate critical mass soon fall below that level and then are unable to support the needs of remaining students. Questions arise such as: How long does it take community to form? Does it form both within and across courses?
How do we analyze emergent structure in communities as we seek to address such issues and questions? What novel computational techniques and analytic lenses of other types will be capable of this? What data do we need -- how many courses, over what time span?

Technology/Development

Ultimately, our research will lead us to development of new environments, which entails development of new technology. An overarching goal is development of a communication medium that can accommodate emerging community/subcommunity structure -- supporting the formation and sustenance of cohorts. A key order of business will be development of supportive technologies including: Development of new kinds of dashboards that display what instructors, facilitators, and research need to know about individuals, groups, and subcommunities as they form and function; Development of technology for expertise tracking, for example, matching help needers with help providers and extending student modeling technology so that it models the ability of students to function productively in groups; and finally, development of computational techniques for monitoring and supporting norm formation and socialization. One potential direction is development of infrastructure for socialization of “online learning survival skills”. Perhaps a MOOC to prepare people for MOOC based education or affordances for socializing civility. All of this will be facilitated by platform/tool development that streamlines creation of affordances for visualization, access, and navigation of community resources and facilitates building large-scale, collaborative, educational applications.

B.4 Machine Learning and Data Mining

Expanded summary prepared by Jack Mostow with input from participants

Leader: Jack Mostow *Scribe:* Amy Collier

Participants: Marianne Bakia, Gautam Biswas, Amy Collier, Lee Giles, Edith Gummer, Jonathan Huang, Jihie Kim, Chris Makler, Jack Mostow, Mack Olson, Roy Pea, Carolyn Rosé, Loren Terveen, Mark Wilson

Description of the Area

Machine learning and data mining input data from such sources as test scores and tutor logs and produce more general information such as assessments of student learning, evaluations of tutor efficacy, and prescriptions for how to improve it. As these transformation processes progress from scouring the data to developing and applying theories of it, they progress in open-endedness from clustering student behaviors into empirical patterns or discovering predictive associations in the data, to estimating the parameters of a given model or training classifiers to predict membership in known categories. How do we use educational data mining and machine learning to effectively store, make available and analyze data for different purposes? How do we ensure security and privacy of student data? How do we address the deluge of data, and the deluge of new data mining and database techniques? Who are the potential consumers of this data, e.g., how can data be distilled for assessment content so it is useful for each stakeholder? How will application imperatives, such as automated grading of complex student inputs, inform new algorithms for data mining of like complex structures? How can machine learning of student models be used to bring students together in like or otherwise complementary learning cohorts?

Research and Engineering Questions and Challenges

Filling sensory, representational, and semantic gaps:

The input data has many gaps relative to the desired output. *Sensory gaps* in data about the student reflect its limited modalities, typically keyboard and mouse. *Representational* gaps reflect the difference between low-level machine-observable events and higher-level human-interpretable phenomena. *Semantic gaps* reflect gaps between observed information and its inferred implications about the student.

1. Given low-level multimodal streams of diverse types, how can we discover educationally significant events and features such as engagement, disengagement, learning, complex problem solving, skills, gaming, cheating, etc.? We are not always interested in the patterns that occur frequently; we need to focus on what indicates or influences meaningful learning.
2. What tools can synchronize diverse educational data streams and help us make sense of them?
3. How can ML/EDM span the representational mismatch of logs collected by various learning systems?
4. To make sense of multiple streams differing in density and signal type, what forms and content of world knowledge can machine learning exploit about students, domain content, context, learning, instruction, social networks, etc., and how?
5. How can machine learning create new representations of content areas, modularizing and organizing course material into reusable objects, and recommending them in a manner tailored to students' individual needs?
6. How can we make sense of complex assignments to develop or generate rich feedback on them?
7. How can we analyze and evaluate rich multimodal data at scale?

What makes online data fruitful to mine:

1. How can we design or transform online learning to log data from which we can usefully learn? We're not sure what is the one behavior we are trying to support; we are not even sure what are the data we want to collect and analyze. As EDM people, we may not be aware of the breadth of questions from the learning side; from the content side,

we may not be aware of what’s possible on the technical side.
2. What automation can support this design or transformation process?

Human-machine division of labor:

1. How can online educational platforms scalably assess learning, annotate student output (such as the massive numbers of submitted assignments in MOOCs), evaluate instruction, or teach better by combining machine learning with human computation such as peer input, referral, and crowdsourcing?
2. What division of labor between human labor and machine processes can provide trusted assessments of student learning?
3. What division of labor can create a loop of efficiency and effectiveness between the human and machine?
4. What division of labor between human and machine can manage the tension between effort and quality?
5. What are powerful new ways to combine human computational power and machine-based computational power?
6. What API for learning machines would output the best stream to provide insights to humans?

Relevant References

1. Mostow, J., & Beck, J. E. (2006). Some useful tactics to modify, map, and mine data from intelligent tutors. *Natural Language Engineering (Special Issue on Educational Applications), 12*(2), 195-208.
2. Romero, C., Ventura, S., Pechenizkiy, M., & Baker, R. S. J. d. (Eds.). (2010). *Handbook of Educational Data Mining*. Boca Raton, Florida: Chapman & Hall/CRC Press.

B.5 Formal and Informal Learning

Expanded summary prepared by Marie Bienkowski with input from participants

Leader: Marie Bienkowski *Scribe:* Brian Butler

Participants: Gautam Biswas, Gerhard Fischer, Jonathan Huang, Dorothy Jones-Davis, Taylor Martin, Roy Pea, Jenny Preece

Description of the Area

This breakout group considered the role of computing in supporting formal and informal learning, especially possible bridges between the two settings. After some discussion about the definitions of formal versus informal, the group agreed that framework by the NSF-funded LIFE Center (URL) provided a useful characterization of the formal/informal space beyond characterization of one as “in school” and the other as “out of school.” The table below, expanded from LIFE Center materials provided by working group participant Roy Pea, describes two important dimensions for characterizing the difference.

Framework: Complexity and nuances of informal and		

formal learning connections		
	Formal Settings	**Informal Settings**
Formal Learning Processes	Designed or planned learning opportunities with curricula in school (e.g., math lessons and assignments) · Little choice and few opportunities for agency · Assessment is integral · Roles (teacher/learner) are assigned and there is awareness of being part of a "learning environment"	Explicitly structured and guided with designed artifacts, environmental features (after-school club, sport) · Choice and agency are at medium levels · Assessment is possible but not systematic · Roles (coach/learner) are assigned but potentially fluid
Informal Learning Processes	Outside of the curriculum: Emergent learning of social or cognitive content (e.g., leadership, gender roles, friendship) · More opportunities for agency · Rarely assessed · Roles are outside of awareness	Spontaneous and improvised, self-organizing (e.g., adolescent gaming friends) · Choice and agency are high · Difficult to assess; can seem "frivolous" to academic pursuits · Roles are emergent and fluid

We also identified characteristics or dimensions of learners that we thought it important for the field to research. These are as follows:

· Embedded Learner...with mediated experiences that flow among settings, and reveal what happens in informal settings

· Social/Collaborative Learner...with shifting roles from teacher to learner, from consumer to prosumer, etc.

· Creative Learner...how does learning the facts differ from creating, designing, making, doing?

· Activated Learner...how does technology help with developing agency and self-regulated learning?

Further reading on formal and informal environments can be found in reports from the National Research Council (see References). Support for research in informal environments is provided by the NSF-supported resource center at informalscience.org.

Research and engineering questions and challenges that the group identified

The following are research questions and challenges the group discussed. Because the group did not discuss priorities, they are listed in alphabetical order so as not to privilege one idea over another.

· **Activating Engagement with STEM.** What role do informal experiences have on interest in STEM? Connecting informal and formal learning is hypothesized to increase the diversity of people represented in the STEM pipeline. What are big data techniques that can examine this hypothesis? What are the mechanisms and technologies that can promote or hinder movement into and through the STEM education pipeline?

· **Adaptivity and Continuous Improvement**. How can learning analytics be used to adaptively alter the user experience (in real time) and also (at longer timescales) to improve online learning environments? Do learning analytic techniques apply when the learning opportunities are unstructured and emergent?

· **Connecting Formal and Informal.** How are informal and formal learning processes and contexts connected for learners? Learning in and across these contexts should appear seamless, so what can computer science (perhaps through virtual personal assistants) do to support connected learning? Can mobile technologies for situational awareness (e.g., GPS) support seamless learning?

· **Enriched Online Learning.** How can we enrich online learning, perhaps through the use of educational data mining and learning analytics, with pedagogical models such as "learning by argumentation," "cognitive apprenticeships" or "learning as reflective conversations with materials" or to support reflection, introspection, and the like?

· **Learner Modeling.** Can we develop (learner) models to predict *when* learners will benefit from specific pedagogies and content and thereby create adaptive tools for personalized learning? Can technology support just-in-time learning?

· **Noncognitive Factors.** What role do so-called noncognitive factors (e.g., persistence, grit, academic mindset, conscientiousness) play across settings and across timescales? How can computer science and computer engineering help collect data to research and measure such factors, especially in informal settings?

· **Open Learner Models.** What human-computer interaction techniques and technologies can help learners, teachers and parents when they confront learning/affective data? What data literacies are required for thinking with data for oneself and for others?

· **Participation in the Digital Commons.** How can we create broad learning communities (including for adult learners) that offer shared experience and resources through a technology-supported digital learning commons? How do we create a culture of participation? What technologies, techniques, and practices are necessary to support co-production and prosumer behavior? How can creativity be supported?

· **Research in a Big Data World.** What are effective techniques for blending qualitative and quantitative data and methods in a big data world? How can computer science help with data collection, analysis, and visualization? Where does computer science meet ethnography?

· **Role of Teachers.** What are the evolving roles for teachers in the new digital learning world? How do they negotiate the recommended resources and learning pathways put forth by analytics-based systems? How can these automated systems be blended with open learner models and teacher input? What are good models of teaching in online or blended environments?

· **Social Roles in Collaborative Environments.** Should technology reflect roles or should they be found or negotiated? What platforms support the co-construction of useful roles and which impede emergent roles? Can technology support people shifting among roles? What supports can help learners adopt teaching roles (e.g., peer graders in MOOCs).

· **The Internet of Things.** What new roles can multiple sensors play in establishing the learner's context? What happens when we have time-stamped and socially proximal streams of data? Are there signals of social context in big data, from individual level data? What can we do with data that is aligned in time to detect what social roles are active and important. Can we use

backend data to show the importance of informal learning processes?
· **Technology as Mediator.** How do you achieve or implement mediation of social roles and information access in large-scale learning environments? What are new mediational artifacts? Alternative mediation strategies? How can learning structures be created to overcome inequity?

Relevant papers for interested readers

1. Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits*. National Academies Press.
2. Bevan, B., Dillon, J., Hein, G. E., Macdonald, M., Michalchik, V., Miller, D., & Yoon, S. (2010). Making science matter: Collaborations between informal science education organizations and schools. *A CAISE Inquiry group report. Washington, DC: Center for advancement of informal science education (CAISE)*.
3. U.S. Department of Education. (2010). National Education Technology Plan. http://www.ed.gov/technology/netp-2010.
4. U.S. Department of Education. (2012). *Enhancing teaching and learning through educational data mining and learning analytics*. Washington, DC: U.S. Department of Education. www.ed.gov/edblogs/technology/files/ 2012/03/edm-la-brief.pdf
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6. U.S. Department of Education. (Under Review). *Promoting grit, tenacity, and perseverance: Critical factors for success in the 21st century*. Washington, DC: U.S. Department of Education. www.ed.gov/edblogs/technology/files/ 2013/02/Expanding-Evidence-Approaches.pdf

B.6 Pedagogical Needs and Constraints of Various Domain Areas
B.7 Interacting with Objects
B.8 Social Computing & Networking
B.9 Long-term implications of online learning for cultural interactions
B.10 Implications for Computer Science Education
B.11 Human-Computer Interaction
B.12 Games & Gamification
B.13 Crowdsourcing of assessment
B.14 MOOCets (K-6) & MOOCoids (65+)
B.15 Blended/flipped classrooms
B.16 Communities of Learners

B.17 Alternatives to MOOCs

Expanded summary prepared by Irene Greif and Mary Lou Maher with input from participants

The breakout group discussed three major research topics that are critical to the development of alternatives to MOOCS: what research is needed to understand existing models for MOOCS, what research is needed to identify new models for MOOE. The group then brainstormed to identify a list of alternative models for MOOE and the research needed to achieve these new models.

Research to understand MOOCs:

a. **Models**: What are the many models for MOOCs where Coursera is only one model, and others include Open University, cMOOCs, xMOOCs, EDx, Kahn Academy, Udacity, and Active Worlds.
b. **Benefits**: What do we want to preserve from MOOCs as we develop better technology support for learning and alternative models for MOOE? These include: support for curiosity-driven learning since there are no prerequisites or credentials needed to sign up for a MOOC, the very large numbers of students that can enrol in a single course, the ability to take a single course without committing to an entire curriculum, the ability to start and stop as needed supporting learning on demand, the benefit of self-directed learning, and the creation of online learning communities.
c. **Problems**: What are the problems with current MOOCs? For example, how well is learning scaling up, is the large drop out rate a problem or an artifact of the large numbers and availability, are learning communities forming effectively or are people feeling left out, is the emphasis on lectures working well?
d. **Populations and Culture**: What populations and cultures are currently served by existing MOOCs? What research is needed to reach those people not served by existing MOOCs? What are the characteristics of MOOC participants and who is not using MOOCs? How can we adapt online learning environments to specific situations of underserved learners, specific situations, different cultures, parent-child learning? What research is needed to design models for learning environments so students can tell different stories to satisfy the different constituencies that are important to them.

Research towards new models:

a. **Scale**: When talking about MOOCs and the future for MOOE, we agree that the ability to scale up is important. Research is needed to explore the idea of scale: What do we want to scale? For example, do we want to scale up the number of teachers, courses, the diversity of learners, the number of student per teacher, the number of teachers per student? What are the economies of scale for developing and distributing online learning, how can scale lead to lower cost education? When scaling up, can we then compare the effectiveness of the use of AI in intelligent tutoring, the role of human professors, and the impact of crowdsourcing peer learning?
b. **Technology**: What technological developments are needed to achieve vary large online courses that can reach students with limited bandwidth and relatively low level technology access?
c. **Learning**: Research is needed to design models for MOOE that break down educational elitism: for example, what is the effect of breaking down conventional course/degree boundaries, or breaking down expectations about completion/credentials.

Alternative models

The group discussed a number of alternative models for MOOE:

Distributed community-based MOOE: What are ways the MOOE can be delivered online but also include communities that are co-located. One example of this is the Stanford comparative democracy class taught using a MOOC but with community-based learning centers located globally, in which people meet locally for discussion and local context. Planning for this from the outset makes it a different model. Another example is an online "course" on nutrition, that is community-based with a goal of improving understanding of healthy eating and promoting healthy eating within a community. This course draws on local chefs with interest in the community, and is delivered in a hybrid of online technology and in person.

Cause-based MOOE: This is a variant of a community-based MOOE, since the community-based classes are often cause-based. But by explicitly stating that the basis of the course is to promote or address a specific cause, might suggest additional mechanisms that should be put in place, to link up the educators with the cause as they shape lesson plans, in addition to supporting teams of students who work on projects for a cause. One example of this is Design for America, in which a university signs up to have students participate in local community-based design projects. The university also reaches out to alumni to fund the program. Another example is a project at IBM called "software for a cause" that had multiple goals: teach college students what it is like to work in the real work in distributed development teams; do that in context of real-world problems to solve; get the problem definition from non-profits organizations in need of software assistance, so that the teams are doing good in the world.

Distributed flipped MOOE: This model is one where a set of professors from different locations would provide content that would be read/viewed ahead of time, and then class time would be on problems (hence the flipped part.) There are some variations on this that might be worth considering: actually getting distributed discussion? having video from students for mini-lectures (presentations?).

Follow the sun MOOE: This model implies that the MOOE is active at different times in different time zones. This model has hve some material live but recorded for shifted time zone matching and have live discussion in that local time zone. This approach could track ideas as they go around the globe and see how they come back.

Guild-based MOOE: This model is about peer learning in an online community around a specific skill or guild. For example, ravelry.com supports people that want to learn to knit as well as experienced knitters. People can keep track of their own projects, along with many others. The projects are available to others to provide tips and corrections and advice and connections with Youtube instructions and written materials online.

Remedial learning MOOE: A target audience for MOOE is students in need of remedial courses, for eample for summer sessions. How can MOOEs provide technology to get students the extra help they need at the time they need it?

Parental involvement in MOOE: If home life is a key predictor of success in school, and, if it may not be too late to educate people past the k-12 years, are there new models of MOOE that involve both parents and students? They might learn different versions of the same things, or just partner on projects. Or teach parents to be tutors to their kinds.

The research opportunities abound, as any one of these models certainly has some applicability. We should be funding research efforts that will find a good population for each model that will drive design. The research needed for new models consists of design, deployment, study -- both user studies and analtyics on the data amassed. The world needs a diversity of models, and the most promising should be investigated and refined in parallel. Technology transfer would follow by taking most successful experiments to the entities that would sponsor that particular form of education: school districts, universities, businesses.

Online Appendix C: Additional Discussion

Appendix C includes additional (often the newest) references and discussion in the areas relevant to the workshop. We welcome community contributions to the online addendum, particularly to appendix C.

Modeling and simulation

We believe that *simulation and modeling* will play an increasingly important role in online education at scale, perhaps with challenges to maintain substantial openness given the computational costs of many simulations. While we discussed online games, a highly interactive and typically social simulation, and online labs in the printed report, attention to more general issues of modeling and simulation could be better represented.

Simulation and the exploitation/exploration tradeoff

Simulation has been used in industry training (e.g., flight school) and medicine (http://www.newyorker.com/archive/2005/05/02/050502fa_fact). Interestingly, in these cases the simulator is a cyber-physical system, with a software aspect that encodes physics or biology of the environment and task, as well as a physical component (e.g., a cockpit, a robotic mannequin) through which students interact with the simulation. This physical aspect of the system could be a bottleneck that would limit openness and scale-up in numbers, for at least certain learning activities, but the computational costs of many simulations, particularly where high-fidelity audio-visual is desired, will challenge openness and scale-up too. In this latter regard, however, simulations in the cloud, a special case of the larger software as a service (SaaS) paradigm, may mitigate equity of access concerns (e.g., https://www.asme.org/engineering-topics/articles/computer-aided-design-(cad)/every-simulation-has-a-cloud, http://www.scs.org/magazines/2010-07/index_file/Files/article_Fujimoto.pdf).

The pedagogical benefits of simulation in selected fields, however, is undeniable. Students who have learned on simulations may be (appropriately) more confident when performing in the real world, for example, in surgeries and in flight, reducing both the time of the performance activity and other aspects of its quality. More generally, can we understand the use of simulations as a way of "optimizing" a ubiquitous tradeoff within the learner between exploiting what the learner knows already, and exploring new territory that will benefit later competence? Simulation enables safer exploration, with exploitation would be dominant in the real world.

Also of pedagogical benefit is the fact that learners can explore to arbitrary depth, at least to the extent that the simulation will allow, the consequences of a course of action. This motivated an observation in the main report that we'd all like our doctors to have made mistakes, just not on us! Research in this area looks at optimal spacing and types of hints in an attent to effectively tradeoff keeping a learner on course, without being so prescriptive so as to prevent the learner from acquiring generalizable knowledge. Scaleup may depend on availability smart artificial tutors for individual students or groups of students. Can methods of crowdsourcing and peer assessment be adapted to the problem of providing "optimal" guidance to learners?

Social simulations

In addition to simulated physical environments, education in the social, economic, and behavioral sciences can also benefit from simulations and models.

The "beer game" is a specific example of an educational social simulation, also interested in improving the product of an exploitation/exploration tradeoff. The bear game is a manufacturing simulation (http://web.mit.edu/jsterman/www/SDG/beergame.html), allowing learners to explore different policies for maufacture through retailing of beer, or any other product. The game can be played with low bandwidth, on primitive hardware with minimal visualization capability. Nonetheless, the game allows an environment with hundreds, if not thousands of participants, all able to explore safely to learn and practice management policy. The Redistricting Game is another educationally-interesting simulation with low computational requirements, particularly client side. Even simulations of the physical world, there are likely to be questions of representations and visualizations that are minimalist, while still being compelling.

What are the computing research possibilities in teh area of social simulations? These social settings may involve involve multi-agent simulations, which usually assume relatively "shallow" representations of individual agents, but there is no reason that research combining multi-agent systems with cognitive architectures, could not produce richer social simulations.

Another area of research would be exploring the roles for cyber-mentors, implemented in the guise of companion avatars or embedded ambient intelligences, which would provide hints, constraints, problem ordering, dynamic assessment, and other guidance in pursuit of effective exploration and exploitation, and ultimately learning

Online labs

Online laboratories are being proposed and implemented in a variety of fields, to include biology, chemistry, biology, and geology (e.g., http://www.acs.org/content/acs/en/education/students/highschool/chemistryclubs/activities/chemclub-update-virtual-chemistry-simulations.html ; http://www.onlinechemlabs.com/; http://www.biologylabsonline.com/). In some cases virtual labs are intended to augment physical labs (e.g., for science majors), and in some cases to replace them (e.g., for non-science majors).

Evidence suggests that online labs lack the educational impact of real labs (http://jolt.merlot.org/vol3no2/stuckey.pdf https://www.nabt.org/websites/institution/File/pdfs/publications/abt/2006/068-09-0023.pdf; http://www.insidehighered.com/news/2013/05/23/cal-state-may-turn-virtual-labs). To what extent will higher-fidelity virtual experience through improved simulations and modeling diminish the differences? Why is it that simulations in other settings, and in the prior section, result in improved educational outcomes, whereas with online labs, improvements may not be seen? Do differences in student outcomes result because in some settings simulations are followed up by experiences in the real world, and in other settings there is no real-world followup? What are the broader societal implications of students “experiencing science” in simulation only?