Visions and Pathways: Online Learning and MOOCs

Stephen Downes

Abstract

This article traces the development of the massive open online course (MOOC) from its origins in online and distance learning technology. It identifies core elements of the distributed model of learning embraced by the first MOOCs and describes the technology supporting this model and the new types of learning the model enabled. Building on these ideas, it then explores the use of massive open online learning to support personal learning, enabling each individual to design and follow his or her own learning path. Some technologies leading in this direction are described and the potential for precision education is explored.

* * *

In the mid-1990s the transition from in-class learning to online learning was just beginning. At the time, and reasonably so, people expected learning online to look very much like it did offline. We would offer classes based on standard courses, these classes would contain resources and tests and assignments, and we would emulate the in-class experience with things like synchronous chat and discussion boards.

It was around that time as well that the first learning managements systems (LMS) began to appear. They were designed to facilitate this transition, and often began as a digital aide or assistant for in-class instructors. Hence, for example, one of the first LMSs was called WebCT – standing for Web Course *Tools* – as opposed to the idea (far-fetched at the time) of offering entire classes online. But that idea would mature quickly.

It was also around this time that design models for online courses began to emerge. These were based on models for distance education and on models for computer-based training (CBT) systems such as Plato, which was focused on the use of course packages, supported (sometimes) by in-person or telephone support. In Canada, for example, the *East-West Project Course Developer's Standards Guide*[1] described standard course components and design elements. Internationally learned from things like the Aviation Industry Computer-Based Training Committee (AICC) online course specifications.[2]

The dominant paradigm that emerged at the time was the *learning object*. This was defined by the IEEE as "any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning." [3] This standardized an idea already widely in use. Distance learning courses typically had their own self-contained modules, an idea we emulated in our own LMS project at Assiniboine Community College[4] (illustrated in Figure 1), and the dream was always to be able to create these once, share them, and reuse them in multiple courses. [5]

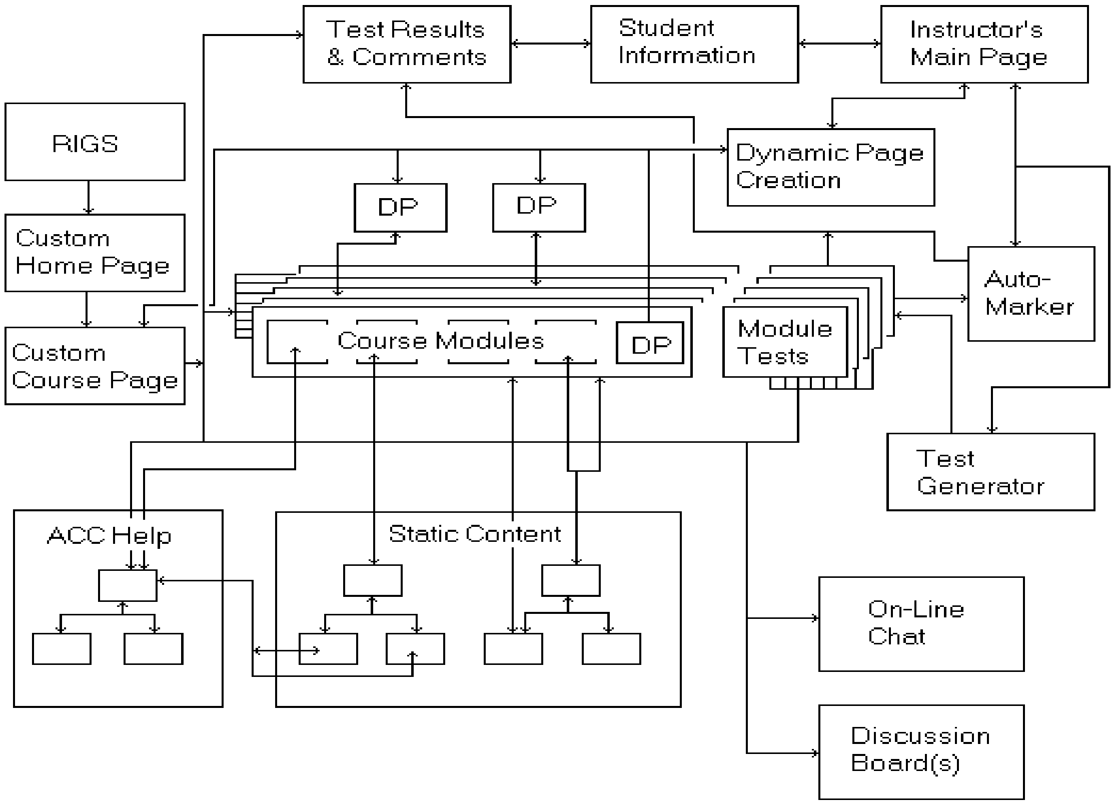

Figure 1. The Assiniboine Model. By the author.

As described, for example, by Wayne Hodgins, learning objects would be put together like Legos[6], smaller blocks of content that would be assembled into large learning resources like courses and programs. Or they might be, as David Wiley suggested, more like atoms that fit together in specific ways, depending on their nature.[7]

The core question regarding learning objects is whether the more important word in their definition was 'learning' or 'object'. Did it matter whether they were specifically *designed* to support learning? My own view at the time was that people should stop thinking of learning objects as though they were classes or lessons or some such thing with built-in intent. It is preferable to think of them as a greatly enhanced vocabulary that can be used in a multidimensional (as opposed to merely linear) language.

This is a difference between defining something accounting to its *nature*, or according to its *function*, between defining something accounting to *what it is*, or *how it's used*. Most of the educational community did and still does define educational resources by their nature, but my preference has always been to defined them by function. If it's *used* to support education, it is by that very fact an educational resource, whether it was designed for the purpose or not.

This becomes relevant when we look at the next step in educational technology, the Open Educational Resource (OER). These were defined by UNESCO in 2002 as "Open Educational Resources (OERs) are any type of educational materials that are in the public domain or introduced with an open license." [8] Numerous projects have sprung up over the years to support the development of OERs; the OER world map lists some 900 projects around the world dedicated to OER. [9]

The MOOC, which emerged just a few years later, in 2008, was designed to take advantage of the emergence of open educational resources. The employment of open online resources led directly to the coining of the acronym MOOC by Dave Cormier and Bryan Alexander. The MOOC is:

- 'Massive' by design – the first MOOC achieved 2200 registrations and its network design helped avoid bottlenecks and enabled scaling by mesh network mechanisms;

- 'Open' – both in the sense that anyone could sign up for it, and in the sense that it was composed entirely of open educational resources;

- 'Online' as in online – in contrast to later open online courses, the first MOOC did not require participation in person at a physical location, and while local events were encouraged, but the course was online;

- 'Course' (as opposed to community) – the course had a defined start and end date, and was about a certain topic, using the term 'course' in a traditional sense, as in 'a course of lectures'.

In addition to the core definition, the first MOOCs were designed with the intent of overcoming the limitations of the traditional LMS. Because these were designed to emulate traditional courses, they embraced an instructivist, or in some cases constructivist, pedagogy. That is, they were instructor-led and content-based. By contrast, the first MOOC was designed on a connectivist model. This model emphasized interaction over content, creating a course in the structure of a network, as opposed to a book or publication.

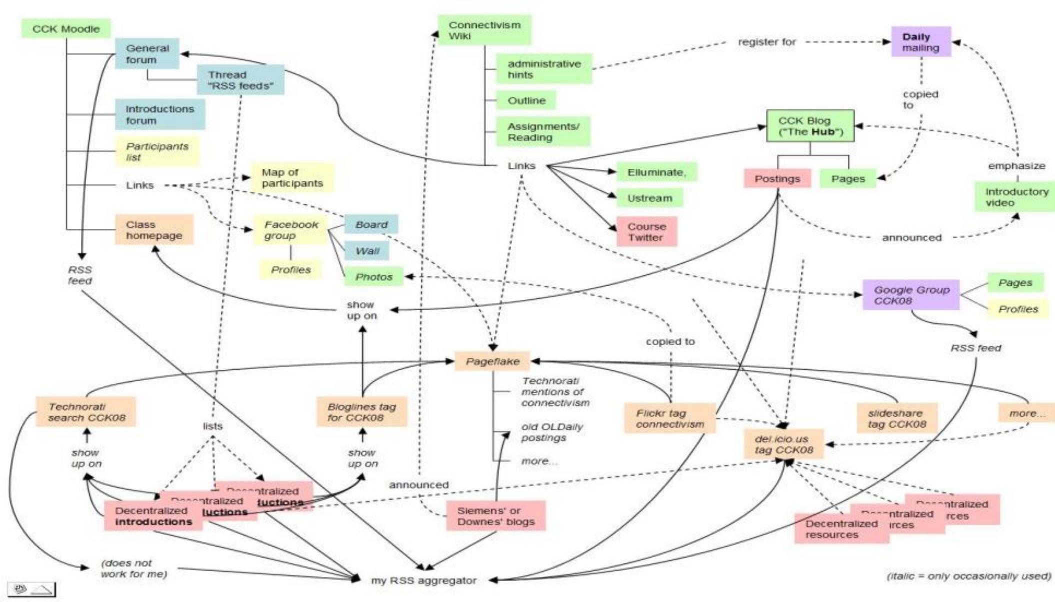

Figure 2. The Connectivist MOOC. By Matthias Melcher.

As mentioned above, the idea was to recreate the concept of the 'course of lectures' from the traditional university. Students are responsible for their own education, often forming communities or societies to collaborate. Students would bring in additional resources, contribute to the discussions, and over time, develop their own thoughts and theses. In the first MOOC[10] there were 2200 course registrations and 1800 people signed up for the course newsletter. This newsletter aggregated contributions from 170 separate websites created by course participants and distributed them daily to the subscribers. These contributions ranged from RSS feeds to Twitter posts to discussions conducted in Google Groups.

In the years that followed numerous MOOCs and MOOC providers emerged. The most significant of these was the Stanford AI MOOC. Launched in 2011, it attracted more than 130,000 students[11] and catapulted the concept of the MOOC into the mainstream. In 2012 the New York Times declared it 'the year of the MOOC'.[12] By 2017 more than 800 universities around the world had launched at least one MOOC, the total number of MOOCs that have been announced stands at 9,400, up from 6,850 the previous year, and about 78 million students were enrolled.[13]

The new MOOCs differed in several ways from the original MOOCs:

- The were much more content-based, and they depended mostly on pre-recorded videos for content

- Community functions were not supported, and what community did exist was confined to discussion boards on the centralized platform.

- The assignments were created centrally, marked automatically, and became the primary (and often only) means of assessment

- Though they started out as free, they quickly launched commercial platforms (in quick succession: Coursera and Udacity, from Stanford; EdX, from Harvard and MIT; and FutureLearn, from the Open University) and monetized the courses.

As a matter of terminology, the original network-based MOOCs were called the 'cMOOC' (with the 'c' standing for 'connectivist') which the new content-based MOOCXs were called the 'xMOOC' (with the 'x' not standing for anything in particular, but drawing on the nomenclature of 'MITx' and 'TEDx').[14] Over time, this division became more of a spectrum than a distinction, with each drawing on elements of the other, and with the emergence of the 'Task Based MOOC' such as Digital Storytelling 106 (DS106).

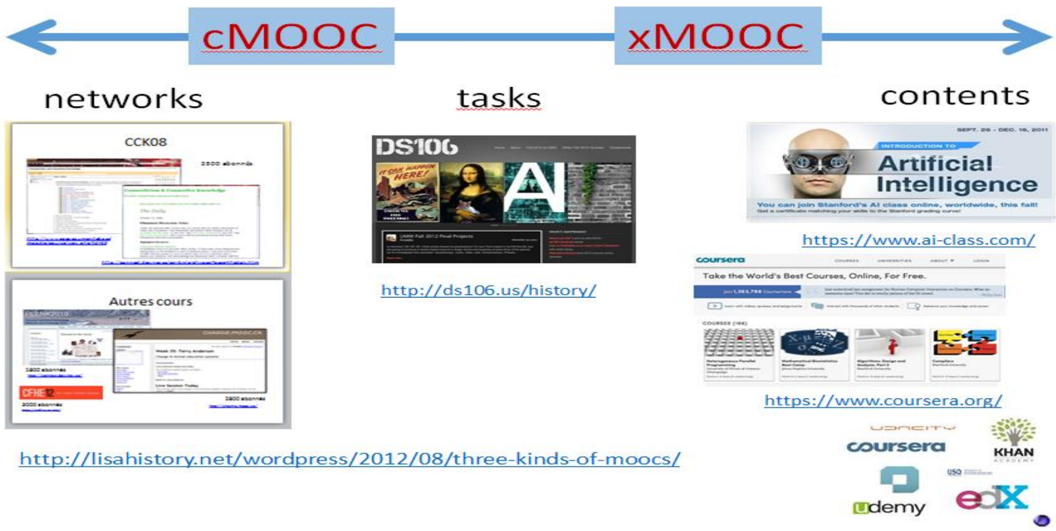

Figure 3. xMOOC and cMOOC. By Lisa M. Lane.

MOOCs today are classified using a variety of criteria, including pedagogical function, organizing principles, degrees of openness and collaboration, size and synchronicity.[15]

In the years since the development of MOOCs, the following three trends have attracted a lot of interest:

The first is learning analytics. This is the use of artificial intelligence to analyze the large volumes of data produced by the thousands of people enrolled in MOOCs.[16] The use of learning analytics can provide the following services as supports (as detailed by Siemens and Long[17]):

- Course-level support, such as the creation of learning trails describing paths users typically take through the materials, the use of social network analysis to identify classroom communities, and discourse analysis to evaluate sentiment and knowledge exchange;

- Educational data-mining, which includes predictive modeling of student success or failure, clustering of resources by topic or subject area, and pattern mining to find places in courses where students encounter difficulties;

- Intelligent curriculum, and specifically, semantically defined curricular resources, which enable course designers to define learning outcomes or desired competencies, and then select resources aligned to these objectives;

- Adaptive content, that is, the automated organization of course content sequence based on behavior, content recommendation engines, or individual or institutional priorities;

- Adaptive learning, that is, the management and creation of new social interactions through such things as automated friend recommendations and intelligent group formation, new learning activities including multi-role activities, and smart learner support.

The second related to competencies and skills. This approach represents a disaggregation of the traditional degree, breaking it into component parts. It also enables independent assessment of these parts, enabling alternative forms of credentialing.[18] As the New Media Consortium reports, "An overarching goal is to cultivate the pursuit of lifelong learning in all students and faculty. Institutions are beginning to experiment with flexible programs that provide credit for prior learning and competencies gained through employment, military, or extracurricular experiences."

The development of an infrastructure supporting the definition of competencies and skills remains a challenge. There is no single repository of competencies, nor even a single specification describing how they ought to be represented. Examples of competency description frameworks include the IMS Reusable Definition of Competency or Educational Objective[19], the IEEE Reusable Competency Definitions[20], and the HR-XML Competencies[21]. "The focus on the syntax of the data exchange and the lack of adequate semantic underpinning… have restricted the usefulness of the existing standards." [22]

More recently, the Advanced Distributed Learning (ADL) initiative in the United States has launched what they call the 'Competencies and Skills System'[23] initiative, part of a 'Total Learning Architecture (TLA)'. Part of the purpose of TLA is "to enable tools and systems to reference common competencies" in order to "report learner information in comparison to competency structures, and to align resources with competencies for recommendation." [24] The competency framework is referenced in a learner profile, which specifies degrees of proficiency in each of the competencies described.

The third relates to badges and blockchain. These two concepts may appear to be quite different, but in educational technology they bind together.

A 'badge' is a small digital credential awarded for the achievement of a task or demonstration of a competency. As the Mozilla/IMS Open Badge website writes, they "are verifiable, portable digital badges with embedded metadata about skills and achievements."[25] The purpose of open badges is to create a multi-institutional credentialing system. As they write, "Because the system is based on an open standard, recipients can combine multiple badges from different Issuers to tell the complete story of their verifiable achievements—both online and off."

A 'blockchain', meanwhile, is a mechanism for creating a public encrypted record of transactions. The most common application of the blockchain is BitCoin, which is a digital currency created by solving encryption problems.[26] Transactions using the currency are encrypted and recorded in the blockchain (so BitCoin is sometimes also referred to as a 'crypto-currency). By ensuring both verisifcation and personal privacy[27], Blockchains can be used to record any sort of transaction, and not merely financial transactions. An example of this is the Dao, which employs the Ethereum blockchain to record contracts.[28]

By thinking of badges as a type of transaction (specifically: an institution K grants a badge B to person P) it is not a great leap to imagine employing the blockchain to record badges. "If we used the blockchain for Open Badges, then we could prove beyond reasonable doubt that the person receiving badge Y is the same person who created evidence X."[29] Sony plans to launch a testing platform powered by blockchain[30] and IBM is offering 'blockchain-as-a-service.'[31]

These three trends feed into what has been called 'personalized learning'. The concept of personalized learning has been widely adopted. The United States Office of Educational Technology hosts a number of case studies demonstrating a range of problems that can be addressed.[32] For example, Highline Public Schools near Seattle employs personalized learning as a means of achieving equity. [33] Bristol Tennessee City Schools is using personalized learning as a means of professional development for staff.[34] And in Rhode Island, the Highlander Institute designed an open source model of personalization to support increasing district collaboration.[35]

The modern version of this concept has been around for at least a decade. Having said that, as Audrey Watters notes, there is no agreed-upon meaning for the concept of personal learning. Instead, proponents[36] depict "'personalized learning,' whatever that is – as an exciting, new corrective to the ways they claim education has 'traditionally' functioned (and in their estimation, of course, has failed)."[37] At its core is the idea of a learning application "which can generate appropriate learning paths according to the incorrect testing responses of an individual learner in a pre-test."[38] It is thought that personalized learning applications could select and sequence learning content based on competencies.[39]

We can see how the new concept of personalized learning could draw on all three technology trends described above. Learning analytics is key to personalized learning because they contain a record of who the student is and what the student has done, and this can be used to match them with content that similar students have preferred in the past. In order to associate learning resources with content options and testing, the notion of competencies is used to draw a thread connecting these with learning outcomes. Successful completion is indicated in a learning record store or with badges verified by blockchain, creating new data for future personalization engines.

This interpretation positions personalized learning as a mechanism for content selection and presentation. "Sure, there's an invocation of 'choice' and 'moving-at-your-own-pace,'" writes Watters, "but the progenitor for much of today's "personalized learning" seems to be *ad-tech* rather than ed-tech."[40] It has more in common, she argues, with the newsfeed provided by social network services than it does with pedagogical theory and learning support.[41] And it creates issues around personal privacy and surveillance, market-driven content selection driven more by technology company interests than student needs.

It is useful in this context to draw an important distinction between personalized learning and what may be called 'personal learning'. In English, the two terms suggest different origins for the two approaches to education technology. The suffix "-ized" suggests that something has been created by reshaping or modifying something that has been prefabricated. For example, a 'customized' car is a production car that might have been given new a paint job and new fabric on the seats. By contrast, a 'custom' car is an original, built to the specifications of a buyer. The suffix "-ized" also connotes a sense of 'not genuine'. So, for example, 'chocolatized' means that something has been made to be *like* chococate (using, for example, carob), but is not, in fact, chocolate.

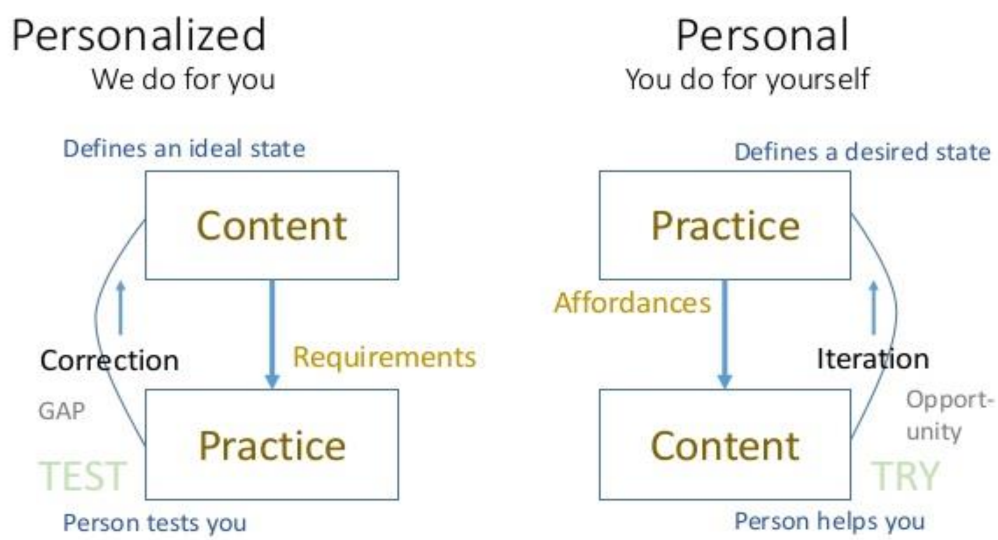

Figure 3. Personal and Personalized Learning. By the author.

The key differentiator between personal and personalized learning lies in the latter's emphasis on learning content. This distinction is drawn from the long-existing distinction between formal and informal learning.[42] As Jay Cross writes, "Informal learning is effective because it is personal. The individual calls the shots. The learner is responsible. It's real. How different from formal learning, which is imposed by someone else." The key is the difference in approach to content selection. "How many learners believe the subject matter of classes and workshops is 'the right stuff'? How many feel the corporation really has their best interests at heart?"[43]

The difference between formal and informal learning is that while the formal learner is attempting to learn something, the informal learner is attempting to *do* something. They're trying to complete a task, solve a problem, accomplish a goal, or simply practice a hobby or avocation. "Think of the way people work together in the work-place," writes Clark Quinn. "They pop over the cubicle to ask a question, they sit together over a document, they brainstorm around a whiteboard, they hold meetings, and they give presentations."[44] These activities are motivated not by the acquisition of some content, but rather, the completion of some task or objective.

Even in formal learning, there is recognition of the importance of learning that occurs as a result of attempting to do something. No science textbook would be complete without problem sets. Constructivist pedagogy encourages the use of problem-based learning[45] or project-based learning[46]. In workplace learning there is the development of job aids, just-in-time learning and electronic performance support systems (EPSS)[47]. To the extent that these approaches support learner independence in learning objectives and content selection, these could be said to be instances of personal learning. However, in other cases, they may be nothing more than non-instructivist methods employed in an attempt to achieve the same objective: the retention of some specific content, [48] in which case, they are not instances of personal learning.

Note that the two approaches differ in process as well. The content-based approach follows presentation with practice, which can include exercises, assignments and tests. The practice is intended to demonstrate mastery of the content presented, with expertise ranging from simple retention to applications of the content in novel situations. The idea here is that the practice will typically reveal a gap between what the learner knows, and what the ideal learner would know, and that it is this gap that informs the next iteration of study. The role of the instructor in this case, in addition to the presentation of content, is to assess the learner and identify the nature and scale of the gap.

By contract, when the learner begins by attempting to complete a task, project or activity, the outcome is some sort of content. This content consists, essentially, of a record of the attempt, and may include the completed task, a partially completed task, questions and conservations surrounding the task, and other incidental media. Examples abound. Recordings of the attempt are typically the outcome of a process known as 'working open'[49], and is demonstrated in phenomena such as open source[50], open content and open data.

The model inherent in personal learning and introduced in the first MOOCs is based on the growth and development of the individual, rather than the idea of stuffing them full of facts. It is based on the idea that education is a cultural and social activity as well as a cognitive activity based on actual contributions to the community, rather than through testing or some other sort of game.

The model of the MOOC is also based on the idea of a learning environment, as opposed to the idea of learning as a focused stand-along activity. The concept of the personal learning environment (PLE) emerged in 2006 as a response to the then-prevalent virtual learning environment (VLE).[51] Unlike the traditional course, the PLE is personal portable access to a learning network. Content isn't placed in one package, but is developed in an infrastructure that links relevant resources such as calling cards, communication tools, credentials, permits and licenses as well as more traditional content creation and consumption applications.

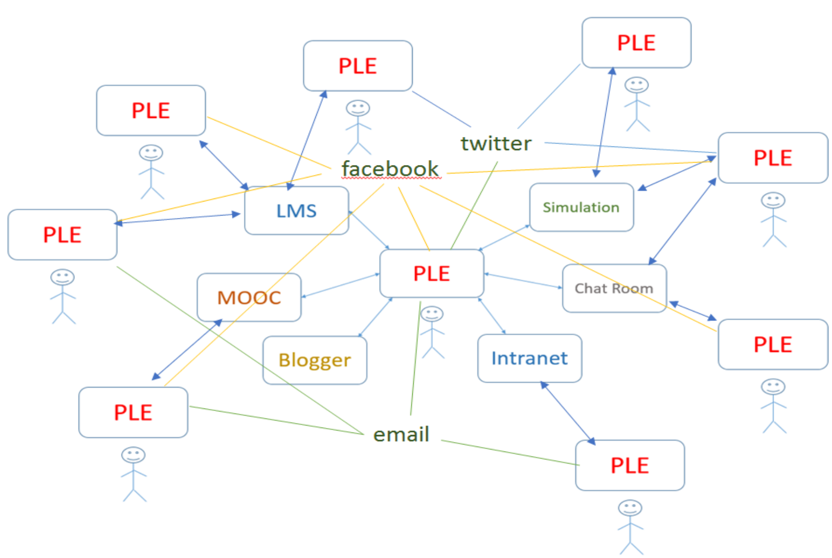

Figure 4. Personal Learning Environment. By the author.

The PLE therefore does not exist in isolation but is rather (as depicted in Figure 4) connected to a collection of other PLEs along with social network services, learning management systems, corporate intranets, and any other relevant learning service. Listed among these is the MOOC, though it could more properly be said that the MOOC is itself a subnet of this entire network. To date commercial MOOC providers haven't embraced the idea of MOOC as network, but the network model is likely to figure prominently in the MOOC's future.

There are several reasons for this. For one thing, even traditional learning management system providers are embracing the idea that they are a 'platform' for a distributed seat of learning applications. This is supported by the Learning Tools Interoperability specification (LTI)[52] which allows the LMS to launch and interoperate with third party applications. Some MOOC systems, such as Open EdX, have adopted LTI.[53] The LTI system can be used to "add remote LTI tools that display content only, and that do not require a learner response… (to) add remote LTI tools that do require a learner response… (or) as a placeholder for synchronizing with a remote grading system."[54]

Additionally, there has been an increase in interest in the idea of serverless and distributed applications. A serverless application does not reside in a specific online location (that is, on a server), but rather, accesses a set of cloud services available from cloud service providers. For example, it may store data in DropBox or a database in Google Sheets and access an artificial intelligence engine being run on Microsoft's Azure web services, presenting the result in an individual's browser. This allows online services to use advanced applications without having to develop or manage them.[55]

A distributed application, by contrast, performs the same functions in different locations. A good example is Mastodon.[56] This application resembles Twitter in that individuals create accounts and enter short messages, sometimes replying to each other, promoting posts, or reposting someone else's message. However, unlike Twitter, Mastodon is not based a single web address. Any individual can launch an instance of the open source software, and then these instances communicate with each other in order to propagate messages across the entire network.

The future personal learning environment is likely to be a mixture of both distributed applications and serverless architecture. Students will be able to use applications offered by different cloud providers, including publishers and universities. They will also operate their own instance of the software, becoming one node in the distributed network of PLEs.

In a sense, the future learning environment is a lot like a personal cloud. The main enablers for this are powerful mobile computing devices such as modern smartphones. Advances in wireless internet access, including greater access speeds promised by 5G telecom services[57], will make it possible for a mobile user to access cloud services wherever they are. These services will include LTI applications such as discussion boards, web conferencing, digital whiteboards, educational games and quizzes, and similar learning technologies. Additionally a range of new learning opportunities will be opened with sensor networks, augmented reality, AI-supported interactivity, remote control drones and bots, and novel interfaces.

New business models will support cloud-based e-learning will be developed. Institutions will purchase services (such as class registration, gradekeeping, marking) instead of buying assets. They will pay for the use of these services, rather than investing in technology up front. Learning services will be accessed over the internet, rather than through the institutions own intranet, and they will be supported on any device, not only on the institutional or corporate desktop. They will share online resources with other tenants, and their service will be scalable and elastic, provided through vendors such as Amazon's Elastic Computing Service (ECS). Deployments will be enabled through deployment scripts and will be fast and automated.[58]

Individuals taking advantage of such services through their own personal learning environment will on the one hand be challenged to maintain their own individual integrity but on the other hand will be the potential beneficiary of advanced learning analytics.

The challenge has been made clear in recent years by the issues arising from the business models of companies working with Facebook such as Cambridge Analytica[59]. These companies retained personal information from millions of users and used it in order to target personalized political advertisements at U.S. voters. They did so without the consent of the people whose data they used, and apparently outside the bounds of U.S. election law. This has led to critics raising concerns about the impact of technology on individual autonomy in the like of phenomena such as clickbait headlines, filter bubbles and fake news. Are we being manipulated by the technology we use to teach and inform us?[60]

On the other hand, the technology offers each of us the opportunity to create an individual personal learning world. Developers have begun to explore the idea of collecting activity records from multiple systems. Using a format called the Experience API[61], these records are collected in a centralized learning record store (LRS) that can be used for corporate or institutional data analytics.[62] Taking the idea further, however, we can imagine individuals creating their own personal record store, which would be preserved in a cloud database. These users could then use their personal record (or some subset of it) as input for job applications, contract positions, or as input to matchmaking services, learning recommendation engines, or any number of personal and support services.

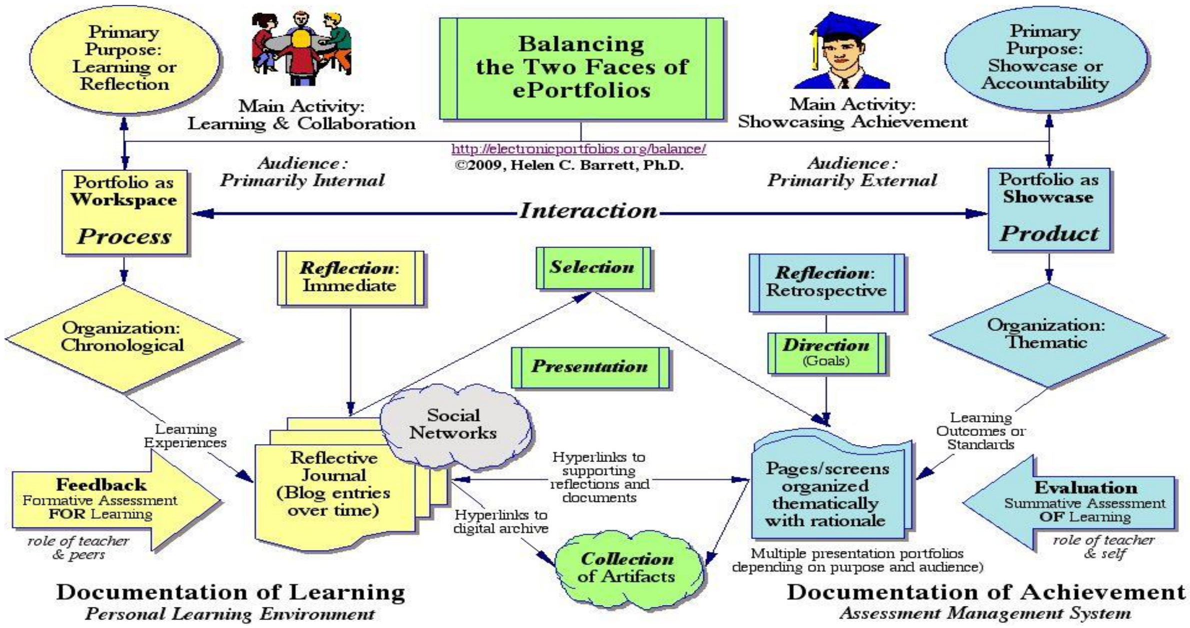

Figure 5. E-Portfolios. By Helen Barrett.(c) 2009. http://electronicportfolios.org/balance/

The personal learning record is based on the idea of the e-portfolio and similar issues arise. As Helen Barrett argues, there are two major (and sometimes competing) roles served by an e-portfolio: on the one hand, to support learning and reflection, and on the other hand, as a method to showcase learning or offer material for grading and assessment, as illustrated in figure 6. These are organized differently, and are released to different audiences (if they are released at all). This requires a degree of personal data management and control on the part of the user, which in turn requires a level of digital literacy that may not yet be widespread.

This points the way to what some are calling 'precision education', which is "the tailoring of education to the specific characteristics of the individual student." The term is meant to be analogous to 'precision agriculture' or 'precision medicine'. The primary target will be specific learning disabilities (LD). "The present educational system of uniform instruction, broad assessment, and inconsistent classification of LD needs to be updated based on current evidence."[63] But a wider application can be anticipated. As ben Williamson writes, "Precision education represents a shift from the collection of assessment-type data about educational outcomes, to the generation of data about the intimate interior details of students' genetic make-up, their psychological characteristics, and their neural functioning."[64]

It should be clear from the discussion in these pages that while MOOCs represent an interesting and important development in online learning, reinforcing the utility of both open educational resources and network-based learning, they are at the same time only one step in a wider transformation of learning. As we look at what technologies offer for us in the year ahead, we will be able to migrate from a closed system of learning based on common sources and common outcomes to an open system of learning based on a diversity of sources and personalized outcomes.

[1] Prescott Klassen, Maureen Stanley, Don Whitty, Roger Doucet, Rory McGreal, and Leon Cooper. 1997. EastWest Project Course Developer Guidelines. TeleEducation NB.https://web.archive.org/web/19990202215819/http://teleeducation.nb.ca:80/eastwest/standards/

[2] AICC-Document-Archive. GitHub. https://github.com/ADL-AICC/AICC-Document-Archive/

[3] 1484.12.1: IEEE Standard for Learning Object Metadata. IEEE. 2005. http://grouper.ieee.org/groups/ltsc/wg12/

[4] Stephen Downes. 1999. Web-Based Courses: The Assiniboine Model. In *Online Journal of Distance Learning Administration* Volume 2, Number 2, Jul 01, 1999. http://www.downes.ca/post/31525

[5] Stephen Downes. 2001. Learning Objects: Resources For Distance Education Worldwide. In *International Review of Research in Open and Distance Learning* Volume 2, Number 1, Jul 01, 2001. http://www.irrodl.org/index.php/irrodl/article/view/32/378

[6] Wayne Hodgins. 2002. The Future of Learning Objects. Proceedings of the 2002 eTEE Conference 11-16 August 2002 Davos, Switzerland. http://dc.engconfintl.org/cgi/viewcontent.cgi?article=1012&context=etechnologies

[7] David Wiley. 2000. Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy. In *The Instructional Use of Learning Objects*, David Wiley, ed. http://www.reusability.org/read/

[8] UNESCO. 2002. What are Open Educational Resources (OERs)? http://www.unesco.org/new/en/communication-and-information/access-to-knowledge/open-educational-resources/what-are-open-educational-resources-oers/

[9] OER World Map. 2018. https://oerworldmap.org/

[10] Connectivism and Connective Knowledge 2008.

[11] Tina Barseghian. 2011. Stanford for Everyone: More Than 120,000 Enroll in Free Classes. *Mind/Shift*, August 23, 2011. https://ww2.kqed.org/mindshift/2011/08/23/stanford-for-everyone-more-than-120000-enroll-in-free-classes/

[12] Laura Pappano. 2012. The Year of the MOOC. *New York Times*, November 4, 2011. https://mobile.nytimes.com/2012/11/04/education/edlife/massive-open-online-courses-are-multiplying-at-a-rapid-pace.html?mcubz=1

[13] Dhawal Shah. 2018. By The Numbers: MOOCS in 2017. In *Class Central*, January 18, 2018. https://www.class-central.com/report/mooc-stats-2017/

[14] Stephen Downes. 2012. Massively Open Online Courses Are 'Here to Stay'. *OLDaily*, July 20, 2012. http://www.downes.ca/post/58676

[15] Stephanie J. Blackmon and Claire H. Major. 2017. Wherefore art thou MOOC?: Defining massive open online courses. Online Learning, 21 (4), 195-221. https://files.eric.ed.gov/fulltext/EJ1163443.pdf

[16] Pierre-Julien Guay. 2016. An introduction to Learning Analytics. *Vitrine technologie-éducation (VTÉ)*. February 1, 2016. https://www.vteducation.org/en/articles/learner-data/introduction-learning-analytics

[17] Philip Long and George Siemens. 2011. Penetrating the Fog: Analytics in Learning and Education. *EDUCAUSE Review*, September 12, 2011. https://er.educause.edu/articles/2011/9/penetrating-the-fog-analytics-in-learning-and-education

[18] New Media Consortium. 2017. NMC Horizon Report: 2017 Higher Education Edition, p. 22. https://www.sconul.ac.uk/sites/default/files/documents/2017-nmc-horizon-report-he-EN.pdf

[19] IMS. 2002. Reusable Definition of Competency or Educational Objective Specification. https://www.imsglobal.org/competencies/index.html

[20] IEEE LTSC. 2004. IEEE Draft Standard for Learning Technology - Standard for Reusable Competency Definitions. http://ltsc.ieee.org/wg20/files/IEEE_1484.20.WD_01_rough.pdf
(11) Inferring and validating skills and competencies over time. Available from: https://www.researchgate.net/publication/262312184_Inferring_and_validating_skills_and_competencies_over_time [accessed Mar 01 2018].

[21] HR-XML Consortium, 2006. HR-XML Consortium Competencies. http://schemas.liquid-technologies.com/hr-xml/2007-04-15/?page=competencies_xsd.html

[22] Maryam Fazel-Zarandi and Mark S. Fox. 2013. Inferring and validating skills and competencies over time. *Applied Ontology* 0 (2013) 1–32. https://www.researchgate.net/publication/262312184_Inferring_and_validating_skills_and_competencies_over_time

[23] Advanced Distributed Learning. 2017. Competencies and Skills System. https://www.cassproject.org/

[24] Advanced Distributed Learning. 2017. Total Learning Architecture (TLA). https://www.adlnet.gov/tla/

[25] Open Badges. 2017. Get Started. https://openbadges.org/get-started/

[26] Satoshi Nakamoto. 2013. Bitcoin A Peer-to-Peer Electronic Cash System. UNICAMP –IA368. https://s3.amazonaws.com/academia.edu.documents/32413652/BitCoin_P2P_electronic_cash_system.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1520268361&Signature=UrMeU32uQ5vqdXZ4YXpBGnT2SzQ%3D&response-content-disposition=inline%3B%20filename%3DBitcoin_A_Peer-to-Peer_Electronic_Cash_S.pdf

[27] Guy Zyskind, Oz Nathan and Alex 'Sandy' Pentland. 2015. Decentralizing Privacy: Using Blockchain to Protect Personal Data. *2015 IEEE CS Security and Privacy Workshops*. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7163223

[28] Seth Bannon. 2016. The Tao of "The DAO" or: How the autonomous corporation is already here. *TechCrunch*, May 16, 2016. https://techcrunch.com/2016/05/16/the-tao-of-the-dao-or-how-the-autonomous-corporation-is-already-here/

[29] Doug Belshaw. 2015. Peering Deep into Future of Educational Credentialing. *DML Central*. http://dmlcentral.net/blog/doug-belshaw/peering-deep-future-educational-credentialing

[30] Jon Russell. 2016. Sony Plans To Develop An Education And Testing Platform Powered By The Blockchain. *TechCrunch*, Feb 22, 2016. https://techcrunch.com/2016/02/22/sony-is-building-an-education-and-testing-platform-powered-by-the-blockchain/

[31] Giulio Prisco. 2016. IBM Deploys Blockchain-As-A-Service, Announces Initiatives to Make the Blockchain Ready for Business. *BitCoin Magazine*. https://bitcoinmagazine.com/articles/ibm-deploys-blockchain-as-a-service-announces-initiatives-to-make-the-blockchain-ready-for-business-1455726071/

[32] The United States Office of Educational Technology. 2017. Case Studies. https://tech.ed.gov/case-studies/

[33] The United States Office of Educational Technology. 2017. Highline Public Schools: Personalized Learning as a Pathway to Equity https://tech.ed.gov/stories/highline/

[34] The United States Office of Educational Technology. 2017. Bristol Tennessee City Schools: Personalized Educator Learning Provides Foundation for Personalized Student Learning. https://tech.ed.gov/stories/bristol-tn/

[35] The United States Office of Educational Technology. 2017. Fuse Fellows of Rhode Island. https://tech.ed.gov/stories/fuse-fellows-of-rhode-island/

[36] Kirsty Hughan. 2011. Learning Record Store: What is an LRS? Rustici Software. https://scorm.com/what-is-an-lrs-learning-record-store/

[37] Audrey Watters. 2017. The Histories of Personalized Learning. *Hack Education*, June 9, 2017. https://hackeducation.com/2017/06/09/personalization

[38] Chih-MingChen. 2008. Intelligent web-based learning system with personalized learning path guidance. *Computers & Education*, Volume 51, Issue 2, September 2008, Pages 787-814. https://www.sciencedirect.com/science/article/pii/S0360131507000978

[39] Pythagoras Karampiperis and Demetrios Sampson. 2006. Adaptive Learning Objects Sequencing for Competence-Based Learning. *Proceedings of the Sixth International Conference on Advanced Learning Technologies* (ICALT'06). http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1652387

[40] Audrey Watters. 2017. 'Personalized Learning' and the Power of the Gates Foundation to Shape Education Policy. *Hack Education*, July 18, 2017. https://hackeducation.com/2017/07/18/personalization

[41] Audrey Watters. 2016. Education Technology and the Ideology of Personalization. *Hack Education*, December 19, 2016. https://hackeducation.com/2016/12/19/top-ed-tech-trends-personalization

[42] Nada Dabbagh and Anastasia Kitsantas. 2012. Personal Learning Environments, social media, and self-regulated learning: A natural formula for connecting formal and informal learning. *The Internet and Higher Education* Volume 15, Issue 1, January 2012, Pages 3-8. https://www.sciencedirect.com/science/article/pii/S1096751611000467

[43] Jay Cross. 2007. *Informal Learning*, Preface. Pfeiffer Books, John Wiley & Sons, Inc.

[44] Clark Quinn. 2009. Social Networking: Bridging Formal and Informal Learning. *Learning Solutions*, February 23, 2009. E-Learning Guild. http://ww.w.cedma-europe.org/newsletter%20articles/eLearning%20Guild/Social%20Networking%20-%20Bridging%20Formal%20and%20Informal%20Learning%20(Feb%2009).pdf

[45] David Jonassen. 2011. Supporting Problem Solving in PBL. *Interdisciplinary Journal of Problem-Based Learning*, 5(2). https://docs.lib.purdue.edu/ijpbl/vol5/iss2/8/

[46] John W. Thomas. 2000. A Review of Research on Project-Based Learning. Buck Institute for Education. http://www.bie.org/object/document/a_review_of_research_on_project_based_learning

[47] Allison Rossett and Lisa Schafer. 2007. *Job Aids and Performance Support: Moving From Knowledge in the Classroom to Knowledge Everywhere*. Pfeiffer Books, John Wiley & Sons. https://books.google.ca/books?id=jkzh56A3xWAC

[48] For example, William Woods says, "teachers should develop their lesson plans in the same way as they design experiments. Instead of following a textbook or syllabus, they should start with a clear goal — the concepts and skills that they want the students to learn." M. Mitchell Waldrop. 2015. Why we are teaching science wrong, and how to make it right. *Nature*, July 15, 2015. https://www.nature.com/news/why-we-are-teaching-science-wrong-and-how-to-make-it-right-1.17963#/ref-link-6

[49] Mozilla Wiki. 2011. Working Open. Mozilla, February 15, 2011. https://wiki.mozilla.org/Working_open

[50] Rafi Santo, et.al. 2016. Working in the Open: lessons from open source on building innovation networks in education. *On the Horizon*, Vol. 24 Issue: 3, pp.280-295, https://doi.org/10.1108/OTH-05-2016-0025

[51] Scott Wilson, 2006. PLEX, Experiences in building a composite application. CETIS. https://www.slideserve.com/ovid/plex-experiences-in-building-a-composite-application

[52] IMS Global, 2017. Learning Tools Interoperability (LTI) and LTI Advantage. https://www.imsglobal.org/activity/learning-tools-interoperability

[53] Open EdX. 2017. Learning Tools Interoperability. https://open.edx.org/learning-tools-interoperability

[54] Open EdX. 2017. 10.21. LTI Component. *Building and Running an EdX Course*. https://edx.readthedocs.io/projects/edx-partner-course-staff/en/latest/exercises_tools/lti_component.html

[55] Mike Roberts. 2016. Serverless Architectures. Martin Fowler dot Com. https://martinfowler.com/articles/serverless.html

[56] Mastodon. http://mastodon.social

[57] Sascha Segan. 2018. What is 5G? PC Magazine. https://www.pcmag.com/article/345387/what-is-5g

[58] Ghazal Riahi. 2015. E-Learning Systems based on Cloud Computing. Procedia Computer Science 62 352-359. https://ac.els-cdn.com/S1877050915025508/1-s2.0-S1877050915025508-main.pdf?_tid=8552fafa-6d2d-4cd5-a34a-45b51c9fe2e0&acdnat=1523987456_bd8d017a876c2db91f2c834c3aeace49

[59] Patrick Greenfield. 2018. The Cambridge Analytica Files: the story so far. The Guardian. https://www.theguardian.com/news/2018/mar/26/the-cambridge-analytica-files-the-story-so-far

[60] Samuel Albanie, Hillary Shakespeare, Tom Gunter. 2017. Unknowable Manipulators: Social Network Curator Algorithms. arXiv:1701.04895 [cs.AI]. https://arxiv.org/abs/1701.04895

[61] Experience API. https://xapi.com/overview/
[62] Advanced Distributed Learning. 2017. xAPI Learning Record Store Test Suite and Adopter Registry Released. https://adlnet.gov/news/xapi-learning-record-store-test-suite-and-adopter
[63] Sara A. Hart. 2016. Precision Education Initiative: Moving Toward Personalized Education. Mind, Brain and Education. https://onlinelibrary.wiley.com/doi/full/10.1111/mbe.12109
[64] Ben Wiolliamson. 2018. Personalized precision education and intimate data analytics. Code Acts in Education. https://codeactsineducation.wordpress.com/2018/04/16/personalized-precision-education/