TECHNOLOGY MEDIATED EDUCATION DELIVERY

Working Paper - MIT Open Learning Workforce Education Project

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EXECUTIVE SUMMARY

As the Industrial Revolution upended social order and the nature of work, and forced a re-thinking of the American education system, current technological shifts also have the potential to transform our education system. As innovations in industrial production guided the development of educational models in the past, so too will innovations in technology and learning science shape our educational systems for the future. This report explores developments in learning science as well as advances in educational technology, and ways that technology can be utilized to deliver education in a way that is more individualized, flexibly delivered, and accessible.

Learning Science: Advances in Neuroscience, Education Research, & Cognitive Psychology
Learning Science is at the junction of three fields: neuroscience, education research, and cognitive psychology. Although these three domains operated

independently of each other for most of the 20th century, researchers are beginning to see the parallels being identified across the boundaries of the disciplines, verifying the findings being noted in the brain, behavior and in the classroom. This research gives new insights into the way students learn and process information into long term memories and skills. Findings have demonstrated that students learn best in situations where they are curious and motivated to learn, where they can interact with the material in a hands-on way, when the material is presented in real world, relatable contexts, and when it is constructed into ambiguous problems or tasks that require connecting disparate information or tools.

CURIOSITY	The brain is most receptive to new information when the student is curious, motivated, and has an internal justification for why possessing this knowledge or skill is important to achieving their higher goals. Curiosity stimulates the hippocampus and releases dopamine, allowing for deeper memory formation and triggering reward centers. [i,ii,iii,iv,v,vi,vii,viii,ix]
INTERACTIVE LEARNING	This approach, known in the education field as constructivism, was first proposed by seminal educators such as John Dewey and Jean Piaget, has since been documented by cognitive psychologists who have demonstrated that as students move along the spectrum of passive to active to constructive to interactive, their learning will increase. Being quizzed or tested on material provides the best learning outcomes, in comparison to studying material or even discussing it in a group setting,[x] because grappling with the material in a hands on, interactive way is more productive than passively hearing or reading about it, or even discussing it with peers.[xi,xii,xiii]
SITUATED LEARNING	Situated learning takes place in the real-world context that the learner would use the knowledge or skill being learned. These theories of learning hold that learning involves "mastering authentic tasks in personally relevant, realistic situations."[xiv,xv] This learning style is based on the concept of embodied cognition, which posits that "retrieving a concept from memory and reasoning about it is enhanced by creating a mental perceptual simulation of it."[xvi]
PROBLEM BASED LEARNING	Problem based learning allows for the development of an effective reasoning process that would be directly used in the real world, by teaching students to practice assessing the problem, posing and testing hypothesis, data gathering and decision making.[xvii] It necessitates that the learner strategize what tools or skills would be required to solve the problem, helping them to combine aspects of their training they might have learned as separate units, and to seek out new information or skills needed.

Learning science can seem very intuitive, though surprisingly few of these developments found their way into our classrooms or the education system. It is challenging to individualize learning experiences so people can work at their own speed in a large classroom or group, and often difficult or impossible to incorporate the real-world scenarios in which the skills will be used. However, technological advances can present real opportunities to incorporate these real-world simulations, enhance communication and collaboration, and to make education more flexible so that it could be delivered outside of the classroom, in real time.

Technologically Enhanced Learning: Using Technology Towards a New Education Model

Advances in learning science call for new advances in the ways in which education is organized and offered. Educational institutions should root their content in real world, relevant contexts, using realistic problems to motivate the students to develop problem solving skills and the ability and love of self-directed learning. Many leaders in education, as well as employers in industry, are calling for more schools to offer more competency-based learning systems.[xviii] This is a model that focuses on teaching and assessing skill proficiency and outcomes, rather than degree completion and is well suited for an atmosphere of continuous learning, in which there are many opportunities to develop skills formally or informally. Another challenge posed by the traditional educational model is the more mundane, existential issues relating to time and space. The 20th century model had a small percentage of the population devote several years of their early adulthood to full time study, to gain a foundational education before embarking on their career. However, the information age has rendered this insufficient as a much larger share of the population now requires access to affordable higher education over the course of their lifetimes. Industries and technology are evolving at a such a rate, that workers will need to be regularly updating their skills to remain relevant in the workforce. The adult working age population has different needs than the traditional full-time student population, in that they have busy schedules and lives, and will need to fit their studies into a constellation of competing responsibilities and pursuits. Educational institutions are now engaged with the project of re-thinking their delivery model. How can they meet the needs of this new cohort of students, who might not be able to convene in a classroom together at the same time? And how can they take advantage of the insights being formed by learning science researchers to create more impactful educational programs?

DISTANCE EDUCATION*:* Distance education has long been an answer to the problem of gathering students at the same time and place to learn. Online courses can simulate an in-person class taught online, in that students often gather in an online space at the same time to hear a presentation or lecture, and complete their assignments on the platform under a shared deadline.[xix] Increasing numbers of colleges offer entire online degree programs where the student can complete a degree without ever stepping foot on the campus.[xx] These classes solve the "space" problem, allowing students to gather together despite their geographic location. However, they do not solve the "time" problem, in that they generally require students to gather at the same time for a set period, for some or all components of the course, and they don't create the immersive learning atmosphere that learning science recommends. The massive open online course (MOOC) was developed to solve the problem of offering an online class to a large number of people, asynchronously, and at their own pace for free or a small fee. These classes a create a learning atmosphere in which the student progresses through a pathway composed of video content, exercises, and assignments at their own pace, and in their own time. These MOOCs allow for instructors to design their course based on the best practices from the fields of learning science.[xxi] Open online courses allow a greater amount of flexibility in providing lecture material in this format, as the students can process the material at their own pace, and wait to move on until they have mastered that component of the course.[xxii] While the open online platform can be designed in a way to take advantage of these best practices and trends in education, it still has a long way to go in terms of creating an immersive learning environment that motivates learning with real world application, and creating an interactive community of learners.[xxiii] In addition, the current learning platforms are rather rigid, in that every learner moves through the material in the same way, despite the fact that many learners will have brought differing levels of skill and ability to the course. Thus, the open online platform are excellent options for self-motivated individuals looking to gain a specific skill, or who have cultivated a deep enjoyment of learning, but less well suited to individuals who haven't acquired the skill set enabling them to direct their own education, without any support or community.[xxiv][xxv] Indeed, the model of online education is often ill-suited for people with low-education or coming from disadvantaged backgrounds. This is particularly true for non-traditional students, who require more external support and lack crucial skills regarding academic self-efficacy, time and environment management, and metacognitive self-regulation.[xxvi] Studies of community college have consistently shown that students tend to perform less well in online courses than on-campus courses[xxvii][xxviii], though blended learning models outperform both.[xxix][xxx]

BLENDED LEARNING: Blended learning is a model which combines aspects of online learning and classroom learning. Students watch lectures, and engage in the online parts of the course on their own time, and then the in-class component can focus on more interactive exercises, discussions, or reviewing challenging problems or materials. Blended learning is a promising model for community colleges, potentially incorporating the best of online and in person learning. Unfortunately, it also contains the high upfront costs associated with making digital course content, while still requiring classroom space and instructor time, making it an unattractive option to colleges strapped for resources, unless other institutions can provide the online content. High quality digital course content is very costly to make, as it requires a diverse team of experts from videographers and animators to computer programmers and educational technologists. One solution

is for schools to re-use existing digital course content created elsewhere. This is a beneficial model to schools for many reasons: the programs are easily adapted into the school offerings, releasing the schools from investing the resources and time of creating a program from scratch. In addition, the elements of the online and in person sessions can be customized, allowing for larger online content to be completed before intensive short term "bootcamps". This combination of offering intensive, short term, in person sessions engaging in active learning with open online education offers tremendous promise for creating avenues for building community in online courses without sacrificing the flexibility and autonomy of online education.

As emerging technologies are driving the need for a better, faster, cheaper, and more inclusive education system, so are they also providing the new tools needed with which to build it. This technology can be incorporated into the education delivery model, providing more interactive and competency-based online and blended classes and programs that can be more easily accessible to working adults, without sacrificing the community and personal connections of classroom learning. Advances in artificial intelligence can be deployed in educational design to give students a more personalized, flexible and adaptive learning experience, allowing them to focus on skills that need practice, and skip components they have already mastered. Virtual and augmented reality could be used both to provide increased opportunities for communication and in person sessions, as well as for constructing real world, problem-based scenarios that allow for rich situated and problem-based learning in the course. These advances in technology give educators and institutions the opportunity to enhance their learning design, both in the classroom and through new models of educational delivery, to improve the quality of learning and to make education more accessible to a broader population.

INTRODUCTION

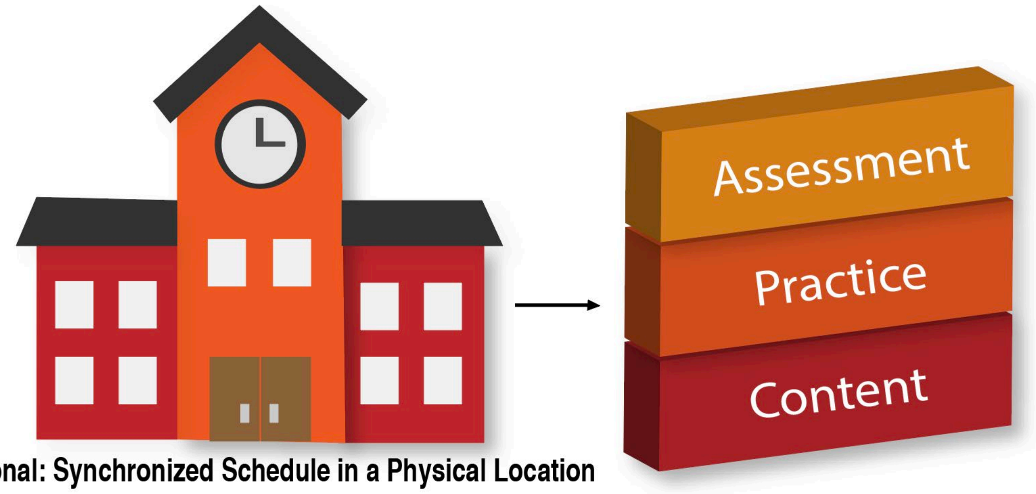
As the Industrial Revolution upended social order and the nature of work, and forced a re-thinking of the American education system, current technological shifts also have the potential to transform our education system. Throughout the 20th century, many scholars noted the similarities of the education system to "the factory model", as if students were "raw goods" that could be molded and sculpted into a finished product along an assembly line.[xxxi] Under this model, all students could be given the same education in a standardized and synchronized format, assessed uniformly with standardized testing, with any issues along the way attributed to the failings or lack of ability of the student.[xxxii] This model did not serve us well in the past, and in the face of the technological change we are experiencing, a new model of teaching is needed to better prepare workers for the new landscape of work. But as innovations in industrial production guided the development of educational models in the past, so too will innovations in technology and learning science shape our educational systems for the future. But the learning advances must better guide the technology advance this time around. This report explores developments in learning science as well as advances in educational technology, and ways that technology can be utilized to deliver education in a way that is more individualized, flexibly delivered, and accessible.

Technologically Enhanced Learning: Taking Advantage of Learning Science

Advances in learning science call for new advances in the ways in which education is organized and offered. Learning Science is at the junction of three fields: neuroscience, education research, and cognitive psychology. Although these three domains operated independently of each other for most of the 20th century, researchers are beginning to see the parallels being identified across the boundaries of the disciplines, verifying the findings being noted in the brain, behavior and in the classroom. This research gives new insights into the way students learn and process information into long term memories and skills. Findings have demonstrated that students learn best in situations where they are curious and motivated to learn, where they can interact with the material in a hands-on way, when the material is presented in real world, relatable contexts, and when it is constructed into ambiguous problems or tasks that require connecting disparate information or tools.

Educational institutions should root their content in real world, relevant contexts, using realistic problems to motivate the students to develop problem solving skills and the ability and love of self-directed learning. This is a challenging feat to accomplish, under the strictures of the current curriculum programs of K-12 and higher education, which require following set tracks through domain-specific fields, gaining a high degree of expertise in subjects like Literature or Physics, often regardless of their relevance to the student's career trajectory. Many leaders in education, as well as employers in industry, are calling for more schools to offer more competency-based learning systems.[xxxiii] This is a model that focuses on teaching and assessing skill proficiency and outcomes, rather than degree completion. By highlighting the mastery of a specific skill set rather than the completion of courses, students could "test out" of lower skill levels that they had already mastered elsewhere, which there are many opportunities to develop skills formally or informally.

Another challenge posed by the traditional educational model is the more mundane, existential issues relating to time and space. Traditionally, classes occur in a physical room during a set time, in which students are expected to attend in person. To maximize efficiency of travel time to and from the classroom, the role of the student has largely been a full-time occupation centered around a physical campus dedicated to providing classroom space. For most of the 20th century, this arrangement made sense as a small percentage of the population's 18 – 25 students could devote several years of their life to full time study, to gain a foundational



Traditional: Synchronized Schedule in a Physical Location

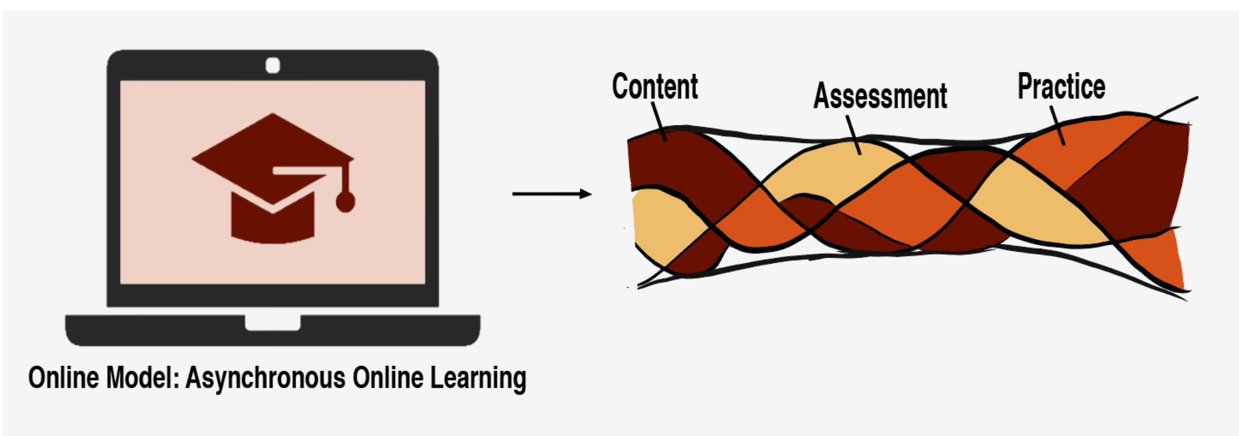
whether that was in a formal classroom, on the job, or in their free time. This type of model is well suited for an atmosphere of continuous learning, in education before embarking on their career. However, the information age has rendered this model insufficient. A much larger share of the population now requires access to affordable higher education, as low skill jobs are phased out of the workforce due to globalization and automation. In addition, spending a few years in dedicated study at the beginning of one's career could not possibly prepare workers for the technologically changes that will occur over the course of their lifetimes. Industries and technology are evolving at a such a rate, that workers will need to be regularly updating their skills to remain relevant in the workforce. The adult working age population has different needs than the traditional full-time student population, in that they have busy schedules and lives, and will need to fit their studies into a constellation of competing responsibilities and pursuits.

Educational institutions are now engaged with the project of re-thinking their delivery model. How can they meet the needs of this new cohort of students, who might not be able to convene in a classroom together at the same time? And how can they take advantage of the insights being formed by learning science researchers to create more impactful educational programs? This segment will give an overview of innovations in educational design and delivery that are being used and piloted, that could address these issues.

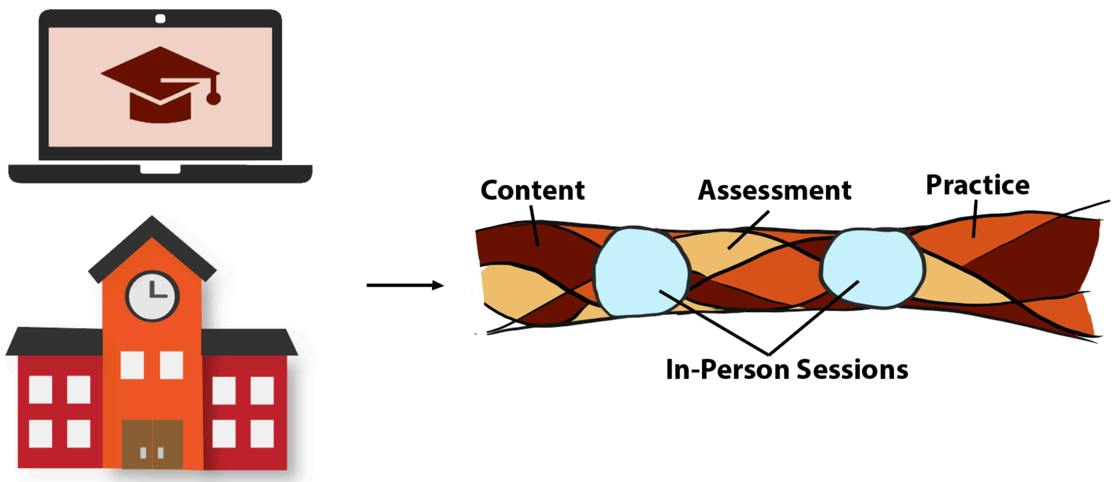
Distance education has long been an answer to the problem of gathering students at the same time and place to learn. In the 1830s, schools in Great Britain began offering correspondence courses where the instructor's lessons and the student's assignments were exchanged by mail.[xxxiv] This practice was widely adopted in the United States by universities and technical schools. As the internet became more sophisticated towards the end of the 20th century, many organizations and for-profit schools began experimenting with hosting classes online as a way to teach small groups of students across wide geographic regions. These online courses, now referred to as "SPOCs" or small private online course simulate an in-person class taught online, in that students often gather in an online space at the same time to hear a presentation or lecture, and complete their assignments on the platform under a shared deadline.[xxxv] Today, these SPOCs are pervasive across the education spectrum from community colleges to the Ivy League, with a majority of college students taking at least one class online over the course of their degree.[xxxvi] Increasing numbers of colleges offer entire online degree programs where the student can complete a degree without ever stepping foot on the campus. SPOCs solve the "space" problem, allowing students to gather together despite their geographic location. However, they do not solve the "time" problem, in that they generally require students to gather at the same time for a set period, for some or all components of the course. And despite relying on a digital platform, referred to as a Learning Management System (LMS) for hosting the course, they don't create the immersive learning atmosphere that learning science recommends.

The massive open online course (MOOC) was developed to solve the problem of offering an online class to a large number of people, asynchronously, and at their own pace. The first MOOC was launched by Stanford University in 2011, "Introduction to AI." In 2012, Coursera and Udacity were founded as private companies offering a standardized LMS platform for universities or educators to host MOOCs, and Harvard and MIT quickly followed by co-founding the nonprofit EdX. All of these offer an LMS to create and host asynchronous online courses at a massive scale, which are typically available free to students or for a small fee. Millions of students around the world have signed up to take classes on these platforms on topics ranging from Shakespearean Poetry to Quantum Computing. These classes a create a learning atmosphere in which the student progresses through a pathway composed of video content, exercises, and assignments at their own pace, and in their own time.

These MOOCs allow for instructors to design their course based on the best practices from the fields of learning science. There is a trend in contemporary instructional design towards deconstructing the traditional hour-long lecture into thematic segments of ~10 – 15 minutes, to aid in concentration.[xxxvii] Open online courses allow a greater amount of flexibility in providing lecture material in this format, as the students can process the material at their own pace, and wait to move on until they have mastered that component of the course. Open online classes can present a short component of the course content, provide a space for the student to practice what they've learned in a worked example, and then be tested online on the material before they move on to the next segment. This model mimics the mastery of skills that are gained in a game design model, as the student can practice the basics of their skill and repeat segments they are having trouble with before moving on to harder and more complex problems.[xxxviii] While the open online platform can be designed in a way to take advantage of these best practices and trends in education, it still has a long way to go in terms of creating an immersive learning environment that motivates learning with real world application, and creating an interactive community of learners.[xxxix]



In addition, the current learning platforms are rather rigid, in that every learner moves through the material in the same way, despite the fact that many learners will have brought differing levels of skill and ability to the course. Thus, the open online platform are excellent options for self-motivated individuals looking to gain a specific skill, or who have cultivated a deep enjoyment of learning, but less well suited to individuals who haven't acquired the skill set enabling them to direct their own education, without any support or community.[xl] In this vein, studies show that the largest demographic user of open online courses are young, employed, and have completed a bachelors or master's degree.[xli] There are very few remedial or even introductory education offerings on these platforms, and no ability to organize content or courses across schools or programs into a stepped curriculum program geared to move learners from basic to advanced content. Indeed, the model of online education is often ill-suited for people with low-education or coming from disadvantaged backgrounds. This is particularly true for non-traditional students, who require more external support and lack crucial skills regarding academic self-efficacy, time and environment management, and metacognitive self-regulation.[xlii] Studies of community college have consistently shown that students tend to perform less well in online courses than on-campus courses[xliii][xliv], though blended learning models outperform both.[xlv][xlvi]



Blended Model: Online Learning + In Person Sessions

BLENDED LEARNING: Blended learning is a model which combines aspects of online learning and classroom learning. Students watch lectures, and engage in the online parts of the course on their own time, and then the in-class component can focus on more interactive exercises, discussions, or reviewing challenging problems or materials. Blended learning is a promising model for community colleges, potentially incorporating the best of online and in person learning.

Unfortunately, it also contains the high upfront costs associated with making digital course content, while still requiring classroom space and instructor time, making it an unattractive option to colleges strapped for resources, unless other institutions can provide the online content. High quality digital course content is very costly to make, as it requires a diverse team of experts from videographers and animators to computer programmers and educational technologists. One solution is for schools to re-use existing digital course content created elsewhere. This strategy is being piloted by many schools through programs like MIT Open Courseware, SkillsCommon.org, or the Open Learning Initiative. This is a beneficial model to schools for many reasons: the programs are easily adapted into the school offerings, releasing the schools from investing the resources and time of creating a program from scratch. Clemson University's Center for Workforce Development, for example, has been developing online content in advanced manufacturing and aerospace industry skills and making it easily available to the state's technical colleges to incorporate into their course loads.[xlvii] Because the content is pre-developed and openly available, the offering school can provide the courses regardless of the class size, which frees them from needing to focus only on programs with high demand from students. Rather than subject matter experts, instructors can be generally knowledgeable in the field, and work as facilitator and guide of the materials, allowing for more individual support to the students. This practice has growing evidence to support it, as studies show that on site facilitators are as effective as a more academically-trained instructor[xlviii]. In this model, rather than lecture or deliver information to the students, the facilitator develops trust and relationships with the students, and encourages student-to-student interaction in solving problems or attempting course material. This model could be particularly beneficial to community colleges or technical schools located in rural areas, or in subject fields in which practitioners make a substantially higher salary than the school can pay, or in other scenarios in which there are substantial challenges in finding and retaining instructors. Because class time is freed from long lecture material, and the instructor is operating more as a guide than a teacher, they can also provide more hands-on support which will benefit vulnerable or disadvantaged students. One promising solution towards incorporating online learning with the blended model in a way that is both accessible to a wide variety of learners and scalable is to combine open online education with the bootcamp model creating a new "blended bootcamp". Bootcamps are an educational delivery model popularized by for-profit coding schools first appearing in 2012, which offer an intensive 8 – 12 weeks in person program in which students quickly learned a series of in demand coding skills. Initially, these programs pitched themselves as alternatives to a bachelor's degree, and cost ~$20,000. The model was quickly innovated upon, and the term is now used for a wide variety of programs, generally ones that are geared towards developing a specific in demand skill in an intensive short term, in person setting. This model has become particularly popular with community colleges, who have long offered similar short-term certificate-based programs. The bootcamp concept also caught the interest of universities making open online classes, as a potential opportunity to provide students with a short term in person capstone, which could be accessed upon completing one or a series of MOOCs. MIT Open Learning provides a number of bootcamps around the world each year, which are offered as intensive companion experiences to online courses available on edX. This combination of offering intensive, short term, in person sessions engaging in active learning with open online education offers tremendous promise for creating avenues for building community in online courses without sacrificing the flexibility and autonomy of online education.

Emerging Educational Technology: Using Technology towards a New Learning Model

Innovations such as open online education, and blended learning show tremendous promise in changing the way education is delivered. However, many emerging technologies are on the horizon that could revolutionize the way learning is conducted, both in the classroom and online, allowing education to be delivered in a way that is structured on learning science theory and principles. Innovations in artificial intelligence, machine learning, virtual reality and augmented reality are being incorporated into classrooms allowing for education designers to utilize best practices from learning science.

PERSONALIZED LEARNING: An emerging solution towards supporting non-traditional students in an online setting could be that of making learning paths more personalized using adaptive learning techniques and digital tutors. Adaptive learning paths would be created in response to the student moving through the material, based on what skills they needed to work on and what they wanted to learn. This technology could help assess whether a student had mastered the material and needed to move on, and periodically retest material that the student had struggled with in the past to ensure that they had retained that lesson. This would support competency-based learning, as students would be able to quickly skip past material they had already mastered either in their studies or at work, and allow students to focus on material they are most interested in learning. This personalized approach to learning could help cultivate curiosity, as students would have the option to move at their own pace and interests. Even in the 19th century, educational visionaries like Maria Montessori, creator of the Montessori pedagogy, or Elizabeth Peabody, the educator who was behind nation-wide kindergartens could see that students learned best when they were engaged and curious to learn.[xlix] Cognitive researchers have since confirmed what they knew - that the brain is most receptive to new information when the student is curious, motivated, and has an internal justification for why possessing this knowledge or skill is important to achieving their higher goals.[l][li][lii][liii] This has been confirmed by neuroscientists, who have shown that curiosity stimulates areas in the midbrain and hippocampus which allows for deeper memory formation.[liv] Research has also shown that curiosity can activate reward circuitry in the brain releasing dopamine[lv], and enhances the ability to form long term memories.[lvi] Parallel to the work being done by neuroscientists, educational researchers are testing interventions for promoting curiosity in the classroom, through efforts to engage students self-expression and interests into the curriculum,[lvii] and research into adult learning in workplace education and training has shown that curiosity improves both technical and interpersonal performance on the job and in training.[lviii]

Some companies are already beginning to offer adaptive learning management systems, in which the instructor could program a series of conditionals into the course itself so that if students achieved certain proficiency levels then new parts of the course would be "unlocked".[lix] Adaptive learning techniques are already being successfully deployed on a number of educational software programs, such as the language learning app Duolingo[lx] which uses AI systems to determine a student's vocabulary and language skills, and identify weak areas that need more work. Using an adaptive learning based LMS would allow for a personalized learning path in a course, without costing an instructor additional time in assessing the individual students' skills and pace of mastery, and cultivating curiosity in the student as they embark on their own learning path.

Like adaptive learning LMS, digital tutors are also poised to allow for a more individualized learning experience with direct support when needed. Digital tutors would resemble traditional tutors, and could make personalized suggestions about the substantive weaknesses of a student in a particular area and provide a path to overcome them. However, digital tutors would be run on artificial intelligence systems, thus allowing students to have full access to the tutor whenever they liked, for a substantially smaller fee than an in-person tutor.

While the idea of digital tutors and adaptive learning is a very compelling one, it remains a feature of the near future as AI systems are not as sophisticated and widespread to be able to tackle this problem yet. A promising example of this was an experiment run by the American military through the Defense Advanced Research Projects Agency (DARPA) in which the Navy experimented with a creating a digital tutor to train Information Systems Technician students. They tested new students against seasoned professionals, students who had worked with real students, and students who had worked with the digital tutor. The students who had used the digital tutor performed better in some tests, and at least as well as the students with a live tutor, and better than the seasoned professionals. Despite the success of the digital tutor program, it is costly to continue updating the system. The DARPA system is no longer being used, as it is out of date with current software requirements.[lxi] Many other schools and companies are experimenting with digital tutor programs, for instance the company ThirdSpace Learning is building an online math tutoring program by hiring real tutors who work with students, and the data from their sessions is collected and used to train artificial intelligence systems. Once these AI systems are advanced enough, the tutors could then supervise their sessions with the students and correct their mistakes until they were performing at such a high rate that they could be trusted to work with students on their own.

INTERACTIVE LEARNING: While curiosity and personalized learning pathways are important mediators for learning, they are best coupled with active, hands on exercises rather than passive listening. This approach, known in the education field as constructivism, was first proposed by seminal educators such as John Dewey and Jean Piaget, has since been documented by cognitive psychologists who have demonstrated that as students move along the spectrum of passive to active to constructive to interactive, their learning will increase.[lxii] The education researcher Seymour Papert defined this interactive learning as "learning by making", an educational theory described constructionism.[lxiii] Studies have shown that merely being quizzed or tested on material provides the best learning outcomes, in comparison to studying material or even discussing it in a group setting.[lxiv] This shows that grappling with the material in a hands on, interactive way is more productive than passively hearing or reading about it, or even discussing it with peers.

Augmented reality could be employed as a tool to provide active, hands on experiences either in the classroom or in online classes. Augmented reality overlays physical reality with a technological lens or layer via a smartphone or tablet camera or smart glasses and allows for interaction with the digital models that can be seen on top of their own physical space. While augmented reality has seen a slower uptake in the classroom environment, it is being widely used in the industrial setting for training and work. A study published in the *Harvard Business Review* noted that wearable technologies are helping workers close the skill gap in advanced manufacturing, allowing workers to be more productive, work at a higher quality, and require less training.[lxv] This is illustrated by workers at Boeing, who are using augmented reality glasses to assemble complex wire harnesses for aircraft. Rather than viewing instructions on a laptop, they are able to call up the schematics on their AR glasses display which can be seen in line the equipment they are working on, and use voice control to navigate through the documentation. According to the Boeing Research and Technology office, the use of AR glasses has significantly reduced error rates and boosted productivity by 25%.[lxvi] At a GE plant in Florence, Italy, workers use AR to inspect gas turbine nozzles, a job requiring lots of very precise and minute measurements which used to take 8 hours to complete and now only takes 1 hour.[lxvii]

AR is beginning to be imagined for the classroom to take advantage of its "unique ability to create immersive hybrid learning environments that combine digital and physical objects, thereby facilitating the development of processing skills such as critical thinking, problem solving, and communicating through interdependent collaborative exercises."[lxviii] It could be used to enhance interaction in learning, through 3D objects that could be manipulated and inspected either in groups or alone. One could imagine that 3D data simulations could replace pictures or diagrams in textbooks, as students could see a chemical process play out in real time in front of them, or parse through layers of an engine to see how different components work together. Medical schools are incorporating AR technology into training doctors and surgeons, allowing them access to more information and checklists as they complete procedures.

SITUATED LEARNING: Another insight emerging from learning science is that people learn best when they understand the relevance of the material to their life, and can orient the material into their existing mental framework or worldview. Skills and information are more relevant when they are presented in their real-world context, a concept known as "situated learning", and when students have the opportunity to master these skills in the pursuit of solving bigger problems that relate to a real-world context, or "constructionism". Situated learning takes place in the context that the learner would use the knowledge or skill being learned. These theories of learning holds that learning involves "mastering authentic tasks in personally relevant, realistic situations."[lxix][lxx] This learning style is based on the concept of embodied cognition, which posits that "retrieving a concept from memory and reasoning about it is enhanced by creating a mental perceptual simulation of it."[lxxi] Everyone formulates their own sense of meaning based on new knowledge and understanding, resting on previous experiences, their sociocultural background and context. A good instructor is able to create rich, varied learning experiences that they guide the learner through, encouraging the learner to develop new meaning and knowledge on their own, rather than to impose a fixed set on knowledge and meanings on the student.

Virtual reality (VR) is another technology that holds a lot of promise for educational purpose, as it allows for real world simulations in which students can learn and practice skills in the context and setting in which they will be applied. Virtual reality training is not as futuristic as it sounds. Pilots have been utilizing flight simulators since the advent of the Link Trainer in 1929, in order to practice their skills without the life or death consequences and expense of flying real planes. And the idea of simulated training has been a mainstay in workforce training for centuries, through practices like medical doctors learning surgery techniques on cadavers, or emergency respondents practicing mouth to mouth resuscitation on specially made dummies. Virtual reality allows for this training to be conducted without specialty equipment, and to create an immersive atmosphere that can convincingly recreate the real-world setting. Virtual reality simulation models are being applied to a wide range of professions. One surprising early adaptor of virtual reality training was professional football teams in the NFL. Many teams began adopting VR training in 2014 to help quarterbacks visualize the field and practice making strategic judgements about which play to use, which was so successful it is now being deployed across all professional sports from basketball to hockey.[lxxii] Many companies are also using virtual reality to train new employees and let them practice scenarios they will encounter in their work, including Wal Mart, which was so impressed with the VR training it decided to go "all in" on virtual training and acquired the virtual reality startup Spatialand in 2018 to design both their employee training but also to bring virtual reality into the in-store consumer experience.[lxxiii]

While many industries are seeking to bring VR into their training regimes, they have been slow to find their way into the classroom. Until recently, VR headsets were very expensive, required a lot of connected computer equipment, and required custom coded software programs to run. However, VR has become more accessible due to the advent of google cardboard and similar devices on which one can convert their smartphone into a VR headset, as well as new stand-alone headsets like the Oculus Go, which retails for ~$200. There are now a wide range of educational VR programs that are easily available that can take the viewer on an up-close tour of the human body, the canals of Venice, or the pyramids of Egypt. Learners can download a VR app that places the viewer inside a taxi in Peru, holding a conversation with a simulated cab driver in Spanish to practice their vocabulary, or in the back of a Lancaster bomber during the Berlin Blitz of 1943 with the BBC war correspondent for World War II, Wynford Vaughan-Thomas. These applications are more than just exciting educational toys. Research has shown that the brain encodes experiences in virtual reality the same way that it would an experience encountered in real life[lxxiv], so much so that physical therapists are using it to retrain the brain to move the body in rehabilitation.[lxxv] It has also been shown to enhance the brain's power to retail information, as researchers found that memorizing or learning concepts physically represented in virtual reality led to better memory recall than people who had learned the material via reading or lecture.[lxxvi]

Another promise of virtual reality is in its use as a communication tool. VR could be a better alternative to distance meetings or online classes, as it would allow users to gather in a physical space and freely move about that space. Rather than a class held over an internet platform like zoom or skype, a VR class could be held in a classroom allowing students to walk around and speak to each other either as a group or privately as in a real-world setting, to work in teams, or present 3D data visualizations. Classes of students could be instantly transported from a classroom environment to a factory floor, where they could practice hands on application on model equipment. As machines are increasingly operated by workers remotely, such as drone pilots flying drones over Afghanistan from warehouses in Las Vegas, Nevada, this method of virtual training could be particularly appropriate for the 21st century.

PROBLEM BASED LEARNING: The idea of problem-based learning takes the ideals of interactive and situated learning a step further, arguing that learning should be structured through the means of solving vague and unbounded problems similar to the ones they would encounter in the real world. This structure would encourage the learner to be curious about the answer, and to interactively incorporate the material into their existing mental framework. It would also necessitate that the learner strategize what tools or skills would be required to solve the problem, helping them to combine aspects of their training they might have learned as separate units, and to seek out new information or skills needed. This was first proposed by HS Barrows as a way to improve medical school instruction, by presenting medical students with problems they would encounter in their practice, and teach the underlying concepts and knowledge to solve the problems.[lxxvii] He proposed that structuring education this way would allow for the development of an effective reasoning process that would be directly used in the real world, by teaching students to practice assessing the problem, posing and testing hypothesis, data gathering and decision making.[lxxviii] It would also allow for the development of self-directed learning, as students would be need to identify the information they needed to solve the problem, and the best way to internalize that information quickly. By guiding students through the task of learning how to approach problems, gather information, and teach themselves the necessary information needed for resolving them, teachers would be giving students the not only the information but the tools needed to be successful in the real world. This could be achieved through the use of virtual simulations. Virtual simulations recreate real world technology, software or settings in a 2D computer setting, and allow the learner to click through training scenarios and practice using the equipment. This is an ideal teaching tool for software, as the computer is the context that the skills would be used anyway. However, virtual simulations are being created for training on a wide variety of topics, from teaching students how to do experiments in a lab, to program high tech equipment in photonics.

CONCLUSION

Learning science can seem very intuitive, as we all have experienced this process in learning the skills and information we need to do our jobs, perform our hobbies, and navigate our lives. However, until recently, surprisingly few of these developments found their way into our classrooms or the education system. If you wanted to see learning theory in practice in the late 20th century, a good place to look was in the video game industry. As James Paul Gee noted in his book What Video Games Have to Teach Us About Learning and Literacy, in the pursuit of engaging players to learn the complex worlds of the video games and master the technical skills to traverse them, developers were hacking into solid cognitive practices for learning by giving players a clear sense of identity, a purpose and meaning, larger goals to achieve, and a stepped framework of skill practice and mastery to get there. The digital world of the game provided freedom to design the a more optimal environment for human learning. While there have been great strides in re-thinking traditional classroom and workforce education, learning in the real world does not have the boundless possibilities that it can in a video game. It is challenging to individualize learning experiences so people can work at their own speed in a large classroom or group, and often difficult or impossible to incorporate the real-world scenarios in which the skills will be used. However, technological advances can present real opportunities to incorporate these real-world simulations, enhance communication and collaboration, and to make education more flexible so that it could be delivered outside of the classroom, in real time.

As emerging technologies are driving the need for a better, faster, cheaper, and more inclusive education system, so are they also providing the new tools needed with which to build it. This technology can be incorporated into the education delivery model, providing more interactive and competency-based online and blended classes and programs that can be more easily accessible to working adults, without sacrificing the community and personal connections of classroom learning. Advances in artificial intelligence can be deployed in educational design to give students a more personalized, flexible and adaptive learning experience, allowing them to focus on skills that need practice, and skip components they have already mastered. Virtual and augmented reality could be used both to provide increased opportunities for communication and in person sessions, as well as for constructing real world, problem-based scenarios that allow for rich situated and problem-based learning in the course. These advances in technology give educators and institutions the opportunity to enhance their learning design, both in the classroom and through new models of educational delivery, to improve the quality of learning and to make education more accessible to a broader population.

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