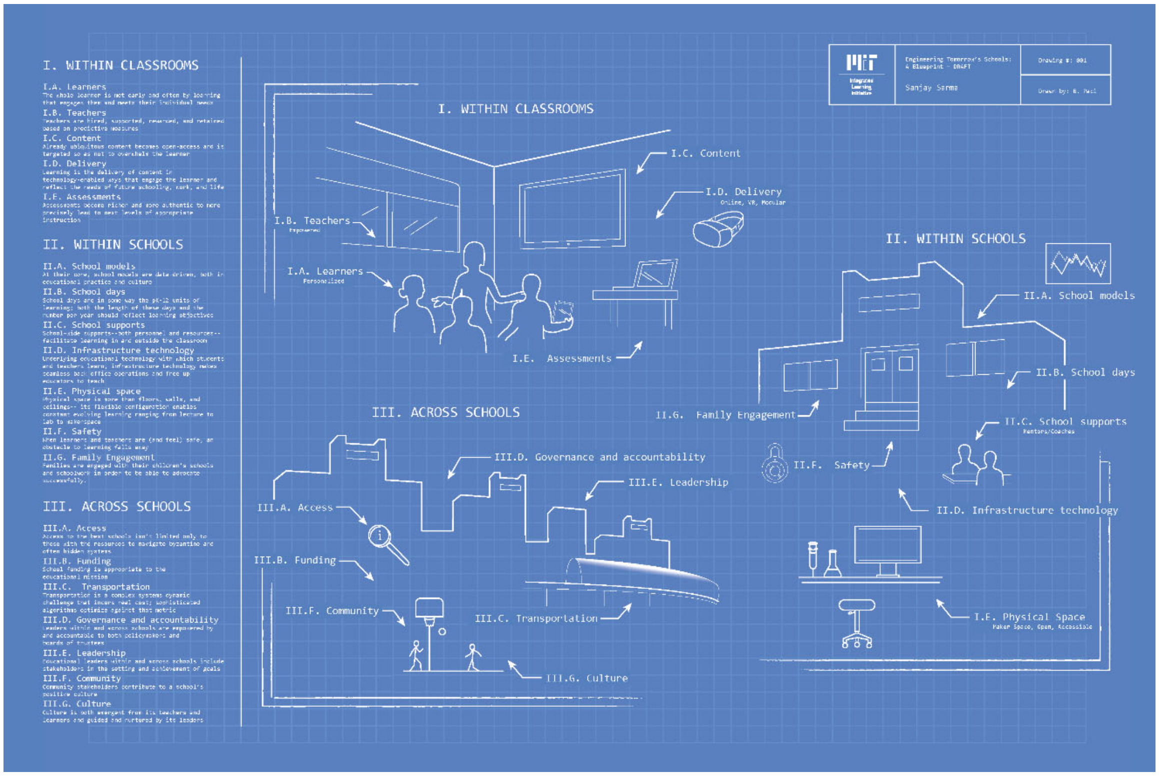
MIT Open Learning:
Playful Journey Lab and MIT Integrated Learning Initiative

Project Blueprint: MIT Learning Engineering White Paper



November 2020

EXECUTIVE SUMMARY

The MIT Integrated Learning Initiative's study of learning engineering both outside of MIT and within culminated in the following articulation, with the important caveat that it represents one MIT articulation--any institution as complex as a research university will inevitably have multiple perspectives on any topic.

> **Learning engineering is the cross-disciplinary evidence-based creation, iterative testing, and improvement of effective human learning experiences.** The successful application of this characterization of learning engineering toward the continual improvement of pK-12 education requires the following commitments:
>
> - **Ground floor participation by/co-design with** educators, parents, and the community
>   - Identification of high-leverage problems with educators, parents, and communities, not for them
>   - Defining criteria for rigor and success with the communities and educators, not for them
> - **Respectful research** sensitive to the academic needs of students and teachers
> - **Consideration of the human element**: social emotional learning before technology advancement
> - **Appropriate funding** for materials, technology, and professional development

Acknowledgement and background

This white paper is an excerpt from a broader report documenting MIT work graciously supported by a foundation grant from Schmidt Futures in response to this initial question: what does MIT believe about pK-12 learning? The MIT Integrated Learning Initiative (MITili) framed its response in the context of an educational system that has plateaued and under the banner "From Neurons to Nations: Advancing the Science of Learning," making the point that from how learning takes place in the brains of individuals to how national policy is set, the evidence of science must be a foundation and that the resulting research alone isn't sufficient without translation to educator-embraced practice.

MITili extended this answer to outline existing and needed research filling out a "within classrooms, within schools, across schools" model. This research addresses subjects as diverse as learners, teachers, and content ("within classrooms"), school models and infrastructure technology ("within schools"), and access and leadership ("across schools").

MITili formed a "Project Blueprint" team composed of faculty, researchers, students, and staff. This team set out to accomplish three main tasks: (1) develop a white paper laying out an MIT perspective on how learner-focused, educator-centered, and technology-powered learning engineering can enable educational change (this document), (2) design representative fundable projects that would apply learning engineering to address specific educational challenges, and (3) begin exploratory research on one such challenge.

Learning Engineering to Support Human Skills: MIT's Learning Engineering Vision for the Future of pK-12 Education

Statement of Purpose

Problem Statement

By numerous qualitative and quantitative measures, public education in the United States fails to meet the high standards that we expect. Academically, American students lag compared to other advanced countries such as Singapore, China, and South Korea based on the international comparison tests PISA (Pisa, 2018) and TIMSS (TIMSS, 2015). Beyond these top level academic scores in the US, an achievement gap exists between white and non-white students, between boys and girls, and between higher and lower socioeconomic status (SES).

In terms of well-being, happiness, and health of young people at school age, the United States also struggles (citation/statistics). At the time of writing this white paper, the world is of course experiencing a pandemic, which in effect is resulting in a large scale experiment that sheds light on deeply rooted problems in our education system. Just one such example is the extent to which the education system relies heavily on a teacher-led in-classroom learning model.

The structure of the current public school system is based largely on industrial age models of living and life. The primary goal of pK-12 education has been to equip citizens with basic literacy and numeracy skills. The rate of change has been slow. The world outside of school, however, driven by technological advances, continues to progress at an ever increasing rate.

Former MIT and current Stanford professor Erik Brynjolfsson and MIT Initiative on the Digital Economy Co-Director Andrew McAfee, in their book "The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies," document new waves of technology: agriculture (10,000 BCE), industry (mid-1700s), information (late 1900s), and now autonomous software machines (Brynjolfsson & McAfee, 2014). While Brynjolfsson and McAfee are optimistic about the future that autonomy will power, others are less so. Thinkers from perspectives as different as Stephen Hawking, Nick Bostrom, and Yuval Noah Harari caution against the unknowns and unintended consequences of autonomous technology (Larson 2015; Hern 2016; Parker 2020). The future is more uncertain than it is bright or dismal--regardless, the advancement of AI and technology will tremendously challenge beliefs about fundamental human work and pressure an already too-large inequality gap. A key question remains in service of this future: what is the fundamental goal and role of pK12 education and how should we innovate the education of the future?

Solution Path

In 2016, MIT Open Learning released its Online Education Policy Initiative (OEPI) report calling for actions for higher education to step up and re-imagine the education of college students using a learning engineering approach (Willcox and Sarma, et.al., 2016). Since then, there has been increased investment in higher education to create learning engineering teams within the institution to integrate learning sciences, instructional design, and learning technologies across disciplines. In the OEPI report, MIT leadership said this about learning engineering:

> *Learning engineers must have a knowledge base in the learning sciences, familiarity with modern education technology, and an understanding of and practice with design principles. Preferably, they will also have a deep grounding in a specific discipline such as physics, biology, engineering, history, or music. An understanding of the contexts for education is also important, as learning engineers must understand the cultures and limitations of the environments in which they design. Learning engineers are not academic researchers, but they must be familiar with the language of several fields in the learning sciences in order to communicate with experts and stay up-to-date on current research. In addition to a foundation in theory, learning engineers should have experience working in the types of environments in which they will be needed, whether in schools, colleges, or edtech companies.*

Since then, the pK-12 community within MIT--professors, lab directors, research scientists, lecturers, and staff whose primary work focuses on learning and development-- has been asking the same question of pK-12 education: What does a learning engineering approach mean for the MIT pK-12 community and what are common goals and practices that we share for what purposes?

There is a high level of optimism that learning engineering, largely based on the possibility of conducting large scale educational research on instruction and intervention that leverages data science, could finally transform pK-12 education in this country. However, if there is one clear lesson that we can learn from the influential work of Tyack and Cuban, it is that the innovative reform effort that magically reforms education does not exist. In fact, educational reform efforts so far have been incremental at best (Tyack & Cuban, 1995). Means similarly cautions us against the idea that new advances--learning engineering being one such example--will necessarily change education (Means, 2018).

Goals

This white paper has several interconnected goals. We first critically review the existing practices of learning engineering and reflect on the current state of this emerging field. Second, we discuss our findings regarding how MIT is defining and applying learning engineering to envision the future of pK-12 education. That is, we describe, based on the internal convenings and interviews of MIT pK-12 leadership, how the MIT pK-12 community has been applying learning engineering since the initial 2016 OEPI report. We then answer the question of "Why?" That is, what high-leverage and high-impact problems does the pK-12 community identify as a place to apply learning engineering as a means to bring innovation for the future of learning. Lastly, we introduce a case from a learning engineering team to illustrate a version of learning engineering that exemplifies the preceding ideas.

White Paper Outline

The organization of this paper is as follows. First, we report the current landscape of learning engineering, particularly for pK-12 education, and discuss the gap and limitations of the current views that are predominant. Second, we report the themes that are identified as the "MIT Way" for learning engineering, answering what, why, and how with descriptions of ongoing research and development efforts with the MIT community that exemplify those ideas. Third, we discuss a vision for a path forward that the community has put together for how MIT's learning engineering principles and practices can be applied.

Overview of the Current Learning Engineering Landscape

The Founding of Learning Engineering

Herbert Simon, a Nobel Laureate and Turing Award winner, first coined the phrase learning engineering in his 1967 paper "The Job of a College President" (Simon 1967). He describes learning engineering as "individuals who are professionals in the design of learning environments." Their most important responsibility is "working in collaboration with members of the faculty whose interest they can excite, they design and redesign learning experiences in particular disciplines.

MIT and Learning Engineering

As detailed in the aforementioned OEPI report, MIT's Digital Learning Lab program, founded in February 2013, expresses MIT's commitment to learning engineering (Willcox and Sarma, et.al., 2016). For a bit more perspective, it's worth turning back the clock a few years to 2011. The then-head of MIT's Computer Science and Artificial Intelligence Lab (CSAIL), Anant Agarwal, pulled together a group of MIT faculty to explore the online learning space. Out of those conversations, MIT and Harvard jointly founded edX as a platform to host MITx, HarvardX, and eventually other online courses, with Agarwal becoming edX's CEO.

With prototype and eventually a production online course platform at hand, the next order of business was the evidence-based development of the courses themselves. MITx pulled together postdoctoral fellows, instructional designers, and others combining subject matter and learning design expertise. By 2015, this group was formalized as MIT Open Learning's Digital Learning Lab (DLL). Their work continues today as they support faculty to create online courses for MITx (roughly, undergraduate level content), MIT MicroMasters (graduate level), and MIT xPRO (workforce). Most recently, the DLL fellows did much of the heavy lifting of MIT's pandemic-driven transition from in-person to remote instruction in the spring of 2020.

Learning Engineering Beyond the MIT Campus

The preceding paragraph notwithstanding, the advancing of learning engineering is certainly not restricted to MIT. The Chan-Zuckerberg Initiative's Vice President of Learning Science Bror Saxberg has done as much as anyone to re-energize "learning engineering" by that name, first in his 2014 book "Breakthrough Leadership in the Digital Age: Using Learning Science to Reboot Schooling" (Hess and Saxberg, 2013), then in his 2015 Chronicle of Higher Education article "Why We Need Learning Engineers" (Saxberg, 2015), and most recently in his book "Learning Engineering for Online Education: Theoretical Contexts and Design-Based Examples" (Dede, Richards, and Saxberg, 2018).

Per Saxberg, "a learning engineer is someone who draws from evidence-based information about human development--including learning--and seeks to apply these results at scale, within contexts, to create affordable, reliable, data-rich learning environments (Saxberg, 2015)."

Given the infancy of the field, there is no single unified definition for learning engineering. However, there is increasing recognition of learning engineering as a profession and increasing efforts toward identifying a set of common competencies and practices. Much of this effort is driven by the industry.

Most notably and perhaps somewhat oddly given IEEE's domain, the organization formed a consortium in 2017 to define learning engineering. In 2019 they hosted their first learning engineering conference. IEEE defines learning engineering as a "process and practice that applies the learning sciences using human-centered engineering design methodologies and data-informed decision making to support learners and their development" (IEEE, 2019). While this definition is fairly broad, it is sufficient to communicate the core of learning engineering to differentiate it from similar roles such as instructional designer and learning scientists.

While the IEEE definition mentions the use of human-centered engineering and design, however, it does not make explicit how the power dynamic between the engineer and the stakeholders (e.g., teachers, learners, parents) plays a "for whom and with whom" role in the human-centered process (Philip et al., 2018). Another definition expands this view by defining learning engineering as, "How do we use promising principles from the science of learning, together with design processes from engineering, and the platforms of technology (where appropriate) to co-create and test rapid-cycle, iterative solutions to grand challenges in education?" (Uncapher, 2019). Uncapher emphasizes in her definition that the learning engineering process should move away from a one-sided, linear transfer of research into practice, and move toward a more bidirectional, action research based conversation between researchers and practitioners.

On the academic front, the growth of learning engineering is evident. Two prominent examples include: Carnegie Mellon University's one year Masters of Educational Technology and Applied Learning Science (METALS) program jointly offered by their Human-Computer Interaction Institute and Department of Psychology; and Boston College's one year M.A. in Learning Engineering from their Lynch School of Education and Human Development.

Assumptions Underlying Learning Engineering

Based on the varying definitions of learning engineering, it is worth discussing some of the implicit assumptions that the advocates of learning engineering make. While these assumptions are not explicitly represented in the definitions of learning engineering, some known practices and examples are often strongly associated with learning engineering.

First, learning engineering's implicit goal is often assumed to be implemented "at scale," as suggested by many of the authors in the first proceedings of IEEE (IEEE, 2019) and the chapters in the Dede book (Dede, Richards, and Saxberg, 2018). Related to the notion of scale, learning engineering often assumes that the ability to examine effectiveness of an educational intervention is driven by the power of big data and data sciences. Learning engineering also implicitly assumes that the primary type of learning environment will be online, technology, or platform. The primary goal of learning engineering is often assumed to increase "efficiency and effectiveness." For example, Dede writes that "learning engineers are professionals who understand theoretical and evidence-based research about learning and learning measurement, apply these findings to test their value in the crucible of specific situation of practice, and refine the initial approach to develop heuristics and models to makes students' learning more efficient and effective" ((Dede, Richards, and Saxberg, 2018)). Additionally, the primary paradigm so far considered as the rigorous way to measure or conduct data-driven improvement is through randomized control trials (Brown & Kurzweil, 2016).

Second, learning engineering has not uniformly examined education across all learning demographics: birth through PreK, pK-12, higher education, and workforce. Today, the majority of examples of learning engineering applications are found in higher education and industry, with fewer in younger learner environments.

One case study coming out of Kaplan University, a for-profit online university now owned by Purdue University, illustrates the most mainstream understanding of learning engineering application. Kaplan University's "Research Pipeline" conducted large scale (more than a hundred) different randomized controlled trials (RCTs) as a systematic way to check "what works" (or doesn't) before deployment. An example of the application of learning engineering in Kaplan University's case saw the research team develop a dashboard and conduct an A/B testing-type RCT across different sections and then implement the dashboard across all courses based on the positive effect.

Critical Perspectives for the Current Perceptions and Practices of Learning Engineering

The previous section reviewed existing notions and practices of learning engineering that are well reflected in the IEEE ICICLE definition as well as other writings on this approach. In summary, the existing practices of learning engineering have mainly been a response to the call for action of increasing the quality of learning in higher education by leveraging new opportunities presented by the advance of online learning and big data. The majority of existing examples that exemplify learning engineering exist largely in well-resourced universities including MIT, Stanford, Harvard, and Carnegie Mellon. There are only a few examples of learning engineering in pK-12 education, and many of those examples are affiliated with CMU, which represents a specific perspective on the way people learn.

Given that learning engineering is a nascent field, it is too early to define what the core of learning engineering will end up being. However, there are several observations that we made that the community should reflect on to apply what is known as learning engineering to the pK-12 education context.

Application of Learning Engineering to Instruction for pK-12 as a Setting

First, in general, engineering involves taking scientific understanding of the natural world and using it to invent, design, and build things to solve problems and achieve practical goals. Therefore, a specific engineering domain (e.g. civil engineering) focuses on specific sets of problems.

The vision that Herbert Simon laid out focuses on the problem of improving quality instruction in higher education. Thus, the learning engineering team for that type of problem may look very different from teams focusing, for example, on recruiting a more diverse student population. So far, it is unclear whether the field has considered where learning engineering is best positioned to solve persistent problems in education. Before jumping on the bandwagon of learning engineering as a solution, there is a need to answer this question.

There is a general notion that use of big data is central to learning engineering's ability to enhance educational outcomes. Broad considerations and creative thinking are needed around what a new pK-12 learning environment is and how learning engineering can be applied. As Long pointed out (Long, 2018), learning engineering will be "old wine in a new bottle if some of the underlying paradigms on which the design practice of creating learning experiences are not rethought."

Application of Learning Engineering to Avoid Systemic Injustice

Second, without being viewed through an inclusive lens, learning engineering runs the risk of being used as a tool, intentionally or not, to further sustain existing racial and social injustices in the education system. Similarly, how learning engineers should take into account systematic racism in education to drive data-driven decision-making is unclear. The perspective that RCTs are the "gold standard of research" often overlooks the fact that it is biased or unjust systems being measured. Seemingly neutral criteria have, at best, overlooked cultural ways of knowing and doing in non-dominant communities; at worst, they have been complicit in forms of linguistic and cultural genocide (Philip et.al., 2018).

Learning engineering using large, existing, and most importantly, biased data to measure effectiveness of interventions so far hasn't been emphasizing how learning engineering will avoid perpetuating injustice into new technological innovations, and how learning engineering can be applied to address racial injustice in the education system.

Application of Learning Engineering Beyond Specifically-Demonstrated Examples

Third, all of the learning engineering examples to date are based on specific models of learning. That is, it is either instructor-led, lecture-based online learning experiences that use video modules (e.g., MOOCs, Kaplan University) or intelligent tutoring systems (e.g., ASSISTments, Carnegie Learning). It is also noticeable that the bulk of pK-12 learning examples are found in the math domain (e.g., Algebra Nation, ASSISTments) and that focus on procedure rather than conceptual understanding and mathematical problem-solving.

In theory, these systems could also be used as a large scale research platform to conduct experiments that allow researchers, content developers, and platform developers to improve system features based on increased learning effectiveness and efficiency. These examples address a specific problem in the education system--American students' lagging overall math proficiency--while missing an opportunity to leverage this advance to create learning environments that support diverse learning outcomes beyond procedural math.

Application of Learning Engineering Beyond Specific STEM Realms

Fourth, beyond math, the type of learning engineering that is being imagined is limited largely to computer science and data science. In a true engineering sense, depending on the nature of the problem, different engineering approaches will need to be chosen. So far, the very engineering approach that emerges from science remains limited to a correspondingly narrow scope of the problems.

Application of Learning Engineering to Assessment

Fifth, types of assessment and measurement that are being utilized in learning engineering examples are largely focusing on the perspective of learning as cognitive development and skill acquisition. Therefore, the measurement of learning largely focuses on mastery of learning measured using less authentic forms of assessment (e.g., multiple choice, true/false, fill in the blank). The power of educational data mining as a foundation for learning engineering goes only so far when faced with constrained assessment capabilities.

Application of Learning Engineering to Research in pK-12 as a Setting

Sixth and finally, the concept of a comprehensive "research pipeline" that is a hallmark of learning engineering is unrealistic in the complex realities of the pK-12 education ecosystem. During a regular school year, implementing different interventions that could affect the learning outcomes can lead to further harm. Also, the rapid changing of instructional and assessment practices based on A/B testing might work in environments with a professional team of researchers and developers, but likely fails in real classrooms and schools.

Learning Engineering for pK-12: What is MIT's Perspective?

MIT Learning Engineering Experience

MIT's 2016 OEPI report addressed learning engineering in the context of higher education and specifically the institute itself. The embodiment of that learning engineering work is via the MIT Teaching + Learning Lab (TLL) and MIT Open Learning (MITOL). In different ways, these two organizations support faculty in the creation and delivery of effective learning experiences.

TLL's focus is on in-person residential instruction. Their foundation is researched-based design. On top of that foundation, they layer a student-centered approach: to the extent possible, instruction needs to meet the student where they are in order to move them toward a course's learning objectives. Finally, TLL assists in the collection and evaluation of data generated during the course of learning. That analysis in turn informs improvements to the underlying instruction.

MITOL's general principles are the same as TLL's: research-based, student-centered, and data-validated. Not coincidentally, those same principles are at the core of learning engineering. MITOL, in which the two groups (PJL and MITili) leading Project Blueprint are housed, adds a focus on the application of technology and on non-residential MIT learners. It's instructive to look at key groups within MITOL--OpenCourseWare, MITx, MITx MicroMasters, MIT xPRO, and Residential Education--to see how they collectively represent learning engineering at MIT.

MIT's OpenCourseWare (OCW) initiative, which celebrates its 20th anniversary next year, set the MITOL wheel in motion. Originally conceived as a publicly-accessible repository for MIT course materials, OCW has evolved to include full-fledged digital course content. Learners can access this content anonymously, and do not earn credentials.

MITx was announced in 2011, ten years after OCW's founding. The organization edX, jointly founded by MIT and Harvard, serves as the platform powering MITx courses (and now, 2,500+ courses in total from close to 150 organizations). Like OCW, MITx content is faculty-driven. Unlike OCW, MITx courses allow learners to engage with each other in the course and earn digital credentials.

Whereas MITx courses represent undergraduate level content, MITx MicroMasters courses (also on the edX platform) represent graduate level content. Moreover, the MicroMasters courses are designed to string together into a longer program. As with MITx, certificates are available. Unlike MITx, however, successful completion of a MicroMasters program allows a learner to apply to come on campus to finish a master's degree with some courses already in hand.

Finally, from a course perspective, there is MIT xPRO. MIT xPRO courses, also faculty-driven, reach workforce level audiences. As with MicroMasters, xPRO courses yield certificates and are designed to be taken as part of a series.

OCW, MITx, MITx MicroMasters, and MIT xPRO content is aimed at the non-residential, non-enrolled learner. The Residential Education group, on the other hand, addresses the online needs of residential, enrolled students seeking an MIT degree. They work with faculty to apply the benefits of technology to enhance residential instruction and maximize learning outcomes. Over and beyond their regular work, and in response to the pandemic and the spring 2020 move of all residential instruction online, MIT had the great fortune to draw on the talents of its Residential Education Group and the Digital Learning Lab (described in the following paragraph) to "save a semester of learning" (Kessler and Barnes, et.al., 2020).

The Digital Learning Lab serves as a critical learning engineering resource supporting all of the MIT programs described above. The DLL website describes two roles: Scientists and Fellows.

> *Digital Learning Lab Scientists are experienced subject matter experts who are also well-versed in the latest teaching and learning theories and technologies. They serve as leaders within their department in developing a digital learning strategy alongside faculty and manage a team that executes that strategy. Scientists generally hold lecturer appointments within their department and participate in both global and residential learning activities, leading the development of innovative course content and tools that faculty use on campus and in MOOCs. They also conduct educational research and regularly present at conferences and other events in support of MIT's mission to advance education through technology.*
>
> *Digital Learning Lab Fellows are generally postdoctoral scholars who support digital learning projects within their departments. As subject matter experts with strong backgrounds in teaching, they collaborate with MIT faculty and Digital Learning Scientists to produce digital content for MITx MOOCs and MIT residential courses, and serve as course staff and discussion moderators while courses are running. They may be assigned to a department, working under a Scientist, or to a specific project such as a MicroMasters program. They facilitate advancements in online learning through tool development, research, and other projects.*

The groups above reside primarily within MIT Open Learning, the exception being the Digital Learning Lab Scientists and Fellows with official appointments within academic departments work in concert with and within MITOL. A less formal group, the MIT pK-12 community, spans the campus.

Their work addresses differences in learners (e.g., Professor John Gabrieli in the Department of Brain and Cognitive Sciences), instruction (e.g., Professors Eric Klopfer and Justin Reich in the Department of Comparative Media Studies and Writing), and policy (e.g., Professors Parag Pathak and Joshua Angrist in the Department of Economics). These and many other faculty tackle the challenge of improving pK-12 education by applying learning engineering principles to real-world scenarios. Project Blueprint draws on the talents of MIT's extended pK-12 community, most directly through November 2019 and February 2020 on-campus convenings. These convenings surfaced an articulation of what MIT means by learning, engineering, and learning engineering.

What MIT Means by Learning, Engineering, and Learning Engineering

Learning: An interactive exercise saw a group of almost 30 members of the MIT pK-12 community surface insights on what is meant by learning. Example responses included the following (the full set of responses can be found in Appendix 8.5).

- Learning is not about simply acquiring knowledge and skill
- Learning should be understood and engineered based on the science of learning
- Learning is a human process, and whole child development,
- Teaching what matters to the people
- Learning is about fundamental human capacity
- Learning is social/situated/complex problems

From that, the project arrives at the following concise working definition:

Learning is the human mastery of new knowledge, new skills, new mindsets, and new understanding of when and how to apply each and all of the three.

It is important to note that a single sentence can't possibly capture the breadth of conversation that resulted in this definition. Additional detail is available in Appendix 8.5. The primary value comes, of course, from the discussion much more than from arriving at a temporary result. As was true for the following two definitions, the intent was not to arrive at the best possible or even most generally accepted characterization, but rather to represent the thinking in the room at the time.

Engineering: Similarly, the assembled group tackled the question of what is meant by engineering.

- Sociotechnical approach: systems engineering approach, implementation science
- Human-centered design: design with and for
- Human and AI collaboration
- Measurements--measuring what matters
- Forward Looking: the future is here, finding solutions for problems that don't exist yet
- Incorporating human skills above/beyond those that AI currently performs: creativity, communication, collaboration, socio-emotional learning

The resulting concise working definition:

Engineering is the human and machine application of scientific principles to the evidence-based design and testing of solutions to complex socio-technical challenges.

Learning engineering: To this conversation, the participants brought a much wider range of experience. Whereas everyone had strong expertise in learning and at least solid experience in engineering, the combination of the two was new to many. Sample responses are as follows:

- I teach, so in that sense I see myself as an engineer of learning opportunities; I also assess, which gives evidence that LE has been successful
- Our work often uses a DBR (domain-based research) style approach (though not often at large scale)
- LE is part of what I do ... at micro level with students, and teachers ... macro with programs
- LE = learning sciences + technology + social systems, which is critical in making edtech that matters

The concise working definition that emerged:

Learning engineering is the cross-disciplinary evidence-based creation, iterative testing, and improvement of effective human learning experiences.

The remainder of this white paper outlines an MIT pK-12 learning engineering vision.

An MIT Vision for Learning Engineering Applied to pK-12 Education

This section summarizes an MIT vision for learning engineering and the future of pK-12 education. It is important to offer this caveat--this is one MIT vision, not the only MIT vision. The very nature of academia and its freedoms requires that unanimity be reached on only the broadest of questions--an institution's mission statement, for instance (and even then, faculty, students, and staff face no requirement to endorse that vision):

The mission of MIT is to advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world in the 21st century.

IEEE's definition of learning engineering makes as good a starting point as any:

Learning engineering is a process and practice that applies the learning sciences using human-centered engineering design methodologies and data-informed decision making to support learners and their development.

The following definition emerged from the Project Blueprint February 2020 convening:

Learning engineering is the cross-disciplinary evidence-based creation, iterative testing, and improvement of effective human learning experiences.

The objectives and realities of public education in the United States require elaboration before learning engineering might be put to the test within its domain. Here, a second caveat is merited--engagement with pK-12 stakeholders is a critical element of the successful application of learning engineering principles. As such, the following vision is provisional.

> **Learning engineering is the cross-disciplinary evidence-based creation, iterative testing, and improvement of effective human learning experiences.** The successful application of this characterization of learning engineering toward the continual improvement of pK-12 education requires the following commitments:

- **Ground floor participation by/co-design with** educators, parents, and the community
  - Identification of high-leverage problems with educators, parents, and communities, not for them
  - Defining criteria for rigor and success with the communities and educators, not for them
- **Respectful research** sensitive to the academic needs of students and teachers
- **Consideration of the human element**: social emotional learning before technology advancement
- **Appropriate funding** for materials, technology, and professional development

REFERENCES

J. Brown and M. Kurzweil, Engineering Learning at Kaplan University. Ithaka S+R, 2016. https://doi.org/10.18665/sr.284711

E. Brynjolfsson and A. McAfee, "The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies," W. W. Norton & Company, 2014.

C. Dede, J. Richards, and B. Saxberg, "Learning Engineering for Online Education: Theoretical Contexts and Design-Based Examples," Routledge, 2018. https://www.routledge.com/Learning-Engineering-for-Online-Education-Theoretical-Contexts-and-Design-Based/Dede-Richards-Saxberg/p/book/9780815394426

A. Hern, "Stephen Hawking: AI will be 'either best or worst thing' for humanity," The Guardian, October 19, 2016. https://www.theguardian.com/science/2016/oct/19/stephen-hawking-ai-best-or-worst-thing-for-humanity-cambridge

F.M. Hess and B. Saxberg, "Breakthrough Leadership in the Digital Age: Using Learning Science to Reboot Schooling," Corwin Press, 2014. https://sk.sagepub.com/books/breakthrough-leadership-in-the-digital-age

IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, "Ethically Aligned Design: A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems," 2019. https://standards.ieee.org/content/ieee-standards/en/industry-connections/ec/autonomous-systems.html

A. Kessler, S. Barnes, K. Rajagopal, J. Rankin, L. Pouchak, M. Silis, and W. Esser, "Saving a semester of learning: MIT's emergency transition to online instruction," A Response to Emergency Transitions to Remote Online Education in K-12 and Higher Education, Information and Learning Sciences, 17 June 2020. https://www.emerald.com/insight/content/doi/10.1108/ILS-04-2020-0097/full/html

E. Larson, "Questioning the Hype About Artificial Intelligence," The Atlantic, May 14, 2015. https://www.theatlantic.com/technology/archive/2015/05/the-humanists-paradox/391622/

P.D. Long, "The Role of the Learning Engineer," Learning Engineering for Online Education: Theoretical Contexts and Design-Based Examples, Chapter 2, Routledge, 2018.

B. Means, "Tinkering Toward a Learning Utopia: Implementing Learning Engineering," Learning Engineering for Online Education: Theoretical Contexts and Design-Based Examples, Chapter 3, Routledge, 2018.

I. Parker, "Yuval Noah Harari's History of Everyone, Ever," The New Yorker, February 10, 2020. https://www.newyorker.com/magazine/2020/02/17/yuval-noah-harari-gives-the-really-big-picture

T.M. Philip, M. Bang, and K. Jackson, "Articulating the 'How,' the 'For What,' the 'For Whom,' and the 'With Whom' in Concert: A Call to Broaden the Benchmarks of our Scholarship," Cognition and Instruction, 36(2), 83–88, 2018. https://doi.org/10.1080/07370008.2018.1413530

PISA, OECD's Programme for International Student Assessment, 2015. https://www.oecd.org/pisa/

B. Saxberg, “Why We Need Learning Engineers.” Chronicle of Higher Education, April 20, 2015. https://www.chronicle.com/article/why-we-need-learning-engineers/

H. Simon, “The Job of a College President,” Educational Record, 48, pp. 68-78, Winter 1967.

TIMSS and TIMSS Advanced Results from 2015. https://nces.ed.gov/timss/timss2015/

D.B. Tyack and L. Cuban, L., Tinkering toward utopia. Harvard University Press, 1995.

M.R. Uncapher, From the science of learning (and development) to learning engineering, Taylor & Francis, 2019.

K. Willcox, S. Sarma, P.H. Lippel, “Online Education: A Catalyst for Higher Education Reforms,” April 2016. https://oepi.mit.edu/files/2016/09/MIT-Online-Education-Policy-Initiative-April-2016.pdf