Personalized Learning:  
The State of the Field & Future Directions

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In the 21st century, humanity is facing severe difficulties at the societal, economic, and personal levels. Societally, we are struggling with greed manifested in financial instability, climate change, and personal privacy invasions, and with intolerance manifested in religious fundamentalism, racial crises, and political absolutism. Economically, globalization and innovation are rapidly changing our paradigms of business. On a personal level we are struggling with finding fulfilling employment opportunities and achieving happiness. Technology’s exponential growth is rapidly compounding the problems via automation and offshoring, which are producing social disruptions. Educational progress is falling behind the curve of technological progress, as it did during the Industrial Revolution, resulting in social pain.

The Center for Curriculum Redesign addresses the fundamental question of "WHAT should students learn for the 21st century?" and openly propagates its recommendations and frameworks on a worldwide basis. The CCR brings together non-governmental organizations, jurisdictions, academic institutions, corporations, and non-profit organizations including foundations.

**Knowledge, Skills, Character, and Meta-Learning**

CCR seeks a holistic approach to deeply redesigning the curriculum, by offering a complete framework across the four dimensions of an education: knowledge, skills, character, and meta-learning. Knowledge must strike a better balance between traditional and modern subjects, as well as interdisciplinarity. Skills relate to the use of knowledge, and engage in a feedback loop with knowledge. Character qualities describe how one engages with, and behaves in, the world. Meta-Learning fosters the process of self-reflection and learning how to learn, as well as the building of the other three dimensions.

To learn more about the work and focus of the Center for Curriculum Redesign, please visit our website at [www.curriculumredesign.org/about/background](http://www.curriculumredesign.org/about/background)
INTRODUCTION

The vision of a highly-personalized learning experience in education is a long-standing notion advocated for by educators for many decades. At the very least, the concept dates back to the beginning of the previous century in the long-standing work of John Dewey, whose powerful writing pre-dated the boon of learning sciences research that would ultimately support his conclusions many decades later: learning is constructed by the individual, and therefore learning must be experiential and active.1 Of course, in addition to this, Dewey advocated that this type of learning is the fundamental right of all students.

More recently, tech visionary Danny Hillis offers a perspective on how emerging technologies might help us realize such a vision:

“...consider what kind of automated tutor could be created using today's best technology. First, imagine that this tutor program can get to know you over a long period of time. Like a good teacher, it knows what you already understand and what you are ready to learn. It also knows what types of explanations are most meaningful to you. It knows your learning style: whether you prefer pictures or stories, examples or abstractions. Imagine that this tutor has access to a database containing all the world’s knowledge. This database is organized according to concepts and ways of understanding them. It contains specific knowledge about how the concepts relate, who believes them and why, and what they are useful for. I will call this database the knowledge web, to distinguish it from the database of linked documents that is the World Wide Web.”

— W. Danny Hillis 2

This may sound like grand visions, but personalized learning is critical because it is a model of teaching and learning that fully aligns with the learning sciences. More than a century since Dewey’s ideas hit print, we might ask how these visions can be actualized in our current world. How do we create personalized, learner-constructed experiences at scale, in schools, and beyond?

We live in an age of personalization. The growth of mobile technologies, big data, and machine learning over the past decade have created an ecosystem that allows for (and consumers now largely demand) personalized content and experiences, from nutrition to finance.

One of the last domains to really leverage these innovations is education—now facing enormous pressure to figure out how to meet the needs of students in a personalized and meaningful manner. 3 Demand is not just coming from students and parents. Even as early as 2006 the OECD

has been promoting the need to move towards personalized learning: "It springs from the awareness that “one-size-fits-all” approaches to school knowledge and organization are ill-adapted both to individuals’ needs and to the knowledge society at large. The issues go well beyond the directions for school reform itself, as the personalization agenda is also about promoting lifelong learning and of reforming public services more broadly.”

Although perhaps off to a bit of a slow start, there has been a significant growth in the development of technologies to support, and the practice of, personalized learning in schools and beyond.

Despite this growth, Personalized Learning (PL) as a concept, and a practice, is still young—with both playing out in many different ways, which will be discussed further in the report. At its broadest definition, it is about creating learning environments and experiences that tailor to the unique needs and strengths of each student, allowing the learner to have greater control and ownership of their learning while giving them a more meaningful and effective education.

Yet, being early days, we are left with many questions: What does personalized learning look like? Both in the classroom and out? What technologies are actually personalizing learning, and what are markers or attributes we should use to truly identify a learning technology as such? Finally, what routes of research and practice are promising, and where should we be doubling-down going forward?

**Overview of Document**

The goal of this document is to offer a review of the state-of-the-field, and point to towards answers to some of these questions. In the summary that follows, we offer a synthesis definition of personalized (and personalizing) learning, give an overview of the state of the field, and provide recommendations for future research and investments. Finally, the appendices offer further details in regards to definitions and the technologies, R&D initiatives, philanthropic programs, and schools that informed this review.

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What is Personalized Learning?

Like many concepts in education, there is no agreed upon definition and ‘personalization’ in learning and in schools can play out in a myriad of ways. It is largely an umbrella term that overlaps with other education concepts—such as adaptive learning, differentiated instruction, competency-based education, and learning analytics. The Data & Society Research Institute offers a schematic for unpacking this range of genres and terms (see Figure 1).

![Personalized Learning Terms Used in Marketing Materials and Media.](source: Data & Society Research Institute (Bulger, 2016, p.3)

This lack of agreement in definition is one of the core challenges facing this fear. This past year the New Media Consortium (NMC) included PL in its annual Horizon report, labeling it a “wicked
challenge: *those that are complex to even define, much less address,* citing the lack of consensus on a definition as one of the aspects that make this challenge particularly wicked.

Prominent organizations in education, including the OECD, the Gates Foundation, iNACOL and others, offer similar yet distinct definitions. Below is a matrix (Figure 2) that captures the overlap in attributes and goals of PL, and a review of the prominent definitions in the field can be found in Appendix A.

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Figure 2. A matrix of definitions for personalized learning from key education organizations.

Although definitions of PL vary, broadly stated there is significant agreement that it is learner-centered and flexible, responsive to individual learners’ needs as they progress on mastery-based progressions or competencies. Additionally, a key distinction made by some is that it is in fact the notion of the learner driving their own learning that distinguishes personalization from other educational pedagogies such as differentiation and individualization. This aspect of student-choice and ownership is essential, as is demonstrated by the learning sciences literature.

A key challenge in agreeing on a definition is that is these sub-concepts are ill-defined or ‘fuzzy’. As such, this table reflects the attributes specifically stated in the provided definitions by each

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organization. As a result, it is quite possible that although a given attribute may not be associated with an organization’s definition because it was not explicitly stated, upon seeing this taxonomy they may in fact agree that the given attribute was intended in their definition.

At the same time, organizations purposefully create terms they feel best capture the form of PL they support. For example, iNACOL in fact advocates for “student-centered learning” which they explain, “encompasses personalized learning, competency-based education, anytime, anywhere learning and student ownership.” This is likely, in part, due to the fact that personalized learning does not have to be competency-based, learner-driven, etc.\(^8\)

For this discussion, we will use the definition offered by the Bill & Melinda Gates Foundation:

> “Personalized learning seeks to accelerate student learning by tailoring the instructional environment—what, when, how and where students learn—to address the individual needs, skills and interests of each student. Students can take ownership of their own learning, while also developing deep, personal connections with each other, their teachers and other adults.”

Though noted separately, we want to draw attention to an additional core aspect of PL that may not always be included in formal definitions, is still highlighted by a number of organizations including the Gates Foundation:

> “Student-teacher bond is at the heart of learning: Teachers and students collaborate to create learning paths that are fueled by student ownership and teachers’ insights about high-quality learning, and based on students’ individual needs, skills and personal interests.” \(^9\)

Many organizations promoting and implementing PL emphasize this belief, and note that although scaling personalized learning is largely not possible without powerful technological tools, the heart of the personalized learning environment still remains to be the student-teacher relationship.

The notion of personalized learning is often conflated with other educational terms, such blended learning, competency-based learning, etc. Many of these are distinct educational practices, that may includes attributes of personalized learning or be a core aspect of a personalized learning model.

At the same time, realizing the potential of personalized learning requires the intersection of a number of core technologies and methodologies—each of which is deep enough to require a report of its own. Figure 3 provides as a summary guide to serve as a touchstone for each of these technologies and methodologies, which will be referenced in this report.

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\(^8\) iNACOL’ “Student-centered learning models personalize learning with the use of competency-based approaches, supported by blended and online learning modalities and environments, as well as extended learning options and resources.”

## CONCEPTS AND TECHNOLOGIES INTERRELATED TO PERSONALIZED LEARNING

**Adaptive Learning (Environments) & Intelligent Adaptive Learning technologies** are responsive to the learner's inputs, and subsequently modify (or adapts) the presentation of material in response to student performance. Some capture fine-grained data and use learning analytics to enable human tailoring of responses. The associated learning management systems (LMS) provide comprehensive administration, documentation, tracking and reporting progress, and user management. Intelligent Adaptive Learning platforms are able to respond to every response by the learner, within and across domains and platforms. These are only just beginning to emerge.

*Examples:* Brightspace (Desire2Learn) • DreamBox • Knewton

**Blended Learning** is a pedagogical approach where classes or learning environments provide an integrated mix of traditional face-to-face instruction and web-based online learning. An array of technologies can be used to support this methodology, but often involves an online content provider (such as Kahn Academy) and an LMS to manage the learning across the two environments.

**Cognitive Analytics** is a field of analytics that tries to mimic the human brain by draw inferences from existing data and patterns, draws conclusions based on existing knowledge bases and then inserts this back into the knowledge base for future inferences – a self-learning feedback loop. A category of technologies that uses natural language processing and machine learning to enable people and machines to interact more naturally to extend and magnify human expertise and cognition. In practical terms, cognitive analytics is an extension of cognitive computing, which is made up of three main components: machine learning, natural language processing, and advancements in the enabling infrastructure.

**Cognitive Learning Systems** is an emerging development in IBM's data analytic approach to education based on neuroscientific methodological innovations, technical developments in brain-inspired computing, and artificial neural networks algorithms.

**Cognitive Tutors** a type of intelligent tutoring system that utilizes a cognitive model to provide feedback to students as they are working through problems. They aim to promote procedural-declarative distinction, knowledge compilation and strengthening of both declarative and procedural knowledge.

*Examples:* Carnegie Cognitive Tutor®

**Competencies & Competency-based Education** is an educational model where learners' progress is measured by demonstrating their progress in a given competency (knowledge, skills, and dispositions), as opposed to a traditional model of education that is based on seat time or the Carnegie Unit.

**Digital Playlists** are lists of digital learning resources, used to support self-directed learning and personalized learning environments.

**Educational Data Mining** an area of educational research that uses data mining, machine learning, and statistics to derive insights and understandings about learning from educational settings (including in person environments such as classrooms as well as digital learning experiences).
Intelligent Tutoring Systems (ITS) a digital technology that provides immediate and customized instruction and feedback to learners, designed to simulate a human tutor's behavior and guidance.

Examples: Wayang Outpost • AutoTutor • DeepTutor

Learning Analytics (LA) is an area of educational research that uses the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs.

Learning Management System (LMS) is a software application for the administration, documentation, tracking, reporting and delivery of educational courses or training programs. They help the instructor deliver material to the students, administer tests and other assignments, track student progress, and manage record-keeping. LMSs support a range of uses, from supporting classes that meet in physical classrooms to acting as a platform for fully online courses, as well as several hybrid forms, such as blended learning and flipped classrooms.

Examples: Moodle • Blackboard • Schoology

Learning Progressions (LPs) are empirically-grounded and testable hypotheses about how students’ understanding of, and ability to use, core concepts and practices grow and become more sophisticated over time, as they move from naive to more sophisticated ideas.

Personalized Learning Plan (PLPs) are plans that guide students in their learning journey and ensure they accomplish what they need academically and socio-emotionally in a way that works best for them. Typically developed through a collaboration between the student and teachers, counselors, and parents, they offer a way to help them achieve short- and long-term learning goals. They often consist of student “daily actionable” goals, action steps, competencies, and sometimes pacing recommendations.
STATE OF THE FIELD

Personalized Learning has gained significant momentum over the past several years. This can in part be attributed to building on the momentum of components of personalized learning, especially the growth in blended learning environments and competency-based learning. Yet also, to the rise of adaptive and AI-enabled technologies.

As noted earlier, the concept of PL has been given to a wide variety of practices; and indeed, if you do a web search for personalized learning tools you will see everything from individualized reading playlists, to intelligent adaptive tutors, to whole redesign school models.

This demonstrates the heart of things: that at its core, PL and the work related to it is reflected in two domains:

- **School Models**, and all that come with that (new policies, new school models and structures, change management, teacher PD, etc.).
- **Innovative Technologies**, especially those able to support the individualized and adaptive nature of PL and the ability to bring it to scale.

In this section, we will look at the state of these two key domains, as well as the state of research and funding.

PL in Practice

PL on some level has existed in pockets of innovative schools across the country for quite some time. Often, this has played out in the used of Personal Learning Plans, or an adaptive technology used to support a given domain. Evans gives an example, “personalized learning in math could mean that students work on their learning objectives using adaptive software to work at their own pace while a teacher roams around acting as a learning coach and tutor”.

This would be a good example of blended learning, which continues to be a popular movement in education. What’s worth noting here is while a school might implement this adaptive tool to help personalize math instruction, this is not necessarily what has been previously defined as Personalized Learning—the rest of the learning day may not be flexible, nor student-centered, nor individualized, etc.

The same can be said for competency-based learning models—also a leading trend of the past 6-10 years in education, with a particular upswing in the past three as it became the number one area of interest for the 50+ school districts in Digital Promise’s League of Innovative Schools. The state of New Hampshire has been the leader in this work in the US, though according to state officials

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leading this work, this has played out in a spectrum of ways across schools in the state. Such is to be expected in school transformation, but many of these schools are poised to be able to much more easily adopt personalized learning models. In Europe, KeyCoNet, has been a pivotal organization in supporting schools to effectively implement key competences education. A growing network of more than 100 organizations representing educational stakeholder groups from 30 European countries, they are helping to define competencies and redesign assessments to support them.

Recently, more robust school models powered by innovative technologies are begin to realize the full vision of PL and implement it in a more expansive fashion, doing away with grade levels, class schedules, bell times, and traditional school architectures and allowed students to take ownership of their learning by choosing where to devote their time throughout the day to complete weekly learning goals.11 Most notably would be Summit Public Schools, a charter management organization in the Bay Area with seven schools. Their first school now more than 15 years old, what’s really exciting is the 100+ partner schools and organizations they have garnered over the past two years as a result of their “Summit PLP”—a PL learning management system, built over the years of their innovative work and developed into a full product through a partnership with Facebook (discussed further in the “Technology & PL” section). Their work has gotten considerable attention, from both the field and funders—and indeed, to hear Summit leaders discuss their work is encouraging, both in terms of the model they have developed and the capacity they have gained as an organization to support others in adopting that model.

Also encouraging is the U.S. Department of Education Race-to-the-Top’s program funding 21 districts, consortia and charter networks with more than $500m to pursue PL models in 2012-13. Yet the research from this is mixed, in part, due to the field of PL not having collect evaluation tools and frameworks.

Enter LEAP Innovations. A Chicago-based non-profit, they are doing innovative work supporting schools in adopting PL models. LEAP works directly with educators and innovators to discover, pilot, and scale personalized learning technologies and innovative practices in the classroom and beyond, and aims to serve as a national hub for collaborators to build a new education ecosystem. They do this through their ‘collaboratory’ workspace for in-person events and trainings, a pilot network of schools seeking to move to PL models, and their Breakthrough Schools program. To date, these initiatives have engaged more than 100 partners and more than 40 schools in Chicago alone. Their impact can be seen now in large-scale districts, where in 2016, Chicago Public Schools announced an opening for a position it called “the nation’s first”: an Executive Director of Personalized Learning. Yet one of LEAP’s biggest contributions to the field is the development of evaluation tools (in partnership with the American Institute for Research), so that the field of PL has shared tools to evaluate the effectiveness of a learning environment.

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There are, of course, less successful examples as well—where implementations towards PL have gone wrong. After attempting to implement a PL pilot using the adaptive Teach to One technology, Mountain View Whisman School District drops it due to significant parent backlash. Among the complaints in a letter signed by 180 parents last December: the curriculum “does not follow a logical pathway” and “much of the instruction is quite shallow, in some cases even misleading and factually incorrect.” The cost of the failed pilot program and training was estimated at $521,000.12 This example points to one of the core challenges plaguing PL (and most innovations in education)—parents are really uninformed by what personalized learning is. Yet it also points to another core challenge in relation to any educational innovation—how it is implemented is everything. The PL models advocated for by many experts and organizations have a wealth of research to support them, as well as powerfully successful examples. However in any given context, a PL model can be implemented well, or poorly. It does not mean that PL should be thrown out because of examples like the Mountain View Whisman School District, but it does mean we need to focus most on how PL models are implemented and the outcomes they are seeking and producing.

A larger list of notable organizations working towards PL or implementing substantial aspects of PL can be found in Appendix B.

In summary, there is a large range of school-based initiatives that on some level demonstrate PL. This ranges from a small focus, such as a new adaptive math program used at the elementary levels, to whole school models that have been redesigned in order to support PL. Achieving the latter is a significant challenge of not only achieving what was previously unachievable, but a huge transformation effort for most schools to make. The organizations to watch are those who have powerful and well-designed technologies, and are successfully supporting this type of whole school redesign and change management.

**Research on PL**

While a fair amount of research exists on specific personalization strategies, such as the use of adaptive math software, the literature includes very little on personalized learning as a comprehensive approach.

The broadest look at how schools have implemented personalized-learning strategies comes via the federal Education Department, which gave more than $500 million to 21 districts, consortia, and charter networks in 2012 and 2013 as part of its Race to the Top-District program. The handful of evaluations and case studies have produced mixed (and at times even dodgy) results, at best.

In 2015, RAND undertook the field’s most comprehensive study to date. They found that 11,000 students at 62 schools trying out personalized-learning approaches made greater gains in math and

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reading than similar students at more traditional schools. The longer students experienced "personalized-learning practices," the greater their achievement growth. According to John Pane, a senior scientist and the distinguished chair in education innovation at the RAND Corp., "Personalized learning holds promise, but there's still a lot of work to do to figure out how well this is working".¹³ That study has led RAND to a better understanding of the school features that seem to help make learning personalized:

- a clear understanding of the needs and goals of each student;
- instruction tailored to meet those needs and goals; and
- frequent and constructive dialogue between teachers, parents, and the students themselves.

In short, technology can enable that kind of learning, and help teachers manage the complexities of it—but it cannot substitute for a good teacher.¹⁴

**Technology & PL**

As one might imagine, realizing the potential of PL at scale inherently will require the use of powerful, and well-designed, technologies. To do this, it requires a lot of data collection, algorithms, and analytics—but perhaps most critically, judgments about what ‘mastery’ looks like, and the pathway and cadence towards that mastery (ultimately, the pedagogy and daily experience of the learner).

We have seen tremendous strides in the development of technologies that must intertwine in order to realize the vision of personalized learning. Yet despite this progress, it is indeed still more of a vision than a reality. This section will explore the technologies that are making impact in PL.

**Genres**

There is an incredible array of technologies labeled ‘personalized’. Below are genres of technologies that make up this spectrum. [Note: these genres are not discrete. These genres capture a general orientation or goal of a technology, but any given example in that genre may contain attributes of another genre. For example, a learning management system may or may not include data-driven learning capabilities. At the same time, a game-based learning environment may also be data-driven but not be a learning management system.] Examples listed in each genre can be cross-referenced in Appendix C.

¹⁴ ibid
**Learning Management Systems (LMS)**

LMSs are not new to the education scene—these are broad platforms (such as Blackboard and Moodle) that help teachers and school systems manage learning progression for a large number of students at a time.

Examples of PL-centric LMSs include:
- BrainHoney
- Class Dojo
- Canvas
- Desire2Learn
- Schoology
- Summit PLP

**Data-driven Learning**

One of the broadest genres, data-driven technologies generally use a “data-capture/evaluate/recommend” cycle to support individual learner pathways. Students often complete some type of assessment to determine instructional needs.

Data-driven platforms use analytics that include grade level, performance on proficiency assessment, or number of incorrect tries to recommend an instructional plan (often referred to as a “playlist” serves as a checklist). Once proficiency or mastery is confirmed, the student is advanced to the next module or level.¹⁵

Examples include:
- PracTutor
- TenMarks
- McGraw-Hill Thrive
- Lexia

**Adaptive Learning**

A more sub-genre of data-driven learning (though still a large and growing part of the market) are adaptive technologies that potentially moves beyond a pre-determined decision tree and uses machine learning to adapt to a students’ behaviors and competency.

Examples include:
- Area9
- SmartSparrow
- Knewton

**Intelligent Tutor Systems (ITS)**

Cognitive tutors and intelligent tutoring systems date back several decades, with cutting edge learning sciences research on how to use technology to support individual learner needs and

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progressions. These technologies model a given domain (most successfully used in areas such as math), and are able to track the mental steps during student problem-solving in order to identify and diagnose misconceptions and learner needs. What distinguishes this genre is instead of providing answers and modular guidance, it aims to inspire questions, interact conversationally, and has enough options to move beyond a limited decision tree. They can provide timely feedback, and prescribe learning activities at the level of difficulty most appropriate for the learner, and mimic some of the benefits of one-to-one tutoring. It is worth noting that some of these systems outperform untrained tutors in specific topics and can approach the effectiveness of expert tutors.\(^{16}\)

Today, ITSs are in widespread (though not saturated) use in K–12 schools and colleges, and are enhancing the student learning experience. For example, 600,000 students in more than 2,600 middle or high schools use Carnegie Learning's Cognitive Tutor mathematics courses regularly.\(^{17}\)

Recent advances in the field have brought about a new sub-genre, known as Conversational ITSs, which have several key features: the addition of learning progressions to increase macro-adaptivity; deeper dialogue and natural language processing to increase accuracy of student input assessment and quality of tutor feedback, improving macro- and micro-adaptivity of ITSs; and modeling students’ affective states in addition to their cognitive states. This provides several advantages: they encourage deep learning as students are required to explain their reasoning and reflect on their approach to solving a problem; conceptual reasoning is more challenging and beneficial than mechanical application of mathematical formulas; and they give students the opportunity to learn the language of scientists, an important goal in science literacy.\(^{18}\)

Examples include:
- Thinkster Math
- Carnegie Learning
- Front Row

Examples of successful conversational ITSs include:
- AutoTutor
- Why2
- CIRCSIM-Tutor
- GuruTutor
- DeepTutor

**Intelligent Game-Based Learning Environments**

Game-based learning was once a quirky, small area of ed-tech research. Fast-forward 20 years, and the field has made significant gains, developing powerful research tools and commercial


technologies, for richly meaningful, engaging, contextual and personalized learning experiences. We are now seeing more examples of intelligent game-based technologies, that leverage the technology of ITS, cognitive systems, and intelligent narrative technologies to create engaging and collaborative learning environments. Their critical features include:\footnote{Lester, J. C., Ha, E. Y., Lee, S. Y., Mott, B. W., Rowe, J. P., & Sabourin, J. L. (2013). Serious games get smart: Intelligent game-based learning environments. *AI Magazine*, 34(4), 31-45.}

A) modeling key aspects of one-on-one human tutoring in order to create learning experiences that are individually tailored to students based on their cognitive, affective, and metacognitive states;

B) maintaining explicit representations of learners’ knowledge and problem-solving skills, intelligent tutoring systems can dynamically customize problems, feedback, and hints to individual learners;

C) fine-grained, temporal models of student knowledge acquisition;

D) models of tutorial dialogue strategies that enhance students’ cognitive and affective learning outcomes;

E) models of students’ affective states and transitions during learning;

F) machine-learning-based techniques for embedded assessment; \textit{and}

G) tutors that model and directly enhance students’ self-regulated learning skills.

Examples include:
- Crystal Island
- Crayon Physics

\textbf{Cognitive (Deep Learning) Systems}

The next step evolution of cognitive tutors (though a quantum leap, literally), are deep learning systems. This genre of technologies uses \textit{natural language processing} and \textit{machine learning} (including ‘deep learning’, a part of artificial intelligence) to enable people and machines to interact more naturally to extend and magnify human expertise and cognition. These systems can read, write, and emulate human behavior—most critically, they can learn. These systems will learn and interact to provide expert assistance to scientists, engineers, lawyers, and other professionals in a fraction of the time it now takes.

IBM, a leader in this genre, advocates that cognitive education services need to be immersive experiences for the student, whilst being complementary to the art and craft of teaching, and reduce the administrative burden on the teacher, effectively giving time back to teach.\footnote{King, M., Cave, R., Foden, M., & Stent, M. (2016). \textit{Personalised education: From curriculum to career with cognitive systems}. IBM Education.}

Examples include:
- Watson (IBM) – and their partners, Cognition, Symscribe and Mari
As you can see from these genres and example technologies, PL is supported in a variety of ways. As with all educational technologies, the devil is in the details of how you actually use the technology in a given learning environment.

So how are they used? According to IBM, who interviewed a number of educational establishments, they found that most are using analytics in a limited ‘rear view’ way (see Figure 4).21

![Figure 4. The use of data analytics in educational institutions, from interviews conducted by IBM. SOURCE: King, M., Cave, R., Foden, M., & Stent, M. (2016). Personalised education: From curriculum to career with cognitive systems. IBM Education.](image)

The broad span of technologies labeled as supporting PL need to be taken with a grain of salt, and caution. We have a big marketplace tagged ‘personalized’ but a much smaller subset that effectively meets the criteria of personalized learning in a way that is backed by learning sciences. For example, LEAP Innovations runs pilots with ed tech companies. Of the more than hundred that have applied, LEAP has only selected two dozen with which to work.22 This is critical LEAP work is doing, and broadly speaking many of these learning technology have not been properly evaluated, and a fair number are in short, not very good. This is an ongoing challenge in ed tech, summarized well by the Data & Society report on personalized learning23:

“While the responsiveness of personalized learning systems hold promise for timely feedback, scaffolding, and deliberate practice, the quality of many systems are low. Most product websites describe the input of teachers or learning scientists into development as minimal and after the fact. Products are not field tested before adoption in schools and offer limited to no research on the efficacy of personalized learning systems beyond testimonials and anecdotes. In 2010, Houghton Mifflin Harcourt commissioned independent randomized studies of its Algebra 1 program: Harcourt

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21 King, M., Cave, R., Foden, M., & Stent, M. (2016). Personalised education: From curriculum to career with cognitive systems. IBM Education.

22 Personal communication with Chris Liang-Vergara, Chief, Learning Innovation at LEAP Innovations. March 2017.

Fuse. The headline findings reported significant gains for a school in Riverside, California. The publicity did not mention that Riverside was one of four schools studied, the other three showed no impact, and in Riverside, teachers who frequently used technologies were selected for the study, rather than being randomly assigned. In short, very little is known about the quality of these systems or their generalizability.

In working with a broad range of ed tech startups and schools moving to personalized learning, Chris Liang-Vergara, Chief of Learning Innovation at LEAP Innovations, has noted a number of observations about the current state of the field of educational technology, and our current capacity to do this work:

- **The data infrastructure is a big challenge.** Everything learning technology approaches this differently, and as a result, you’re at the mercy of however they feed back the data to you—if they can even do that at all. It feels like smoke and mirrors. Some technologies do not even have a unique student identifier, and broadly speaking the database designs underlying these technologies need a lot of work. That is significant, long-range work that doesn’t appear to be coming together in the near future.

- **Data security makes this especially tricky.** Schools are asking for this because the law requires it, but the data standards are not there yet.

- **Few technologies really support student choice.** This is a critical element for most in the definition of personalized learning, yet few technologies have really designed for this yet.

- **The products that have been really effective thus far all have a clear role for the facilitator.** In other words, product designs that empower the teacher. When the teacher knows what they are learning, everyone makes significant gains.

- **There is still a large gap between where schools are and what they’re familiar with and what companies are building.** There is an inherent tension between where we are supporting schools to go and the types of technologies schools are willing and able to purchase/adopt.

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**AI in Education**

It is worth discussing here specifically the state of Artificial Intelligence in education. AI has made significant strides in the past few years, fruits of which are finally coming to light in education. To some (and a varying) degree, AI is the new T.A. in the classroom. The application of intelligent tutors and of AI tools such as IBM’s Watson to educational settings have given us a glimpse of where this headed, but we must envision beyond these current applications.

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24 These are paraphrased from a larger conversation with Chris Liang-Vergara, March 2017.

Companies like Pearson are one of the major figures in education promoting the research, development, and application of AI, proposing a ‘marketplace’ of thousands of AI components will eventually combine to enable system-level data collation and analysis that help us learn much more about learning itself and how to improve it. In late 2016, Pearson and IBM announced a the creation of a global education ‘alliance’ to support the application of Watson’s cognitive capabilities to create a dialogue-based tutor that will provide more personalized learning at the collegiate level, but also to better help students learn how to learn. Yet realizing such a vision will require the significant development of models (computational models of learners, pedagogies, domains, and more)—the likes of which we’ve only just begun to utilize collectively as a field.

Woolf and colleagues propose “5 AI Grand Challenges for Education” which include:

1. **Mentors for Every Learner** – Designing and building systems that can interact with learners in natural ways and act as mentors to individuals and collaborative groups when a teacher is not available.

2. **Learning 21st Century Skills** – A rapid revision of what is taught and how it is presented to take advantage of evolving knowledge in a field where technology changes every few years, which includes improved and expanded competencies in modern skill areas, and research on how learner can use technology to develop these competencies.

3. **Interaction Data to Support Learning** – Exploring and leveraging the unique types of data available from educational settings, and the use of this data to better understand students, groups, and the settings in which they learn. Building on the work of existing fields of learning analytics (LA) and educational data mining (EDM), this must include analysis of systems thinking, critical thinking, self-regulation, and active listening, and data analysis should move across individual tutoring systems, games, classes, to evaluate students' general competencies.

4. **Universal Access to Global Classrooms** – Providing learning that is universal, inclusive, available any time/anywhere, and free at the point of use. Global classrooms could potentially support individuals and groups to learn remarkably better than if they were taught by a single human teacher. Recent implementations of this vision are in their infancy, where the work is becoming increasingly complex and computational.

5. **Lifelong and Lifewide Learning** – Learning continuously over the entirety of one’s life (lifelong) and across all aspects of that life (lifewide); this includes the need not just for research on technologies that enable this, but on the very nature and process of supporting individuals in learning that is both lifelong and lifewide.

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These challenges offer a nice example of what it means to think of PL beyond just the traditional system, in a world that is already applying AI in so many other ways. Moving in this direction means both visioning beyond the current reality, but also better bridging the research of AI and learning.

The field of the learning sciences has also made significant strides in the past several decades—a field that is on the cusp of additional significant breakthroughs, when combined with AI. The new field of learning technologies are presenting us with a wealth of learning data, but AI techniques will be essential for developing representations and reasoning about these new cognitive insights, for providing a richer appreciation of how people learn, and for measuring collaborative activity. Additionally, AI will be essential in bringing the vision of PL to fruition at scale. It is the future of learning, but we have only just begun. AI will become increasingly critical and education environments would be well-advised to take notice soon.

**Emerging Research in Personalized Learning Technologies**

It is worth noting the array of research projects that are also working in this space, that have not (yet?) made the leap from research to practice, as some offer powerful and promising directions that should not go unnoticed. They are called out separately here, as many are still research projects and have not yet complete technologies developed and/or have yet to be used in practices and therefore evaluated. A number of these represent research initiatives critical to building a coherent landscape to support PL at scale, and while emergent areas of research, as such deserve considerable attention and support in their own right. Examples of these include:

**Guided Learning Pathways (GLP)** – A modular platform that supports personalized learning across a variety of learning platforms (i.e. MOOCs) through crowd-sources domain expertise.

**Architectures for integrating adaptive systems** – How to use several adaptive systems in parallel (or a distributed adaptive system), so that each of the systems should have a chance to improve the quality of user modeling and adaptation based on integrated evidence about the user collected. [examples include KnowledgeTree and Madea]

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Central Ontology Integration – One of the first steps toward interoperable adaptive systems would be implementation of domain models as ontologies.\(^{33}\) When two systems rely on a common domain ontology, they can be exchanged and consistently interpreted as needed. This is critical to creating the architecture necessary for integrated adaptive systems\(^{34}\) and cross-system personalization.\(^{35}\) [examples include OntoAims\(^{36}\) and ELENA\(^{37}\)]

Adaptive, Affective State Feedback – Adaptive and dynamic feedback types according to students’ affective states, in order to evoke positive affective states and as such improve their learning experience. [examples include iTalk2Learn\(^{38}\)]

Supporting Collaborative e-Learning – Collaborative learning has been shown to be a powerful and critical aspect to learning environments. Yet as e-discussions move at an increasingly rapid pace, how do help teachers leverage AI technologies to support and evaluate this learning in digital environments, and at scale? [examples include ARGUNAUT project\(^{39}\)]

Philanthropic Supporters & Initiatives

A growing number of foundations, non-profit, and philanthropic organizations that have stated and funded support for personalized learning initiatives. Since 2009, the Bill & Melinda Gates Foundation has committed $300 million to support research and development around personalized learning. Significant research initiatives, and those supporting them, include:

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\(^{38}\) www.elena-project.org


The Bill & Melinda Gates Foundation (BMGF)
k12education.gatesfoundation.org/student-success/personalized-learning

Situated with a number of learning initiatives, the Gates Foundation has funded the largest evaluation of PL to date; conducted by the RAND Corporation, it is an ongoing long-term study of foundation-funded schools that are using a variety of approaches to personalized learning.

Chan Zuckerberg Initiative
www.chanzuckerberg.com/initiatives

Perhaps one of the largest funders of PL in addition to the Gates Foundation, the Chan Zuckerberg Initiative is in fact an LLC, choosing a more flexible structure than a foundation to support their philanthropic work. Their primary focus is doubling-down on technologies and school models that will bring PL to scale for all learners.

European Schoolnet
www.eun.org

A not-for-profit organization and network of 31 European Ministries of Education, based in Brussels, Belgium, that supports key education stakeholders (including schools, teachers, researchers, industry partners) in bringing transformative innovation to education systems.

EvaluateRI – Rhode Island Personalized Learning Initiative
eduvateri.org/projects/personalized

The Rhode Island Office of Innovation, in partnership with the Rhode Island Department of Education, Highlander Institute, NE Basecamp by RIMA, and other partners launched the RI Personalized Learning Initiative in September 2016. The aim of the initiative is to help define what PL looks like in action, source high-quality PL management tools, provide a supported on-ramp for schools, and create an education innovation research network to provide actionable, real-time research-backed answers to key questions that arise as schools move to a PL model.

MAPLE (Massachusetts Personalized Learning EdTech Consortium)
learnlaunch.org/maple

A new public-private partnership between the LearnLaunch Institute and the Massachusetts Department of Elementary and Secondary Education, aimed to get personalized learning tactics and tools exchanged and successfully implemented in more schools. The program brings together 12 innovative “catalyst districts” to share funding strategies, digital tools and solutions they’ve gathered with other schools looking to implement personalized learning approaches.

Nellie Mae Education Foundation (NMEF)
www.nmefoundation.org/our-vision/personalization

Framed as Student-Centered Learning where ‘PL’ is a core component, NMEF funds a number of organizations, districts and initiatives in the pursuit of a redesigned education system.
TENSIONS, TAKEAWAYS & PERSPECTIVES

How do we make sense of this broad and emerging field? Below are some considerations from this emerging landscape.

**We are currently at peak hype.** All innovations go through the ‘hype cycle’—the successful ones make it all the way through to the ‘plateau of productivity’. Figure 5 shows Gartner’s 2016 Hype Cycle projections, which interestingly didn’t include PL. Yet according to Michael Horn, a leading consultant on innovations cycles in ed tech, PL is today’s most hyped term and at the peak of the Gartner Hype Cycle. That means that what comes next is the trough of disillusionment, what he currently sees blended learning entering into. For PL, and for all of us interested in seeing it thrive, there are still some challenging, long cycles ahead before we see success at scale.

![Gartner Hype Cycle](source: Gartner, 2016)

**Like all educational innovations, implementation is everything.** As mentioned previously, the devil is in the details of how you actually use the technology in a given learning environment. In other words, you could take any one of the more innovative or powerful learning technologies referenced in Appendix C, and see it used effectively to support PL in one school, and much less...
effectively in another. This points to the critical need for a better agreed upon definition of what Personalized Learning is, and how to evaluate it. Which leads us exactly to the next point:

**We need a collective, agreed upon definition of what PL is, and agreed upon tools to measure/evaluate it.** As mentioned previously, the latter is one of the recent contributions to the field by LEAP Innovations. Hopefully in the next year or so, we will see how those tools do and if the rest of the field agrees to use them. The former will likely come in time, but like most things in education, not any time soon.

**Technology is a critical piece of the toolkit, but get PL to scale is about people and systems.** At this point in education reform, this should go without saying. However, the complexity and radically different nature of PL schools really doubles-down on this. Learning environments that start with the technology often go down unwanted paths—‘unwanted’ here being defined as manifesting pedagogies not supported by the learning sciences.

**Transformation doesn’t come easy.** Massive system change and redesign requires us to overcome inertia of status quo and get to the dramatically different future. Incredible innovations have come and gone in education because we haven’t put the effort (and the capital behind) supporting on-the-ground change.\(^\text{41}\) The focus must be on the people and the system, not on the innovation itself.

**Equity: Access to these technologies won’t be cheap, and very much not evenly distributed.** A long-standing problem in education, the cost and complexity of implementing this new system presents the opportunity for the equity gap to be compounded. According to iNACOL, PL raises concerns about equity in two ways. First, there is a worry that personalized pathways could result in different expectations. Second, if educational experiences vary, they may also create or exacerbate/increase patterns of inequity unless careful attention is given to monitoring student progress and outcomes and providing the necessary supports for all students to achieve mastery.\(^\text{42}\) IBM predicts that in five years the “classroom will learn you”. A good portion of the US will realize this reality, as many districts are adopting blended learning—yet equity/access are still preventing this from being ubiquitous, and many schools are still not 1-to-1. According to Carol Connor at the University of California, "Unless the field steps up to accelerate the translation of research on how children learn and how to better teach the full diversity of learners, and how to bring this to

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teachers effectively through personalized instruction, we risk the continued marginalization and underachievement of these children in the new technology-enabled world of learning”.

These concerns get to the long-standing challenge in education: allowing the freedom for learning environments to design effective learning, while making sure all learners receive a high quality and rigorous education. To this, we suggest a design challenge: How can the redesign of PL and the powerful technologies that come with it enable us to overcome this challenge?

**Much more research is needed—in multiple dimensions.** PL as a concept encompasses a very large range of innovations needed to make it happen. Combine that with the relatively young nature of the field, and it equates to a lot of research that needs to be done yet. There are fundamental questions about learning development that still need to be answered in order to achieve the vision of PL. Pearson’s research agenda lays these out as the “research building blocks of personalization”:

1. How do students progress from novice to expert in a particular learning topic?
2. How do we assess where a student is in the progression process defined in Part 1?
3. What should a student do next to move forward in the progression process?
4. What are the best ways to provide feedback to students, teachers, and parents?

These questions largely point to the basic infrastructure of learning maps that are missing in education (see point “II. A Common Learning Map” on page 28 of this document). Answering these questions will in part go hand-in-hand with the technologies needed to help answer them as well. The question remains, however, if AI-related technologies and approaches are able to help us derive this knowledge from the data we currently have, or if we simply have more basic research to

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do on understanding how expertise is developed across the skills and competencies we value. Either way, answering these questions are at the very core of building a foundation for PL, and should be the critical focus of funders and research initiatives.

Many technologies labeled as PL often get picked up in the market place before any real research has been conducted on them. Furthermore, there are very poor structures in place to encourage or enable this evaluation to be done even after one or more learning environments have implemented it. A recent EDUCAUSE report frames these additional dimensions and concerns as well45:

“Because personalized learning models are new and evolving quickly, a lack of independent research data on outcomes currently leaves many questions unanswered. What, for example, happens to group dynamics or to social and collaborative dimensions? Personalized learning appears to be more effective in courses such as math, particularly at introductory or remedial levels, but what might be its role in, for instance, upper-level courses in English or history? Do personalized learning systems present privacy concerns, given that various systems might be exchanging student data?”

– EDUCAUSE

There’s still much work to be done in the core technologies as well. Progress in artificial intelligence and machine learning has been impressive, but there is still much work to be done to advance learning science and the R&D of assessments. While some progress is being made to bring artificial intelligence to the education space as described above, these efforts pale in comparison to advancements in the non-education space.46 Similarly, there is growing support for the investment of R&D in assessment design, but more needs to be done. One promising program is the Assessment Research Consortium47, a collaborative entity structured as a “pre-competitive Research & Development consortium” to collectively push this work forward.

Building out the infrastructure needed to support PL. A new vision as ambitious at PL requires the confluence of a number of key factors discussed previously. This includes a number of elements that help create the overall ‘infrastructure’ needed to support this vision—which currently do not exist, which creates a critical barrier inhibiting both the R&D as well as the implementation of these powerful technologies. These include:

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47 http://curriculumredesign.org/assessment-research-consortium
I. **A universal data infrastructure.** One of the key challenges for cutting-edge technologies, like cognitive systems, is the foundation they need in place in order to thrive. As Harvard’s Chris Dede has suggested, “One overarching challenge for the community of researchers in the field of AI and education is to move beyond the realm of isolated projects in which each research team develops idiosyncratic conceptual frameworks and methods”.\(^{48}\) According to IBM, “cognitive systems are only as good as the data available to learn from (what we refer to as the ‘corpus’); if the corpus is restricted to a single educational establishment or service, this is not as insightful as having access to a wider data pool, such as state-wide or country-wide data”.\(^{49}\) Essentially, they are arguing for the critical need of ‘universal education records’—which was the goal of inBloom and has yet to be realized in U.S. public education. iNACOL has suggested a new model for this infrastructure, one specifically designed to support personalized learning at scale (see Figure 7).

![Figure 7. Suggested infrastructure to support student-centered learning.](source)


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II. **A common learning map.** This also was a key aspect of inBloom, and is essentially a critical sub-component of the ‘universal data architecture’. In essence, it’s a robust but shared map of the learning progressions/curriculum/competencies against which the PL technology supports the learner over time. inBloom called it the “Learning Map”; iNACOL calls it a “reference framework”. Every powerful learning technology needs something that serves as this, and most of them create their own; in fact, it’s quite likely that there are robust learning map architectures in a number of educational technologies today, but they end up becoming the proprietary IP of the technology, and as a result, are not shared in a way that other tools can use, build on, or leverage their data infrastructure.

Building such a map is critical, but not trivial. In part, because they are a number of critical related areas of research that are also not yet well developed. First, learning progressions have made a big splash in both research and practice. In research, they are quickly growing yet fiercely contested. Are they real? How many are there? Do they vary by domain? How do we know they are accurate? How should they be used? There are still many unknowns, but the direction is promising. They’ve been more easily adopted in practice (both classrooms and technologies), but since they aren’t well defined in the research they also aren’t well defined in practice, meaning they look very different depending on what school or technology you’re looking at. This is of course concerning for a number of reasons, most especially because we don’t want false knowledge or structures actually hindering kids learning. Second, the emergence of competency-based learning, and particularly its role in PL, raises similar concerns. We still do not yet have a shared definition or framework on what a competency is and how it should be modeled. This needs to be derived from the learning sciences, and it needs to be collectively adopted. This work is yet to be done. Figure 8 offers a brief description of how iNACOL frames the role of competencies and the learning map (called the “reference framework” by iNACOL) in enabling student-centered, personalized learning.
III. **A common infrastructure of models.** As discussed earlier in the section on AI in education, we need to be able to compare data across learning technologies and to enable a larger ecosystem of AI-empowered education, we need common models of domains, learners, pedagogies, etc. In many ways, the “learning map” discussed in the previous paragraph is just that—a common set of domain models. That would be a critical starting point, but not adequate on its own. Many of the visions of PL laid out in this paper, and areas of further research, are only possible when we are sharing other common computational models as well. This again, points to the infrastructure that is currently lacking to collectively progress as a field.

*Teachers are integral to the development of these learning technologies and practices—and need significant support to do so.* Teachers must be co-designers of this work, and as such, methodologies such as participatory co-design and design-based research (DBR) are useful frameworks to guide the work forward. Yet additionally, as this transformation takes place, teachers will need to develop a broad range of new skills, significantly different from how they are trained today. This will include a sophisticated understanding of what advanced AI technology systems can do, be able to evaluate them and effectively select amongst them, understand how to

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interpret and work with the data they provide, and an overall new pedagogical practice once they have such powerful co-teaching technologies in their classrooms.\textsuperscript{51}

\textbf{We are not paying enough attention to the unintended consequences.} As with any innovation, a number of (often unintended) consequences come along with the technologies and the changes in practice. The focus on individualized pathways runs the inherent risk in ignoring the social dimension of learning, one of the most fundamental principles of learning found in the learning sciences. Not enough attention is paid to how this focus on performance and the individualization of the learning experience may impact a student’s psychological well-being, or learners’ ability to self-regulate in these learning environments. Additionally, there is a risk of personalized learning systems is that the wealth of data now available to track and report students’ progression will translate into a laser focus on numbers and performance metrics.\textsuperscript{52}

\textbf{We need to truly be designing from the learning sciences.} Much of the commercial field of personalized learning is focused on tailoring content and learning pathways in traditional content domains. Yet the real challenge is using AI and technology to leverage the findings of the learning sciences, in supporting the entire learner.

As noted by a group of leading learning scientists, applying such new insights about human learning in digital learning environments requires far deeper knowledge about human cognition, including dramatically more effective constructivist and active instructional strategies.\textsuperscript{53} Together, these aspects represent one of the ‘Grand Challenges’ for AI in Education laid out by Woolf et al., developing AI-based tutors/mentors for every learner, in a way that supports the findings and design implications from the learning sciences.\textsuperscript{54} Their recommendations of core traits for a truly personalized mentoring system include instructional tools which:

- Harmonize with learners’ traits (i.e., personality, preferences), states (affect, motivation, engagement), and a student’s strengths, weaknesses, challenges, and motivational style.
- Effectively mentor and support both individuals and groups by modeling the changes that occur in learners dynamically explain themselves to learners and switch modalities as appropriate also support the very social nature of learning.
- Mentoring systems should also support learners with their decision making and reasoning, especially in volatile and rapidly changing environments.
- User models provide estimates that go beyond identifying the knowledge and skills mastered by the student. User modeling is beginning to support collaboration by representing students’ communicative competencies and collaborative achievements. User models represent students’ misconceptions, goals, plans, preferences, beliefs, and students’...


\textsuperscript{54} ibid
metacognitive, emotional, and teamwork skills. Models also track when and how skills were learned and what pedagogies worked best for each learner.

- User models represent students’ misconceptions, goals, plans, preferences, beliefs, and students’ metacognitive, emotional, and teamwork skills. Models also track when and how skills were learned and what pedagogies worked best for each learner.\(^\text{55}\)

- User models might also include information about the cultural preferences of learners\(^\text{56}\) and their personal interests and learning goals.

- Finally, providing a mentor for every learning group means improving the ability of intelligent instructional systems to provide timely and appropriate guidance. In other words, the system needs to determine in real time what to say, when to say it, and how to say it. This grows more complicated as the skills demanded by society increase in complexity.

- Perhaps the ultimate meta-arching goal is for Future learning environments should build student confidence, inspire interest, promote deep engagement in learning, and reduce or eliminate barriers to learning, as described in grand challenge.

**Stop trying to define personalizing learning, and start looking at how we are personalizing education.** A number of authors advocate for a reframing of the concept of personalized learning, to *personalizing*—with the argument being that there is no ‘end state’ of personalized education that we are striving for, but rather we should be looking at how we are personalizing learning for every learner in school systems.

“Instead, I increasingly think of “personalizing learning” as a verb. Educators are personalizing learning for their students, or helping their students personalize their own learning. The key question right now shouldn’t be about defining “it,” but instead objectively observing, categorizing, and measuring the different ways educators and students are personalizing learning and understand which approaches are and are not getting the results they seek.”

– Hernandez\(^\text{57}\)


ENABLING PERSONALIZED LEARNING & AREAS OF FUTURE WORK

We have made great strides towards PL, yet there is still much work to do. As work on the ‘pieces’ of PL continues, we must also think about the ‘space in between’—in other words, the infrastructure that is both tangible and intangible, that ultimately creates our systems of education.

In the report, Student-Centered Learning: Functional Requirements for Integrated Systems to Optimize Learning, iNACOL has laid out a respectable first pass at what those elements might be:

“A student-centered learning integrated system that is composed of multiple information systems that work together to enable the desired learning ecosystem. The system must support a complicated set of processes and functionality that make up personalized and competency-based learning, anytime, anywhere learning in multiple settings and during varying periods of time and student ownership. Therefore, this design is modular and based on the integration of multiple technologies. The following core considerations prove essential to a well-designed student-centered learning system:

- A reference framework for aligning learning experiences, resources, assessment and reporting to the competencies;
- Customized learner profiles that combine data from source systems and input from students, parent, educators and others who work with the student;
- Personalized learning plans that are responsive to the learner as he or she progresses and changes;
- A variety of learning experiences within and beyond the school setting and calendar plus the collection of associated data to inform student progress;
- Access to content, digital resources, human resources and tools through a user-centric interface;
- Meaningful, timely feedback during the learning process;
- Multiple ways of demonstrating and assessing mastery towards competency;
- Relationships, collaboration and communication;
- Dashboards that reveal in real time which concepts and objectives students struggle with, pinpoint at-risk students and enable targeted intervention;
- Analytic tools to support data-informed practices (learning, teaching, administration);
- Integration of multiple systems and data flows using data and interoperability standards and practices.

The software, services and learning content needed to support student-centered learning must be distributed. The integrated system must be flexible and draw on the best-in-the-world resources and technology. In this design, the functions may be provided by different enabling technologies and will require the integration of different teaching, learning and
business system applications. Using consistent data standards and establishing interoperability between these applications will enable data to flow more seamlessly. Standards are critical, especially at the points in which separate systems need to integrate and the data from those systems need to interoperate. Numerous data and technical standards exist within the educational space to support interoperability.”

– iNACOL

We cannot wait for these research threads to be fully explored before pursuing personalized learning and mentoring technologies. At the same time, pursuing that work without understanding and planning for the foundation and potential for pursuit and integration of these research threads into said platform, severely limits the potential for impact and the ongoing development of the field. We must be engineering for a new system, and conducting the multi-faceted R&D in partnership with real learning environments to help us arrive at a new vision for education systems.

The core challenge remains how to deliver personalized learning with equity and at scale. But most of all, how to ensure each learner receives a valuable and meaningful educational experience in order to obtain the competencies they seek. Solving this challenge will take the utmost engagement of all stakeholders in the system—from policymakers, to AI researchers, to educators, and to the learners themselves.

We must use the lessons from the past – particularly as it relates to educational reform – to help us better navigate our envisioned future. This includes doing a better just of funding and executing the necessary research to navigate these unknown waters.

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APPENDIX A. Review of Definitions of Personalized Learning from the Field

**OECD** is an international economic organization with 35 member countries, conducting data and policy analysis in a wide range of domains. In their 2006 report, they suggest five components to personalized learning (summarized below):

>“First, a personalised offer in education depends on really knowing the strengths and weaknesses of individual students...Second, it demands that we develop the competence and confidence of each learner through teaching and learning strategies that build on individual needs...Third, curriculum choice engages and respects students...Fourth, it demands a radical approach to school organisation...Fifth, it means the community, local institutions and social services supporting schools to drive forward progress in the classroom.”

— OECD, Personalising Education, 2006

**The Bill & Melinda Gates Foundation**, is one of the leading funders of research and development in K-12 education in the US, and is a central supporter of personalized learning:

>“Personalized learning seeks to accelerate student learning by tailoring the instructional environment—what, when, how and where students learn—to address the individual needs, skills and interests of each student. Students can take ownership of their own learning, while also developing deep, personal connections with each other, their teachers and other adults.” And includes four key features:

* Learner Profiles: each student has an up-to-date record of his/her individual strengths, needs, motivations and goals.

* Competency-Based Progression: each student’s progress toward clearly-defined goals is continually assessed, advancing as soon as he/she demonstrates mastery.

* Personal Learning Paths: All students are held to clear, high expectations, but each student follows a customized path that responds and adapts based on his/her individual learning progress, motivations and goals.

* Flexible Learning Environments: Student needs drive the design of the learning environment. All operational elements—staffing plans, space utilization and time allocation—respond and adapt to support students in achieving their goals.

— BILL & MELINDA GATES FOUNDATION, 2015
iNACOL is an international association for K-12 online learning to catalyze the transformation of K-12 education policy and practice towards personalized, learner-centered experiences through competency-based, blended and online learning. Based on surveys from thousands of the educators and administrators who are members of iNACOL, the organization identifies four key attributes to personalized learning:

<table>
<thead>
<tr>
<th>Four key attributes to personalized learning:</th>
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<tbody>
<tr>
<td>I. Learner Profiles</td>
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<td>II. Personal Learning Paths</td>
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<td>III. Flexible Learning Environment</td>
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<td>IV. Individual Mastery</td>
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</tbody>
</table>

— iNACOL, 2016

The Association of Personalized Learning Schools and Services (APLUS+) is a membership-based organization consisting of over 40 personalized learning charter schools in California that has also attempted to develop a definition of personalized learning. APLUS+ defines the fundamental aspects of personalized learning as follows:

“Personalized learning is characterized by:

- Putting the needs of students first
- Tailoring learning plans to individual students
- Supporting students in reaching their potential
- Providing flexibility in how, what, when, and where students learn
- Supporting parent involvement in student learning”

— APLUS

The US Department of Education – Office of Educational Technology provides a definition on their website:

“Personalized learning is a student experience in which the pace of learning and the instructional approach are optimized for the needs of each learner. Standards-aligned learning objectives, instructional approaches, and instructional content (and its sequencing) may all vary based on learner needs. In addition, learning activities are meaningful and relevant to learners, driven by their interests and often self-initiated.”

— THE U.S. DEPT. OF EDUCATION, 2017
KnowledgeWorks is a national organization whose mission is to provide every learner with meaningful personalized learning experiences that ensure success in college, career and civic life. The components of personalized learning for which they advocate include:

“Instruction is aligned to rigorous college- and career-ready standards and the social and emotional skills students need to be successful in college and career.

*Instruction is customized*, allowing each student to design learning experiences aligned to his or her interests.

*Pace of instruction is varied* based on individual student needs, allowing students to accelerate or take additional time based on their level of mastery.

*Educators use data* from formative assessments and student feedback in real-time to differentiate instruction and provide robust supports and interventions so that every student remains on track to graduation.

*Student and parent access* to clear, transferable learning objectives and assessment results so they understand what is expected for mastery and advancement.”

— KNOWLEDGEWORKS, 2014

LEAP Innovations is a Chicago-based nonprofit organization connecting innovation and education to reinvent our one-size-fits-all system and transform the way kids learn, and works directly with educators and innovators to discover, pilot and scale personalized learning technologies and innovative practices in the classroom and beyond. The fundamentals of PL they support include:

“The fundamental elements of personalized learning are:

*Learner Focused*: Empower learners to understand their needs, strengths, interests, and approaches to learning.

*Learner Demonstrated*: Enable learners to progress at their own pace based on demonstrated competencies.

*Learner Led*: Entrust learners to take ownership of their learning.

*Learner Connected*: Anytime, Anywhere, and Socially Embedded: Learning transcends location in relevant and valued ways, connected to families, communities, and caring networks.”

— LEAP INNOVATIONS, 2016
Software & Information Industry Association (SIIA), Association for Supervision and Curriculum Development (ASCD) & Council of Chief State School Officers (CCSSO) collaboratively hosted an invitation-only convening of education leaders in 2010, to focus on the need for the systemic redesign of our K-12 education system to one that is centered on the personalized learning needs of each student. Their report from this convening outlines the top five essential elements central to personalized learning:

“1. Flexible, Anytime/Everywhere Learning
2. Redefine Teacher Role and Expand ‘Teacher’
3. Project-Based/Authentic Learning Opportunities
4. Student Driven Learning Path
5. Mastery/Competency-Based Progression/Pace”

— SIIA, ASCD & CCSSO, 2010

The Nellie Mae Education Foundation is the largest philanthropy in New England dedicated exclusively to education. They frame their focus as “student-centered approaches”:

“Learning is Personalized: Recognizes that students engage in different ways and in different places. Students benefit from individually-paced, targeted learning tasks that start from where the student is, formatively assess existing skills and knowledge, and address the student's needs and interests.

Learning is Competency-Based: Students move ahead when they have demonstrated mastery of content, not when they've reached a certain birthday or endured the required hours in a classroom.

Learning Happens Anytime, Anywhere: Learning takes place beyond the traditional school day, and even the school year. The school's walls are permeable—learning is not restricted to the classroom.

Students Take Ownership Over Their Learning: Student-centered learning engages students in their own success—and incorporates their interests and skills into the learning process. Students support each others progress and celebrate success.”

— NELLIE MAE EDUCATION FOUNDATION, 2017
APPENDIX B. R&D Initiatives – selected examples

Adaptive Learning Market Acceleration Program – Bill & Melinda Gates Foundation
BMGF commissioned the “Adaptive Learning Market Acceleration Program” to provide ten $100,000 grants to accelerate the implementation of personalized learning in higher education. BMGF convened the “Personalized Learning Network,” which brought together leading higher education institutions in adaptive learning to discuss the potential of adaptive learning (including American Public University, Arizona State University, Capella, Kaplan, Southern New Hampshire University, and Western Governors University).

Chan Zuckerberg Initiative
chanzuckerberg.com/initiatives
With a significant endowment, they are aimed at helping to build and deploy personalized models and tools, so that over the next 10 or 20 years, every student in every classroom can have the same kind of education that you would have if you were working with a one-on-one tutor.

Center for Digital Data, Analytics, and Adaptive Learning – Pearson
Part of Pearson’s research division, the Center has been promoting itself as a new source of expertise in educational big data analysis, and “are making progress in harnessing the power of that data to assess, enable, and personalize learning without the disruption of traditional tests.”

Center for Applied Innovation – IBM and USC
As part of IBM’s Cognitive Computing for Education Program, in partnership with the University of South Carolina (USC), the Center will be using $25m in funding to develop new solutions for personalized learning in order to “advance higher education in the cognitive era.” The Center is currently developing the Intelligent Tutor app, which uses the Watson Language Speech to Text API, which would allow students to verbally ask a question, set a learning objective and then work with the app over time on assessments that help them master their objective. USC’s Admissions Advisor tool uses the same cognitive API to enable on-campus advisors to effectively compile data so they have a 360-degree view of each applicant.

inBloom*
inBloom59 was a $100 million initiative, largely funded through the Bill & Melinda Gates Foundation, aimed at developing a universal data and information architecture to support K12 education. Although inBloom shut down in 2014, it listed here because of the magnitude of its

59 To learn more, see: https://points.datasociety.net/the-inbloom-legacy-3d8f086565ce#.ujvcli85o and https://points.datasociety.net/inbloom-analyzing-the-past-to-navigate-the-future-77e24634bc34#.q19xr5m4k and https://points.datasociety.net/inbloom-data-privacy-and-the-conversations-we-could-have-had-b2b42eecd4b7#.blsv4nu6
efforts and the learnings that has to offers. There is considerable overlap with the technical aspects of what inBloom developed, and the technical architecture needed to support personalized learning in public education at scale. Most notable is the reason they folded: they did not understand the political landscape in relation to school boards, school districts, and student data privacy.

**Learner Positioning Systems (LPS) Initiative – Digital Promise**

global.digitalpromise.org/learner-positioning-systems

Launched in 2015, the vision of LPS draws inspiration from Global Positioning Systems (GPS) in that we seek to support learners as they locate themselves in the context of a learning trajectory. The LPS Initiative is bringing together leading researchers across neuroscience, cognitive science and social-emotional learning fields with innovative developers and practitioners to explore and design new models for research-based personalization of learning.

**Open Learning Initiative (OLI) – Carnegie Mellon University**

oli.cmu.edu

The Open Learning Initiative (OLI) is a grant-funded group at Carnegie Mellon University, offering innovative online courses to anyone who wants to learn or teach. Our aim is to create high-quality courses and contribute original research to improve learning and transform higher education. Funded by the Hewlett Foundation in 2001, the project builds on Carnegie Mellon's expertise in cognitive tutoring and has built out an extensive library to undergird online courses using their cognitive tutor models.
APPENDIX C. Examples of Technologies that Support Personalized Learning

ADAPTIVE LEARNING

ALEKS [McGraw-Hill]
aleks.com
Web-based adaptive, artificially intelligent assessment and learning system for math, which uses adaptive, open-response questioning to identify a personalized learning path for each student.

Area9
area9learning.com
Adaptive learning and content-authoring platform.

Brightspace
d2l.com
Integrated adaptive learning platform with embedded predictive analytics via IBM’s Cognos® technologies.

Core Learning Exchange
core-lx.com
A suite of tools that allow teachers to create (CoreCreator), find (CoreCollection) and use (CoreClassroom) personalized learning materials in the classroom.

DreamBox Learning
dreambox.com
Adaptive learning platform with continuous formative assessment in and between lessons, analyzes over 48,000 data points per student, per hour to provide the right next lesson at the right time.

enLearn
enlearn.org
An adaptive learning algorithm that can take exemplary problems and generate new content items based on individual student needs.

Front Row
frontrowed.com
An adaptive learning platform supporting learners in Math, ELA, and Social Studies.
Gooru

goorulearning.org
Free, teacher curated search engine that uses learning analytics engine for multimedia resources and lesson plans for grades K-12.

Inquire

inquireproject.com
An electronic textbook with expanded content and interactive features enabled by deep integration with AI technologies.

Knewton

knewton.com
Adaptive learning platform that customizes educational content based on student needs.

LearnSmart [McGraw-Hill]

mheducation.com/highered/platforms/learnsmart.html
An online study tool that maximizes time spent with your course textbook or eBook, by testing your knowledge of key concepts and pinpoints the topics on which you need to focus your study time.

Lexia

lexialearning.com
Adaptive assessment and personalized instruction for literacy improvement.

Redbird Advanced Learning

redbirdlearning.com
Built on 25 years of research at Stanford University, this suite of tools is designed to support each student’s individual pace and comprehension level.

Sparkx

sparx.co.uk
Real-time analytics platform that generates data about the unique way in which each student learns.

Teach To One: Math

ewnclassrooms.org
Adaptive personalized curriculum for early secondary mathematics.

Thinkster Math

hellothinkster.com
Tablet-based math learning program that combines curriculum with personalization from real teachers and AI in order to track how a child arrives at an answer.
AUTHORING TOOLS

Acrobatiq
acrobatiq.com
A software-as-a-service (SaaS) course-building platform for traditional or competency-based adaptive courses in higher education.

FishTree
fishtree.com
Adaptive courseware and flexible authoring tools to streamline course creation, automated alignment between content and key learning objectives or competencies, and real-time analytics on learner progress and outcomes.

SmartSparrow
smartsparrow.com
A learning design platform that enables you to create rich, interactive and adaptive e-learning courseware.

CLASSROOM MANAGEMENT TOOLS

Class Dojo
classdojo.com
An online classroom and behavior management system intended to foster positive student behaviors and classroom culture.

Gradescope
gradescope.com
Helps teachers grade assessments or exams online by speeding up the grading process. It also allows teachers to view statistics of the entire class and notify students once their work is graded.

LiFT
schoolhack.io
Classroom management platform connecting student Personalized Learning Plans with competency-based graduation requirements.

MassiveU
massiveu.com
Platform to support project-based collaborative learning.
Watson Element
www.ibm.com/watson/education
Deep learning platform designed to transform the classroom by providing critical insights about each student – demographics, strengths, challenges, optimal learning styles, and more – which the educator can use to create targeted instructional plans, in real-time.

COGNITIVE TUTORS / INTELLIGENT TUTORING SYSTEMS

AutoTutor
autotutor.org
An intelligent tutoring system that holds conversations with the human in natural language, and has shown to produce learning gains across multiple domains (e.g., computer literacy, physics, critical thinking).

Carnegie Learning
carnegielearning.com
A suite of intelligent tutoring tools for mathematics, with customizable professional learning and data analysis.

DeepTutor
deeptutor.org
An advanced intelligent tutoring system that fosters students’ deep understanding of complex science topics through quality interaction and instruction

Wayang Outpost
wayangoutpost.com
Digital intelligent tutoring system designed to learn along with the student, helping to prepare middle and high school students for standardized math tests, such as the SAT, MCAS and CA-Star.

LEARNING MANAGEMENT SYSTEMS

AltSchool LMS
altschool.com
The AltSchool platform is a system of tools and services that helps educators offer a whole-child, personalized education that fosters student agency.

Buzz [Agilix Labs]
agilix.com
LMS facilitating blended learning in the classroom.
Canvas [Instructure]
www.instructure.com
Open source, online LMS designed to overall classroom management.

Schoology
schoology.com
Online LMS with integrated assessment management system.

Spark [Matchbook Learning]
matchbooklearning.com/methodology/spark
Platform that extracts and manages learning data against mastery-based progressions.

Summit PLP
info.summitlearning.org/program/personalized-learning-platform
Built in partnership with Facebook, this personalized learning platform combines the content and technologies of Illuminate Education for on-demand assessments, Activate Instruction for playlists and ShowEvidence for projects.
**APPENDIX D. Conferences and Events for Personalized Learning**

**Blended and Personalized Learning Conference**
http://blendedlearningconference.com

**iNACOL Symposium**
www.inacol.org/events

**Learning Analytics & Knowledge Conference**
http://lak17.solaresearch.org

**Mid-Atlantic Conference on Personalized Learning (MACPL) 2017**
www.caiu.org/macpl

**National Convening on Personalized Learning**
http://convening.institute4pl.org

**Personalized Learning Summit**
www.edelements.com/personalized-learning-summit-2017
Please continue the conversation and join our mailing list at www.curriculumredesign.org/subscribe