Sparking the Future of Education*

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Abstract

Developing a transformative technological pedagogy to drive student academic achievement requires a fundamental focus on the student as an individual. Each student needs the opportunity to be surrounded by a personalized learning ecosystem tailored to the specific needs, desires, and learning style of that student. eSpark Learning is developing a unique and strategic approach to optimally educate students. eSpark Learning has already demonstrated striking educational achievements and aims to be the first to create a fully developed, interactive and scalable learning environment producing transformative academic gains.

* The ideas expressed in this paper are authored by eSpark Learning, and inspired by a presentation given by John Couch, Vice President of Education at Apple.

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1 Introduction

Superintendents, principals, teachers, and others involved in education are all undeniably aware of a fundamental fact: people learn differently. Scientific studies have long documented evidence of this variance, like differences between visual and auditory learners, the relative effectiveness of distinct approaches in producing both engagement and long term learning recall, the utility of practices including game-like means of interacting with learners, and the importance of motivation, desire, and engagement in producing positive learning outcomes.

The individual is at the center of effective learning. And, for the first time, technological advances have made it possible to tailor learning programs to individual preferences and styles on a mass scale. Innovations including the ability to deliver stunning visual and auditory messages and the capacity to provide interactive learning and testing, in the context of effectiveness metrics, allow a Deming-like\(^1\) continuous process improvement of the teaching system. Moreover, now, learning can take place without the once necessary condition that students are in the same place at the same time as their teacher.

To design an interactive system that is proven to track progress toward the education outcomes that society values it is crucial to understand an individual learner’s capabilities and needs. To understand the approach that eSpark Learning is taking to move toward this technologically-empowered future for education we should start by understanding eSpark's current results, its future direction, and its technological and pedagogical underpinnings.

2 The eSpark Learning Solution

Core to making this future a reality is to acknowledge the importance of tapping the ample resources already available, codifying and coalescing them into a unique, powerful environment for student learning. Academically, eSpark Learning is developing a kernel knowledge learning system supported by a powerful adaptive Artificial Intelligence system designed to integrate existing student academic and motivation data, sensory input, database access, graphics generation, multi-sensory output, game-style learning, learning response calculation, and performance metrics, with a technology basis at the core that makes access to content seamless for the student. This system relies on a cadre of elite pedagogical coders and technological programmers dedicated to development of these learning systems. Strategically, eSpark Learning has chosen to use Apple’s iPad technology, which supports many of the sensory, mobile, and environmental supplements necessary to develop a complete and lasting learning system. We have built modular initial products to fund the larger system, the modules of which cover the basics of Mathematics as well as English and Language Arts with content available from the Kindergarten to Eighth Grade levels. Ultimately, this combination of hardware and software will develop into a full-fledged proprietary learning system, the first of its kind.

eSpark Learning has proven success in driving academic outcomes for students. In a recent control group study with Elizabeth Forward School District in western Pennsylvania, personalizing learning through eSpark showed extreme academic gains for students who utilized eSpark compared to their peers who did not. 248 students utilized eSpark for one semester (winter and spring) while their peers received only the benefit of the other great and innovative education work in that district. The average percentile of eSparking students prior to utilizing eSpark (Winter 2014) on the NWEA MAP, a nationally standardized benchmark test, was 47.8. For context, NWEA

generally estimates that scores near the 70th percentile on NWEA MAP correspond to a strong probability of college readiness, and typically, percentile growth for an individual student is zero.\(^2\) These students, in one semester leaped ahead to an average percentile of 72.7, with similar gains in both Mathematics as well as English and Language Arts. By contrast, non-eSparking students at the same school started with a higher average percentile of 63 and grew to the 71st percentile. The control group's growth of 7.5 percentile points is impressive in itself, but adding eSpark for their peers contributed to an average 25 percentile point growth (Figure 1).

eSpark Learning is developing this system to utilize existing standardized test data for individual students as an initial diagnosis for their learning level aligned to Common Core State Standard domains, which sets the opening levels in a personalized learning plan for each individual student. This plan is constantly updated with new data about the student from external sources such as test data and teacher inputs, and is growing to include internal sources like the student's emotional state, choice of lesson topic, and performance on lessons. Goals and lessons (called "quests") are adapted on an ongoing basis to ensure the optimal learning environment for that individual student academically. eSpark curates the best available paid and free content, using a sophisticated system of codification with hundreds of tags to determine the quality of content and alignment to student curriculum and personalization attributes. Students’ learning plans are regularly refreshed with the ideal content for them personally and academically. No two students are exactly alike in their learning plans.

This plan is based on academic needs as described above, but will also incorporate elements of the student's personal style, emotional state, and topics of interest. Student choice will enable much of this initially, but over time eSpark can learn each student's habits and preferences and begin to predictively change the options available to that particular student. For example, each student will be able to select an "edutar," a personalized avatar-like creature that guides students through their learning journey, high-fiving them upon successes, encouraging them through learning opportunities and flying with a jetpack into the sky to see their progress. The edutar will be accompanied by a series of themes that students see, which change based on their selected edutar and other elements of mood, progress, and interests.

All this personalization is enabled by eSpark’s underlying technology. eSpark has strategically chosen to use the iPad platform, which enables multi-sensory engagement for students through

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\(^2\) Percentile varies depending on definition of college readiness. For full detail, see: Northwest Evaluation Association “College Readiness Linking Study,” 2011.
sight, sound, and a sophisticated sensory experience facilitating natural and instinctive movement—essentially transporting the student into their learning environment by enveloping them in a completely surrounding experience. The experience for students is transformational academically but also engaging to all their senses, providing them with the feeling of power over their learning environment and experience. eSpark Learning has also enabled technology to provide students with updated content on the fly, having developed a proprietary Mobile Device Management system that allows iPad content syncing to be completed wirelessly and just in time for students to give them the content they need, at the level they need, when they need it.

3 Strategy: Focus on the Student

In order to achieve an ideal state of technology-supported learning, eSpark Learning has begun to approach the development of the product from the point of view of the student (rather than the teacher, the technology, or the parent—although commercially we intend to engage all the parties in integrating the technology into the educational system optimally). We have learned through this process that we as an industry must view each student as a unique individual. We must provide them with a holistic learning environment to succeed. In order to do so, eSpark Learning's strategy is to teach them: What they need to learn, Why they are motivated to learn it, How they want to learn it, Who they want to learn with, as well as When and Where they want to learn.

By focusing first on "what" the student needs to learn, we have developed a Personalized Learning Plan for each student. This begins by analyzing the student's existing needs, identifying key areas for growth (as well as areas in which we can capitalize on existing success), and developing an ideal learning journey for that student. We start by identifying the areas of greatest need, enabling the student to successively work through modules of instruction that match their diagnosed learning needs - and simultaneously verify and update their diagnosis as they learn. Through this process, we incorporate patterns in learning success, finding the ebbs and flows of a successful learning experience for that individual student - the right balance of challenge and success to fully engage the student to feel motivated, encouraged, and successful through a challenging but delightful experience.

Designed into this strategic pathway is an analysis of "how" students want to learn, and a genuine recognition of the uniqueness of each student. Each student comes in with a different personality, different experiences in life and learning, different knowledge and gaps in knowledge and different preferences for the methods, speeds, and styles in which they receive information. This area of the personalization includes an understanding of each individual student's learning preferences (visual, auditory, bodily kinesthetic), and topics that will stimulate learning for that child. This requires a live and ongoing analysis of a student's response to topics or information presented to them and a nimble adjustment to provide content that is stimulating and interesting to that individual, which necessarily will be different from the student sitting next to them. Each day, information as detailed as a student's mood or latest interaction in the lunchroom is highly relevant to what information they will respond to best, and the technology we are developing must be very sensitive and tuned to that student to truly elevate the learning journey.

Carefully enveloped in the journey is information about that student's motivation and engagement—"why" students learn. The goal here is to ensure we do not replicate the feeling of reading chapters upon chapters of a long textbook, but instead to build a new experience and a new world for students to explore and enjoy as they progress through instruction. Assuming that students have the right level, type and topic of content available to them, research shows that a large part of student engagement is in fact related to choice. This means that they can build their

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own experience - choose their own adventure - and traverse through content in a way that is most meaningful and relevant to them. The key to making choice effective for students is a combination of both having the right choices available to make (a product of strong predictive algorithms), and then presenting the choice in a meaningful way. When the Personalized Learning Plan is indifferent to which lessons a student does in what order, or there are lessons teaching the same academic topic with different subject choice (for example, teaching the domain of "inferences" through a lesson about nature vs. one about social engagement), allow the student to choose. Incorporating projects, assessments and lessons that are relevant to students in the real-world has been shown to increase motivation and interest significantly. Finally, ensuring that the learning is fun for the student and that it feels like a game that tracks their progress and rewards them based on significant milestones is also a key motivator in students' learning journeys.

Next we must consider "who" students want to learn with on a given day. For students, this means the ability to learn from a teacher whom they like, respect, understand and relate to; it also means students should have the ability to work individually or in teams of people who will best support their learning journey on that day at that time. In a technology system, this also includes the system itself as a companion to the learner, which should have a "personality" comprised of a look and feel that mimic human traits. As humans we are highly social creatures, but just as topics and learning methods can vary by mood, so too we want different things from social interactions on different days. Incorporating the appropriate mode and level of socialization at the right time for students is again a combination of powerful predictive algorithms and the strength behind choosing when and how they engage in that social behavior. Here, consider the analogy to the popular social engagement website Facebook, which uses an algorithm to determine which friends you want to read about, and which of their posts you want to read when. As you select these, the algorithm updates knowing which ones you skimmed past, which ones you read and moved on from, and which you clicked, to enable more and more predictive ability (but always enabling choice). Similarly in education, we can predict whether a student is more likely to work individually, or whether they want to work with other students or with a teacher (and which students/teacher, and why). We can also predict what students will want the "mood" of their technology companion to be, as well as use data about their choices of that look and feel to inform instructional practice and drive engagement in the technology.

Finally, in an increasingly mobile society, students need the ability to learn "when" and "where" they want (or are able). The classroom of the future is not confined to exist between the walls of a traditional schoolhouse, and instead meets the student at the place and time they are most able and available to learn. In our constantly connected society, students need and expect the ability to learn day or night, laying on the ground or sitting up, in a plane or a train; as social individuals we need the ability to connect with others or to disconnect with others based on our needs and wants at that moment. It has not escaped our notice that the fact that a learning environment system can be made to be effective at a distance, even with students from very isolated or impoverished environments, has potential for being transformative far beyond the markets of the developed world and rather a potential of exerting a world-changing influence developing and unleashing talents in billions of people around the world.

Understanding the importance of the what, why, how, who, when, and where of the learner, one can see that the path eSpark Learning is forging from today's world to the future of education—to the personalized learning ecosystem—has requirements that quickly deviate from what can possibly be supported in today's classrooms by today's teachers and students. Indeed the fact that technology can act at a level of scale and detail impossible to achieve with any number of learned teachers is part of the key to a better future. Purely considering the amount of time needed to

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4 | The importance of establishing relevance in motivating student learning, Active Learning in Higher Education (November 2008) 9: 249-263.
curate the content for a personalized learning plan for a student—the content alone—that would best support a student's learning needs, eSpark Learning estimates it would take a total of 62 hours per week for a class of 30 students (Figure 2). Enabled by technology and economies of scale, we can reduce this amount of time to 40 minutes per student per week to execute the tasks and minimal time for the teacher to engage in the process and manage the learners. Inspired by John Couch’s quotation “I believe in miracles, but I don’t believe in scheduling them,” eSpark Learning has identified a way to truly schedule this miracle. The nimbleness of teachers to be able to respond to a student's needs or mood is limited by class size today, whereas the flexibility of algorithms to predict and refine each microsecond for each student is unlimited.

The primary focus of technological learning system development must be on the individual both because the mind of the individual is where much of the key learning occurs and because it is in this aspect of education that technology and its interactivity and other characteristics are most impactful. But such a system cannot succeed and indeed cannot optimally serve its purpose if it does not include the existing educational system and its own unique contributions. As a practical matter, education in the developed world occurs mainly within the context of the larger educational system. For eSpark Learning to be adapted today, it must fit into the existing educational system in a synergistic manner. Even more importantly, that system has important capacities that can synergize with a technological learning system, examples of which include: allowing group interactions, discussion and dialectic, social interactions, grading and assessment, as well as prioritization of topics. For this reason, while the bulk of technology development has to be focused on optimizing the educational advantages for the individual, it is important to add the features on to the system that make it the friend and ally of teachers. Teachers have much important work to do that can be well supported by a comprehensive technological learning system. This system could be used to apply testing, grading and computation directly in many cases (multiple choice, fill-in, etc.) and could be a useful technical support for other graded testing such as essay examinations.

Interestingly, the system could change the nature of grading all together. Right now a teacher will teach a one-size-fits-all lesson to a class and give a grade on their comparative performance relative to one another. This serves some useful purposes. But eSpark Learning's potential, when fully recognized, can assess students in a very different way—at what level they actually achieve mastery. Hence, instead of getting a grade that one has an A on an eighth grade reading test, students would get grades listing what their actual reading grade level is. Such grading could still be useful for ranking, but the focus is on quantifying the actual level of achievement and the gap to be met, rather than the deficit from an arbitrary age standard. Taken to its logical end point, this learning system could have software facilitating lesson planning, updating lesson plans based on results, and reducing the bureaucratic demands on teachers. This grading could facilitate teacher-student and teacher-parent communication. In this model, as in existing differentiated classrooms,
the role of the teacher is most successful as the facilitator of learning for students. The more useful
the software is to the teacher, providing them with the information they need when they need it, the
easier the system makes it for teachers to be successful in their work and the smoother adoption
of the system will be.

4 Technological and Educational Underpinnings

Looking at the landscape of educational technology today, there are two categories of popular
models that are prevalent: technology models and pedagogical models. Within technology, the
focus is on ways technology can be best integrated into the existing classrooms. One example of
that is the Substitute Addition Modification Redefinition (SAMR) model⁶, an innovation continuum
developed by Dr. Ruben Puentedura which states that technology that acts as a Substitute or
Addition to today's classroom doesn't engage students in a different or unique way while technology
that Modifies the learning process or Redefines the activities involved in learning does change the
learning experience (Figure 3). For example, a teacher who uses an online tool to conduct a quiz
replaces a paper version of the same activity, but does not fundamentally change the activities of
the student in a meaningful way educationally. In a sense this is the equivalent to replacing the
typewriter with a computer, then using the computer as a typewriter and ignoring its additional
extended capabilities. There may be some time, cost, or technical advantages stemming from
Substitution or some functional benefits such as almost immediate feedback enabled by
augmentation, either of which provide some evolutionary advantage. But it is unlikely they will
provide a transformative advantage. By contrast, using technology to Modify the learning process
actually begins to move into potentially transformative activity - for example allowing writing activity
to rapidly be exposed for feedback to a broader audience within or even outside the classroom. Of
even greater potential importance are the situations where computer technology allows new tasks
to be conducted that were not possible or conceivable with older technology. For example, a
teacher could replace writing an old-style essay about an event with a team effort to create a
documentary video or website incorporating information from the event itself, its subsequent
downstream consequences, and answers to essential questions about the event. This moves into
the territory of collaborative and potentially multi-media endeavors, interactive consideration of
questions, and broader communication of information in a format more likely to generate reaction

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and engagement by other students.

Using technology to Redefine the activities of the student is the ideal usage of technology in the classroom. Today, this might be identifying a research topic for the class, with students working in teams to conduct primary and secondary research and develop a multi-media presentation to contribute to a class research question. When one considers the SAMR model, one cannot help but see that at its root is a process of creative destruction. Moving to Modification and even more so Redefinition happens best if one lets go of the old process (forgets the way you habitually used the typewriter) and rather looks at the new technology (perhaps a computer or an iPad) to see what its possibilities are.

Just as SAMR provides a transformational model to implement technology in the classroom, the Technological Pedagogical and Content Knowledge (TPACK) model provides a structure for an integrated approach to technology education (Figure 4). This model originated by Koehler and Mishra suggests that the education environment of the student must fully integrate Technology, Pedagogy, and Content Knowledge. A personalized learning ecosystem must consider fully each of these components and the necessary interplay between them. A classroom with sophisticated technology available, without including the necessary components of the best of breed practices in teaching and learning, or the depth of content appropriate for the student to learn a given subject, becomes a classroom with a very expensive paperweight. Taken to its logical conclusion, educators and schools cannot simply purchase technology and put it in the classroom without adjusting or acting on changes to the pedagogy or content. Similarly, including content or pedagogy or technology without the supporting structures of the others creates a suboptimal classroom lacking the balance, synergy, and system needed to surround the student with the tools to fully absorb the content in a meaningful and lasting way. Including a balance of all three of these categories (technology, pedagogy, and content) in a classroom provides results greater than the sum of the parts—the essence of synergy.

To be successful in actually being implemented in the real world, it is critical to note that such “creative destruction” always entails change in the way work is done, in the way people function, and such change always entails disruptions in the social and political context of the human organizations being changed. Some roles become more important, others less important, careers are affected. While the focus of the technologist is always on meeting the needs of the individual, for technologies to be implemented fully, rationally, in a manner that optimizes effectiveness, care and attention will need to be paid to the needs, structures, and politics of the organizations the technology is being introduced to with much marketing, adjustments, incentives, and positioning intended to minimize the “friction” accompanying introduction and to maximize the transition to a

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Turning to the mind of the user, pedagogically, Mihaly Csikszentmihalyi’s Flow model analyzes when learners are at their optimal state of engagement (Figure 5). This state of engagement, which Csikszentmihalyi first noticed with artists in the 1980’s, drives individuals to participate so intensely in an activity that they do not notice the passage of time and that the “real world” falls away. The state of Flow is characterized by complete concentration in an activity and a sense that it is worth it for its own sake, not just for some end product. The reader may have personally noticed being in a state of Flow when playing a challenging piece on the piano, being completely involved in a sports match, or playing chess while calculating a variation several moves ahead, thinking for example, “When did it get dark out?” What Csikszentmihalyi found is that this state can be attributed to the product of skill and challenge. When the skill level and challenge level match each other, individuals are susceptible to enter into Flow. Students, too, are subject to such intense participation in learning activities that they enter into this state of Flow, as long as the learning is targeted at the proper level of skill and challenge for that individual. The Flow model focuses on what the learner can do with or without help, examines what functions the learner partially has, and what functions are embryonic or partially developed. If students find themselves facing a task for which the challenge level is too high, they fall into a state of anxiety; if the task’s challenge level is too low, they enter boredom. The theme of this pedagogical framework focuses on students as individuals, and in fact as human beings, with individual strengths, needs, motivations, and preferences. This model provides insight on the ideal lesson to target for students—a lesson that suits their needs as a learner based on their developmental state, past experience, skill level, and a plethora of other factors. Viewed from the perspective of the SAMR model, an optimal technological learning system could move from Substitution or Addition in the conventional classroom system to Redefinition. It could do so by: monitoring what kind of feedback works best for a given student, what information modalities are most effective for a student to progress to a new perceptual or conceptual or skill level by measuring attributes such as response time and error rates, and could craft future output to speed and enhance the breadth of the learners progress. In doing so, this technology system would Redefine the learning environment in a manner individualized to meet the needs of the student.

Expanding upon the need for students to be in an optimal state, Vygotsky’s Zone of Proximal Development (ZPD) proposes an additional critical component to student learning: a social element.

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The ZPD (Figure 6) focuses on the social development of learning, indicating that social learning comes prior to academic learning. Students’ learning should focus not on what they can do themselves without help, but on what they can do with help from others, expanding their knowledge and ultimately increasing what they understand themselves. Students must play an active role in their own learning, ideally interacting with peers and teachers to collaborate in order to build meaning behind student learning. In application during the educational process, the conceptual shift is to move away from the model of a teacher lecturing or presenting information, and toward the idea of a teacher as a facilitator, with students driving their learning by interacting with others from whom they can learn.

Psychologists and educators focused on developing a scientifically based pedagogy have been aware that much of mainstream intelligence research does support the concept of a broad mental ability referred to as "general intelligence" underlying a range of more specific abilities. This concept is supported by strong data suggesting reasonably high internal correlation between measures of a range of cognitive abilities. Yet for some decades driven in part by the seminal work of Howard Gardner, it has been noted that human beings differ in and potentially can be successful in many areas of cognitive gifts. Each human has capacities, and some correlations have been noted between capacities in some of these areas, but humans differ from one another in predilection, innate ability and level of development of their capacities. Some musicians show superior gifts in musical matters but are unaccomplished in other areas while highly verbally talented authors may not show the same propensity to become great mathematicians. From logical-mathematical capacities to conceptualize symbolic matters or relationships between factors, to linguistic capacities to understand the meanings, structuring, and sounds of words to interpersonal skills including the ability to detect/read, react to and interact with the feelings of others, to superior mnemonic capacities supporting learning and classification of information to musical sensitivity to the details of sounds and their interactions, to the kinesthetic use of body parts and movements in key skills or artistic expression to spatial cognition capacities, human minds are multi-faceted and diverse in their predilections and skills. Indeed, educational performance data clearly indicates that while correlations exist between capabilities, students not only have different abilities and sometimes relatively isolated exceptional abilities in some areas, they use different strategies in their functioning in life and educationally reflecting their differences in capacity. Perhaps the most extreme illustrative example of this differentiation are the various savants—often

very poorly functional in almost all areas but possessed of a special computational or mnemonic or observational or other capacity. But beyond savants, normal humans vary in their capacities and use their variations to their advantage.

While much of traditional education in most areas has focused on verbal and logical/mathematical abilities, success in other areas turns heavily on mnemonic capacities and the ability to acquire and retain information, spatial cognition, musical ability and other capacities. These differences are pertinent to learning theory and to the development of learning systems in so far as they suggest that ideally one learner may progress in a different skill or gain certain cognitive knowledge when information is presented in one manner—for example listening to a speaker describe an issue—while another learner may progress in the same skill or knowledge acquisition by having that knowledge presented in a different manner—for example seeing a set of graphic data or mathematical data or even kinesthetically graphing a path out across an image.

The concepts of psychological and learning theory are to a significant degree paralleled in increasingly sophisticated studies using functional imaging of the brain to map the location and sequencing of human brain function. This is unsurprising since structural changes in the brain driven by experience are a key component of learning and a common system for the direction of attention from visual or verbal stimuli exists. Beginning with the use of Positron Emission Tomography (PET) and functional Magnetic Resonance Imaging (fMRI) studies in the 1980s, cognitive neuroscientists and neuroimagers have for decades systematically been mapping both the anatomical substrates supporting tasks employing different aspects of the multiple intelligences of man and different neuroanatomical-functional patterns of brain engagement in solving the same mental task on the part of different people. At an anatomical level, basic systems are quite similar in their layout in each human being, possibly corresponding to or even underlying the similarities in general intelligence detected as correlations in psychological testing. The integration of sensory function and cognitive learning are paralleled by anatomical studies that often show a logical association between related capabilities. For example phonological coding in reading words and working memory used for the retention of verbal information show a substantial correspondence in the brain areas involved. But functional brain imaging studies of a population of people involved in the same mental task show that different learning strategies show up as the engagement of different brain functional systems in different regions. This opens up the possibility that by detecting the learning strategy (e.g. visual or auditory) used by the student (through their performance) it may be possible to facilitate learning and recall by delivering information in a form and format consistent with their natural learning strategy. For example, if a student shows evidence of recalling lists of words or topics better when they are presented visually with pictures than verbally with spoken names, their vocabulary lesson may be better tailored to them with an emphasis or repetition using the modality they attend to best.

5   The Future of Educational Technology

The SAMR, TPACK, Flow, and ZPD models offer important value in their respective focus on the need to use learning technology in a transformative manner and on the need of that transformation to focus on the progress in the mind of each individual learner. Their implication for learning technology is this: to use technology in a transformative manner that technology must mate to the current state of the learner. But to date these models, conceived before the progression of

technology, stop short of calling for a personalized learning ecosystem. This restraint in part derives from the few options available at the time. But limits of concept, limits of vision, and limits of goals can result in the failure to achieve what is possible and desirable now and in the future. Most current technology solutions, hardware and software alike, suffer from this same defect. They build a part of the solution in order to fit into today's classrooms. Limitations in their conception or in their technology constrain them to merely Substituting for an existing technology or adding some marginal features but not grasping the full opportunity to Redefine activities in a manner mating more optimally to the learning needs of each individual learner. These types of "one-size-fits-all" technologies have some utilities but are mere way stations on the road to a truly transformative technological learning system.

One might draw an analogy to a different field, medicine. In the 1950s, America was struck with an epidemic of polio, a terrible disease that destroyed the nervous system of its victims and damaged their ability to breathe and move. The first technology applied to the disease was the iron lung, an expensive tube patients' bodies were placed into while their head remained outside that applied a vacuum to their chest to pull their lungs open so that they could breathe air in through their mouths. At the time concern was for how it would be possible to build huge tower buildings filled with polio-afflicted children kept alive by the iron lung but crippled permanently. Then Dr. Salk and later Dr. Sabin invented the polio vaccines that took the different approach of preventing the disease. Many of the current educational technologies are like "iron lung" approaches—expensive, difficult, facilitating a way of teaching that is in itself fairly ineffective.

Apple identified this problem in the early 1980's and undertook a research project, Apple Classrooms of Tomorrow (ACOT), to study how technology use in the classroom affected student learning engagement, which led to Apple Classrooms of Tomorrow—Today (ACOT²) to develop a learning environment tailored to the student's needs, wants, and expectations with the goal of high school persistence.¹⁸ Through this experiment, Apple found that education must be creative, collaborative, and relevant to students in order to fully engage students in the outcome of learning. An example of an ACOT² classroom's Challenge Based Learning approach is for a group of students to choose to tackle a challenge in their community—such as improving water safety of a local stream. The students treat their selected problem as their vehicle for learning the curriculum that would normally be taught through textbooks and lectures. Choosing a real problem to solve shifts students' goals from turning in homework for accountability to a teacher, to transforming curriculum to be relevant applications of academic concepts with informative assessments. In this example, for students to understand the local stream, they must do research into the hydrosphere, the impact of humans on local systems, and the effects of the hydrosphere on humans; rather than feeling like a disconnected standard to memorize, students see the curriculum is relevant and applicable to their lives. Apple also provides, "Ubiquitous Access to Technology," technological resources to support students' learning and creativity in the classrooms, surrounding the students with the resources and information they need to solve their problems in a connected and integrated fashion. This approach is reflective of the SAMR model; instead of layering technology on top of what students would normally do, students use technology to connect to relevant resources and innovative tools that Redefine their learning process.

The goal is to produce an educational technology that operates at a different level, that does not just marginally improve the old process but that actually solves the problem by giving each individual exactly what they need when they need it, to rapidly extend their skill level to encompass new areas of learning. Existing technology in classrooms often focuses on making it easier to manage the classroom as it exists today, often falling into one of two common mistakes: first, either Substituting or Adding onto the existing classroom model from a technology perspective, or

second, a pedagogical error, attempting to teach students the same content in the same manner despite their differences as people and learners. Such technologies are better than nothing but only marginally so. They will never solve the need to move every student at their own speed and in the way that works for them to become a fully effective individual, with the knowledge and skills to create their own future and to become an effective part of a larger more functional, more effective, and more fulfilled society. Older technologies stop short of what is really needed by students in the classroom, which is a personalized learning ecosystem.

Given the complexity of human beings and the variations of human learning patterns to be fully effective, is it essential that a powerful educational technology adapt to the user to simplify and enhance the learning process for the user. Creation of the educational technology of the future turns on the individual, on meeting the needs of the user. While there are many technological, procedural, content and other challenges, the key focus has to be on the needs of the mind of the learner. The key to the future is a personalized learning ecosystem that enables students to learn what they need to learn, when they need to learn it, in the way it will be most meaningful and engaging to them. The industry has been stuck in the balance between enabling teachers to do their jobs more quickly and efficiently, and targeting personalized learning for each student. When we design for the teacher, the student's individual learning suffers; when we personalize curriculum for students, it requires more time than teachers could humanly spend to curate material, plan, and support students on individual learning journeys. This redefinition requires us to integrate the overabundance of content that exists into a space for collaborative learning to solve a problem that is very relevant to the student.

Technological advances have been the major driver of improvements in a wide and disparate array of categories in modern life - from improvements in medicine and healthcare, to entertainment, transportation, manufacturing, energy, warfare - touching virtually all areas of modern life. As classrooms and teaching have become more influenced by tools that technology makes available - from information resources, data analysis and processing on computers to presentation software and advanced graphics to support teaching in the classroom - technology has had some impact on the classroom. But much of the impact of the technology has been unimaginative, partial and has failed to fully utilize what the technology makes possible - essentially taking the typewriter off the desk, replacing it with a computer, and then using the computer like a typewriter instead of tapping the full potentiality the computer allows that the typewriter did not. The issue is this - is there a better way? Is it possible to create a solution that moves beyond the merely evolutionary and adaptive that instead becomes transformative and empowering? Is it possible to create a technological solution that will provide superior results? Is it possible to create a technological solution that will sufficiently transform the educational system to allow it to achieve its mission of educating the learner population to competency in the skills needed to live in an advanced technological civilization, to fully develop their own gifts and contributions, and to develop their intellects and skills in a manner allowing self realization? The answer to these questions, as detailed in earlier sections of the paper, is a resounding "Yes," which leads one to consider the question "What are the impacts of such a system?"

6 Implications of Adaptive Learning through a Personalized Learning Ecosystem

In student learning, the whole is greater than the sum of its parts - focusing on each of the individual elements of student learning will not lead to vast levels of achievement without a cohesive environment for student learning. Hardware, while a critical advancement in the education sphere, alone will not create educational change. Hardware makes capability development possible.
Hardware can even add new capabilities for monitoring progress and providing information, teaching and opportunity in wholly different modalities. Hardware can be important in reducing costs of systems. Over time screen size, processor speed, and memory size become replicable and commoditized. Content, while a relevant addition to today's world, is also quickly becoming a commodity. The availability of content in the current world is truly overwhelming. Today, a search for "Fifth Grade Geometry Lessons" yields a half million results. Teachers, while important to bridge the gap with students, are now becoming quickly outnumbered and out-manned in the classroom, unable to individualize learning to the level students today need and expect. Implementation models that are able to streamline learning to improve efficiencies in the classroom today reach limits of scalability and fidelity of implementation. There have been attempts to personalize learning by focusing on a portion of the implementation, but the holistic solution has as yet eluded the industry. Each solution is a stepping stone, but so far falls short of the ultimate goal of developing a personalized learning ecosystem for students.

Although we want to use the technology most appropriate to the task and to be aware of and access the very best content available, creating the future actually begins by developing the combination of hardware and software that can deliver educational material in the major modes needed by different learners, together with ongoing continuous assessment of student response coupled to adaptive delivery of subsequent learning.

The implications of creating a truly effective technological learning system are staggering. For the first time mankind will have a teaching system that fully responds to and utilizes the propensities and capabilities of the individual learner in a manner that enables them to understand any body of material in the way that works best for them and that is capable of monitoring in real time their successful acquisition of that information so that one can be certain that they had progressed to the necessary level of capability but that they do not waste their time repeating things that they already know beyond a level that is desirable to do so. For the first time the human race will have a system that enables the full range of people to be educated effectively on any topic that they choose without generating significant incremental cost per individual. Human time is expensive. Technology is cheap. There is expense in creating the software, expense in improving and modifying the software, but that expense can be amortized over a very large number of learners and over the course of time it becomes essentially negligible. There is an expense in the technology, the computer systems, potentially the accessory "sensory" systems for the computer to monitor the learner, but thanks to Moore's law and the rapid advance of many technologies as well as economies of scale and the possibility of using cloud and other technologies the cost of technology is unlikely to be a rate limiting step. Once technology software platforms are created translation to address the different languages of the world, while always a challenge, would be relatively straightforward as a technical problem and simply an issue of resources and marketing. Apple, eSpark Learning, our customers, learners, and collaborators working together are engaged systematically and with focus to develop a transformative personalized learning system, a system that will change the lives of billions of learners.

What would a world be like in which every person was well-educated, understood words, language, analytic and synthetic thinking well, was familiar with the humanities heritage that is the patrimony of mankind, understood how to think in a logical, reason, and quantitative way, had the academic development and skills to be able to learn whatever work skills they needed to prosper in the world? What would a world be like in which every man woman and child, regardless of location, nationality or ethnicity, gender, economic circumstances had the full opportunity to develop their own mind and skills to the limits of their natural capacity with the support of the most sophisticated and effective teaching system in the world?

We believe it will be a better world... A much better world.