

Empowering 21st Century Learners in STEM

An Impetus for Change



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Executive Summary

We live in a world of rapid change, a world where demographic, digital, and cultural shift are norms. Today's children are growing up in a world where the lines between information and entertainment have been blurred. Students today prefer on-demand learning with visual stimulation in flexible but structured learning environments that have collaborative, experiential and authentic activities, and applied technologies. However, when we look at K-12 classrooms, we tend to find that most are still mired in a 19th century, industrial model of learning; they still tend to be teacher fronted, teacher driven, and focused, for the most part, on passive information exchange. Recent research suggests that we should move away from these more traditional practices. A recent meta-analysis of 225 studies of success in STEM courses comparing traditional lecture to active learning found that students in the traditional classes were 1.5 times more likely to fail; students taught with active learning outperformed those taught by lectures by 6 percentage points on exams (Freeman et. al).

Simply put, it is time to begin re-evaluating not only how we are teaching our students, but the materials we are using to teach them. Research into the expectations of 21st century learners reveals that we want learners to be able to do much more than read, write, and do math; we expect learners to also think critically and creatively, solve real life problems, use foreign languages, work in teams, collaborate and embrace diversity (Casner-Lotto & Barrington, 2006). And many educators have begun to agree with Sir Ken Robinson's position that we are not going to get students to where they need to be by continuing to solve the problems of the future with the strategies of the past.

It is time to begin forging partnerships with organizations that offer innovative and engaging products and content delivery modalities that are not limited by the industrial model of learning. Lectures and traditional book learning need to be replaced with active engaging tools, hands-on activities and teaching strategies that equitably serve all populations of students. In the United States, Spanish speakers currently comprise less than one-fifth of the population, yet they are expected to make up nearly one-third of the population by 2060 (Krogstad & Lopez, 2014). So, in addition to engaging, interactive materials, content providers will also need to provide tools that embrace dual language, and allow students to learn literacy and content both in English and in their native/heritage languages.

This paper discusses cultural and academic impetus for change. It explains some of the historical underpinnings limiting that change, and offers a warning to the publishing industry, an industry that could stand to learn a little from the research on disruptive innovation. Static content online is still static content; it does not actively engage learners. Teachers and decision makers know this and are looking for companies like LJ Create who can provide interactive online and hands on learning resources that meet the standards and exceed the expectations of teachers.

Historical Underpinnings Limiting Change

Today we live in a world of rapid change, a world where demographic, digital, and cultural shift are norms. However, instead of considering ways to embrace the change and identify methods to leverage and empower our movement into a brighter future, we often find ourselves mired in the traditions and practices of an industrial model of learning.

Now, while a detailed history of the industrial model is outside the scope of this paper, it is important to identify a few of its underlying and embedded traditions, for these traditions seem to be limiting forward progress with respect to more innovative teaching practices and updated models of learning.

More than 150 years ago, Horace Mann¹ introduced his vision of a publicly funded system of education designed to create tolerant, civilized citizens. His vision resonated well within the industrial-minded thinking of the time, and we began to see the introduction of an industrial model of learning. If the factory line was the most efficient way to scale production in factories, why then wouldn't it also be the best candidate for scaling literacy and numeracy instruction (The 3 R's: Reading, wRiting, & aRithmetic) in classrooms? In the early twentieth century, Frederick Winslow Taylor's *Principles of Scientific Management*², analysis, and efficiency, were added as principles of the system. This was due in large part to Ellwood Cubberley's book *Public School Administration* (1916). In which he wrote:

Our schools are, in a sense, factories in which the raw products (children) are to be shaped and fashioned into products to meet the various demands of life. The specifications for manufacturing come from the demands of twentieth century civilization and is the business of the school to build its pupils according to the specifications laid down. (p. 338)

This industrial model served the American workforce well through the 20th Century when the goal was still to efficiently teach citizenship, literacy, numeracy, and also behaviorally condition a workforce for life on the production line, or in the management of the production line. But many modern educators now question the efficacy of the model. How should we be teaching students now that the factory line has been digitized, automated and/or outsourced to cheaper global markets? How do we best prepare an

American workforce to compete in a global marketplace with a knowledge-based economy where foreign language and critical thinking are key skills?

According to a research report commissioned by The Conference Board, the Partnership for 21st Century Skills ³, Corporate Voices for Working Families, and the Society for Human Resource Management, the needs of our workforce continue to change. Jill Casner-Lotto & Linda Barrington, the authors of the report (2006), found that when respondents were asked to identify which of 20 basic knowledge areas and applied skills would be changing in importance over the next five years, nearly two-thirds (63.3 percent) reported Foreign Languages as a basic skill that would “increase in importance.” The top five applied skills that respondents expected to increase in importance were: Critical Thinking/Problem Solving (77.8%); Information Technology Application (77.4%); Teamwork/Collaboration (74.2%); Creativity/Innovation (73.6%); and Diversity (67.1%) (Casner-Lotto & Barrington, 2006). As a result of this work, the Partnership for 21st Century Skills now recommends a new framework for 21st Century Learning, one that overlays the four C’s (Critical Thinking, Communication, Collaboration and Creativity) on top of the 3R’s of the industrial era.

Unfortunately, as many modern educators are slowly beginning to embrace the characteristics of 21st Century learning, there are still many educators and, more

importantly, decision makers who seem locked in the more traditional approaches of an industrial model of learning. In fact, the majority of school classrooms haven’t changed much in centuries. Figure 1 represents learning in the 14th Century. Students today still tend to sit in rows, and receive teacher-fronted instruction. Our inability to adapt,





Figure 1 – Laurentius de Voltolina (2nd half of 14th century)

update and change in education has even become the brunt of jokes in some circles. Consider the following:

Question: *How many educators does it take to change a light bulb?*

Answer: *Change? Who said anything about change?*

Perhaps Daniel Kahneman's⁴ theory of cognitive bias "What You See Is All There Is (WYSIATI)" helps to explain why we are so reluctant to update and change the way we teach and learn. WYSIATI suggests that we are biased to limit our thinking to what we know and are familiar with; in other words, we tend to treat the information we have as if it is the only information there is (Kahneman, 2011). Given that many educators, especially those in decision-making positions, are themselves products of the industrial model, perhaps their experiences cognitively bias them from seeing other possibilities. Or perhaps Cathy Davidson's⁵ ideas on attention blindness better explain this inability to recognize a need for shift. Decision makers simply can't see, what they can't see. In her widely popular book, *Now you see it: How technology and brain science will transform schools and business for the 21st century* (2011), she discusses our inability to see things from other perspectives. Perhaps the reason we can't and often don't win arguments about educational shift is not necessarily because we, or our opponents viewpoints are wrong, but instead because we fail to see that we are arguing from completely different perspectives and we are each blind to the others' ideas and inclinations. Regardless of the reasoning behind our inability to shift, I tend to agree with the ideas presented by Sir Ken Robinson⁶ in his RSA animate (2010). Essentially, we can't solve the problems of the future doing what we have done in the past, and continuing to do so is only "alienating millions of kids who don't see any purpose in going to school" (The RSA, 2010). Before giving a final example of the glacial pace at which we seem to be shifting from the industrial model, take a second to look at the juxtaposition of the two models in the table on the next page. Consider your views on education. What is learning? What should learning be? Which model best fits your ideas on learning? Could you be biased by WYSIATI? Have you had any opportunities to experience learning from a 21st century perspective?

20 th Century Learning	21 st Century Learning
	
Factory Model	Engaged, Collaborative Model
Teacher Centered	Self, Peer, Other or Problem Centered
Teacher Driven	Teacher Facilitated
Technology as Distraction	Technology Embraced
Emphasis on Order and Discipline	Emphasis on Edutainment
Teacher as Judge	Teacher as Collaborator and Mentor
Fixed Mindset Oriented	Growth Mindset Oriented
Curriculum Detached from Life	Curriculum Connected to Real Issues
No Student Freedom	Enhanced Learner Autonomy
Diversity Ignored	Collaboration by Difference
3 Rs: Reading wRiting & aRithmetic	Five E's: Engage, Explore, Explain, Elaborate, Evaluate
Textbook Driven – Read to Learn	Media Driven: Read, Watch, Play & Learn
Competition Between Students - Limited Sharing	Gamification of the Problem, Shared Solutions
Students Work Alone	Students Chose How and When to Collaborate
Classroom Bound by 4 Walls	Global Learning
Focus on Memorization of Discrete Facts	Memory Outsourced – Just-in-Time Learning Applied to Real Problems
Seat time	Process and Product Driven
Passive Reception	Active Production & Remixing
Remember, Understand, & Apply	Analyze, Evaluate, Create

As a final note in this section on historical underpinnings limiting our ability to change, consider the following quote:

“Books will soon be obsolete in public schools...[Students] will be instructed through the eye... Our school system will be completely changed inside of ten years.”

Many readers wrongly attribute this quote to modern change agents of education. They think it must have been from Steve Jobs, a man whose “iCreations” and ability to “Think Different” radically altered learning landscapes. Others wrongly attribute the quote to Bill or Melinda Gates, who together through their foundation have funneled billions into education reform. Readers are often surprised, however, to learn that this quote is actually over one hundred years old and that it comes from the inventor of the phonograph, the light bulb, and the motion picture, namely, Thomas A. Edison. Edison made this quote in 1913, why is it that more than one hundred years later, our classrooms are still teacher fronted, text driven, and largely governed by an industrial model of learning?

Additional Impetus for Change

In addition to the shifts we have seen in employer expectations and recommended pedagogies, in 2012, the Programme for International Student Assessment (PISA) conducted a survey of 510,000 students from thirty-four Organization for Economic Cooperation and Development (OECD) countries. The findings revealed that the U.S. was below average with a ranking of seventeen among the thirty-four OECD countries, the U.S. ranked 26th in Math, 21st in Science, and 17th in reading. And while some suggest temperance in the interpretations of these findings given the expanded role that socio-economic class plays in the United States when compared to other countries, there are other concerns. Eric Hanushek, a senior fellow at Stanford University's Hoover Institution, suggested that “Rising PISA scores means economic growth will rise;” “A steeper line of the test scores should cause a steeper line for annual growth rates” (Qtd. In Khaopa 2011). So where does that leave the United States given that our scores are not suggesting growth? The PISA scores unfortunately, are not the only data indicating problems within the system. According to the National Math + Science Initiative:

- **56 percent** of 2013 U.S. high school graduates **ARE NOT READY** for college-level math.
- **64 percent** of 2013 U.S. high school students **ARE NOT READY** for college-level science.

- **58 percent** of American fourth graders and **65 percent** of eighth graders tested in 2013 performed **BELOW** proficient levels in mathematics.
- **68 percent** of eighth graders tested in 2011 performed **BELOW** proficient levels in science.

According to Ed.Gov, “only 16percent of American high school seniors are proficient in mathematics and interested in a STEM career.” What does that say for a country that has long been a global leader in STEM? Especially given the projected percentage increases in STEM jobs throughout the rest of this decade?

Perhaps it is time to begin re-evaluating how we are teaching our students. It is time to begin forging partnerships with organizations that offer more innovative and engaging products and content delivery modalities that are not limited by

20th century models of learning. Lectures and traditional book learning need to be replaced with active engaging tools, hands-on activities and teaching strategies that equitably serve all populations of students. Research has long demonstrated that active learning is preferred to the more passive practices of the industrial model, why then are we still mired in the practices of the past? Especially given the benefits of active learning for all students. Scott Freeman notes “active learning differentially benefits students of color, students from disadvantaged backgrounds, and women in male-dominated fields” (Cited in Bhatia 2014).

Projected Percentage Increases in STEM Jobs 2010 - 2020

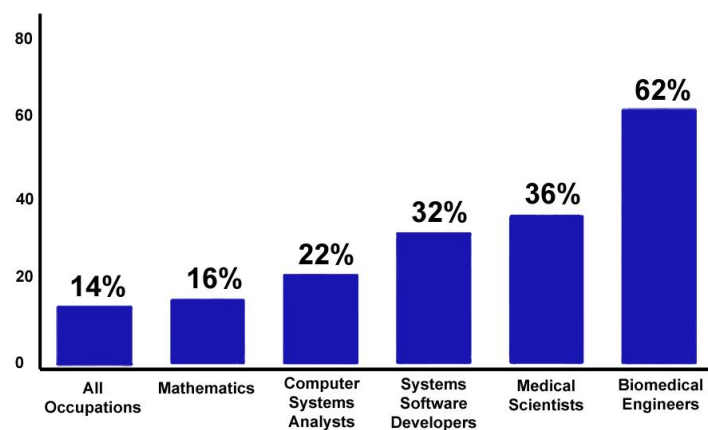


Figure 2 - Projected Percentage Increases in Stem Jobs 2010-2020

For those not familiar with the concept, active learning is a modality where students learn through active direct experiences and construct their knowledge by testing and revising (Holzer, 1994) Problem Based Learning (PBL), one of a variety of active learning approaches, employs the non-traditional, active approach and centers on complex tasks designed, among other things, to have students create, build, test, prove or improve things, fostering active learning, collaboration, real-life problem solving, critical thinking and more (Barrows, 1998; Burgess 2004; Hmelo-Silver, 2004; Springer, Stanne, & Donovan, 1999). When compared to traditional models of teaching, PBL has been found to double learning gains (Yadav et al., 2011) Researchers have suggested “Learning by doing is a powerful tool to promote learning for both teachers and their students” (De La Hoz & De Blas Del Hoyo, 2009). Moreover, it is the modality that is preferred by today’s learners. While all learners are different from their preceding generations, today’s students truly are unique. K-12 students today cannot conceive of a world before Google, because for them, it has always been there. It should be of little surprise that children who have grown up in a world where information and entertainment are on demand prefer visual stimulation in flexible but structured learning environments that have collaborative, experiential and authentic activities, and that embrace applied technologies (Sweeney, 2006; Pardue & Morgan, 2008; Brown, Hansen-Brown & Conte 2011). Today’s students prefer to “seek, sieve, and

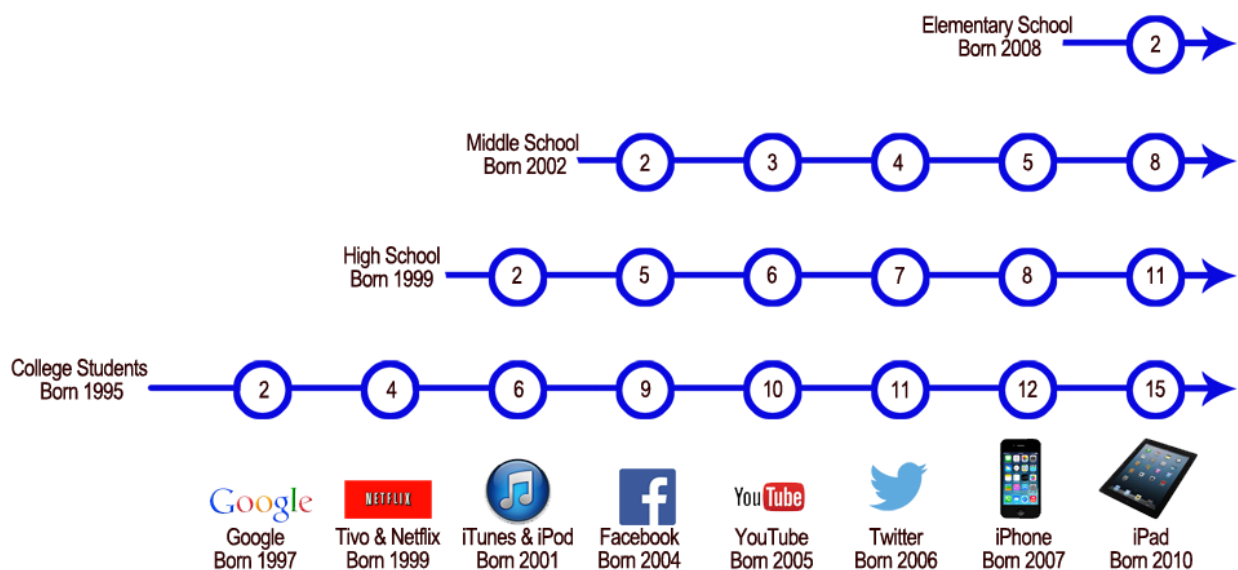


Figure 3 - In A Student's Lifetime Information Graphic

synthesize” learning (Dede, 2005). We know that traditional teacher-fronted, passive learning environments result in limited retention of knowledge by students (Prince, 2004). And research continues to demonstrate that active hands-on learning is the way to teach students. In a meta-analysis of 225 studies (Freeman et. al) of success in STEM courses comparing traditional lecture to active learning, students in the traditional classes were 1.5 times more likely to fail. Students taught with active learning outperformed those taught by lectures by 6 percentage points on their exams.

Given these findings, I have to ask again, how is it that traditional practices and the industrial model of learning continue to persist? But given the length of time educational reformists have been suggesting hands-on models, I guess a better question is “should we really be all that surprised?” According to Haury and Rillero (1994)

The Committee of Ten (National Education Association, 1893) was instrumental in securing a permanent place for science in the American school curriculum. The science committees repeatedly stressed the importance of object manipulation by students. The Physics, Chemistry and Astronomy Committee recommended "That the study of simple natural phenomena be introduced into the elementary schools and that this study, so far as practicable, **be pursued by means of experiments carried on by the pupil**" (National Education Association, 1893, p. 118). They added, "The study of books is well enough and undoubtedly important, but **the study of things and of phenomena by direct contact must not be neglected**" (National Education Association, 1893, p. 119).

I am optimistic that things will soon change. Many teachers want change, and continued research efforts like the Freeman et al study are likely to help them achieve it. According to Scott Freeman, “The impact of these data (specifically the meta-analysis of 225 studies) should be like the Surgeon General’s report on “Smoking and Health” in 1964—they should put to rest any debate about whether active learning is more effective than lecturing.”

Unfortunately, embracing active learning is only one piece of the puzzle. We also need products and materials that open doorways to the growing segments of our population. According to a recent Pew Research article:

Latinos are the nation's largest minority, and one of its fastest growing. Since 1970, the Latino population has increased sixfold, from 9.1 million to 53 million by 2012. It is projected to grow to 129 million by 2060, according to the latest projections from the U.S. Census Bureau ([2012](#)). Its share of the U.S. population, currently at 17%, is expected to reach 31% by 2060 (Krogstad & Lopez, 2014).

The rapid growth of this segment, begs the question, "How are these students performing within the current system?" According to a report commissioned by the League of United Latin American Citizens, Hispanic students do show initiative in majoring in STEM; however, "they do not graduate at the same rates" (Chen & Weeko 2009). "A mere 16% of Latino students who began college in 2004 pursuing a STEM major actually completed that degree, whereas the number of whites completing a STEM degree was significantly higher, at 25%" (Torres, Peña, Camacho, and Silva, 2014). Moreover, according to Facethefactsusa.org (2013), a project of George Washington University, while "10 percent of U.S. public school students struggle with the English language, just 1 percent of its teachers are qualified to instruct them." In other words, "there is just one ESL instructor for every 150 ESL students." Simply put, our existing models are ill equipped to deal with this growing segment. Moreover, as baby boomers continue to retire, we are going to have even fewer teachers prepared to work with these second language populations. "The National Center for Education Statistics estimates that public schools will need more than 440,000 new elementary and secondary teachers by the end of the decade to replace retiring baby boomers" (Gardner, 2012).

To make up for this existing shortage, schools would benefit from products that allow for dual language instruction. With dual language, students learn literacy and content in both in English and in their native/heritage language. This allows students to benefit from Common Underlying Proficiencies (discussed below). Access to content in the native/heritage language also allows parents to relate better to what students are learning in school and better connect that content to learning in the home. Moreover, according to Collier & Thomas, two researchers who have spent nearly thirty years researching the

model, Dual Language is the “only program for English learners that fully closes the [achievement] gap; in contrast, remedial [ESL] models only partially close the gap” (Collier & Thomas, 2004).

Dr. James Cummins⁷ suggests that there are Common Underlying Proficiencies between languages. In other words, many of the linguistic and metalinguistic skills learned in the acquisition of one language can later be drawn upon in the acquisition of other



Figure 4 - Common Underlying Proficiency

languages. This suggests to educators the need to encourage English Language Learners (ELLs) to continue developing their native language skills in the home. When ELLs have content made available to them in their native languages, they can practice reading, writing, math, and science in their native language and acquire concepts that will become part of their common underlying proficiencies. Then later at school students will be able to draw upon these proficiencies as they learn new labels for their already established concepts. "Conceptual

knowledge developed in one language helps to make input in the other language comprehensible" (Cummins 2000). Cummins also notes that providing support for learning in the home language supports additive bilingualism, and his research suggests that students learning in additive bilingual environments succeed at greater rates than those in subtractive bilingual environments where students' first languages and cultures are devalued or unsupported.

Juggernauts Beware!

So where does that leave us? A recent infographic from Learnstuff.com points out that seventy percent of children between the ages of 2-5 know how to operate a computer mouse, but only eleven percent of the same group know how to tie their own shoe laces (2012). And believe it or not, in 2015 the iPad will turn 5, YouTube will turn 10, and Google will turn 17. Put a different way, existing K-12 students are currently unable to conceive of a world before Google. Next year's kindergarteners will have no concept of life before the

tablet interface. All of these students will be learning via video-on-demand, yet they will be getting assessed by criterion-based state standards, so simply setting them loose on the Internet is not the answer.

While change is not happening as quickly as Thomas Edison may have predicted, I believe we are at the beginning of a major shift. In the beginning of this century, about 50% of K-12 classrooms had Internet access; today 98% of classrooms have Internet access (Learnstuff.com, 2012). This is good news because it suggests that classrooms will soon be able to rely less on text and begin to take advantage of the multimodal, interactive nature of digital content. Perhaps Edison's belief that textbooks would become obsolete in public schools by 1923 was flawed, but then again, it just might come to pass, just 100 years later than originally predicted.

The publishing industry for K-12 education continues to be big business, and the juggernauts of publishing McGraw-Hill, Pearson, and Houghton Mifflin Harcourt make up 85% of this \$8 billion industry (Owen, 2012). However, if they continue to go along business as usual, and they fail to learn the lessons of disruptive innovation, they too may suffer the same fate as other large industries. Consider how the things have changed for the newspaper industry, music stores, and the movie rental business in the last decade. These industries have experienced dramatic upset as a result of disruptively innovative products and services. Companies that can provide interactive online and hands on learning resources that meet the standards and exceed the expectations of teachers will soon prove disruptive to the publishing industry.

Educational procurement policies for textbooks and other content delivery resources continue to evolve, albeit slowly. For example, DigitalPromise.org (2014) reported that the Houston Independent School District recently launched a project called PowerUp, "A 1:1 initiative aimed at transforming teaching and personalizing learning, which will provide all 65,000 HISD high school students with a laptop in school and at home by 2016." And Metro Nashville Public Schools (MNPS) and other Middle Tennessee school systems are simply opting out of purchasing books in some cases. For example, in 2008 the MNPS system spent 5.3 million on social studies textbooks; this year (2014) they opted to use those funds to purchase new digital materials instead (Garrison 2014). Across the country we are seeing similar trends. In fact, according to a recent report from the

Center for Digital Education (2014) “When asked whether a move to digital content was important to their education institution, 75 percent of K-20 education decision-makers who responded to a recent CDE survey said yes.” The time is right for digital innovators.

Another force driving this move from text based learning to digital learning is that National Standards continue to push assessment online. Common Core, Next Generation Science Standards (NGSS), California NGSS, Texas Essential Knowledge and Skills (TEKS), and Florida Next Generation Sunshine State Standards, all recognize the importance of technology for tomorrow’s students. In fact, starting spring of 2015, Florida students in grades 5–11 will take English Language Arts and Mathematics assessment tests online. Figure 5 shows a screen capture of an interactive math question for the

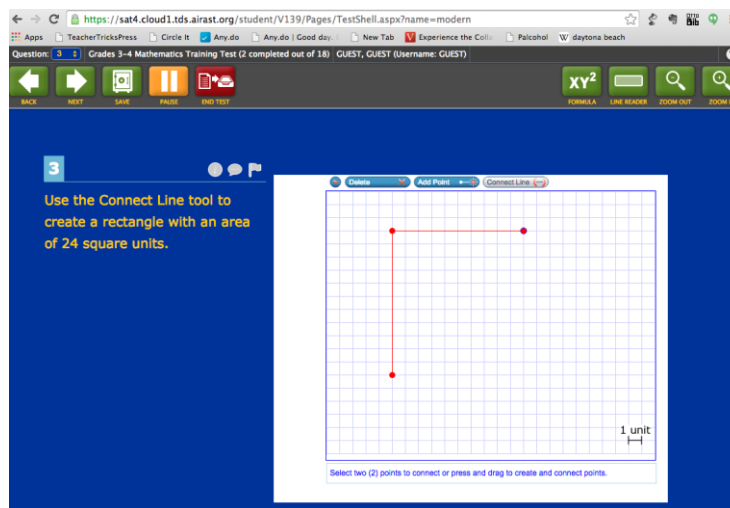


Figure 5 - Florida Standards Assessments Screen Capture

fourth grade assessment. Given that assessment is often the tail that wags the dog in education, this could lead to faster adoption rates with respect to digital content, thereby opening the door even wider to disruptive innovators. Research in testing has demonstrated the importance of making sure that students have the ability to learn and produce work in the classroom in the same ways that they will produce responses on a given test. In fact “Discrepancies between the way in which students produce writing while learning and the way in which they produce writing during testing has a significant impact on the validity of information provided by writing tests” (Russell, Goldberg, & O’Connor 2003). Therefore, it won’t be long, in the state of Florida at least, before schools will be looking to adopt content providers that provide instruction and formative assessment through online delivery.

The good news is that there are already companies providing highly interactive and engaging online resources that allow students to learn and better prepare themselves for these new online assessments. For example, LJ Create provides a wide variety of teaching

and learning resources for students in engineering, automotive, science & STEM. I was recently given a tour and had the opportunity to tryout some of their online offerings, I couldn't help but be inspired by the design. LJ Create uses a mixed media approach to offer both synchronous and asynchronous learning opportunities for students. This allows for students to learn together in the classroom, but it also allows for teachers to flip the classroom and assign learning to students at home. The content utilizes active learning approaches, and the online resources provide video instruction, online simulation, and a variety of interactive online learning tools and assessments. This modular design also allows for teachers to assign additional and/or supplemental work to students at home or in the classroom. Teachers can therefore differentiate instruction for students to better meet the needs of different abilities within a class. Moreover, the content is available in both Spanish and English, thereby making it a resource for dual language instruction, and better reaching a growing demographic of students. In the classroom, students use learning kits to get hands on time with a variety of STEM resources and projects. The teacher interface is clean, easy to navigate and it is standards driven, which makes it easy for teachers to identify and assign content that addresses national, state, and local learning outcomes. Simply put, I was impressed.

Given that we do live in a world of rapid change, a world where demographic, digital, and cultural shift are norms, teachers require and are currently looking for engaging digital tools to help them meet the expectations of a new generation of learners. They are not looking for traditional texts or their static digital equivalents (publishers need to stop offering digital PDFs and calling them digital resources, static content online is still static content. It does not actively engage learners). Teachers are looking for companies like LJ Create who can bring together a wide variety of digital tools to better engage diverse learners and better help them prepare for next generation standards. So, juggernauts beware!

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Footnotes

¹ Horace Mann (1796-1859) was an American educational reformer, who is often called the Father of the Common School. His ideas and leadership of the Common School Movement ensured that all American children receive a basic education funded by local taxes.

² Frederick Winslow Taylor is often called "The Father of Scientific Management, " and his approach is also often referred to, as Taylor's Principles, or Taylorism. His work was a theory of management that analyzes and synthesizes workflows to improving economic efficiency, especially labor productivity.

³ Partnership for 21st Century Skills (P21.org) is a coalition that brings together the business community, education leaders, and policymakers to position 21st century readiness at the center of US K-12 education and to kick-start national conversations on the importance of 21st century skills for all students.

⁴ Daniel Kahnemen is the Nobel Prize winning economics professor and author of the widely popular book *Thinking, Fast and Slow* (2011). In his book he summarizes research

he conducted over decades, often in collaboration with Amos Tversky. His book discusses, among other things, the power of cognitive biases.

⁵ Cathy N. Davidson is an American scholar and university professor. She is currently a Distinguished Professor and the Director of the Futures Initiative at the Graduate Center of the City University of New York.

⁶ Sir Ken Robinson is an international advisor on education who challenges the way we're educating our children. He champions a radical rethink of our school systems and argues that one of the reasons our school systems are failing is because we've been educated to become good workers, rather than creative thinkers.

⁷ Dr. James Cummins is a leading authority on bilingual education and second language acquisition. His theories on Basic Interpersonal Communication Skills (BICS), Cognitive Academic Language Proficiency (CALP), Common Underlying Proficiency (CUP), and Context Embedded and Context Reduced Task Difficulty are foundational elements in the training of teachers of English as a Second or Foreign language.